DRAFT

Low Density Parity Check Coding

The bit sequence input for a given code block to channel coding is denoted by $u_1 \quad u_2 \quad \dots \quad u_K$, where K is the number of bits to be encoded. The parity check bit sequence produced by FEC Encoder is denoted by $p_1 \quad p_2 \quad \dots \quad p_M$, where M is the number of parity check bits. The output of FEC Encoder is denoted by $\mathbf{c} = [c_1 \quad c_2 \quad \dots \quad c_N] = [u_1 \quad u_2 \quad \dots \quad u_K | p_1 \quad p_2 \quad \dots \quad p_M]$, where $N = K + M$ is length of encoder output sequence.

The FEC encoding scheme is shown in Figure x1. The scheme consists of a systematic QC-LDPC encoder and a shortening and puncturing mechanism. The parameters of the FEC encoding scheme are:

– the LDPC parity check matrix is a 13-by-75 quasi-cyclic matrix, with circulant size $Z = 256$; LDPC user bit length before shortening is $62 \times 256 = 15{,}872$, the parity bit length before puncturing is $13 \times 256 = 3{,}328$; the codeword length before any shortening and puncturing is 19,200;
– the number of transmitted information bits, K (with maximum user length $K_{\max} = 15{,}677$);
– the number of shortened information bits, S ($S_{\min} = 195$);
– the number of punctured parity check bits, P ($P = 512$);
– the number of parity-check bits after puncturing, M ($M = 3{,}328 - 512 = 2{,}816$);
– the number of output bits, N ($N = K + M$, FEC codeword, whose size depends on the burst length pattern to determine shortening length); $N_{max} = K_{max} + M = 18{,}493$;
– the code rate, $R = K/N$, defined as the code rate after puncturing and after shortening.

The encoder supports highest code rate $R_{\max} = \frac{K_{\max}}{N_{max}} = 0.8477$. Codes with lower code rates/shorter block length shall be obtained through shortening. The puncturing length and location are fixed for all scenarios.

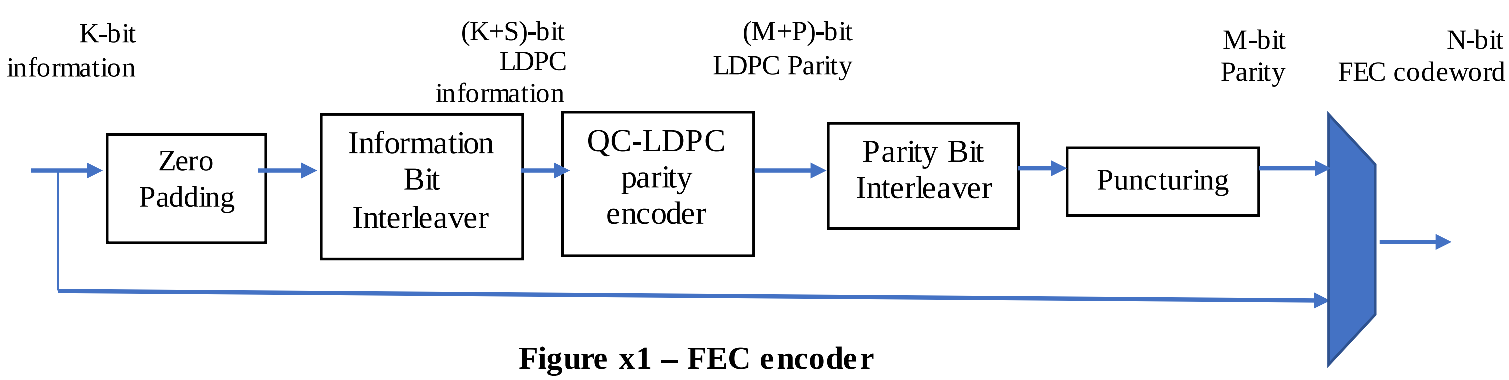

Figure x1 – FEC encoder

LDPC Encoder

The full LDPC code is defined by a (M+P)×(K+S+M+P) = 3328 ×19200 size parity-check matrix H composed by a 13×75 array of 256×256 sub-matrices $\mathbf{A}_{i,j}$,:

$$\mathbf{H} = \begin{bmatrix} \mathbf{A}_{1,1} & \cdots & \mathbf{A}_{1,75} \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{13,1} & \cdots & \mathbf{A}_{13,75} \end{bmatrix}$$

The sub-matrices $\mathbf{A}_{i,j}$ are either a cyclic shifted version of identity matrix or a zero matrix, and have a size of 256×256. The parity-check matrix can be described in its compact form:

$$\mathbf{H}_c = \begin{bmatrix} \mathrm{a}_{1,1} & \cdots & \mathrm{a}_{1,75} \\ \vdots & \ddots & \vdots \\ \mathrm{a}_{13,1} & \cdots & \mathrm{a}_{13,75} \end{bmatrix}$$

where $\mathrm{a}_{i,j} = -1$ for a zero sub-matrix in position (i,j), and a positive integer number $\mathrm{a}_{i,j}$ defines the number of right column shifts of the identity matrix.

Note to Editor (to be removed prior to publication): If the parity matrix font size is too small for publication, suggest following what Clause 55 / 55A did by having a zip file made downloadable from http://standards.ieee.org/downloads/802.3/ containing han_3ca_1_0118.txt. Also an option, create larger tables like as was done in Clause 101.

The compact form of parity-check matrix $\mathbf{H}_c$ shown below:

-1 190 -1 134 -1 221 -1 -1 157 -1 238 87 -1 223 -1 207 -1 -1 -1 16 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 132 0 -1 -1 -1 -1 -1 90 53 76 -1 -1 203 -1 -1 77 -1 -1 222 -1 122 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 23 -1 212 -1 11 -1 145 61
4 -1 -1 -1 44 173 -1 -1 5 52 -1 -1 -1 90 29 255 -1 69 -1 -1 -1 -1 -1 -1 87 -1 132 -1 -1 -1 -1 -1 -1 -1 -1 -1 190 -1 -1 171 202 -1 -1 27 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 232 -1 102 -1 -1 84 -1 -1 166 -1 -1 -1 -1 -1 -1 25 -1 -1 -1 163 176
144 -1 -1 179 -1 -1 0 228 -1 -1 39 -1 -1 13 0 -1 -1 188 -1 -1 -1 -1 -1 242 -1 0 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 125 0 -1 29 -1 0 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 126 -1 194 117
-1 -1 154 -1 89 60 -1 169 -1 242 -1 -1 107 -1 -1 -1 105 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 87 -1 -1 -1 166 -1 -1 -1 -1 -1 46 -1 -1 45 -1 -1 -1 -1 250 -1 -1 120 76 214 -1 -1 173 -1 -1 124 -1 -1 -1 130 -1 -1 -1 -1 -1 -1 -1 222 47 119
190 -1 184 -1 158 -1 150 -1 241 45 -1 -1 195 -1 25 -1 -1 -1 173 -1 250 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 84 27 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 41 -1 -1 -1 -1 -1 -1 111 -1 -1 -1 -1 -1 -1 0 -1 197 -1 -1 143 -1 0 -1 -1 234 198
250 231 -1 5 -1 80 105 -1 -1 135 -1 7 -1 -1 -1 -1 -1 -1 -1 -1 -1 39 -1 -1 -1 164 -1 -1 -1 -1 -1 -1 -1 112 -1 237 -1 143 -1 -1 -1 -1 50 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 71 -1 130 -1 -1 163 -1 175 -1 125 -1 -1 -1 -1 46 53
-1 223 232 -1 -1 0 -1 -1 0 -1 0 109 -1 57 -1 -1 -1 -1 0 -1 -1 -1 0 -1 0 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 205 -1 -1 -1 0 -1 -1 -1 -1 0 -1 0 -1 -1 0 -1 0 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 0 0 212 209
0 -1 -1 0 166 -1 -1 214 -1 -1 215 -1 0 -1 -1 -1 0 -1 -1 0 -1 -1 183 142 -1 -1 -1 -1 22 178 -1 0 -1 -1 0 0 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 30 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 112 29
-1 121 -1 -1 174 -1 98 -1 107 -1 54 -1 102 232 -1 -1 -1 -1 41 -1 -1 -1 -1 -1 -1 -1 -1 109 -1 -1 0 -1 102 -1 139 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 4 0 -1 -1 196 -1 -1 -1 0 14 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 71 -1 -1 242 -1
-1 0 0 -1 0 -1 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 -1 0 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 0 0 -1 -1 -1 -1 0 0 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0 -1 -1 0 -1 -1 -1 0 0
-1 -1 227 181 -1 -1 173 -1 156 -1 -1 126 27 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 118 186 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 43 -1 -1 -1 -1 -1 27 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 104 0 15 -1 -1 29 21 -1 -1 60 -1 24 145 24
-1 43 -1 38 -1 48 -1 217 -1 -1 159 48 -1 -1 -1 -1 -1 -1 -1 -1 -1 125 220 -1 185 104 10 -1 21 -1 -1 -1 -1 -1 -1 -1 87 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 60 -1 -1 -1 -1 -1 -1 -1 -1 -1 54 -1 -1 108 -1 183 29 -1 40 -1 -1 -1 -1 -1 -1 -1 62 160
123 -1 191 -1 -1 -1 145 18 -1 247 -1 -1 101 -1 -1 -1 124 -1 -1 149 17 -1 -1 -1 -1 -1 -1 17 -1 -1 18 238 250 -1 -1 -1 -1 -1 232 -1 -1 -1 -1 213 -1 155 -1 168 239 -1 -1 76 221 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 19 225

Figure x2 is an image of the matrix $\mathbf{H}_c$ to show non-zero locations, and parity/user bit assignments corresponding to parity check matrix columns. A dot represents a non-zero 256×256 circulant in the 13×75 H matrix.

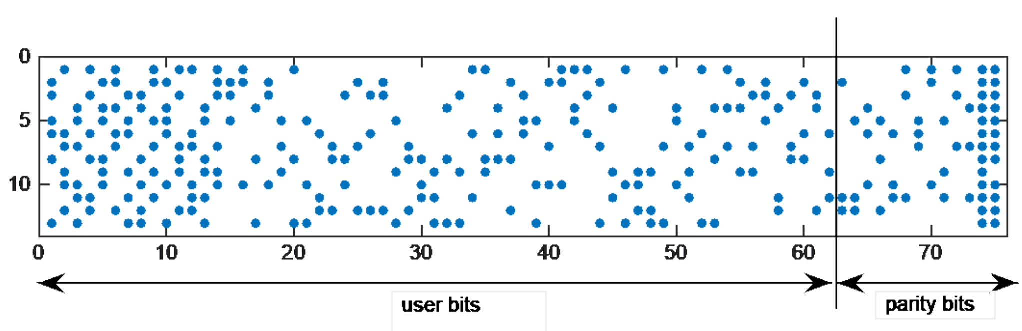

Figure x2 – Parity Check Matrix Image

A fixed amount (512 bits) and locations of the parities are punctured on the full LDPC matrix; a minimum amount (195 bits) and locations of the user bits are shortened on the full LDPC matrix. The effective maximum code rate 0.8477.

Figure x3 – Codeword Information/Parity Location assignments

Encoding Operation

The encoding process shall be as follows:

1) A group of K information bits $\mathbf{u} = [u_1 \quad u_2 \quad \cdots \quad u_K]$ are collected and copied to the output of the encoder to form a block of systematic code bits. They are also the input to the zero-padding block (see Figure x1).
2) A total of S zero bits are appended at the end of $\mathbf{u}$ to form the full-length information bit vector $\mathbf{u}^* = [\mathbf{u}|0, \ldots ,0]$, which is then sent to the information bit interleaver module, which in turn produces the bit-interleaved sequence $\hat{\mathbf{u}} = \boldsymbol{\pi}_{\mathbf{info}}(\mathbf{u}^*)$.
3) The interleaved LDPC information bits $\hat{\mathbf{u}}$ is sent to the QC-LDPC parity encoder, and used to compute parity-check bits $\hat{\mathbf{p}}$ with the parity-check matrix $\mathbf{H}$, which is then interleaved to get $\boldsymbol{p}^* = \boldsymbol{\pi}_{\mathbf{parity}}(\hat{\mathbf{p}})$.
4) $M + P$ parity bits $\boldsymbol{p}^* = [p_1 \quad p_2 \quad \cdots \quad p_M \,|\, p_{M+1} \quad \cdots \quad p_{M+P}]$ are sent to the puncturing block.
5) The last P bits of $\boldsymbol{p}^*$ are truncated, and M parity bits $\boldsymbol{p} = [p_1 \quad p_2 \quad \cdots \quad p_M\,]$ are being copied to the output of the encoder to form the parity check bits.
6) At the encoder output $\mathbf{c} = [\mathbf{u}\,|\boldsymbol{p}] = [u_1 \quad u_2 \quad \cdots \quad u_K|p_1 \quad p_2 \quad \cdots \quad p_M\,]$, such that $[\hat{\mathbf{u}}\,|\hat{\boldsymbol{p}}]\mathbf{H}^{\boldsymbol{T}} = \mathbf{0}$.