

Reference:

optimization based on 'Flexible 5G New Radio LDPC Encoder Optimized for High Hardware Usage Efficiency'

<https://www.mdpi.com/2079-9292/10/9/1106>

LDPC encoder without optimization

LDPC encoding is to calculate parity bits w (38.212 5.3.2)such as

$$H \begin{bmatrix} c \\ w \end{bmatrix} = [H1 \ H2] \begin{bmatrix} c \\ w \end{bmatrix} = H1 \cdot c + H2 \cdot w = 0$$
$$\implies w = -H2^{-1} H1 \cdot c$$

$H1$ is $46Z_c \times 22Z_c$ for LDPC base graph 1 and $42Z_c \times 10Z_c$ for LDPC base graph 2

$H2$ is $46Z_c \times 46Z_c$ for LDPC base graph 1 and $42Z_c \times 42Z_c$ for LDPC base graph 2

The matrix inverse takes a very long time. The optimization method is as below.

The structure of H matrix

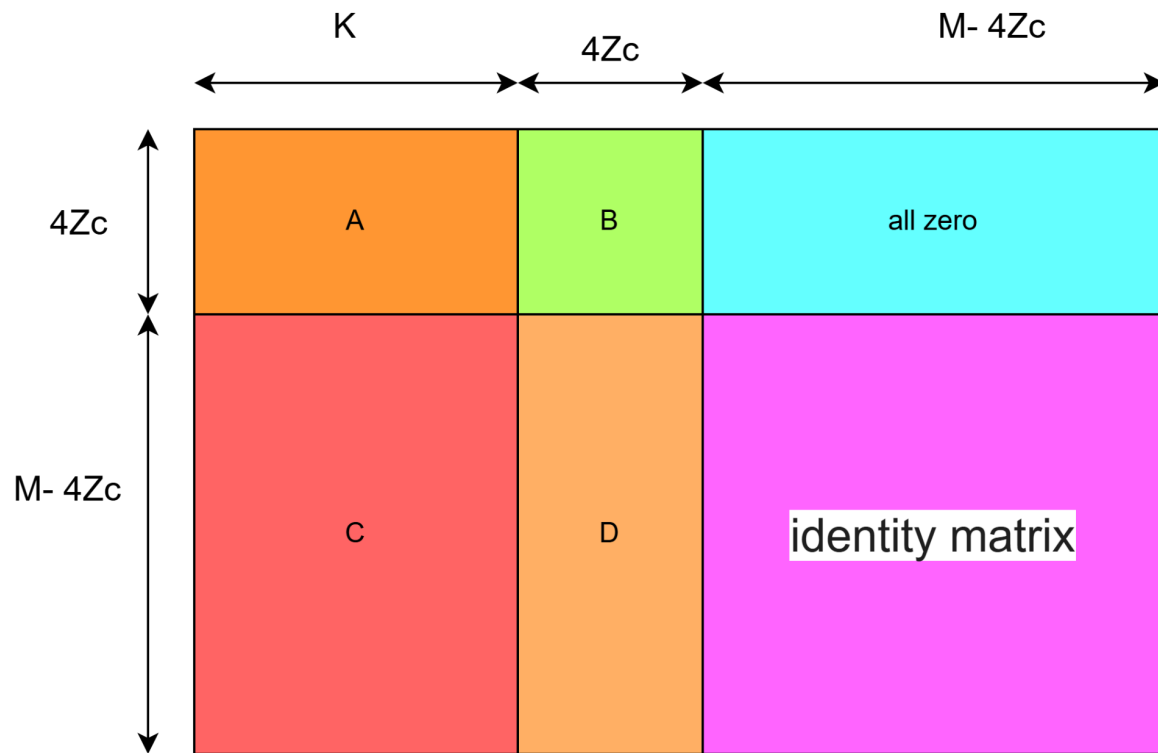
Z_c : lifting sizes in 38.212 Table 5.3.2-1

$K = 22Z_c$ for LDPC base graph 1 and $K = 10Z_c$ for LDPC base graph 2; in 38.212 5.2.2

$N = 66Z_c$ for LDPC base graph 1 and $N = 50Z_c$ for LDPC base graph 2; in 38.212 5.3.2

$M = N + 2Z_c - K$: $46Z_c$ for LDPC base graph 1 and $42Z_c$ for LDPC base graph 2

Below is H matrix format



$$H \begin{bmatrix} c \\ w \end{bmatrix} = \begin{bmatrix} A & B & zero \\ C & D & I \end{bmatrix} \begin{bmatrix} c \\ pc \\ ps \end{bmatrix} = 0$$

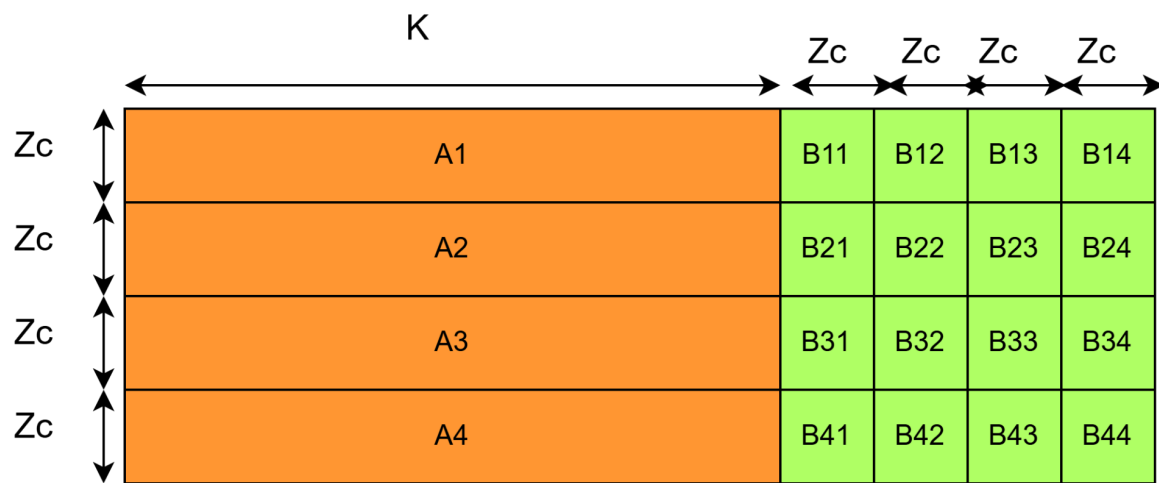
w vector is divided into pc and pa , where

pc represents a $4Zc$ length vector of so-called core parity bits

pa represents a $M - 4Zc$ length vector of so-called additional parity bits

pc calculation

Rewrite matrix A and B in this way,



Divide pc into 4 Z_c length vectors :

$$pc = \begin{bmatrix} pc1 \\ pc2 \\ pc3 \\ pc4 \end{bmatrix}$$

From:

$$H \begin{bmatrix} c \\ w \end{bmatrix} = \begin{bmatrix} A & B & zero \\ C & D & I \end{bmatrix} \begin{bmatrix} c \\ pc \\ ps \end{bmatrix} = 0$$

$$\begin{matrix} & & & & \\ & & & & \\ & & & & \\ \text{Get:} & \begin{bmatrix} A & B \end{bmatrix} & \begin{bmatrix} c \\ pc \end{bmatrix} & = & \\ & & & & \end{matrix}$$

$$\begin{bmatrix} A1 & B11 & B12 & B13 & B14 \\ A2 & B21 & B22 & B23 & B24 \\ A3 & B31 & B32 & B33 & B34 \\ A4 & B41 & B42 & B43 & B44 \end{bmatrix} \cdot \begin{bmatrix} c \\ pc1 \\ pc2 \\ pc3 \\ pc4 \end{bmatrix} = 0$$

Get

$$\begin{bmatrix} A1 \\ A2 \\ A3 \\ A4 \end{bmatrix} \cdot c + \begin{bmatrix} B11 & B12 & B13 & B14 \\ B21 & B22 & B23 & B24 \\ B31 & B32 & B33 & B34 \\ B41 & B42 & B43 & B44 \end{bmatrix} \cdot \begin{bmatrix} pc1 \\ pc2 \\ pc3 \\ pc4 \end{bmatrix} =$$

$$\begin{bmatrix} L1 \\ L2 \\ L3 \\ L4 \end{bmatrix} + \begin{bmatrix} B11pc1 + B12pc2 + B13pc3 + B14pc4 \\ B21pc1 + B22pc2 + B23pc3 + B24pc4 \\ B31pc1 + B32pc2 + B33pc3 + B34pc4 \\ B41pc1 + B42pc2 + B43pc3 + B44pc4 \end{bmatrix} = 0$$

For modulo 2 operation, we get :

$$\begin{bmatrix} L1 \\ L2 \\ L3 \\ L4 \end{bmatrix} = \begin{bmatrix} B11pc1 + B12pc2 + B13pc3 + B14pc4 \\ B21pc1 + B22pc2 + B23pc3 + B24pc4 \\ B31pc1 + B32pc2 + B33pc3 + B34pc4 \\ B41pc1 + B42pc2 + B43pc3 + B44pc4 \end{bmatrix}$$

B matrix format for BG1 and BG2 are as below

$$\mathbf{B}_{BG1} = \begin{bmatrix} \mathbf{I}^{(1)} & \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{I} & \mathbf{I} & \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{I} & \mathbf{I} \\ \mathbf{I}^{(1)} & \mathbf{0} & \mathbf{0} & \mathbf{I} \end{bmatrix}; \mathbf{B}_{BG2} = \begin{bmatrix} \mathbf{I} & \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & \mathbf{I} & \mathbf{0} \\ \mathbf{I}^{(1)} & \mathbf{0} & \mathbf{I} & \mathbf{I} \\ \mathbf{I} & \mathbf{0} & \mathbf{0} & \mathbf{I} \end{bmatrix}.$$

Based on B matrix structure, when adding four lines together on right side, there would be $3pc1, 2pc2, 2pc3, 2pc4$,

For modulo 2 operation, we have

$$2pc1 = 2pc2 = 2pc3 = 2pc4 = 0$$

Now get:

$$L1 + L2 + L3 + L4 = 3pc1 + 2pc2 + 2pc3 + 2pc4 = pc1$$

Calculate pc2, pc3, pc4 for BG1.

$B11=B12=B21=B22=B23=B33=B34=B41=B44 = I$, all other sub-matrixs = 0

Method 1 to calculate pc2, pc3, pc4:

$$L1 = pc1 + pc2 \implies pc2 = L1 - pc1 = L1 + pc1$$

$$L4 = pc1 + pc4 \implies pc4 = L4 - pc1 = L4 + pc1$$

$$L3 = pc3 + pc4 \implies pc3 = L3 - pc4 = L3 + pc4$$

Method 2 to calculate pc2, pc3, pc4:

$$L2 + L3 + L4 = 2pc1 + pc2 + 2pc3 + 2pc4 = pc2$$

$$L1 + L2 + L3 = 2pc1 + 2pc2 + 2pc3 + pc4 = pc4$$

$$L1 + L2 = 2pc1 + 2pc2 + pc3 = pc3$$

Calculate pc2,pc3,pc4 for BG2.

$B11=B12=B22=B23=B31=B33=B34=B41=B44=I$, all other sub-matrixs = 0

Method 1 to calculate pc2,pc3,pc4:

$$L1 = pc1 + pc2 \implies pc2 = L1 - pc1 = L1 + pc1$$

$$L4 = pc1 + pc4 \implies pc4 = L4 - pc1 = L4 + pc1$$

$$L2 = pc2 + pc3 \implies pc3 = L2 - pc2 = L2 + pc2$$

Method 2 to calculate pc2,pc3,pc4:

$$L2 + L3 + L4 = 2pc1 + pc2 + 2pc3 + 2pc4 = pc2$$

$$L1 + L2 + L3 = 2pc1 + 2pc2 + 2pc3 + pc4 = pc4$$

$$L3 + L4 = 2pc1 + pc3 + 2pc4 = pc3$$

pa additional parity bits calculation

From

$$H \begin{bmatrix} c \\ w \end{bmatrix} = \begin{bmatrix} A & B & zero \\ C & D & I \end{bmatrix} \begin{bmatrix} c \\ pc \\ ps \end{bmatrix} = 0$$

get:

$$C \cdot c + D \cdot pc + ps = 0 \implies ps = C \cdot c + D \cdot pc$$