### 142.2.4 FEC encoder

The Nx25G-EPON PCS shall encode the transmitted data stream using LDPC(16952,14392) FEC, defined in 142.2.4. FEC encoder test vectors are provided in Annex 142A.

#### 142.2.4.1 Low Density Parity Check coding

The FEC encoder is shown in Figure 142–6. The encoder consists of a systematic QC–LDPC encoding engine followed by a shortening and puncturing mechanism and the addition of a 10-bit delimiter. The parameters of the FEC encoder are:

— the LDPC parity check matrix is a 12–by–69 array of circulant sub-matrices (see 142.2.4.2) with circulant size Z = 256; LDPC user bit length before shortening is 57 × 256 = 14592, the parity bit length before puncturing is 12 × 256 = 3072; the codeword length before any shortening and puncturing is 17664;
— the number of transmitted information bits, K (with maximum user length $K_{max}$ = 14392);
— the number of shortened information bits, S (S = 14592 - K);
— the number of punctured parity check bits, P (P = 512);
— the number of parity-check bits after puncturing, M (M = 3072 - P = 2560);
— the length of the FEC encoder output + delimiter is N where N = K + M + 10-bits and $N_{max} = K_{max}$ + M + 10-bits = 16962;
— the code rate, R = K / N, defined as the code rate after puncturing and after shortening.

The encoder supports highest code rate $R_{max} = K_{max} / N_{max}$ = 0.848. Codes with lower code rates/shorter block length shall be obtained through shortening. The puncturing length and location are fixed for all scenarios.

The LDPC encoder as shown in Figure 142–6 places the M-bit FEC parity bits into the *ParityStagingBuffer* for use by the PCS Transmit Process (see 142.2.5.4.3) and the FecParity() function. The buffer is comprised of 2560 bits of calculated parity along with the 10-bit codeword delimiter (FEC_CW_DELIM). This results in the parity bits assigned to *ParityStagingBuffer*<2559:0> and the 10-bit FEC_CW_DELIM value to *ParityStagingBuffer*<2569:2560>. The transmission order starts with bit 0 and ends with bit 2569.

#### 142.2.4.2 LDPC encoding engine

The full LDPC code is defined by a (M + P) × (K + S + M + P) = 3072 × 17664 size parity-check matrix H composed by a 12 × 69 array of 256 × 256 sub-matrices $A_{i,j}$:

$$H = \begin{bmatrix} A_{1,1} & \cdots & A_{1,69} \\ \cdots & & \cdots \\ A_{12,1} & \cdots & A_{12,69} \end{bmatrix}$$

The sub-matrices $A_{i,j}$ 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:

$$H_C = \begin{bmatrix} a_{1,1} & \cdots & a_{1,69} \\ \cdots & & \cdots \\ a_{12,1} & \cdots & a_{12,69} \end{bmatrix}$$

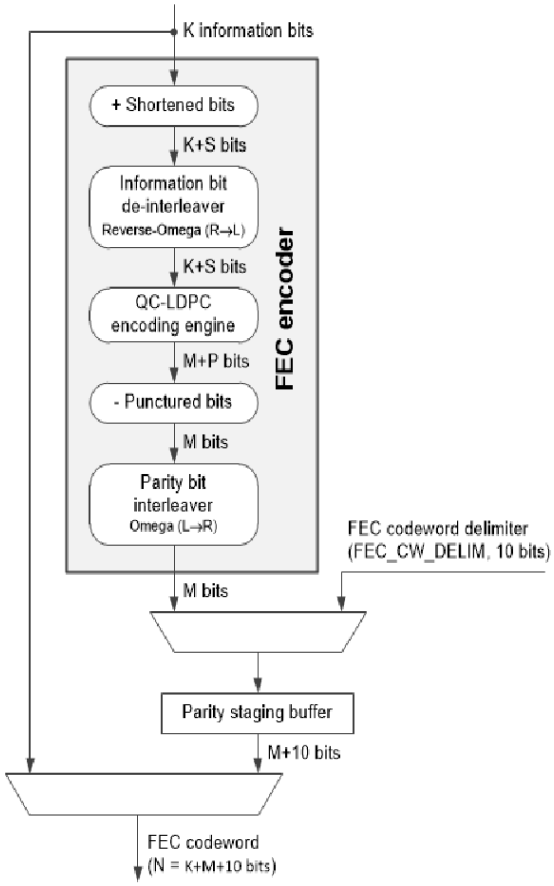


**Figure 142–6—FEC encoder**

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

The compact form of parity-check matrix $H_c$ is shown in Table 142–1.

**Table 142–1—Compact form of parity-check matrix $H_c$**

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | –1 | –1 | 105 | -1 | -1 | 137 | –1 | –1 | 0 | 209 | 53 |
| –1 | 0 | 91 | –1 | 170 | 46 | -1 | 118 | 208 | -1 | –1 | -1 |
| –1 | –1 | –1 | -1 | 250 | –1 | 104 | 15 | 0 | –1 | 252 | 93 |
| 60 | 0 | 74 | 87 | –1 | 37 | –1 | –1 | –1 | 123 | –1 | –1 |
| 169 | –1 | –1 | –1 | –1 | –1 | 238 | 93 | 0 | –1 | 39 | 216 |
| –1 | 0 | 237 | 43 | 195 | 49 | –1 | –1 | –1 | 41 | –1 | –1 |
| 11 | -1 | 202 | -1 | 139 | 150 | –1 | –1 | 0 | 191 | –1 | –1 |
| -1 | 0 | -1 | 165 | –1 | –1 | 228 | 228 | –1 | –1 | 159 | 57 |

**Table 142–1—Compact form of parity-check matrix $H_c$ *(continued)***

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 143 | -1 | -1 | -1 | -1 | 65 | -1 | -1 | 0 | 211 | 69 | 9 |
| -1 | 0 | 201 | 180 | 135 | -1 | 225 | 78 | -1 | -1 | -1 | -1 |
| -1 | -1 | 136 | -1 | -1 | -1 | 247 | -1 | 0 | 217 | 37 | 130 |
| 222 | 0 | -1 | 80 | 92 | 177 | -1 | 16 | -1 | -1 | -1 | -1 |
| -1 | -1 | 178 | 227 | -1 | 144 | -1 | 0 | -1 | 243 | 134 | -1 |
| 59 | 0 | -1 | -1 | 147 | -1 | 191 | -1 | 251 | -1 | -1 | 130 |
| -1 | -1 | 239 | 221 | -1 | 70 | -1 | 48 | 0 | 97 | -1 | -1 |
| 218 | 0 | -1 | -1 | 1 | -1 | 177 | -1 | -1 | -1 | 201 | 238 |
| -1 | -1 | 183 | 77 | -1 | 95 | -1 | 0 | -1 | 252 | 49 | -1 |
| -1 | 0 | -1 | -1 | -1 | -1 | 255 | -1 | 44 | -1 | -1 | -1 |
| 178 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | 123 | -1 | -1 | -1 |
| -1 | -1 | 217 | 0 | -1 | 221 | -1 | -1 | -1 | -1 | -1 | -1 |
| -1 | 0 | -1 | -1 | 13 | -1 | -1 | 62 | -1 | -1 | -1 | -1 |
| -1 | -1 | 232 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | 104 | -1 |
| -1 | -1 | -1 | -1 | -1 | -1 | 192 | 0 | -1 | -1 | -1 | 144 |
| -1 | -1 | -1 | -1 | 98 | 192 | -1 | -1 | 0 | -1 | -1 | -1 |
| 105 | 0 | -1 | 16 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | 169 | -1 | -1 | 128 | -1 | 0 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | -1 | 142 | -1 | -1 | -1 | 0 | -1 | 129 | -1 |
| 19 | 0 | -1 | -1 | -1 | -1 | 51 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | -1 | -1 | 214 | -1 | -1 | -1 | 0 | -1 | 162 |
| -1 | -1 | -1 | 252 | -1 | -1 | -1 | -1 | -1 | -1 | 157 | 0 |
| 126 | -1 | -1 | -1 | 225 | -1 | -1 | 0 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | 96 | -1 | -1 | -1 | -1 | 0 | 41 | -1 | -1 |
| -1 | 0 | 129 | -1 | -1 | -1 | 195 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | 60 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | 222 | -1 |
| 211 | -1 | -1 | -1 | -1 | 51 | 0 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | 29 | -1 | 175 |
| -1 | 0 | -1 | -1 | 23 | -1 | -1 | 112 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | -1 | 108 | -1 | 172 | -1 | -1 | 0 | -1 | -1 |
| -1 | -1 | -1 | 17 | -1 | 100 | -1 | 0 | -1 | -1 | -1 | -1 |
| -1 | 0 | 19 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 145 |
| 247 | -1 | 76 | -1 | -1 | -1 | -1 | -1 | 0 | -1 | -1 | -1 |

**Table 142–1—Compact form of parity-check matrix $H_c$ *(continued)***

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | -1 | -1 | -1 | -1 | 19 | -1 | -1 | -1 | -1 | 139 | 0 |
| 255 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | 39 | -1 |
| -1 | 0 | -1 | -1 | -1 | -1 | 219 | -1 | 153 | -1 | -1 | -1 |
| -1 | -1 | -1 | 219 | 0 | 235 | -1 | -1 | -1 | -1 | -1 | -1 |
| 85 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | -1 | -1 | -1 | 36 |
| -1 | -1 | 77 | -1 | 0 | -1 | 236 | -1 | -1 | -1 | -1 | -1 |
| -1 | 0 | -1 | 198 | -1 | -1 | -1 | -1 | -1 | 193 | -1 | -1 |
| -1 | -1 | -1 | 165 | -1 | -1 | -1 | -1 | 0 | -1 | 203 | -1 |
| -1 | -1 | -1 | -1 | -1 | -1 | 136 | 0 | -1 | 145 | -1 | -1 |
| -1 | -1 | 2 | -1 | -1 | -1 | -1 | 0 | -1 | -1 | 94 | -1 |
| -1 | -1 | -1 | -1 | 135 | -1 | -1 | -1 | 0 | -1 | -1 | 91 |
| 246 | 0 | -1 | -1 | -1 | 4 | -1 | -1 | -1 | -1 | -1 | -1 |
| 94 | -1 | -1 | 36 | -1 | -1 | 0 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | 101 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | -1 | 22 |
| -1 | -1 | -1 | -1 | -1 | 251 | -1 | 22 | 0 | -1 | -1 | -1 |
| -1 | 0 | -1 | -1 | 121 | -1 | -1 | -1 | -1 | -1 | 194 | -1 |
| -1 | -1 | 217 | -1 | 0 | -1 | 159 | -1 | -1 | -1 | -1 | -1 |
| -1 | -1 | -1 | 171 | -1 | 109 | -1 | -1 | -1 | -1 | -1 | 0 |
| 242 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3 | 0 |
| -1 | 0 | -1 | -1 | -1 | -1 | 10 | -1 | -1 | -1 | -1 | 212 |
| -1 | -1 | 48 | -1 | -1 | -1 | -1 | 0 | -1 | 140 | -1 | -1 |
| -1 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | -1 | 46 | 43 | -1 |
| -1 | -1 | -1 | 228 | 0 | -1 | -1 | -1 | -1 | -1 | 153 | -1 |
| 129 | -1 | -1 | -1 | -1 | 140 | -1 | -1 | -1 | -1 | -1 | 0 |
| -1 | -1 | -1 | -1 | -1 | -1 | 5 | -1 | 0 | 58 | -1 | -1 |
| 19 | -1 | -1 | -1 | 46 | -1 | -1 | -1 | 0 | -1 | -1 | -1 |
| 58 | 0 | 172 | 39 | 242 | 193 | 25 | 120 | 16 | 202 | 207 | 69 |
| 27 | -1 | 42 | 234 | 228 | 241 | 94 | 192 | 0 | 215 | 109 | 88 |

NOTE—A CSV file containing the entire parity-check matrix Hc show in Table 142–1 is available at: **{URL}**

**Editor's Note (to be removed prior to publication): Link to the CSV file containing matrix shown in Table 142–1 to be added here prior to publication.**

### 142.2.4.3 Encoding operation

The encoding process shall be as follows:

— A group of K information bits $u = [u_1, u_2, ..., u_K]$ 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.

— A total of S zero padding bits are appended at the end of u to form the full-length information bit block $u^* = [u \mid 0, ..., 0]$, which is then sent to the information bit de-interleaver module, which in turn produces the bit-de-interleaved sequence $u'' = \pi^{-1}_{info}(u^*)$.

— The de-interleaved LDPC information bits u" is sent to the QC-LDPC Encoding Engine, and used to compute parity-check bits p" with the parity-check matrix H, which is then interleaved to get $p^* = \pi_{parity}(p'')$.

— $M + P$ parity bits $p^* = [p_1, p_2, ..., p_M \mid p_{M+1}, ..., p_{M+P}]$ are sent to the puncturing block.

— The last P bits of $p^*$ are truncated, and M parity bits $p = [p_1, p_2, ..., p_M]$ are being copied to the output of the encoder to form the parity check bits.

— The FEC codeword without delimiter is $c = [u \mid p] = [u_1, u_2, ..., u_K \mid p_1, p_2, ..., p_M]$, such that $[u'' \mid p''] H^T = 0$.

— A 10-bit delimiter (FEC_CW_DELIM) is appended producing an output FEC codeword of bit length $N = K + M + 10$ bits.