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. ~~Annex 142A gives an example of LDPC(16952,14392)~~ FEC ~~encoding and interleaving~~encoder test vectors are provided in Annex 142A.

142.2.4.1 Low Density Parity Check coding

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

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

- the LDPC parity check matrix is a 12–by–69 ~~quasi~~array of circulant sub-~~cyclic matrix,~~ 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_{min}~~S = ~~20~~14592 - K);
- the number of punctured parity check bits, P (P = 512);
- the number of parity-check bits after puncturing, M (M = 3072 - ~~512~~P = 2560);
- the ~~number~~ length of the FEC encoder output ~~bits,~~ + delimiter is N ~~(~~where N = K + M~~, FEC codeword, whose size depends on the burst length pattern to determine shortening length);~~ + 10-bits and $N_{max} = K_{max} + M$ + 10-bits = ~~16952~~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.~~849~~848. Codes with lower code rates/shorter block length shall be obtained through shortening. The puncturing length and location are fixed for all scenarios~~.~~.

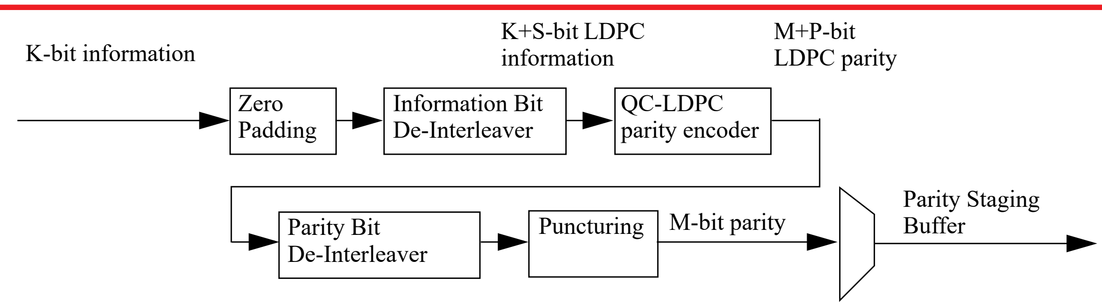

Figure 142–1—FEC encoder

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.

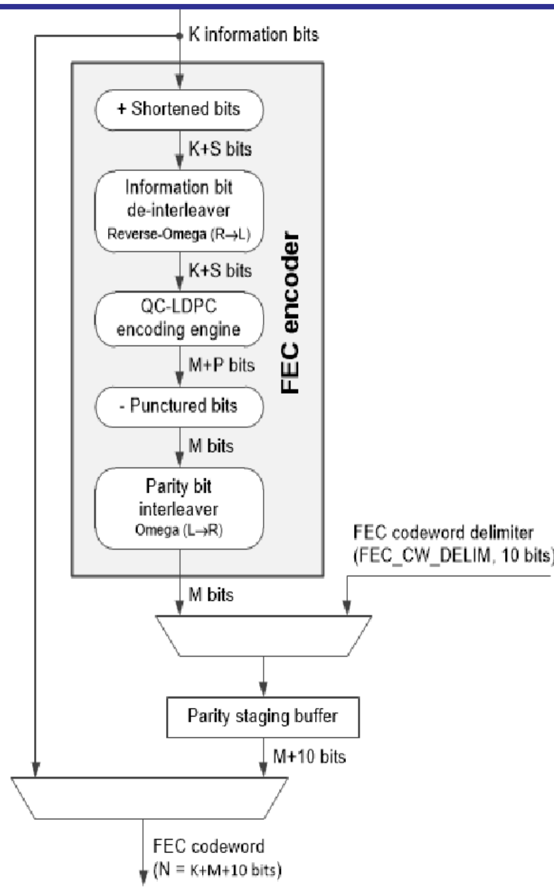

Figure 142–6—FEC encoder

142.2.4.2 ~~LDPC encoder~~

142.2.4.3 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 $A_{i,j}$:

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

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:

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

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
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

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	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
-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

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	-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.

~~A fixed amount (512 bits) and locations of the parities are punctured on the full LDPC matrix; a minimum amount (200 bits) and locations of the user bits are shortened on the full LDPC matrix. The effective maximum code rate 0.849. The codeword information/parity location assignment is shown in Figure 142–2.~~

Figure 142–7—Codeword information/parity location assignments

NOTE—~~When the last codeword of an upstream burst is shortened, the shortening bits are at the end of the transmitted user bits effectively expanding the number of zero bits (see Figure 142–2).~~

142.2.4.4 Encoding operation

The ~~Encoding Process~~ 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 (see Figure 142–2)~~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 ~~parity encoder~~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.

— ~~At the encoder output~~ 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~~"+"~~" | 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.