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Abstract	For the CTC and mobile cellular operation of 802.16, FEC structure should satisfy some requirements. The requirements include the codeword length and the robustness of FEC against the mobility. In this contribution, we propose a new FEC structure suitable for CTC and mobile cellular operation of 802.16 OFDMA.
Purpose	To propose a new FEC structure for CTC and mobile cellular operation of 802.16 OFDMA.
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FEC structure suitable for CTC and mobile Cellular Operation of 802.16 OFDMA

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Introduction

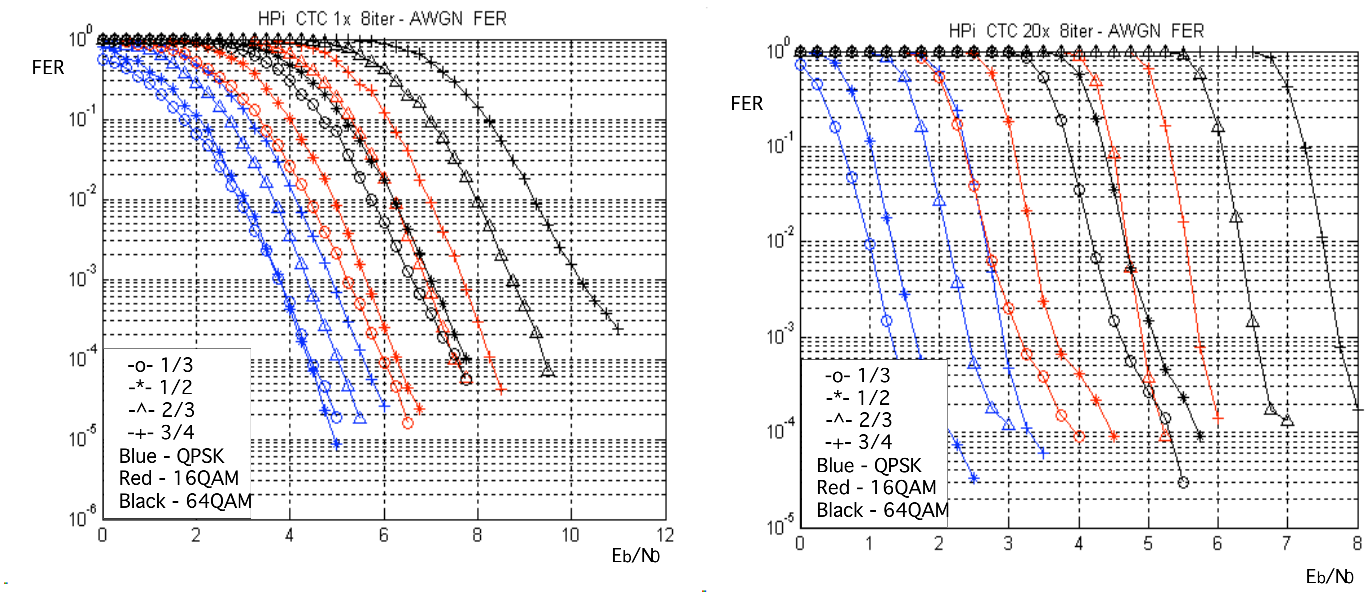
For the CTC and mobile cellular operation of 802.16 OFDMA mode, new requirements should be defined. In this contribution, new requirements are presented and a FEC structure that satisfies the new requirements is proposed.

Requirements for the FEC structure

Requirement for CTC encoding

Like other Turbo code families, the convolutional Turbo code (CTC) shows that its link performance is very sensitive to the codeword length. Figure 1 shows the BER performance of various combinations of CTC rate and modulation in AWGN. The number of iteration is eight. Figure 1 (a) and (b) show BER performances when the allocated subchannel(s) are one and 20, respectively. The graphs show that the BER performance for large codeword is superior to the short codeword at most 2.5 dB in Eb/No.

In 802.16, it is assumed that the information bit size for a physical burst varies in large range (from 48 to thousands bits). Thus, it happens to have very short codeword. However, it should be guaranteed that the whole information bits for a burst are to be encoded as one codeword. It makes the coding gain for a long information bits to be maximized.



(A) (B)

Figure1. BER performance of CTC with different codeword size.

Requirement Mobile cellular operation

In 802.16 OFDMA mode, adaptive modulation and coding (AMC) is exploited against the long and short term fading and path loss. In mobile cellular operation, the difference between channel conditions when it is reported (feedbacked) and it is applied for AMC is inevitable. Thus, any mobile system should provide some countermeasures against the difference. For example, the margin for SNR threshold for each AMC level is possible solution.

It is known that Hybrid Automatic Request (HARQ) is very efficient against the channel quality difference. In case of the previous transmission failure (NACK), HARQ schemes retransmit more redundancy and receiver combines whole redundancy received. The combining makes more SNR and coding gain against the change of channel condition.

There are many variants in HARQ schemes. Among them, chase combining (CC) and incremental redundancy (IR) are sited in many literatures. When the previous transmission is failed CC sends the same copy that was sent in the previous transmission and IR sends part of codeword that may different from previous first transmission. The IR scheme shows better performance due to the additional coding gain over the CC. Thus, the IR scheme is very viable solution for 802.16d OFDMA FEC against the mobility.

For the implementation of IR scheme, the generation of subpackets from the mother codeword is necessary. Further, the subpacket should show a complementary property for better performance.

For CTC and mobile Cellular Operation of 802.16 OFDMA, the following requirements should be satisfied with FEC structure.

1. The whole information bits for a burst are to be encoded as one codeword
2. FEC structure should support IR type HARQ scheme.
3. For the support of IR type HARQ scheme, the subpacket should show complementary property.

Proposed DL/UL FEC structure for OFDMA mode

Generation of CTC encoded codeword

The mother code is rate 1/3 convolution Turbo code (CTC) and the polynomials defining the connections are described in octal and symbol notations as follows:

- For the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
- For the Y parity bit: 0xD, equivalently $1+D^2+D^3$
- For the W parity bit: 0x9, equivalently $1+D^3$

The 1/3 CTC shows better BER performance over 1/2 CTC. Figure 2 compares BER performance of the two codes. The more coding gain will be reflected on the HARQ performance too. The increase of coding gain is minimal with the lower code rate CTC.

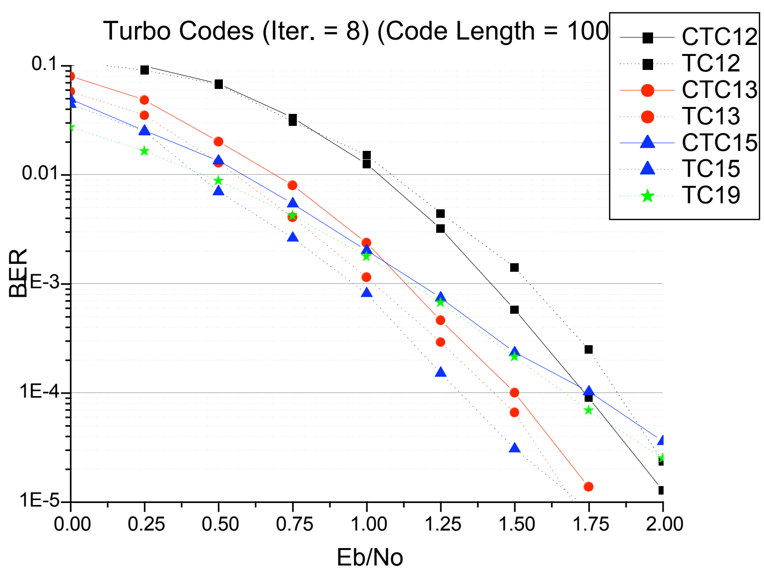


Figure 2. BER performance of 1/2 CTC and 1/3 CTC

The whole information bit sequence of length Nep is encoded into a codeword of length 3*Nep. Nep is limited to the allowable number of {48, 96, 144, 192, 288, 384, 480, 960, 1920, 2880, 3840, 4800}. Because the increase of CTC coding gain is saturated when the length of input is larger than 5000 bits the maximum of Nep is 4800. Figure 3 shows block diagram of CTC encoder. The output sequence is represented as follows.

$$A, B, Y_1, W_1, Y_2, W_2 =$$
$$A_1, A_2, \cdots, A_N, B_1, B_2, \cdots, B_N, Y_{11}, Y_{12}, \cdots, Y_{1N}, W_{11}, W_{12}, \cdots, W_{1N}, Y_{21}, Y_{22}, \cdots, Y_{2N}, W_{21}, W_{22}, \cdots, W_{2N}$$

CTC interleaving scheme is same as described in the current 802.16dr3 specifications except the new parameters for the allowable Nep.

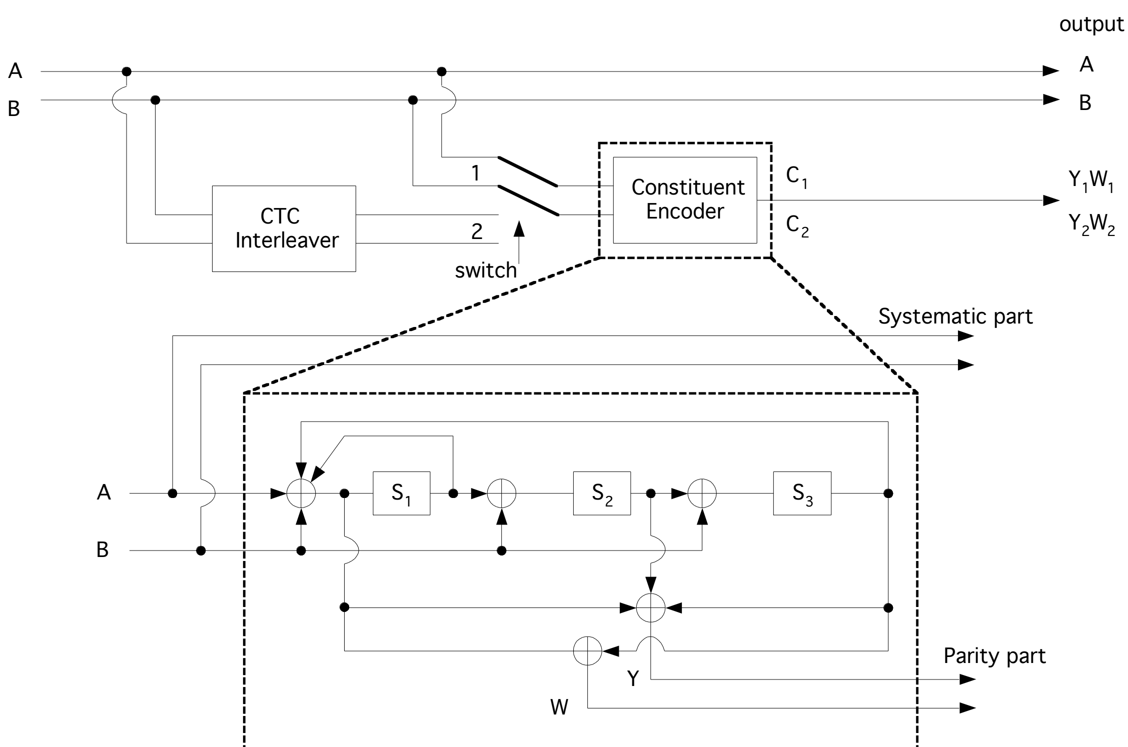


Figure 3. Block diagram of rate 1/3 CTC encoder

Subpacket generation

Proposed FEC structure punctures mother codeword to generate subpacket with various coding rates. The subpacket is also used as HARQ packet transmission. Figure 4 shows block diagram of subpacket generation. 1/3 CTC encoded codeword goes through interleaving block and the puncturing is performed. The puncturing is performed to select the consecutive interleaved bit sequence that starts at any point of whole codeword. For the first transmission, the subpacket is generated to select the consecutive interleaved bit sequence that starts from the first bit of the systematic part of the mother codeword. The length of the subpacket is chosen according to the needed coding rate reflecting the channel condition. The first subpacket can also be used as a codeword with the needed coding rate for a burst where HARQ is not applied.

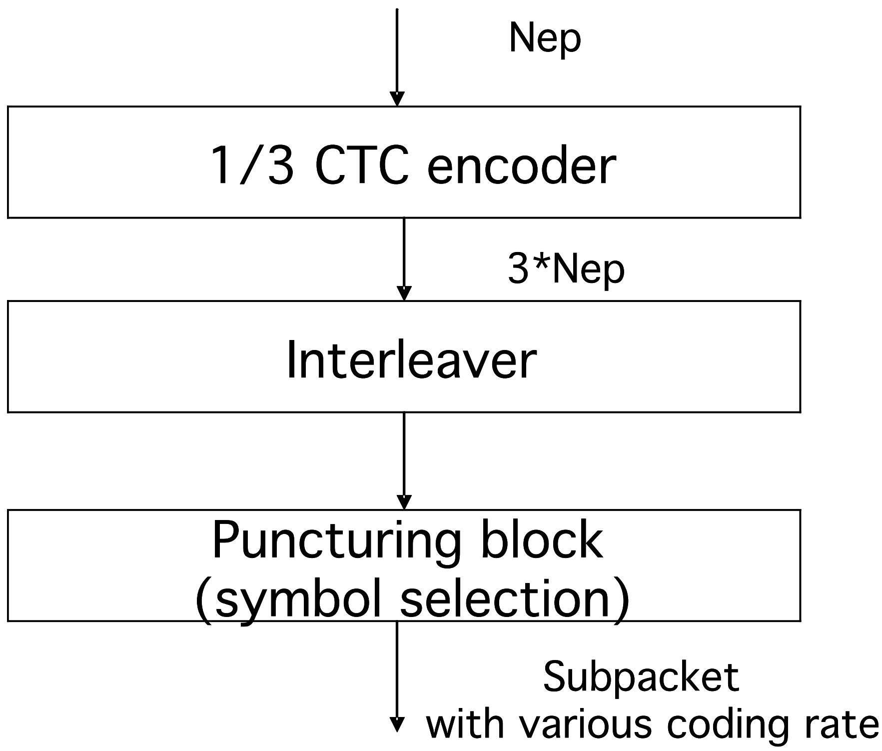


Figure 4. Block diagram of subpacket generation

Interleaving block: QCTC (Quasi Complementary Turbo Code)

A puncturing process is very common to generate various coding rates with Turbo code families. However, the puncturing should guarantee the complementary characteristics of the punctured codeword. In other words, the parity bits of the punctured codeword should be chosen uniformly from the parity bits of a constituent encoder. The parity bits of the punctured codeword should have even number of parities from the two constituent encoders. We call such Turbo code as complementary Turbo code. Because the puncturing is just a simple process to select the subpacket, the proposed FEC structure rely such complementary property on the interleaving block.

Figure 5 shows block diagram of the interleaving scheme of the proposed FEC structure. At first, the CTC encoder output is separated into a sublock. Then the interleaving is applied for the bit sequence within the sublock. It guarantees the uniformity of the interleaved codeword. Next, Symbol grouping is performed such that the parity bits from the two constituent encoders are interlaced bit by bit. The systematic part of the 1/3 CTC encoder is located at the head of the interleaved codeword. In this way, the proposed FEC structure ensures the quasi complementary characteristics of the interleaved codeword and thus, complementary characteristics of the subpacket. We just say "quasi complementary" for the case of breaking the complementariness of few bits after puncturing.

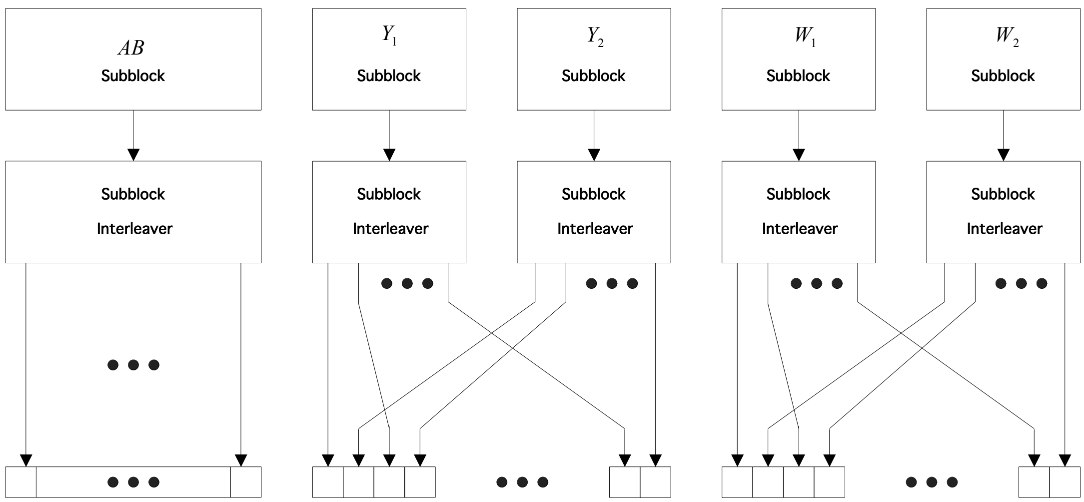


Figure 5. Block diagram of the interleaving scheme

Symbol selection

Lastly, symbol selection is performed to generate the subpacket. We call the puncturing block as the symbol selection in the viewpoint of subpacket generation.

Mother code is transmitted with one of subpackets. The symbols in a subpacket are formed by selecting specific sequences of symbols from the interleaved CTC encoder output sequence. The resulting subpacket sequence is a binary sequence of symbols for the modulator.

Let

k be the subpacket index when HARQ is enabled. k=0 for the first transmission and increases by one for the next subpacket;

N_{EP} be the number of bits in the encoder packet (N_{EP} = 48, 96, 144, 192, 288, 384, 480, 960, 1920, 2880, 3840, 4800);

N_{SCHk} be the number of subchannel(s) allocated for the k-th subpacket (1~480);

m_k be the modulation order for the k th subpacket ($m_{k=0}$ = 2 for QPSK, 4 for 16QAM, and 6 for 64-QAM); and

$SPID_k$ be the subpacket ID for the k-th subpacket, (for the first subpacket, $SPID_{k=0} = 0$).

Also, let the scrambled and selected symbols be numbered from zero with the 0-th symbol being the first symbol in the sequence. Then, the index of the i-th symbol for the k-th subpacket shall be

$$S_{k,i} = (F_k + i)\bmod(3 * N_{EP})$$

where $i = 0\ to\ L_K - 1$,

$$L_k = 48 * N_{SCHk} * m_k \text{, and}$$

$$F_k = (SPID_k * L_k)\bmod(3 * N_{EP})\,.$$

The N_{EP}, N_{SCHk} , and SPID values are determined by the access point and are provided to the access terminal through the MAP bursts. The m_k parameter is determined in the next subsection. The above symbol selection makes the followings possible.

1. The first transmission includes the systematic part of the mother code. Thus, it can be used as the codeword for a burst where the HARQ is not applied.
2. The location of the subpacket can be determined by the SPID itself without the knowledge of previous subpacket. It is very important property for HARQ retransmission.

Selection of Modulation order

Modulation order (m_k) is determined by the number of bits per subcarriers. For the same Nep, smaller number of the allocated subchannels (Nsch) means low coding rate and low modulation order, the larger number of the allocated subchannels (Nsch) means higher coding rate and higher modulation order. For DL, the modulation order (2 for QPSK, 4 for 16QAM, and 6 for 64QAM) shall be set for all the allowed transmission formats. For UL, only QPSK and 16 QAM are allowed.

The current 802.16d OFDMA mode, modulation order is determined by the channel condition. So the above description looks different. However, the modulation order determined also reflects the channel condition. Once the modulation order is determined for each Nep and Nsch combination, one can determine SNR threshold for each combination. Then the channel conditions reported from each user terminal can decide the possible combinations of Nep and Nsch for the current channel condition for each user terminal. Then, the selection of Nep and Nsch is a task of a system scheduler.

Suitability of the proposed FEC structure for CTC and mobility

As described above, the proposed FEC structure is suitable for CTC and mobile operation of cellular operation.

1. Full exploitation of CTC coding gain:
   A. The proposed structure encodes the whole information bit sequence of length Nep as one codeword.
   B. The proposed structure can generate the punctured codeword with various coding rate. The punctured codeword shows the property of QCTC which guarantees its CTC coding gain.
2. Efficient HARQ support:
   A. The proposed structure generates subpackets for HARQ transmission.
      i. The subpackets show the property of QCTC which guarantees its CTC coding gain.
      ii. IR scheme is possible (The subpacket can be different from the previous subpacket).
      iii. The location of each subpacket is independent of the previous subpacket.

Conclusions

The proposed FEC structure satisfies the CTC and mobile cellular operation of 802.16d OFDMA mode.

Proposed Text Changes

[Substitute IEEE P802.16-REVd/D3-2004 “8.4.9 Channel coding” with the following text.]

8.4.8 Channel coding and modulation

The channel coding and modulation schemes for DL/UL bursts and ranging channel are defined. The channel coding and modulation schemes for SICH, UL-DL-MAP are also defined.

8.4.8.1 Channel coding for DL/UL traffic burst

8.4.8.1.1 Padding

MAC PDU(or concatenated MAC PDUs) is a basic unit processed in this channel coding and modulation blocks. When the size of MAC PDU(or concatenated MAC PDUs) is not the element in the allowed set, '1's are padded at the end of MAC PDU(or concatenated MAC PDUs). The amount of the padding is the same as the difference between the size of the PDU(or concatenated MAC PDUs) and the smallest element in the allowed set that is not less than the size of the PDU(or concatenated MAC PDUs). The padded packet inputs into the CRC encoding block.

The allowed set is {48, 96, 144, 192, 288, 384, 480, 960, 1920, 2880, 3840, 4800, 9600, 14400, 19200, 24000} bits when no HARQ is applied. The allowed set is {32, 80, 128, 176, 272, 368, 464, 944, 1904, 2784, 3824, 4784, 9584, 14384, 19184, 23984} bits when HARQ is applied.

8.4.8.1.2 CRC encoding

When HARQ shall be applied to a padded packet, error detection is provided on the padded packet through a Cyclic Redundancy Check (CRC). When HARQ shall not be applied to a padded packet, no operation is done for the packet in the CRC encoding. The size of the CRC is 16 bits. The CRC parity bits are generated by the following cyclic generator polynomials:

$$g_{CRC}(D) = D^{16} + D^{12} + D^{5} + 1$$

Denote the bits in a padded packet by $d_1, d_2, d_3, \cdots, d_n$, and the parity bits are $p_1, p_2, p_3, \cdots, p_{16}$. n is the size of a padded packet. The encoding is performed in a systematic form, which means that in GF(2), the polynomial:

$$d_1 D^{n+15} + d_2 D^{n+14} + \cdots + d_n D^{16} + p_1 D^{15} + p_2 D^{14} + \cdots + p_{15} D^{1} + p_{16}$$

yields a remainder equal to 0 when divided by $g_{CRC}(D)$.

8.4.8.1.3 Fragmentation

When the size after the padding and CRC encoding is n*4800 bits they are separately processed by the block of 4800 bits and concatenated as the same order of the separation before modulation. No operation is performed on the size after the padding and CRC encoding is not more than 4800 bits.

8.4.8.1.4 Randomization

The randomization is performed on each allocation (burst), which means that for each allocation of a data block the randomizer shall be used independently.

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 1. Each data byte to be transmitted shall enter sequentially into the randomizer, MSB first. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The randomizer sequence is applied to the output from the fragmentation block. The bit issued from the randomizer shall be applied to the encoder.

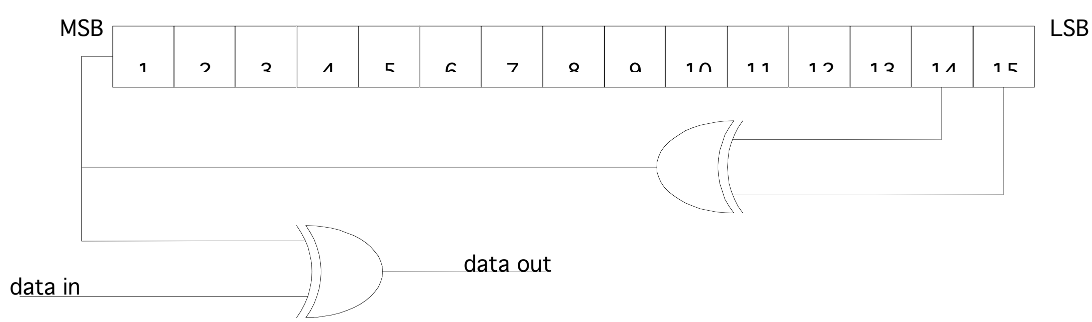


Figure 1 – PRBS of the randomizer

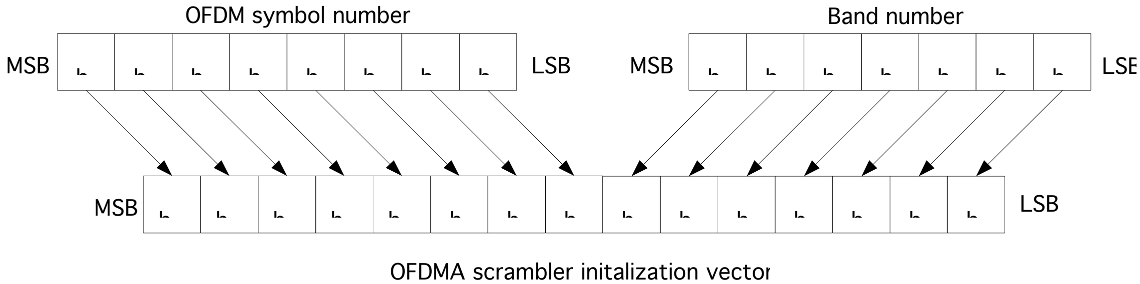


Figure 2 – Initialization construction for the PRBS of the randomizer

The scrambler is initialized with the vector created as shown in Figure 2. OFDMA symbol number is the number of the first OFDMA symbol where the burst is allocated. Band number is the number of the first band where the burst is allocated. OFDMA symbol number is counted after the preamble OFDMA symbols for DL and ranging OFDMA symbols for UL. The OFDMA symbol number and band number are counted from ‘0’.

The bits output from the randomizer are denoted by $r_1, r_2, r_3, \cdots, r_{N_{EP}}$, and this sequence is defined as encoder packet. N_{EP} is the number of the bits in an encoder packet and defined as encoder packet size. The values of N_{EP} are 48, 96, 144, 192, 288, 384, 480, 960, 1920, 2880, 3840, 4800.

8.4.8.1.5 Convolutional Turbo Code (CTC)

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 3. It uses a double binary CRSC (Circular Recursive Systematic Convolutional) code. The bits of the data to be encoded are alternatively fed to A and B, starting with the MSB of the first byte being fed to A, followed by the next bit being fed to B. The encoder is fed blocks of N_{EP} bits or N couples (N_{EP}=2*N bits). The encoder packet size N_{EP} shall be limited to:

$$48 \le N_{EP} \le 4800 \quad (1.)$$

The polynomials defining the connections are described in octal and symbol notations as follows:

- For the feedback branch: 0xB, equivalently $1 + D + D^3$ (in symbolic notation)
- For the Y parity bit: 0xD, equivalently $1 + D^2 + D^3$
- For the W parity bit: 0x9, equivalently $1 + D^3$

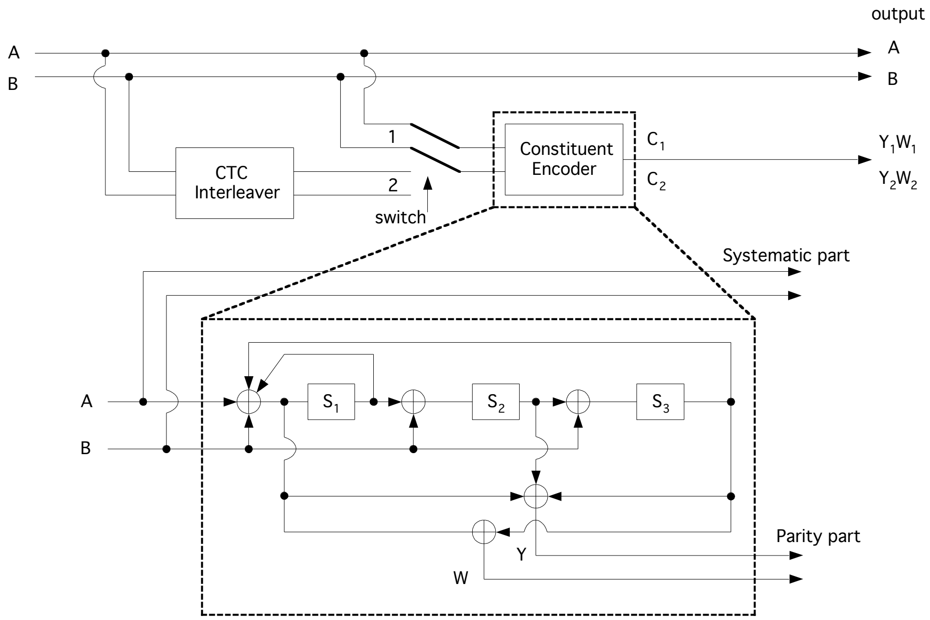


Figure 3 – Encoder block diagram

First, the encoder (after initialization by the circulation state S_{C_1}, see 0) is fed the sequence in the natural order (switch 1 in Figure 3) with incremental address $i = 1, 2, \cdots, N$. This first encoding is called C_1 encoding.

Then the encoder (after initialization by the circulation state S_{C_2}, see 0) is fed by the interleaved sequence (switch 2 in Figure 3) with incremental address $i = 1, 2, \cdots, N$. This second encoding is called C_2 encoding.

The order in which the encoded bits shall be fed into the interleaver is:

$$A, B, Y_1, W_1, Y_2, W_2 = A_1, A_2, \cdots, A_N, B_1, B_2, \cdots, B_N, Y_{11}, Y_{12}, \cdots, Y_{1N}, W_{11}, W_{12}, \cdots, W_{1N}, Y_{21}, Y_{22}, \cdots, Y_{2N}, W_{21}, W_{22}, \cdots, W_{2N} \quad (2.)$$

Table 1 – CTC Interleaver parameters

Data block size (byte)	N	P_0	P_1	P_2	P_3
6	24	7	12	0	12
12	48	11	24	0	24
18	72	11	6	0	6
24	96	7	48	24	72
36	144	17	74	72	2
48	192	11	96	48	144
60	240	13	120	60	180
120	480	13	240	120	360
240	960	13	480	240	720
360	1440	17	720	360	540
480	1920	17	960	480	1440
600	2400	17	1200	600	1800

8.4.8.1.5.1 CTC Interleaver

The CTC interleaver requires the parameters P_0, P_1, P_2, P_3, shown in Table 1.

The two-step interleaver shall be performed by:

Step 1 : Switch alternate couples

for $j = 1, 2, \cdots, N$

$if\,(j_{\mathrm{mod}\,2} == 0)\;\; let\,(B, A) = (A, B)$ (i.e. switch the couple)

Step 2 : $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the considered couple j.

for $j = 1, 2, \cdots, N$

$switch\;\; j_{\mathrm{mod}\,4}$:

$case\;\; 0 : i = (P_0 \cdot j + 1)_{\mathrm{mod}\,N}$

$case\;\; 1 : i = (P_0 \cdot j + 1 + N/2 + P_1)_{\mathrm{mod}\,N}$

$case\;\; 2 : i = (P_0 \cdot j + 1 + P_2)_{\mathrm{mod}\,N}$

$case\;\; 3 : i = (P_0 \cdot j + 1 + N/2 + P_3)_{\mathrm{mod}\,N}$

8.4.8.1.5.2 Determination of CTC circulation states

The state of the encoder is denoted S with the value calculated by $S = 4 \times s_1 + 2 \times s_2 + s_3$, $0 \le S \le 7$. The circulation states S_{C_1} and S_{C_2} are determined by the following operations:

- Initialize the encoder with state 0.
- Encode the sequence in the natural order for determination of S_{C_1} or in the interleaved order for determination of S_{C_2}.
- In both cases the final state of the encoder is S_{N-1}^{0}.

- According to the length N of the sequence, use Table 2 to find S_{C_1} or S_{C_2}.

Table 2 – Circulation state lookup table (S_C)

$N_{\bmod 7}$	S_{N-1}^0							
	0	1	2	3	4	5	6	7
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.4.8.1.6 Interleaving

Interleaving consists of sublock symbol separation, interleaving, and grouping.

8.4.8.1.6.1 Symbol separation

All of the encoded symbols shall be demultiplexed into 5 subblocks denoted AB, Y_1, W_1, Y_2 and W_2. The encoder output symbols shall be sequentially distributed into 5 subblocks with the first and second encoder output symbols going to the AB subblock, the third to the Y_1 subblock, the fourth to the Y_2 subblock, the fifth to the W_1 subblock, the sixth to the W_2 subblock, etc. The AB subblock is the symbol-by-symbol multiplexed sequence of the input sequence A and B.

$$AB = A_1, B_1, A_2, B_2, \cdots A_N, B_N$$

8.4.8.1.6.2 Subblock interleaving

The five subblocks shall be interleaved separately. For the AB subblock, the interleaving is performed by the unit of pair of two symbols (A_n, B_n). For other subblocks, the interleaving is performed by the unit of symbol. The sequence of interleaver output symbols for each subblock shall be generated by the procedure described below. The entire subblock of symbols (pairs for AB subblock) to be interleaved is written into an array at addresses from 0 to the number of the symbols (pairs for AB subblock) minus one (N-1), and the interleaved symbols (pairs for AB subblock) are read out in a permuted order with the i-th symbol (pair for AB subblock) being read from an address, A_i ($i = 0$ to $N-1$), as follows:

1. Determine the subblock interleaver parameters, m and J. Table 3 gives these parameters.

2. Initialize i and k to 0.

3. Form a tentative output address T_k according to the formula

$$T_k = 2^m (k \bmod J) + BRO_m(\lfloor k/J \rfloor),$$

where $BRO_m(y)$ indicates the bit-reversed m-bit value of y (i.e., BRO3(6) = 3).

4. If T_k is less than N, $A_i = T_k$ and increment i and k by 1. Otherwise, discard T_k and increment k only.

5. Repeat steps 3 and 4 until all N interleaver output addresses are obtained.

The parameters for the subblock interleavers are specified in Table 3.

Table 3 – The parameters for the subblock interleavers

N_{EP}	**N**	**Subblock Interleaver Parameters**	
		m	**J**
48	24	3	3

96	48	4	3
144	72	5	3
192	96	5	3
288	144	6	3
384	192	6	3
480	240	7	2
960	480	8	2
1920	960	9	2
2880	1440	9	3
3840	1920	10	2
4800	2400	10	3

8.4.8.1.6.3 Symbol grouping

The channel interleaver output sequence shall consist of the interleaved AB subblock sequence followed by a symbol-by-symbol multiplexed sequence of the interleaved Y_1 and Y_2 subblock sequences followed by a symbol-by-symbol multiplexed sequence of the interleaved W_1 and W_2 subblock sequences. The symbol-by-symbol multiplexed sequence of interleaved Y_1 and Y_2 subblock sequences shall consist of the first output bit from the Y_1 subblock interleaver, the first output bit from the Y_2 subblock interleaver, the second output bit from the Y_1 subblock interleaver, the second output bit from the Y_2 subblock interleaver, etc. The symbol-by-symbol multiplexed sequence of interleaved W_1 and W_2 subblock sequences shall consist of the first output bit from the W_1 subblock interleaver, the first output bit from the W_2 subblock interleaver, the second output bit from the W_1 subblock interleaver, the second output bit from the W_2 subblock interleaver, etc.

Figure 4 shows the interleaving scheme.

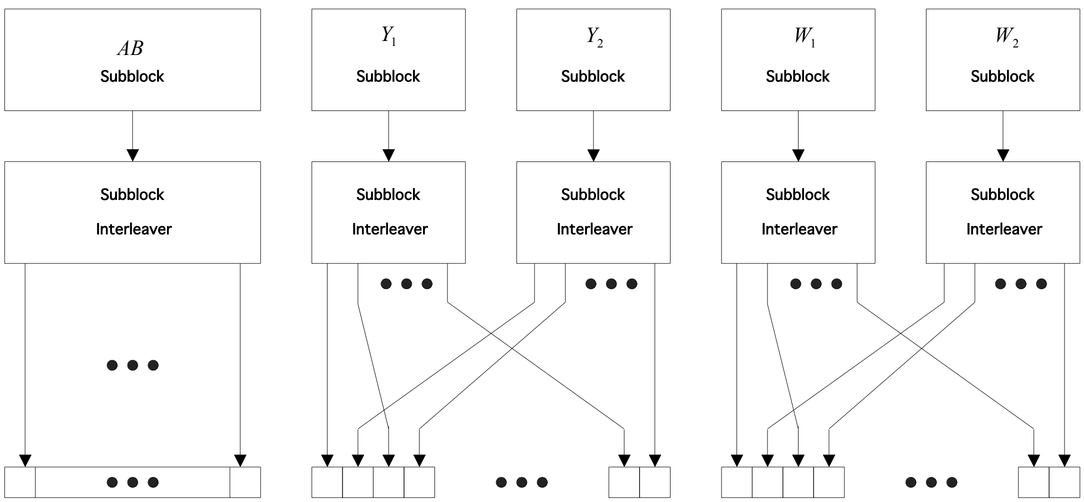


Figure 4 – Interleaving scheme (Subblock symbol separation, interleaving and grouping)

8.4.8.1.7 Symbol selection

Encoder packets are transmitted with one of subpackets. The symbols in a subpacket are formed by selecting specific sequences of symbols from the interleaved and scrambled CTC encoder output sequence. The resulting subpacket sequence is a binary sequence of symbols for the modulator.

Let

k be the subpacket index when H-ARQ is enabled. k=0 for the first transmission and increases by one for the next subpacket;

N_{EP} be the number of bits in the encoder packet (N_{EP} = 48, 96, 144, 192, 288, 384, 480, 960, 1920, 2880, 3840, 4800);

N_{SCHk} be the number of subchannel(s) allocated for the k-th subpacket (1~480);

m_k be the modulation order for the k-th subpacket ($m_{k=0}$ = 2 for QPSK, 4 for 16-QAM, and 6 for 64-QAM); and

$SPID_k$ be the subpacket ID for the k-th subpacket, (for the first subpacket, $SPID_{k=0}$ = 0).

Also, let the scrambled and selected symbols be numbered from zero with the 0-th symbol being the first symbol in the sequence. Then, the index of the i-th symbol for the k-th subpacket shall be

$$S_{k,i} = (F_k + i) \bmod (3 * N_{EP})$$

where $i = 0 \ to \ L_K - 1$,

$$L_k = 48 * N_{SCHk} * m_k \text{, and}$$

$$F_k = (SPID_k * L_k) \bmod (3 * N_{EP}).$$

The N_{EP}, and N_{SCHk} values are determined by the access point and are provided to the access terminal through the MAP bursts. The m_k parameter is determined as specified in **Error! Reference source not found.**. for DL and **Error! Reference source not found.** for UL.

8.4.8.2 Channel coding for SICH and MAP bursts

8.4.8.2.1 Padding

Table 4 shows the allowed values of the number of bits for MAP bursts. Only the number of bits marked with ‘1’ is allowed for each MAP burst. The allowed values guarantee that the encoded and modulated symbol sequence for the input size fits into the integral number of subchannels. When the size of MAP burst is not the allowed value, '1's are padded at the end of burst. The amount of the padding is same as the difference between the size of the MAP burst and the smallest allowed value that is not less than the size of the burst. No padding is applied for SICH.

8.4.8.2.2 Randomization

The randomization is performed on the padded MAP burst. The Pseudo Random Binary Sequence (PRBS) generator shall be $1+X^{14}+X^{15}$ as shown in Figure 1. Each data byte to be transmitted shall enter sequentially into the randomizer, MSB first. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The bit issued from the randomizer shall be applied to the encoder. The scrambler is initialized for each MAP burst with 15 LSB of Cell ID. The randomization is not applied to SICH.

SICH message or the padded and randomized MAP burst is denoted by $r_1, r_2, r_3, \cdots, r_{N_{EP}}$, and these sequences are defined as encoder packet. N_{EP} is the number of the bits in an encoder packet and defined as encoder packet size. The allowed values of N_{EP} are shown in Table 4.

8.4.8.2.3 Convolutional Turbo Code (CTC)

For the encoder packet from the randomization block, CTC is applied as defined in 0. In this case, Nep is defined as Table 4.

8.4.8.2.3.1 CTC interleaver

CTC interleaver is the same as the one in 0. The CTC interleaver parameters for each N_{EP} are defined in Table 4.

Table 4 – CTC Interleaver parameters

N_{EP}	N	P0	P1	P2	P3	1/12QPSK	1/2QPSK	1/2 16QAM
64	32					1	0	0
80	40					1	0	0
96	48					1	1	1
128	64					1	0	0
144	72					1	1	0
160	80					1	0	0
176	88					1	0	0
192	96					1	1	1
208	104					1	0	0
240	120					1	1	0

256	128					1	0	0
272	136					1	0	0
288	144					1	1	1
304	152					1	0	0
320	160					1	0	0
352	176					1	0	0
368	184					1	0	0
384	192					1	1	1
400	200					1	0	0
416	208					1	0	0
432	216					1	1	0
464	232					1	0	0
480	240					1	1	1
496	248					1	0	0
512	256					1	0	0
528	264					1	1	0
544	272					1	0	0
576	288					1	1	1
592	296					1	0	0
608	304					1	0	0
624	312					1	1	0
640	320					1	0	0
656	328					1	0	0
688	344					1	0	0
704	352					1	0	0
720	360					1	1	0
736	368					1	0	0
752	376					1	0	0
768	384					1	1	1
800	400					1	0	0
816	408					1	1	0
832	416					1	0	0
848	424					1	0	0
864	432					1	1	1
880	440					1	0	0
912	456					1	1	0
928	464					1	0	0
944	472					1	0	0
960	480					1	1	1
976	488					1	0	0
992	496					1	0	0
1024	512					1	0	0

1040	520					1	0	0
1056	528					1	1	1
1072	536					1	0	0
1088	544					1	0	0
1104	552					1	1	0
1136	568					1	0	0
1152	576					1	1	1
1168	584					1	0	0
1184	592					1	0	0
1200	600					1	1	0
1216	608					1	0	0
1248	624					1	1	1
1264	632					1	0	0
1280	640					1	0	0
1296	648					1	1	0
1312	656					1	0	0
1328	664					1	0	0
1360	680					1	0	0
1376	688					1	0	0
1392	696					1	1	0
1408	704					1	0	0
1424	712					1	0	0
1440	720					1	1	1
1472	736					1	0	0
1488	744					1	1	0
1504	752					1	0	0
1520	760					1	0	0
1536	768					1	1	1
1552	776					1	0	0
1584	792					1	1	0
1600	800					1	0	0

8.4.8.2.3.2 Determination of CTC circulation states

Determination of CTC circulation states is same as 0.

8.4.8.2.4 CTC Puncturing

For SICH and the 1/12 coding rate QPSK MAP burst, no puncturing is applied. For the 1/2 coding rate QPSK and 16QAM MAP burst, all the output from W are punctured (only the output from Y is used).

8.4.8.2.5 Interleaving

The sublock interleaver defined in 0 is used as the outer interleaver. The outer interleaver parameters are defined in Table 5.

Table 5 – Outer Interleaver parameters

N	m	J	N	m	J	N	m	J
128			1440			2736		
160			1472			2752		
192			1488			2784		
240			1504			2816		
256			1536			2832		
288			1584			2848		
320			1600			2880		
352			1632			2928		
384			1664			2944		
416			1696			2976		
432			1728			3008		
480			1760			3040		
512			1776			3072		
528			1824			3104		
544			1856			3120		
576			1872			3168		
608			1888			3200		
624			1920			3216		
640			1952			3264		
704			1968			3312		
720			1984			3408		
736			2048			3456		
768			2064			3504		
800			2080			3552		
816			2112			3600		
832			2144			3648		
864			2160			3744		
912			2176			3792		
928			2208			3840		

960			2256			3888		
992			2272			3936		
1024			2304			3984		
1056			2336			4080		
1088			2368			4128		
1104			2400			4176		
1152			2432			4224		
1184			2448			4272		
1200			2496			4320		
1216			2528			4416		
1248			2544			4464		
1280			2560			4512		
1296			2592			4560		
1312			2624			4608		
1376			2640			4656		
1392			2656			4752		
1408			2720			4800		

8.4.8.2.6 Repetition

For SICH and the 1/12 coding rate QPSK MAP burst, the interleaved output of 1/3 coding is repeated 4 times. For 1/2 coding rate QPSK and 16QAM MAP burst, no repetition is applied.

8.4.8.3 Coded symbol scrambler

The coded symbol scrambler is performed on each burst, which means that the scrambler shall be used independently for each allocation of a data burst. Only the data durst shall be scrambled while SICH and MAP bursts will not be scrambled.

The coded symbol scrambler is performed on the FEC output bit stream, which means that each coded bit is scrambled by Pseudo Random Binary Sequence (PRBS). The PRBS generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 5. Each coded bit to be modulated shall enter sequentially into the coded symbol scrambler, MSB first. The seed value shall be used to calculate the scrambled bits, which are combined in an XOR operation with the serialized bit stream of each FEC output stream. The bit issued from the scrambler shall be applied to the modulator.

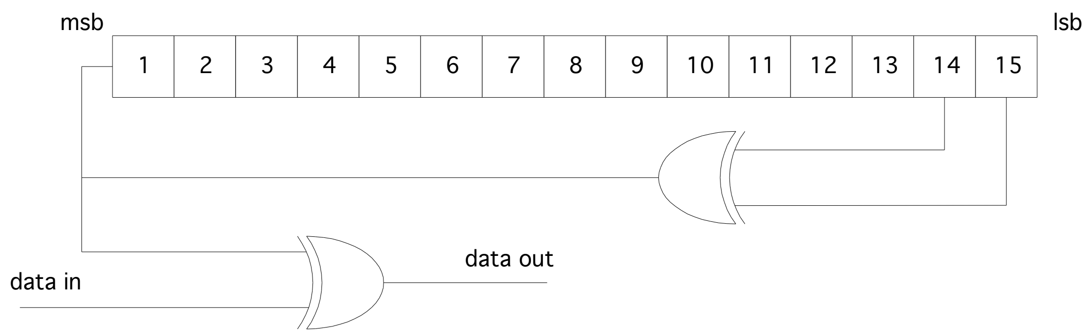


Figure 5 – PRBS of the coded symbol scrambler

The scrambler is initialized with the vector created as shown in Figure 6. AP specific identifier (Cell ID) and frame number which is counted from the start of transmission of AP shall be the initialization vector. The Cell ID and frame number for the initialization vector are truncated by 8 bits and 7 bits, respectively.

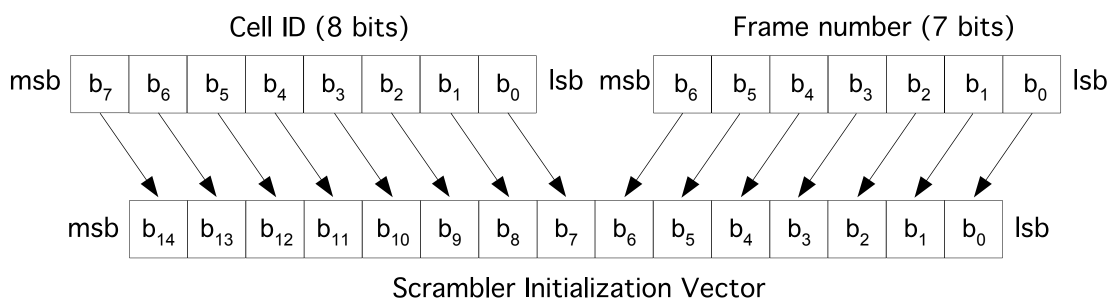


Figure 6 –Initialization construction for the PRBS of the Coded Symbol Scrambler