Introduction

This document includes CRs on editorial corrections in Turbo code internal interleaver section to clarify the correct interleaving function and to align mathematical notations with preferred notations shown in TS25.201 Annex A. The interleaving algorithm itself is not changed through these corrections at all. The major corrections, which should be applied for both 25.212 and 25.222 identically, are as follows:

Section 4.2.3.2.3 Turbo code internal interleaver
- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.1 Bits-input to rectangular matrix
- Add the explicit description about the dummy bits padding: the previous description has included the implicit padding function corresponding to the explicit pruning function. However, both functions should be described explicitly to indicate the correct bit operation. The specific value should not be specified for dummy bits since the value will not affect the interleaving function itself.
- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.2 Intra-row and inter-row permutations
- Align the mathematical notations with preferred notations.

Section 4.2.3.2.3.3 Bits-output from rectangular matrix with pruning
- Add the explicit description about the dummy bits padded in bits-input.
- Align the mathematical notations with preferred notations.
**CHANGE REQUEST**

**25.212  CR 085**

**Current Version:** 3.3.0

<table>
<thead>
<tr>
<th>GSM (AA.BB) or 3G (AA.BBB) specification number</th>
<th>CR number as allocated by MCC support team</th>
</tr>
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For submission to: RAN #9
For approval
Strategic

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**Proposed change affects:**
(U)SIM ME UTRAN / Radio Core Network

**Source:** NTT DoCoMo, Nokia and Nortel Networks
**Date:** 17-August-2000

**Subject:** Editorial corrections in Turbo code internal interleaver section

**Category:**
- F Correction
- A Corresponds to a correction in an earlier release
- B Addition of feature
- C Functional modification of feature
- D Editorial modification

**Release:**
- Phase 2
- Release 96
- Release 97
- Release 98
- Release 99
- Release 00

**Reason for change:**
To clarify bits padding and pruning for rectangular matrix.
To align mathematical notations with preferred notations shown in TS25.201 Annex A.

**Clauses affected:** 4.2.3.2.3 of TS25.212

**Other specs affected:** Other 3G core specifications → List of CRs;
Other GSM core specifications → List of CRs;
MS test specifications → List of CRs;
BSS test specifications → List of CRs;
O&M specifications → List of CRs;

**Other comments:**
The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

Output from the Turbo coder is

\[ x_1, z_1', x_2, z_2', \ldots, x_K, z_K', z_K'' \]

where \( x_1, x_2, \ldots, x_K \) are the bits input to the Turbo coder i.e. both first 8-state constituent encoder and Turbo code internal interleaver, and \( K \) is the number of bits, and \( z_1, z_2, \ldots, z_K \) and \( z_1', z_2', \ldots, z_K'' \) are the bits output from first and second 8-state constituent encoders, respectively.

The bits output from Turbo code internal interleaver are denoted by \( x_1', x_2', \ldots, x_K' \), and these bits are to be input to the second 8-state constituent encoder.

![Figure 4: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)](image)

**Figure 4: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)**

### 4.2.3.2.2 Trellis termination for Turbo coder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 4 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 4 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

\[ x_{K+1}, z_{K+1}, x_{K+2}, z_{K+2}, x_{K+3}, z_{K+3}, x_{K+4}', z_{K+4}', x_{K+5}', z_{K+5}' \]

### 4.2.3.2.3 Turbo code internal interleaver

The Turbo code internal interleaver consists of bits-input to a rectangular matrix with padding, intra-row and inter-row permutations of the rectangular matrix, and bits-output from the rectangular matrix with pruning. The bits input to the Turbo code internal interleaver are denoted by \( x_1, x_2, \ldots, x_K \), where \( K \) is the integer number of the bits and takes one value of 40 ≤ \( K \) ≤ 5114. The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by \( x_k = o_{ik} \) and \( K = K_i \).

The following subclause specific symbols are used in subclauses 4.2.3.2.3.1 to 4.2.3.2.3.3:

- \( K \) Number of bits input to Turbo code internal interleaver
- \( R \) Number of rows of rectangular matrix
The bit sequence $x_1, x_2, x_3, \ldots, x_K$ input to the Turbo code internal interleaver $x_p$ is written into the rectangular matrix as follows:

(1) Determine the number of rows $R$ of the rectangular matrix, $R$, such that:

\[
R = \begin{cases} 
5, & \text{if } (40 \leq K \leq 159) \\
10, & \text{if } ((160 \leq K \leq 200) \text{ or } (481 \leq K \leq 530)) \\
20, & \text{if } (K = \text{any other value})
\end{cases}
\]

where the rows of rectangular matrix are numbered $0, 1, 2, \ldots, R - 1$ from top to bottom.

(2) Determine the number of columns $C$ of the rectangular matrix, $C$, such that:

if $(481 \leq K \leq 530)$ then

$p = 53$ and $C = p.$

else

Find minimum prime $p$ such that

\[
(p + 1) \leq R \times (p + 1)
\]

and determine $C$ such that

\[
C = \begin{cases} 
p - 1, & \text{if } K \leq R \times (p - 1) \\
p, & \text{if } R \times (p - 1) < K \leq R \times p \\
p + 1, & \text{if } R \times p < K
\end{cases}
\]

if $(p - K/R \geq 0)$ then

else

if $(p - 1 - K/R \geq 0)$ then

$C = p + 1.$

else

$C = p.$

end if

else

$C = p + 1$
The columns of rectangular matrix are numbered 0, 1, 2, ..., C - 1 from left to right.

(3) Write the input bit sequence \(x_1, x_2, x_3, \ldots, x_K\) into the \(R \times C\) rectangular matrix row by row starting with bit \(x_1\) in column 0 of row 0:

\[
\begin{bmatrix}
  x_1 & x_2 & x_3 & \cdots & x_C \\
  x_{(C+1)} & x_{(C+2)} & x_{(C+3)} & \cdots & x_{2C} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  x_{(R-1)(C+1)} & x_{(R-1)(C+2)} & x_{(R-1)(C+3)} & \cdots & x_{RC}
\end{bmatrix}
\]

where if \(R \times C > K\), the dummy bits are padded such that \(y_k = 0\) or 1 for \(k = K + 1, K + 2, \ldots, R \times C\). These dummy bits are pruned away from the output of the rectangular matrix after intra-row and inter-row permutations.

4.3.2.3.2 Intra-row and inter-row permutations

After the bits-input to the \(R \times C\) rectangular matrix, the intra-row and inter-row permutations for the \(R \times C\) rectangular matrix are performed by using the following algorithm.

(1) Select a primitive root \(v\) from table 2 on the right side of the value of the prime \(p\).

**Table 2: Table of prime \(p\) and associated primitive root \(v\)**

<table>
<thead>
<tr>
<th>(p)</th>
<th>(v)</th>
<th>(p)</th>
<th>(v)</th>
<th>(p)</th>
<th>(v)</th>
<th>(p)</th>
<th>(v)</th>
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<td>7</td>
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<td>5</td>
<td>101</td>
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<td>73</td>
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<td>5</td>
<td>151</td>
<td>8</td>
<td>211</td>
<td>2</td>
</tr>
</tbody>
</table>

(2) Construct the base sequence \(s(j)\) for intra-row permutation as:

\[s(i) = \left( v \times s(i-1) \right) \mod p \quad \text{for } i = 1, 2, \ldots, (p - 2), \text{ and } s(0) = 1.\]

(3) Let \(q_0 = 1\) be the first prime integer in \(\{q_j\}\), the sequence \(\langle q_j \rangle_{j \in \{1, \ldots, R-1\}}\) and select/determine the consecutive minimum prime integers \(q_j\) in the sequence \(\langle q_j \rangle_{j \in \{1, \ldots, R-1\}}\), \(j = 1, 2, \ldots, R-1\) to be a least prime integer such that:

\[\text{g.c.d}(q_j, p - 1) = 1, \quad q_j > 6, \quad \text{and } q_j > q_{(j-1)}, \text{ for each } i = 1, 2, \ldots, R-1.\]

Here where g.c.d. is greatest common divisor.

(4) Permute \(\langle q_j \rangle_{j \in \{1, \ldots, R-1\}}\) to make \(\langle r_j \rangle_{j \in \{1, \ldots, R-1\}}\) such that
Release 1999                                                                    19                                                  3G TS 25.212 V3.3.0 (2000-6)

\( r_{(q)} = q^2, \ \phi^2 = 0, 1, \ldots, R - 1, \)

where \( T(j) \) (\( j = 0, 1, 2, \ldots, R - 1 \)) \( \{ T(i) \}_{i=0,1,\ldots,R-1} \) is the inter-row permutation pattern defined as the one of the following four kind of patterns, which are shown in table 3, \( \text{Pat}_1, \text{Pat}_2, \text{Pat}_3, \text{Pat}_4 \) depending on the number of input bits \( K \).

\[ \{ T(0), T(1), T(2), \ldots, T(R - 1) \} = \]

\[
\begin{align*}
\text{Pat}_4 & \quad \text{if } (40 \leq K \leq 159) \\
\text{Pat}_3 & \quad \text{if } (160 \leq K \leq 200) \\
\text{Pat}_1 & \quad \text{if } (201 \leq K \leq 480) \\
\text{Pat}_3 & \quad \text{if } (481 \leq K \leq 530) \\
\text{Pat}_2 & \quad \text{if } (531 \leq K \leq 2280) \\
\text{Pat}_2 & \quad \text{if } (2281 \leq K \leq 2480) \\
\text{Pat}_1 & \quad \text{if } (2481 \leq K \leq 3160) \\
\text{Pat}_2 & \quad \text{if } (3161 \leq K \leq 3210) \\
\text{Pat}_1 & \quad \text{if } (3211 \leq K \leq 5114)
\end{align*}
\]

where \( \text{Pat}_1, \text{Pat}_2, \text{Pat}_3, \text{Pat}_4 \) have the following patterns respectively.

\( \text{Pat}_1 = \{ 19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11 \} \)

\( \text{Pat}_2 = \{ 19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10 \} \)

\( \text{Pat}_3 = \{ 9, 8, 7, 6, 5, 4, 3, 2, 1, 0 \} \)

\( \text{Pat}_4 = \{ 4, 3, 2, 1, 0 \} \)

Table 3: Inter-row permutation patterns for Turbo code internal interleaver

<table>
<thead>
<tr>
<th>Number of input bits ( K )</th>
<th>Number of rows ( R )</th>
<th>Inter-row permutation pattern ( &lt;T(0), T(1), \ldots, T(R - 1)&gt; )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 40 \leq K \leq 159 )</td>
<td>5</td>
<td>( &lt;4, 3, 2, 1, 0&gt; )</td>
</tr>
<tr>
<td>( 160 \leq K \leq 200 ) or ( 481 \leq K \leq 530 )</td>
<td>10</td>
<td>( &lt;9, 8, 7, 6, 5, 4, 3, 2, 1, 0&gt; )</td>
</tr>
<tr>
<td>( 2281 \leq K \leq 2480 ) or ( 3161 \leq K \leq 3210 )</td>
<td>20</td>
<td>( &lt;19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10&gt; )</td>
</tr>
<tr>
<td>( K ) = any other value</td>
<td>20</td>
<td>( &lt;19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11&gt; )</td>
</tr>
</tbody>
</table>

(5) Perform the \( (ji)_\text{th} \) (\( ji = 0, 1, 2, \ldots, R - 1 \)) intra-row permutation as:

\[
U_{ji} = s((ji \times r_j) \mod (p - 1)) U_j(i) = s((j \times r_j) \mod (p - 1)), \quad ji = 0, 1, 2, \ldots, (p - 2) \quad \text{and} \quad U_j(p - 1) = 0,
\]

where \( U_j(i) \) is the input \( \text{original} \) bit position of \( ji \)-th output after the permutation \( \text{permuted} \) bit of \( ji \)-th row.

end if

if \( (C = p) \) then

\[
U_{ji} = s((ji \times r_j) \mod (p - 1)) U_j(i) = s((j \times r_j) \mod (p - 1)), \quad ji = 0, 1, 2, \ldots, (p - 2) \quad \text{and} \quad U_j(p - 1) = 0,
\]

where \( U_j(i) \) is the input \( \text{original} \) bit position of \( ji \)-th output after the permutation \( \text{permuted} \) bit of \( ji \)-th row.

end if

end if

end if
if \((C = p - 1)\) then

\[
U_j(i) = \alpha \left( \left( \left( i \times r_j \right) \mod (p - 1) \right) \right), \quad U_j(i) = s \left( \left( i \times r_j \right) \mod (p - 1) \right) - 1, \quad i = 0, 1, 2, \ldots, (p - 2),
\]

end if

(6) Perform the inter-row permutation based on the pattern \(T(i)\) where \(T(i)\) is the original row position of the \(i\)-th permuted row.

### Table 2: Table of prime \(p\) and associated primitive root \(v\)

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<td>6</td>
<td>211</td>
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</tr>
</tbody>
</table>

4.2.3.2.3.3 Bits-output from rectangular matrix with pruning

After intra-row and inter-row permutations, the bits of the permuted rectangular matrix are denoted by \(y'_k\):

\[
\begin{bmatrix}
    y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots & y'_{(C-1)(R+1)} \\
    y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots & y'_{(C-1)(R+2)} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    y'_R & y'_{2R} & y'_{3R} & \cdots & y'_{CR}
\end{bmatrix}
\]

The output of the Turbo code internal interleaver is the bit sequence read out column by column from the intra-row and inter-row permuted \(R \times C\) rectangular matrix starting with bit \(y'_1\) in row 0 of column 0 and ending with bit \(y'_{CR}\) in row \(R - 1\) of column \(C - 1\). The output is pruned by deleting dummy bits that were not present padded into the input bit sequence of the rectangular matrix before intra-row and inter row permutations, i.e. bits \(y'_1\) that corresponds to bits \(x'_k\) with \(k > K\) are removed from the output. The bits output from Turbo code internal interleaver are denoted by \(x'_1, x'_2, \ldots, x'_K\), where \(x'_1\) corresponds to the bit \(y'_1\) with smallest index \(k\) after pruning, \(x'_2\) to the bit \(y'_1\) with second smallest index \(k\) after pruning, and so on. The number of bits output from Turbo code internal interleaver is \(K\) and the total number of pruned bits is:

\[R \times C - K.\]
CHANGE REQUEST

<table>
<thead>
<tr>
<th>GSM (AA.BB) or 3G (AA.BBB) specification number</th>
<th>Current Version: 3.3.0</th>
</tr>
</thead>
</table>

For submission to: RAN #9
For approval: X
For information: □

Strategy: □
Non-strategic: X
(for SMG use only)

Proposed change affects: (U)SIM □ ME X UTRAN / Radio X Core Network □

Source: NTT DoCoMo, Nokia and Nortel Networks
Date: 17-August-2000

Subject: Editorial corrections in Turbo code internal interleaver section

Work item: Category: F Correction X Release: Phase 2

Category: A Corresponds to a correction in an earlier release

Category: B Addition of feature

Category: C Functional modification of feature

Category: D Editorial modification

Category: (only one category shall be marked with an X)

Reason for change: To clarify bits padding and pruning for rectangular matrix.
To align mathematical notations with preferred notations shown in TS25.201 Annex A.

Clauses affected: 4.2.3.2.3 of TS25.222

Other specs affected: Other 3G core specifications □ → List of CRs:
Other GSM core specifications □ → List of CRs:
MS test specifications □ → List of CRs:
BSS test specifications □ → List of CRs:
O&M specifications □ → List of CRs:

Other comments:
where \( x_1, x_2, \ldots, x_K \) are the bits input to the Turbo coder i.e. both first 8-state constituent encoder and Turbo code internal interleaver, and \( K \) is the number of bits, and \( z_1, z_2, \ldots, z_K \) and \( z'_1, z'_2, \ldots, z'_K \) are the bits output from first and second 8-state constituent encoders, respectively.

The bits output from Turbo code internal interleaver are denoted by \( x'_1, x'_2, \ldots, x'_K \), and these bits are to be input to the second 8-state constituent encoder.

![Figure 3: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)](image)

4.2.3.2.2 Trellis termination for Turbo coder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 4 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 4 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

\[
x_{K+1}, z_{K+1}, \ldots, x_{K+3}, z_{K+3}.
\]

4.2.3.2.3 Turbo code internal interleaver

The Turbo code internal interleaver consists of bits-input to a rectangular matrix with padding, intra-row and inter-row permutations of the rectangular matrix, and bits-output from the rectangular matrix with pruning. The bits input to the Turbo code internal interleaver are denoted by \( x_1, x_2, x_3, \ldots, x_K \), where \( K \) is the integer number of the bits and takes one value of \( 40 \leq K \leq 511 \). The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by \( x_k = a_{ik} \) and \( K = K_i \).

The following subclause specific symbols are used in subclauses 4.2.3.2.3.1 to 4.2.3.2.3.3:

- \( \mathbb{K} \) \( \mathbb{K} \) \( \mathbb{K} \) Number of bits input to Turbo code internal interleaver
- \( \mathbb{R} \) \( \mathbb{R} \) \( \mathbb{R} \) Number of rows of rectangular matrix
- \( \mathbb{C} \) \( \mathbb{C} \) \( \mathbb{C} \) Number of columns of rectangular matrix
- \( \mathbb{P} \) \( \mathbb{P} \) \( \mathbb{P} \) Prime number
- \( \mathbb{v} \) \( \mathbb{v} \) \( \mathbb{v} \) Primitive root
- \( \mathbb{R}(s(j)) \) \( \mathbb{R}(s(j)) \) \( \mathbb{R}(s(j)) \) Base sequence for intra-row permutation
- \( \mathbb{q}_{\min} \) \( \mathbb{q}_{\min} \) \( \mathbb{q}_{\min} \) Minimum prime integers
- \( \mathbb{r}_{\min} \) \( \mathbb{r}_{\min} \) \( \mathbb{r}_{\min} \) Permuted prime integers
The bit sequence \( x_1, x_2, x_3, \ldots, x_K \) input to the Turbo code internal interleaver \( x_1 \) is written into the rectangular matrix as follows:

1. **Determine the number of rows** \( R \) of the rectangular matrix, \( R \), such that:
   
   \[
   R = \begin{cases} 
   5, & \text{if } (40 \leq K \leq 159) \\
   10, & \text{if } (160 \leq K \leq 200) \text{ or } (481 \leq K \leq 530) \\
   20, & \text{if } (K = \text{any other value})
   \end{cases}
   \]

   The rows of rectangular matrix are numbered 0, 1, 2, \ldots, \( R - 1 \) from top to bottom.

2. **Determine the number of columns** \( C \) of the rectangular matrix, \( C \), such that:
   
   \[
   C = \begin{cases} 
   p, & \text{if } R \times (p - 1) < K \leq R \times p \\
   p + 1, & \text{if } R \times p < K
   \end{cases}
   \]

   if \( p - K/R \geq 0 \) then
   
   if \( p - 1 - K/R \geq 0 \) then
   
   \( C = p - 1 \)
   
   else
   
   \( C = p \)
   
   end if
   
   else
   
   \( C = p + 1 \)
   
   end if

   The columns of rectangular matrix are numbered 0, 1, 2, \ldots, \( C - 1 \) from left to right.
(3) Write the input bit sequence $x_1, x_2, x_3, \ldots, x_K$ into the $R \times C$ rectangular matrix row by row starting with bit $x_1$ in column 0 of row 0:

\[
\begin{bmatrix}
  x_1 & x_2 & x_3 & \ldots & x_C \\
  x_{(C+1)} & x_{(C+2)} & x_{(C+3)} & \ldots & x_{2C} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  x_{((R-1)C+1)} & x_{((R-1)C+2)} & x_{((R-1)C+3)} & \ldots & x_{RC}
\end{bmatrix}
\]

\[
\begin{bmatrix}
  y_1 & y_2 & y_3 & \ldots & y_C \\
  y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \ldots & y_{2C} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \ldots & y_{RC}
\end{bmatrix}
\]

where if $R \times C > K$, the dummy bits are padded such that $y_k = 0$ or 1 for $k = K + 1, K + 2, \ldots, R \times C$. These dummy bits are pruned away from the output of the rectangular matrix after intra-row and inter-row permutations.

### 4.2.3.2.3.2 Intra-row and inter-row permutations

After the bits-input to the $R \times C$ rectangular matrix, the intra-row and inter-row permutations for the $R \times C$ rectangular matrix are performed by using the following algorithm.

(1) Select a primitive root $v$ from table 2 on the right side of the value of the prime $p$.

<table>
<thead>
<tr>
<th>$p$</th>
<th>$v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>31</td>
<td>3</td>
</tr>
<tr>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>41</td>
<td>6</td>
</tr>
<tr>
<td>43</td>
<td>3</td>
</tr>
</tbody>
</table>

(2) Construct the base sequence $\{s(i)\}_{i \in \{0, 1, \ldots, p - 2\}}$ for intra-row permutation as:

\[
s(i) = \{v \times s(i - 1)\} \mod p \quad s(j) = \{v \times s(j - 1)\} \mod p, \quad \text{if } i = 1, 2, \ldots, (p - 2), \text{ and } s(0) = 1.
\]

(3) Let $q_0 = 1$ be the first prime integer in $\{q_i\}$ in the sequence $\{q_i\}_{i \in \{0, 1, \ldots, R - 1\}}$ of prime integers, and select determine the consecutive minimum prime integers $\{q_i\}$ in the sequence $\{q_i\}_{i \in \{0, 1, \ldots, R - 1\}}$ for each $i = 1, 2, \ldots, (R - 1)$, such that:

\[
g.c.d.(q_i, p - 1) = 1, \quad q_i > 6, \text{ and } q_i > q_{i-1} \text{ for each } i = 1, 2, \ldots, R - 1.
\]

Here where $g.c.d.$ is greatest common divisor.

(4) Permute $\{q_i\}$ in the sequence $\{q_i\}_{i \in \{0, 1, \ldots, R - 1\}}$ to make $\{r_i\}$ in the sequence $\{r_i\}_{i \in \{0, 1, \ldots, R - 1\}}$ such that

\[
r_{r(q)} = q_r, \quad j_i = 0, 1, \ldots, R - 1,
\]
where \( T(j) (j = 0, 1, 2, \ldots, R - 1) \) is the inter-row permutation pattern defined as the one of the following four kind of patterns, which are shown in table 3, \( Pat_1, Pat_2, Pat_3 \) and \( Pat_4 \) depending on the number of input bits \( K \).

\[ \{ T(0), T(1), T(2), \ldots, T(R - 1) \} = \begin{cases} Pat_1 & \text{if } (531 \leq K \leq 2280) \\ Pat_2 & \text{if } (2281 \leq K \leq 2480) \\ Pat_1 & \text{if } (2481 \leq K \leq 3160) \\ Pat_2 & \text{if } (3161 \leq K \leq 3210) \\ Pat_1 & \text{if } (3211 \leq K \leq 5114) \\ \end{cases} \]

where \( Pat_1, Pat_2, Pat_3 \) and \( Pat_4 \) have the following patterns respectively.

\( Pat_1 \): \( \{19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11\} \)

\( Pat_2 \): \( \{19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10\} \)

\( Pat_3 \): \( \{9, 8, 7, 6, 5, 4, 3, 2, 1, 0\} \)

\( Pat_4 \): \( \{4, 3, 2, 1, 0\} \)

Table 3: Inter-row permutation patterns for Turbo code internal interleaver

<table>
<thead>
<tr>
<th>Number of input bits ( K )</th>
<th>Number of rows ( R )</th>
<th>Inter-row permutation patterns (&lt;T(0), T(1), \ldots, T(R - 1))&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>((40 \leq K \leq 159))</td>
<td>5</td>
<td>(&lt;4, 3, 2, 1, 0&gt;)</td>
</tr>
<tr>
<td>((160 \leq K \leq 200) \text{ or } (481 \leq K \leq 530))</td>
<td>10</td>
<td>(&lt;9, 8, 7, 6, 5, 4, 3, 2, 1, 0&gt;)</td>
</tr>
<tr>
<td>((2281 \leq K \leq 2480) \text{ or } (3161 \leq K \leq 3210))</td>
<td>20</td>
<td>(&lt;19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10&gt;)</td>
</tr>
<tr>
<td>(K = \text{any other value})</td>
<td>20</td>
<td>(&lt;19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11&gt;)</td>
</tr>
</tbody>
</table>

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

if \((C = p)\) then

\[ U_j(i) = s((i \times r_j) \text{mod}(p - 1)) U_j(i) = s((j \times r_j) \text{mod}(p - 1)), \quad i = 0, 1, 2, \ldots, (p - 2), \text{ and } U_j(p - 1) = 0, \]

where \( U_j(i) \) is the \text{input original} bit position of \( ji \)-th output after the permutation \text{permuted bit} of \( ji \)-th row.

end if

if \((C = p + 1)\) then

\[ U_j(i) = s((i \times r_j) \text{mod}(p - 1)) U_j(i) = s((j \times r_j) \text{mod}(p - 1)), \quad i = 0, 1, 2, \ldots, (p - 2), \text{ and } U_j(p - 1) = 0, \text{ and } U_j(p) = p, \]

where \( U_j(i) \) is the \text{input original} bit position of \( ji \)-th output after the permutation \text{permuted bit} of \( ji \)-th row, and

if \((K = C \times R \times C)\) then

Exchange \( U_j,1 \text{(p)} \) with \( U_j,1 \text{(0)} \).

end if

end if

if \((C = p - 1)\) then

...
$$U_j(i) = s((i + r_i \mod (p - 1)) - 1) U_i(j) = s((j + r_j) \mod (p - 1)) - 1, \quad i, j = 0, 1, 2, \ldots, (p - 2),$$

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

end if

(6) Perform the inter-row permutation based on the pattern $T(j) = (0, 1, 2, \ldots, R - 1)$ for $j = 0, 1, 2, \ldots, R - 1$.

where $T(j)$ is the original row position of the $j$-th permuted row.

<table>
<thead>
<tr>
<th>$p$</th>
<th>$p$</th>
<th>$p$</th>
<th>$p$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3</td>
<td>47</td>
<td>5</td>
<td>103</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>53</td>
<td>2</td>
<td>103</td>
</tr>
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<td>103</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>67</td>
<td>2</td>
<td>113</td>
</tr>
<tr>
<td>19</td>
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</tr>
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</tr>
<tr>
<td>43</td>
<td>3</td>
<td>97</td>
<td>5</td>
<td>151</td>
</tr>
</tbody>
</table>

Table 2: Table of prime $p$ and associated primitive root $v$

$\text{Table 2: Table of prime } p \text{ and associated primitive root } v$

4.2.3.2.3.3 Bits-output from rectangular matrix with pruning

After intra-row and inter-row permutations, the bits of the permuted rectangular matrix are denoted by $y'_k$:

$$y'_1 \ y'_{(R+1)} \ y'_{(2R+1)} \ \cdots \ y'_{((C-1)R+1)} \ y'_2 \ y'_{(R+2)} \ y'_{(2R+2)} \ \cdots \ y'_{((C-1)R+2)} \ \cdots \ y'_R \ y'_{2R} \ y'_{3R} \ \cdots \ y'_{CR}$$

The output of the Turbo code internal interleaver is the bit sequence read out column by column from the intra-row and inter-row permuted $R \times C$ rectangular matrix starting with bit $y'_1$ in row 0 of column 0 and ending with bit $y'_{CR}$ in row $R - 1$ of column $C - 1$. The output is pruned by deleting dummy bits that were not present padded into the input bit sequence of the rectangular matrix before intra-row and inter-row permutations, i.e. bits $y'_k$ that corresponds to bits $x'_k$ with $k > K$ are removed from the output. The bits output from Turbo code internal interleaver are denoted by $x'_1, x'_2, \ldots, x'_K$, where $x'_1$ corresponds to the bit $y'_1$ with smallest index $k$ after pruning, $x'_2$ to the bit $y'_2$ with second smallest index $k$ after pruning, and so on. The number of bits output from Turbo code internal interleaver is $K$ and the total number of pruned bits is:

$$R \times C - K.$$