

TSG-RAN Working Group 1 meeting #9

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Dresden, Germany

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Agenda item:

Source: Nokia

Title: CR 25.222-010: Update for 4.2.3.2.3 of TS25.222-v300

Document for: Decision

The current text of the section 4.2.3.2.3 of TS 25.222 V3.0.0 explains the Turbo Code Internal Interleaver in a bit complicated way. The algorithm to generating indexes for turbo interleaving is proposed to rewrite in a clearer manner. Furthermore, the connection to 4.2.2.2 is shown as well.

4.2.3.2.3 Turbo code internal interleaver

Figure 4-34 depicts the overall 8-State PCCC Turbo coding scheme including Turbo code internal interleaver. A length of a turbo code internal interleaver is allowed to take any value from 320 to 5114 inclusive assigned according to the rules described in 4.2.2.2. The length is denoted by $K=K_i$ for a TrCH i . Elements of a turbo code internal interleaver are denoted by $T(k)$, $k = 1, 2, \dots, K$, and each of them stands for the original position of an k :th interleaved bit. The range of $T(k)$ is $1 \leq T(k) \leq K$.

The bits input to the turbo code internal interleaver are denoted by $o_{ir1}, o_{ir2}, o_{ir3}, \dots, o_{irK}$ and the bits after interleaving are denoted by $x_{ir1}, x_{ir2}, x_{ir3}, \dots, x_{irK}$, where i is a TrCH number and r is a code block number (for details see 4.2.2.2). The relationship between the two is defined by: $x_{irk} = o_{iT(k)}$ for $k = 1, 2, \dots, K$.

Every interleaving index $T(k)$ shall satisfy the following stepwise algorithm:

4.2.3.2.3.1 Algorithm for turbo interleaver

The following section specific notation is used for the parameters in the algorithm:

K	Length of Turbo Code Internal Interleaver for a TrCH
A	Number of rows of an A times B matrix
B	Number of columns of an A times B matrix
I	Prime number
m	Primitive root for I
ROP	Row order pattern
BR	Base sequence
Q	Minimum prime integer sequence
MIS	Minimum row order index sequence
i	Index in row dimension
j	Index in column dimension
i_0	Index in row dimension
z	Candidate index for Turbo Code Internal Interleaver

1. Assign values for the number of rows A , the number of columns B , the prime number I , and the primitive root m depending on K :

If $480 < K < 531$ then

$$A = 10;$$

$$I = 53;$$

$$B = 53;$$

$$m = 2;$$

else

$$A = 20;$$

find a least prime I such that $K \leq A*(I+1)$;

select B by

$$B = \begin{cases} I-1 & \text{if } K \leq A*(I-1), \\ I & \text{if } A*(I-1) < K \leq A*I, \\ I+1 & \text{if } A*I < K \leq A*(I+1). \end{cases}$$

select m from Table 2 below on the right side of I .

endif

2. Select the row order pattern ROP out of $Pattern_1$, $Pattern_2$, and $Pattern_3$ depending on K :

K ROP

320 to 480: $Pattern_1$; (inclusive)

481 to 530: $Pattern_3$;

531 to 2280: $Pattern_1$;

2281 to 2480: $Pattern_2$;

2481 to 3160: $Pattern_1$;

3161 to 3210: $Pattern_2$;

3211 to 5114: $Pattern_1$;

$Pattern_1$: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11}.

$Pattern_2$: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10}.

$Pattern_3$: {9, 8, 7, 6, 5, 4, 3, 2, 1, 0}.

3. Construct the base sequence $BR(j)$, $j=0,1,2,\dots, I-2$, by $BR(0)=1$ and

$$\underline{BR(j) = (m * BR(j-1)) \text{ modulo } I \text{ for } j = 1, 2, \dots, I-2.}$$

4. Select the minimum prime integer sequence $Q(i)$, $i=0,1,\dots, A-1$, such that $Q(0)=1$ and $\gcd(Q(i), I-1)=1$, $Q(i) > 6$, and $Q(i) > Q(i-1)$ for $i=1,2,\dots, A-1$. Here $\gcd(x, y)$ is the greatest common divisor of integers x and y .

5. Calculate the minimum row index sequence $MIS(i)$, $i=0,1,\dots, A-1$, by

$$\underline{MIS(i) = \begin{cases} ROP(i) * B & \text{if } B = I-1, \\ ROP(i) * B + 1 & \text{if } B = I \text{ or } B = I+1. \end{cases}}$$

6. Elements of $T(k)$ are same as ones obtained from the steps 6.1-6.4

6.1. Set $i_0 = 0$ and $k = 1$;

6.1.1 if $K=A*B$ and $B=(I+1)$ then $T(k)=MIS(i_0) + I$; $k = k + 1$; $i_0 = i_0 + 1$; endif

6.1.2 for $i = i_0, i_0 + 1, i_0 + 2, \dots, A-1$ do

6.1.3 $z = MIS(i) + BR(0)$;

6.1.4 if $z \notin K$ then $T(k) = z$; $k = k + 1$; else prune z ; endif

6.1.5 endfor

6.2. for $j = 1, 2, \dots, I - 2$ do

6.2.1 for $i = 0, 1, 2, \dots, A - 1$ do

6.2.2 $z = MIS(i) + BR(j * Q(i))$ modulo $(I - 1)$;

6.2.3 if $z \notin K$ then $T(k) = z$; $k = k + 1$; else prune z ; endif

6.2.4 endfor

6.2.9 endfor

6.3. if $(I - 1) < B$ then

6.3.1 for $i = 0, 1, 2, \dots, A - 1$ do

6.3.2 $z = MIS(i)$;

6.3.3 if $z \notin K$ then $T(k) = z$; $k = k + 1$; else prune z ; endif

6.3.4 endfor

6.3.9 endif

6.4. if $I < B$ then

6.4.1 $i_0 = 0$;

6.4.2 if $K = A * B$ then $T(k) = MIS(i_0) + 1$; $k = k + 1$; $i_0 = i_0 + 1$; endif

6.4.3 for $i = i_0, i_0 + 1, i_0 + 2, \dots, A - 1$ do

6.4.4 $z = MIS(i) + I$;

6.4.5 if $z \notin K$ then $T(k) = z$; $k = k + 1$; else prune z ; endif

6.4.6 endfor

6.4.5 endif

The total number of pruned indexes is $A * B - K$.

A length of a turbo code internal interleaver is allowed to take any value from 320 to 5114 inclusive assigned according to the rules described in 4.2.2.2. The length is denoted by $K = K_i$ for a TrCH i . Elements of a turbo code internal interleaver are denoted by $T(n)$, $n = 1, 2, \dots, K$, and each of them stands for the original position of an n :th interleaved bit. The range of $T(n)$ is $1 \leq T(n) \leq K$.

The bits input to the turbo code internal interleaver are denoted by $o_{ir1}, o_{ir2}, o_{ir3}, \dots, o_{irK}$ and the bits after interleaving are denoted by $x_{ir1}, x_{ir2}, x_{ir3}, \dots, x_{irK}$, where i is a TrCH number and r is a code block number (for details see 4.2.2.2). The relationship between the two is defined by: $x_{irn} = o_{irT(n)}$ for $n = 1, 2, \dots, K$.

Every interleaving index $T(n)$ shall satisfy the following stepwise algorithm:

1. Assign values for the row number R , the column number C , the prime p , and the primitive root g depending on K :

If $480 < K < 531$ then

$R = 10$;

$p = 53$;

$C = 53$;

$g = 2$;

else

$R = 20$;

find a least prime p such that $K \leq R * (p + 1)$;

select C by

$$C = \begin{cases} p - 1 & \text{if } K \leq R * (p - 1), \\ p & \text{if } R * (p - 1) < K \leq R * p, \\ p + 1 & \text{if } R * p < K \leq R * (p + 1). \end{cases}$$

select g from Table 2 below on the right side of p .

endif

2. Select the row order pattern ROP out of P_A , P_B , and P_C depending on K :

K ——— ROP

320 to 480: P_A ; (inclusive)

481 to 530: P_C ;

531 to 2280: P_A ;

2281 to 2480: P_B ;

2481 to 3160: P_A ;

3161 to 3210: P_B ;

3211 to 5114: P_A ;

P_A : {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11}.

P_B : {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10}.

P_C : {9, 8, 7, 6, 5, 4, 3, 2, 1, 0}.

3. Construct the base sequence $B(j)$, $j=0,1,2,\dots,p-2$, by $B(0)=1$ and

$$B(j) = g * B(j-1) \text{ modulo } p \text{ for } j = 1, 2, \dots, p-2.$$

4. Select the minimum prime integer sequence $q(i)$, $i=0,1,\dots,R-1$, such that $q(0)=1$ and $\text{gcd}(q(i), p-1)=1$, $q(i)>6$, and $q(i) > q(i-1)$ for $i=1,2,\dots, R-1$. Here $\text{gcd}(x,y)$ is the greatest common divisor of integers x and y .

5. Calculate the minimum row index sequence $MIS(i)$, $i=0,1,\dots, R-1$, by

$$MIS(i) = \begin{cases} ROP(i) * C & \text{if } C = p - 1, \\ ROP(i) * C + 1 & \text{if } C = p \text{ or } C = p + 1. \end{cases}$$

6. Elements of $T(n)$ are same as ones obtained from the steps 6.1-6.4:

6.1. Set $i_0=0$ and $n=1$;

6.1.1 if $K=R*C$ and $C=(p+1)$ then $T(n)=MIS(i_0)+p$; $n=n+1$; $i_0=i_0+1$; endif

for $i=i_0, i_0+1, i_0+2, \dots, R-1$ do

$m=MIS(i)+B(0)$;

if $m \notin K$ then $T(n)=m$; $n=n+1$; else prune m ; endif

6.1.5 endfor

6.2. for $j=0, 1, 2, \dots, p-2$ do

for $i=0, 1, 2, \dots, R-1$ do

$m=MIS(i)+B((j*q(i)) \text{ modulo } (p-1))$;

if $m \notin K$ then $T(n)=m$; $n=n+1$; else prune m ; endif

endfor

6.2.9 endfor

6.3. if $(p-1) < C$ then

for $i=0, 1, 2, \dots, R-1$ do

$m=MIS(i)$;

if $m \notin K$ then $T(n)=m$; $n=n+1$; else prune m ; endif

endfor

6.3.9 endif

6.4. if $p < C$ then

$i_0=0$;

if $K=R*C$ then $T(n)=MIS(i_0)+1$; $n=n+1$; $i_0=i_0+1$; endif

for $i=i_0, i_0+1, i_0+2, \dots, R-1$ do

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m = MIS(i) + p;
if m < K then T(n) = m; n = n + 1; else prune m; endif
endfor
6.4.15 endif


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~~The total number of pruned indexes is $R * C - K$.~~

The Turbo code internal interleaver consists of mother interleaver generation and pruning. For arbitrary given block length K , one mother interleaver is selected from the 134 mother interleavers set. The generation scheme of mother interleaver is described in section 4.2.3.2.3.1. After the mother interleaver generation, l bits are pruned in order to adjust the mother interleaver to the block length K . The definition of l is shown in section 4.2.3.2.3.2.

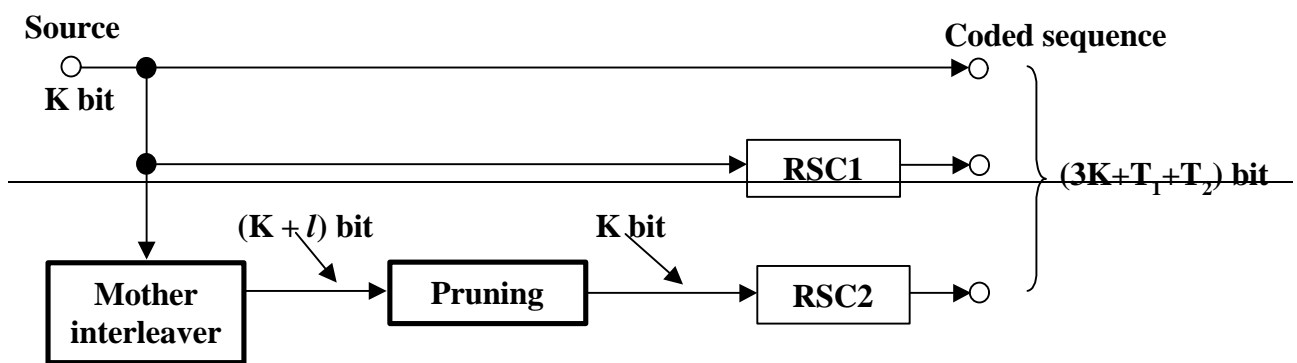


Figure 4-4: Overall 8 State PCCG Turbo Coding

4.2.3.2.3.1 Mother interleaver generation

The interleaving consists of three stages. In first stage, the input sequence is written into the rectangular matrix row by row. The second stage is intra row permutation. The third stage is inter row permutation. The three stage permutations are described as follows, the input block length is assumed to be K (320 to 5114 bits).

First Stage:

(1) Determine a row number R such that

$R=10$ ($K = 481$ to 530 bits; Case-1)

$R=20$ ($K =$ any other block length except 481 to 530 bits; Case-2)

(2) Determine a column number C such that

Case 1; $C = p = 53$

Case-2;

(i) find minimum prime p such that;

$0 = \langle (p+1) K/R$

(ii) if $0 = \langle p K/R$ then go to (iii)

else $C = p+1$.

(iii) if $0 = \langle p-1 K/R$ then $C = p-1$.

Else $C = p$.

(3) The input sequence of the interleaver is written into the $R \times C$ rectangular matrix row by row.

Second Stage:

A. If $C = p$

(A-1) Select a primitive root g_0 from table 4.2.2-2.

(A-2) Construct the base sequence $c(i)$ for intra row permutation as:

$$c(i) = [g_0 \times c(i-1)] \bmod p, i = 1, 2, \dots, (p-2), c(0) = 1.$$

(A-3) Select the minimum prime integer set $\{q_j\}$ ($j = 1, 2, \dots, R-1$) such that

$$\text{g.c.d}\{q_j, p-1\} = 1$$

$$q_j > 6$$

$$q_j > q_{(j+1)}$$

where g.c.d. is greatest common divider. And $q_0 = 1$.

(A-4) The set $\{q_j\}$ is permuted to make a new set $\{p_j\}$ such that

$$p_{P(j)} = q_j, j = 0, 1, \dots, R-1,$$

where $P(j)$ is the inter row permutation pattern defined in the third stage.

(A-5) Perform the j -th ($j = 0, 1, 2, \dots, C-1$) intra row permutation as:

$$c_j(i) = c([i \times p_j] \bmod (p-1)), i = 0, 1, 2, \dots, (p-2), \text{ and } c_j(p-1) = 0,$$

where $c_j(i)$ is the input bit position of i -th output after the permutation of j -th row.

If $C = p+1$

(B-1) Same as case A-1.

(B-2) Same as case A-2.

(B-3) Same as case A-3.

(B-4) Same as case A-4.

(B-5) Perform the j -th ($j = 0, 1, 2, \dots, R-1$) intra row permutation as:

$$c_j(i) = c([i \times p_j] \bmod (p-1)), i = 0, 1, 2, \dots, (p-2), c_j(p-1) = 0, \text{ and } c_j(p) = p,$$

where $c_j(i)$ is the input bit position of i -th output after the permutation of j -th row.

(B-6) If $(K = C \times R)$ then exchange $c_{R-1}(p)$ with $c_{R-1}(0)$.

If $C = p-1$

(C-1) Same as case A-1.

(C-2) Same as case A-2.

(C-3) Same as case A-3.

(C-4) Same as case A-4.

(C-5) Perform the j -th ($j = 0, 1, 2, \dots, R-1$) intra row permutation as:

$$c_j(i) = c([i \times p_j] \bmod (p-1)) - 1, i = 0, 1, 2, \dots, (p-2),$$

where $c_j(i)$ is the input bit position of i -th output after the permutation of j -th row.

Third Stage:

— Perform the inter row permutation based on the following $P(j)$ ($j=0,1, \dots, R-1$) patterns, where $P(j)$ is the original row position of the j -th permuted row.

$P_A: \{19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11\}$ for $R=20$

$P_B: \{19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10\}$ for $R=20$

$P_C: \{9, 8, 7, 6, 5, 4, 3, 2, 1, 0\}$ for $R=10$

— The usage of these patterns is as follows:

Block length $K: P(j)$

320 to 480 bit: P_A

481 to 530 bit: P_C

531 to 2280 bit: P_A

2281 to 2480 bit: P_B

2481 to 3160 bit: P_A

3161 to 3210 bit: P_B

3211 to 5114 bit: P_A

(2) The output of the mother interleaver is the sequence read out column by column from the permuted $R \times C$ matrix.

Table 4.2.3-2: Table of prime p and associated primitive root

p	g_0	P	g_0	p	g_0	P	g_0	p	g_0
17	3	59	2	103	5	157	5	211	2
19	2	61	2	107	2	163	2	223	3
23	5	67	2	109	6	167	5	227	2
29	2	71	7	113	3	173	2	229	6
31	3	73	5	127	3	179	2	233	3
37	2	79	3	131	2	181	2	239	7
41	6	83	2	137	3	191	19	241	7
43	3	89	3	139	2	193	5	251	6
47	5	97	5	149	2	197	2	257	3
53	2	101	2	151	6	199	3		

4.2.3.2.3.2 Definition of the number of pruning bits

The output of the mother interleaver is pruned by deleting the I -bits in order to adjust the mother interleaver to the block length K , where the deleted bits are non-existent bits in the input sequence. The pruning bits number I is defined as:

$$I = R \times C - K,$$

where R is the row number and C is the column number defined in section 4.2.3.2.3.1.