

### 142.2.4 FEC encoder

The Nx25G-EPON PCS shall encode the transmitted data stream using [LDPC\(16952,14392\)](#) a quasi-cyclic LDPC FEC, defined in [142.2.4.1](#). FEC encoder test vectors are provided in Annex 142A.

#### 142.2.4.1 Low Density Parity Check density parity check coding

The full LDPC code is defined by a  $(M + P) \times (K + S + M + P) = 3072 \times 17664$  size parity-check matrix  $H$  composed by a  $12 \times 69$  array of  $256 \times 256$  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  $256 \times 256$ . 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

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

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
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
-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

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**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	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  $H_c$  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.**

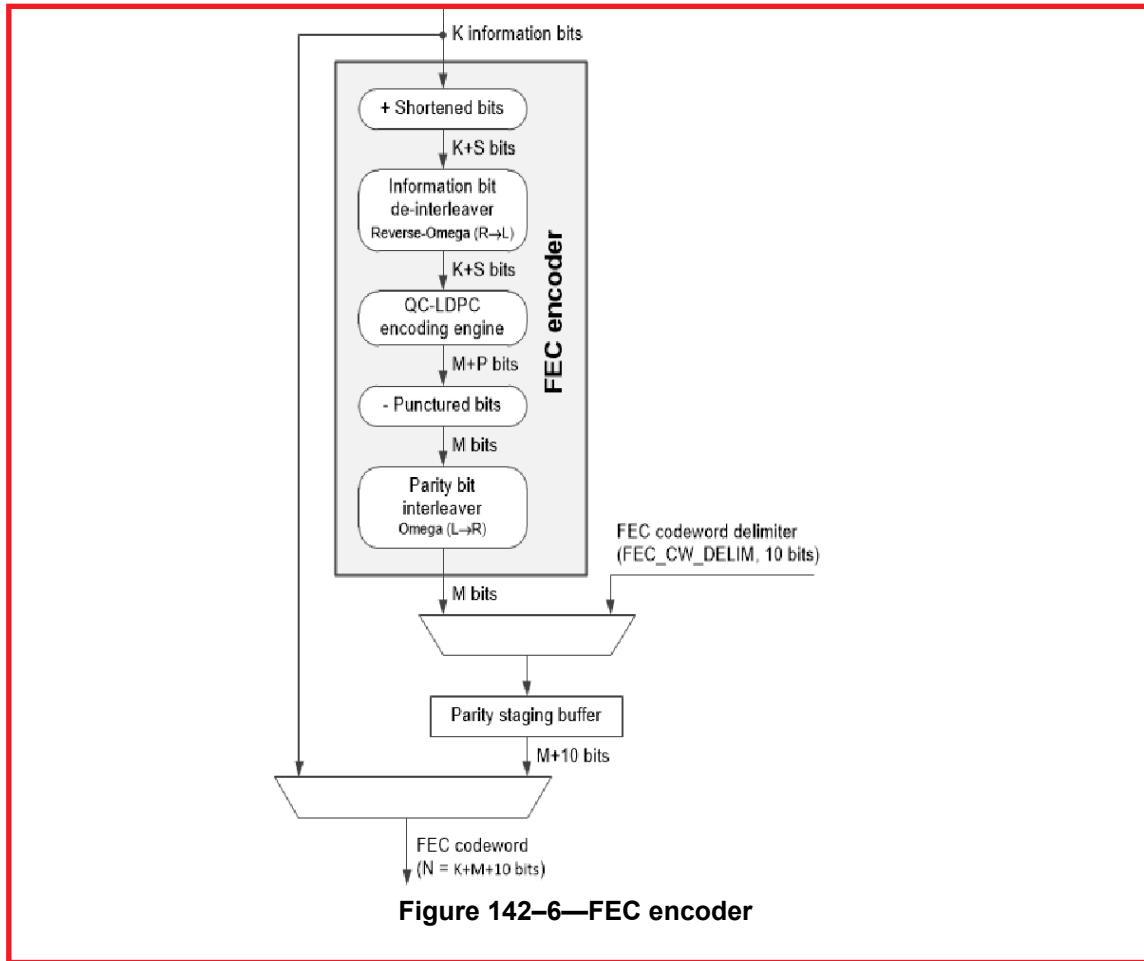
#### 142.2.4.2 FEC encoder processing

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 142.2.4.1) with circulant size  $Z = 256$ ; LDPC user bit length before shortening is  $57 \times 256 = 14592$ , the parity bit

- length before puncturing is  $12 \times 256 = 3072$ ; 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.



**Figure 142-6—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.

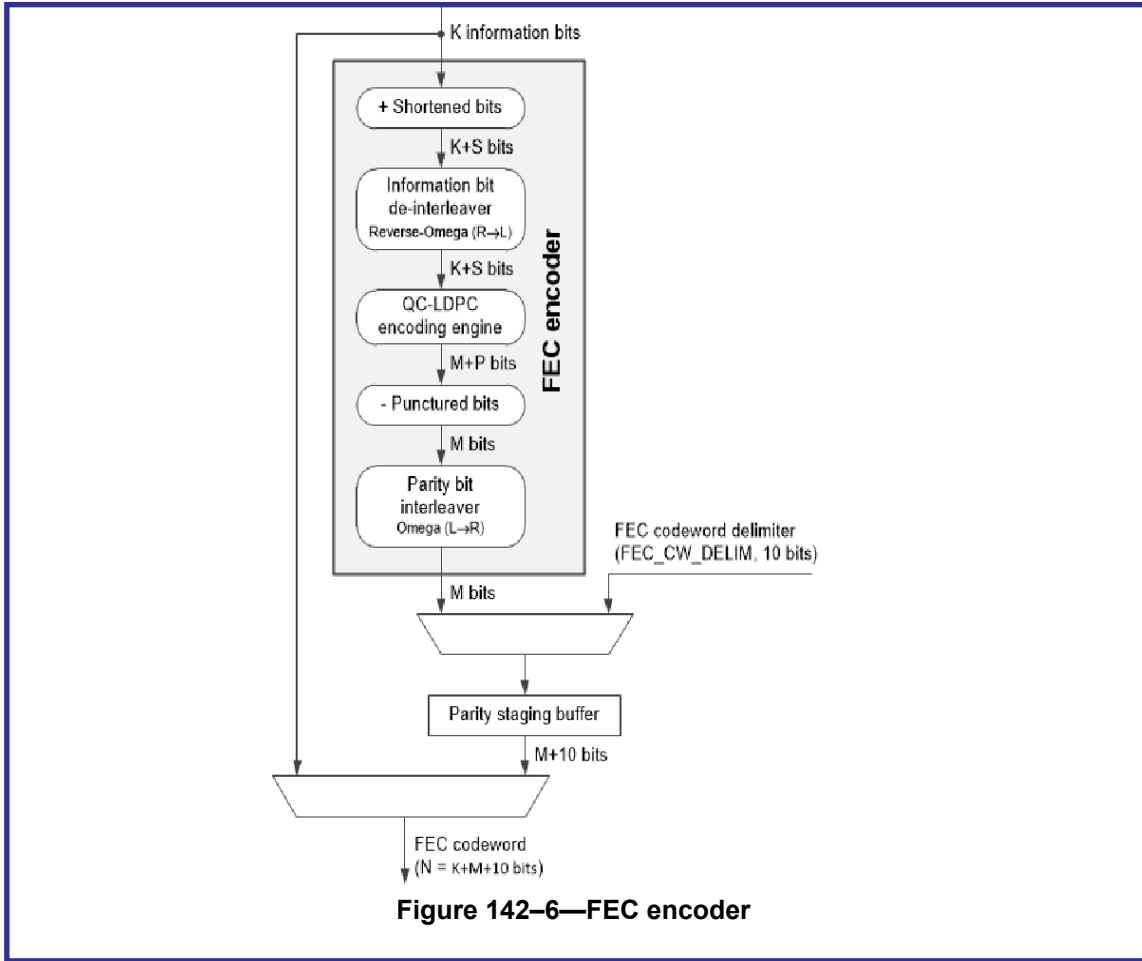


Figure 142-6—FEC encoder

### 142.2.4.3 LDPC-encoding-engine

The full LDPC code is defined by a  $(M + P) \times (K + S + M + P) = 3072 \times 17664$  size parity-check matrix  $H$  composed by a  $12 \times 69$  array of  $256 \times 256$  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  $256 \times 256$ . 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.

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

**Table 142-2—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
-1	-1	-1	252	-1	-1	-1	-1	-1	-1	157	0
126	-1	-1	-1	225	-1	-1	0	-1	-1	-1	-1

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**Table 142–2—Compact form of parity-check matrix  $H_c$  (continued)**

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
-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
-1	-1	-1	-1	-1	-1	-1	0	-1	46	43	-1
-1	-1	-1	228	0	-1	-1	-1	-1	-1	153	-1

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**Table 142–2—Compact form of parity-check matrix  $H_c$  (continued)**

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
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  $H_c$  shown 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.~~

#### 142.2.4.4 Encoding operation

The encoding process [therefore](#) shall be as follows:

- A group of  $K$  information bits  $u = [u_1, u_2, \dots, u_K]$  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  $u^* = [u \mid 0, \dots, 0]$ , which is then sent to the information bit de-interleaver module, which in turn produces the bit-de-interleaved sequence  $u'' = \pi_{\text{info}}^{-1}(u^*)$ .
- 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  $p^* = \pi_{\text{parity}}(p'')$ .
- $M + P$  parity bits  $p^* = [p_1, p_2, \dots, p_M \mid p_{M+1}, \dots, p_{M+P}]$  are sent to the puncturing block.
- The last  $P$  bits of  $p^*$  are truncated, and  $M$  parity bits  $p = [p_1, p_2, \dots, p_M]$  are being copied to the output of the encoder to form the parity check bits.
- The FEC codeword without delimiter is  $c = [u \mid p] = [u_1, u_2, \dots, u_K \mid p_1, p_2, \dots, p_M]$ , 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.~~

The LDPC encoder 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.