TSG-RAN Meeting #9
Hawaii, U.S.A. , 20-22 September 2000

RP-000345

Title: **Agreed CRs to TS 25.222**

Source: **TSG-RAN WG1**

Agenda item: **5.1.3**

No.	R1 T-doc	Spec	CR	Rev	Subject	Cat	Current	New
1	R1-000944	25.222	040	1	Update of TS 25.222	F	3.3.0	3.4.0
2	R1-001134	25.222	041	1	Editorial corrections in Turbo code internal interleaver section	F	3.3.0	3.4.0
3	R1-000943	25.222	042	-	Paging Indicator Terminology	F	3.3.0	3.4.0
4	R1-001143	25.222	043	1	Bit separation and collection for rate matching	F	3.3.0	3.4.0
5	R1-001104	25.222	048	-	Puncturing Limit definition in WG1 specification	F	3.3.0	3.4.0

3GPP TSG RAN Meeting #9
Hawaii, USA, 20-22 September 2000

Document *R1-00-0944*
e.g. for 3GPP use the format TP-99xxx
or for SMG, use the format P-99-xxx

CHANGE REQUEST

Please see embedded help file at the bottom of this page for instructions on how to fill in this form correctly.

25.222 **CR** **040r1** Current Version: 3.3.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑   *↑ CR number as allocated by MCC support team*

For submission to: RAN#9
list expected approval meeting # here
↑

for approval ☒
for information ☐

strategic ☐
non-strategic ☐
(for SMG use only)

Form: CR cover sheet, version 2 for 3GPP and SMG   The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc

Proposed change affects: (U)SIM ☐ ME ☒ UTRAN / Radio ☒ Core Network ☐
(at least one should be marked with an X)

Source: TSG RAN WG1   **Date:** 21-Aug-2000

Subject: Update of TS 25.222

Work item:

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

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: Tracking corrective changes in FDD. Specification language improved. Statistical notation clarified, Clarify the order of TFCI encoding. LSBs should be depicted on the right hand side in the figures, as usually done in binary notations.

Clauses affected: 4.2.5, 4.2.6, 4.2.7 and subsections, 4.2.9, 4.2.10 and subsections, 4.2.11 and subsections, 4.3 and subsections

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:

<--------- double-click here for help and instructions on how to create a CR.

4.2.5 1st interleaving

The 1st interleaving is a block interleaver with inter-column permutations. The input bit sequence to the 1st interleaver is denoted by $x_{i,1},x_{i,2},x_{i,3},\dots,x_{i,X_i}$ ~~$x_{i1},x_{i2},x_{i3},\dots,x_{iX_i}$~~ where i is TrCH number and X_i the number of bits (at this stage X_i is assumed and guaranteed to be an integer multiple of TTI). The output bit sequence is derived as follows:

1) select the number of columns C1~~C_I~~ from table 3;

2) determine the number of rows R1~~R_I~~ defined as ~~R_I~~ R1 = X_i/C1~~C_I~~;

3) write the input bit sequence into the ~~R_I~~R1 × C1~~C_I~~ rectangular matrix row by row starting with bit $x_{i,1}$ in the first column of the first row and ending with bit $x_{i,(R1\times C1)}$ ~~$x_{i,(R_I C_I)}$~~ in column ~~C_I~~C1 of row ~~R_I~~R1;

$$\begin{bmatrix} x_{i,1} & x_{i,2} & x_{i,3} & \dots & x_{i,C1} \\ x_{i,(C1+1)} & x_{i,(C1+2)} & x_{i,(C1+3)} & \dots & x_{i,(2\times C1)} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ x_{i,((R1-1)\times C1+1)} & x_{i,((R1-1)\times C1+2)} & x_{i,((R1-1)\times C1+3)} & \dots & x_{i,(R1\times C1)} \end{bmatrix}$$

~~$\begin{bmatrix} x_{i1} & x_{i2} & x_{i3} & \dots & x_{iC_I} \\ x_{i,(C_I+1)} & x_{i,(C_I+2)} & x_{i,(C_I+3)} & \dots & x_{i,(2C_I)} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ x_{i,((R_I-1)C_I+1)} & x_{i,((R_I-1)C_I+2)} & x_{i,((R_I-1)C_I+3)} & \dots & x_{i,(R_I C_I)} \end{bmatrix}$~~

4) ~~p~~Perform the inter-column permutation based on the pattern $\left\langle P1_{C1}(j)\right\rangle_{j\in\{0,1,\dots,C1-1\}}$ ~~{P1 (j)} (j=0,1, …, C-1)~~ shown in table 3, where ~~P1~~ $P1_{C1}(j)$ is the original column position of the j-th permuted column. After permutation of the columns, the bits are denoted by $y_{i,k}$:

$$\begin{bmatrix} y_{i,1} & y_{i,(R1+1)} & y_{i,(2\times R1+1)} & \dots & y_{i,((C1-1)\times R1+1)} \\ y_{i,2} & y_{i,(R1+2)} & y_{i,(2\times R1+2)} & \dots & y_{i,((C1-1)\times R1+2)} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ y_{i,R1} & y_{i,(2\times R1)} & y_{i,(3\times R1)} & \dots & y_{i,(C1\times R1)} \end{bmatrix}$$

~~$\begin{bmatrix} y_{i1} & y_{i,(R_I+1)} & y_{i,(2R_I+1)} & \dots & y_{i,((C_I-1)R_I+1)} \\ y_{i2} & y_{i,(R_I+2)} & y_{i,(2R_I+2)} & \dots & y_{i,((C_I-1)R_I+2)} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ y_{iR_I} & y_{i,(2R_I)} & y_{i,(3R_I)} & \dots & y_{i,(C_I R_I)} \end{bmatrix}$~~

5) ~~r~~Read the output bit sequence $y_{i1},y_{i2},y_{i3},\dots,y_{i,(C1\times R1)}$ ~~$y_{i1},y_{i2},y_{i3},\dots,y_{i,(C_I R_I)}$~~ of the 1st interleaving column by column from the inter-column permuted R1~~R_I~~ × C1~~C_I~~ matrix. Bit $y_{i,1}$ corresponds to the first row of the first column and bit $y_{i,(R1\times C1)}$ ~~$y_{i,(R_I C_I)}$~~ corresponds to row R1~~R_I~~ of column C1~~C_I~~.

The bits input to the 1st interleaving are denoted by $t_{i,1},t_{i,2},t_{i,3},\dots,t_{i,T_i}$ ~~$t_{i1},t_{i2},t_{i3},\dots,t_{iT_i}$~~, where i is the TrCH number and T_i the number of bits. Hence, ~~$x_{ik} = t_{ik}$~~ $x_{i,k} = t_{i,k}$ and $X_i = T_i$.

The bits output from the 1st interleaving are denoted by $d_{i,1},d_{i,2},d_{i,3},\dots,d_{i,T_i}$ ~~$d_{i1},d_{i2},d_{i3},\dots,d_{iT_i}$~~, and ~~$d_{ik} = y_{ik}$~~$d_{i,k} = y_{i,k}$.

Table 3

TTI	Number of columns ~~C_1~~C1	Inter-column permutation patterns <$P1_{C1}(0)$, …, $P1_{C1}(C1-1)$>
10 ms	1	<~~{~~0~~}~~>
20 ms	2	<~~{~~0,1~~}~~>
40 ms	4	<~~{~~0,2,1,3~~}~~>
80 ms	8	<~~{~~0,4,2,6,1,5,3,7~~}~~>

4.2.6 Radio frame segmentation

When the transmission time interval is longer than 10 ms, the input bit sequence is segmented and mapped onto consecutive F_i radio frames. Following radio frame size equalisation the input bit sequence length is guaranteed to be an integer multiple of F_i.

The input bit sequence is denoted by $x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$ where i is the TrCH number and X_i is the number bits. The F_i output bit sequences per TTI are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_i}$ where n_i is the radio frame number in current TTI and Y_i is the number of bits per radio frame for TrCH i. The output sequences are defined as follows:

$$y_{i,n_ik} = x_{i,((n_i-1)Y_i)+k}\ ,\ n_i = 1\ldots F_i,\ k = 1\ldots Y_i$$

where

$Y_i = (X_i / F_i)$ is the number of bits per segment.

The n_i –th segment is mapped to the n_i –th radio frame of the transmission time interval.

The input bit sequence to the radio frame segmentation is denoted by $d_{i1}, d_{i2}, d_{i3}, \ldots, d_{iT_i}$, where i is the TrCH number and T_i the number of bits. Hence, $x_{ik} = d_{ik}$ and $X_i = T_i$.

The output bit sequence corresponding to radio frame n_i is denoted by $e_{i1}, e_{i2}, e_{i3}, \ldots, e_{iN_i}$, where i is the TrCH number and N_i is the number of bits. Hence, $e_{i,k} = y_{i,n_ik}$ and $N_i = Y_i$.

4.2.7 Rate matching

Rate matching means that bits on a TrCH are repeated or punctured. Higher layers assign a rate-matching attribute for each TrCH. This attribute is semi-static and can only be changed through higher layer signalling. The rate-matching attribute is used when the number of bits to be repeated or punctured is calculated.

The number of bits on a TrCH can vary between different transmission time intervals. When the number of bits between different transmission time intervals is changed, bits are repeated to ensure that the total bit rate after TrCH multiplexing is identical to the total channel bit rate of the allocated physical channels.

If no bits are input to the rate matching for all TrCHs within a CCTrCH, the rate matching shall output no bits for all TrCHs within the CCTrCH.

Notation used in subclause 4.2.7 and subclauses:

$N_{i,j}$: Number of bits in a radio frame before rate matching on TrCH i with transport format combination j.

$\Delta N_{i,j}$ ~~ΔN_{ij}~~: If positive – number of bits to be repeated in each radio frame on TrCH i with transport format

If negative – number of bits to be punctured in each radio frame on TrCH i with transport format combination j.

RM_i: Semi-static rate matching attribute for TrCH i. Signalled from higher layers.

PL: Puncturing limit. This value limits the amount of puncturing that can be applied in order to minimise the number of physical channels. Signalled from higher layers.

$N_{data,j}$: Total number of bits that are available for a CCTrCH in a radio frame with transport format combination j.

P: number of physical channels used in the current frame.

P_{max}: maximum number of physical channels allocated for a CCTrCH.

U_p: Number of data bits in the physical channel p with p = 1...P.

I: Number of TrCHs in a CCTrCH.

Z_{ij}: Intermediate calculation variable.

F_i: Number of radio frames in the transmission time interval of TrCH i.

n_i: Radio frame number in the transmission time interval of TrCH i ($0 \le n_i < F_i$).

q: Average puncturing or repetition distance(normalised to only show the remaining rate matching on top of an integer number of repetitions).

~~I_F~~$P1_F(n_i)$: The ~~inverse interleaving~~ column permutation function of the 1st interleaver, $P1_F(x)$ is the original position of column with number x after permutation. P1 is defined on table 3 of section 4.2.5 (note that $P1_F$ ~~the inverse interleaving function is identical to the interleaving function itself for the 1st interleaver~~self-inverse).

S[n]~~$S(n_i)$~~: The shift of the puncturing or repetition pattern for radio frame n_i when $n = \mathrm{P1}_{F_i}(n_i)$.

$TF_i(j)$~~$TF_i(j)$~~: Transport format of TrCH i for the transport format combination j.

$TFS(i)$~~$TFS(i)$~~: The set of transport format indexes l for TrCH i.

e_{ini}: Initial value of variable e in the rate matching pattern determination algorithm of subclause 4.2.7.3.

e_{plus} Increment of variable e in the rate matching pattern determination algorithm of subclause 4.2.7.3.

e_{minus} Decrement of variable e in the rate matching pattern determination algorithm of subclause 4.2.7.3.

b: Indicates systematic and parity bits.

b=1: Systematic bit. $X(t)$ in subclause 4.2.3.2.1.

b=2: 1st parity bit (from the upper Turbo constituent encoder). $Y(t)$ in subclause 4.2.3.2.1.

b=3: 2nd parity bit (from the lower Turbo constituent encoder). $Y'(t)$ in subclause 4.2.3.2.1.

4.2.7.1 Determination of rate matching parameters

The following relations, defined for all TFC j, are used when calculating the rate matching pattern:

$$Z_{0,j} = 0$$

$$Z_{i,j} = \left\lfloor \frac{\left(\left(\sum_{m=1}^{i} RM_m \times N_{m,j}\right) \times N_{data,j}\right)}{\sum_{m=1}^{I} RM_m \times N_{m,j}} \right\rfloor \quad \cancel{Z_{ij} = \left\lfloor \frac{\left\{\left(\sum_{m=1}^{i} RM_m \cdot N_{mj}\right) \cdot N_{data,j}\right\}}{\sum_{m=1}^{I} RM_m \cdot N_{mj}} \right\rfloor}$$ for all i = 1 …~~..~~ ~~I~~I (1)

$$\Delta N_{i,j} = Z_{i,j} - Z_{i-1,j} - N_{i,j} \quad \cancel{\Delta N_{ij} = Z_{ij} - Z_{i-1,j} - N_{ij}}$$ for all i = 1 …~~..~~ ~~I~~I

Puncturing can be used to minimise the required transmission capacity. The maximum amount of puncturing that can be applied is signalled from higher layers and denoted by PL. The possible values for N_{data} depend on the number of physical channels P_{max} , allocated to the respective CCTrCH, and on their characteristics (spreading factor, length of midamble and TFCI, usage of TPC and multiframe structure), which is given in [7].

Denote the number of data bits in each physical channel by $U_{p,Sp}$, where p refers to the sequence number $1\leq p\leq P_{max}$ of this physical channel in the allocation message, and the second index Sp indicates the spreading factor with the possible values {$16, 8, 4, 2, 1$}, respectively. For each physical channel an individual minimum spreading factor Sp_{min} is transmitted by means of the higher layer. Then, for N_{data} one of the following values in ascending order can be chosen:

$$\{U_{1,16},\ldots,U_{1,S1_{\min}},U_{1,S1_{\min}}+U_{2,16},\ldots,U_{1,S1_{\min}}+U_{2,S2_{\min}},\ldots,U_{1,S1_{\min}}+U_{2,S2_{\min}}+\ldots+U_{P_{\max},16},\ldots,U_{1,S1_{\min}}+U_{2,S2_{\min}}+\ldots+U_{P_{\max},(SP_{\max})_{\min}}\}$$

$N_{data,\, j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} such that

$\left(\min_{1\leq y\leq I}\{RM_y\}\right)\times N_{data} - PL\times\sum_{x=1}^{I} RM_x \times N_{x,j}$ ~~$\min_{1\leq y\leq I}\{RM_y\}\cdot N_{data} - PL\cdot\sum_{x=1}^{I} RM_x\cdot N_{x,j}$~~ is non negative }

$N_{data,\, j}$ = min SET1

The number of bits to be repeated or punctured, $\Delta N_{i,j}$~~ΔN_{ij}~~, within one radio frame for each TrCH i is calculated with the relations given at the beginning of this subclause for all possible transport format combinations j and selected every radio frame.

If $\Delta N_{i,j}$~~ΔN_{ij}~~ = 0 then the output data of the rate matching is the same as the input data and the rate matching algorithm of subclause 4.2.7.3 does not need to be executed.

Otherwise, the rate matching pattern is calculated with the algorithm described in subclause 4.2.7.3. For this algorithm the parameters e_{ini}, e_{plus}, e_{minus}, and X_i are needed, which are calculated according to the equations in subclauses 4.2.7.1.1 and 4.2.7.1.2.

4.2.7.1.1 Uncoded and convolutionally encoded TrCHs

a = 2

$\Delta N_i = \Delta N_{i,j}$

$X_i = N_{i,j}$

R = $\Delta N_{i,j}$ mod $N_{i,j}$ ~~ΔN_{ij} mod N_{ij}~~ -- note: in this context $\Delta N_{i,j}$ mod $N_{i,j}$ ~~ΔN_{ij} mod N_{ij}~~ is in the range of 0 to ~~N_{ij}~~$N_{i,j}$-1 i.e. -1 mod 10 = 9.

if R ≠ 0 and 2×R ≤ ~~N_{ij}~~$N_{i,j}$

then q = $\lceil N_{i,j}$ ~~N_{ij}~~ / ~~R~~ $R\rceil$

else

q = $\lceil N_{i,j}$ ~~N_{ij}~~ / (~~R~~R - ~~N_{ij}~~$N_{i,j}$) $\rceil$

endif

NOTE 1: q is a signed quantity.

If q is even

then q' = q + gcd(|q|, F_i ~~F_i~~)/ F_i~~F_i~~ -- where gcd (|q|, F_i ~~F_i~~) means greatest common divisor of |q| and F_i ~~F_i~~

NOTE 2: q' is not an integer, but a multiple of 1/8.

else

```
            q' = q
        endif
    for x = 0 to $F_i$ ~~$F_i$~~-1
        S[~~(I_F (~~|⌊x×~~*~~q'⌋| mod $F_i$ ~~$F_i$))~~] = (|⌊x*q'⌋| div $F_i$ ~~$F_i$~~)
    end for
```

~~$e_{ini} = (a\cdot S(n_i)\cdot|\Delta N_i| + 1) \bmod (a\cdot X_i)$~~ $e_{ini} = (a\times S[P1_{Fi}(n_i)]\times|\Delta N_i| + 1) \bmod (a\cdot N_{i,j})$.

~~$e_{plus} = a\cdot X_i$~~ $e_{plus} = a \times X_i$

~~$e_{minus} = a\cdot|\Delta N_i|$~~ $e_{minus} = a\times|\Delta N_i|$

puncturing for ~~ΔN_i~~ΔN_i<0, repetition otherwise.

4.2.7.1.2 Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. ~~Δ~~$\Delta N_{i,j}$ >0, the parameters in subclause 4.2.7.1.1 are used.

If puncturing is to be performed, the parameters below shall be used. Index *b* is used to indicate systematic (*b*=1), 1st parity (*b*=2), and 2nd parity bit (*b*=3).

a = 2 when *b*=2

a = 1 when *b*=3

$$\Delta N_i = \begin{cases} \lfloor \Delta N_{i,j}/2 \rfloor, & b=2 \\ \lceil \Delta N_{i,j}/2 \rceil, & b=3 \end{cases}$$

If ΔN_i is calculated as 0 for *b*=2 or *b*=3, then the following procedure and the rate matching algorithm of subclause 4.2.7.3 don't need to be performed for the corresponding parity bit stream.

```
    $X_i = \lfloor N_{i,j}/3 \rfloor$,
    $q = \lfloor X_i/|\Delta N_i| \rfloor$
    if($q \le 2$)
        for ~~x~~r=0 to $F_i$-1
        S[~~I_F[~~(3×r~~x~~+b-1) mod $F_i$~~Fi]~~] = ~~x~~r mod 2;
        end for
    else
        if ~~q~~q is even
            then ~~q'~~q′ = ~~q~~q – gcd(~~q~~q, $F_i$)/ $F_i$   -- where gcd (~~q~~q, $F_i$) means greatest common divisor of ~~q~~q and $F_i$
    NOTE:   ~~q'~~q′ is not an integer, but a multiple of 1/8.
        else   ~~q'~~q′ = ~~q~~q
    endif
    for x=0 to $F_i$ –1
        r = ⌈~~x*~~x×q'⌉ mod $F_i$ ~~$F_i$~~;
    S[~~I_F[~~(3×r+b-1) mod $F_i$ ~~$F_i$]~~] = ⌈~~x*~~x×q′~~q'~~⌉ div $F_i$ ~~$F_i$~~;
```

```
endfor
endif
```

For each radio frame, the rate-matching pattern is calculated with the algorithm in subclause 4.2.7.3, where:

X_i is as above,

~~e_{ini}~~ e_{ini} = (a~~·~~×S[P1 F_i (n_i)]×~~(n_i)~~ |Δ N_i~~N_i~~| + X_i~~X_i~~) mod (a·X_i), if ~~e_{ini}~~ e_{ini} = 0 then ~~e_{ini} = a·X_i~~ e_{ini} = a×X_i.

~~e_{plus} = a·X_i~~ e_{plus} = a×X_i

~~e_{minus} = a·|ΔN_i|~~ e_{minus} = a×|ΔN_i|

4.2.7.2 Bit separation and collection for rate matching

The systematic bits of turbo encoded TrCHs shall not be punctured, however systematic bits for trellis termination may be punctured. The systematic bits, first parity bits, and second parity bits in the bit sequence input to the rate matching block are therefore separated into three sequences, one sequence containing all of the systematic bits and some systematic, first and second parity trellis termination bits; the second sequence containing all of the first parity bits and some systematic, first and second parity trellis termination bits and the third sequence containing all of the second parity bits and some systematic, first and second parity trellis termination bits. Puncturing is only applied to the second and third sequences.

The bit separation function is transparent for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition. The bit separation and bit collection are illustrated in figures 4 and 5.

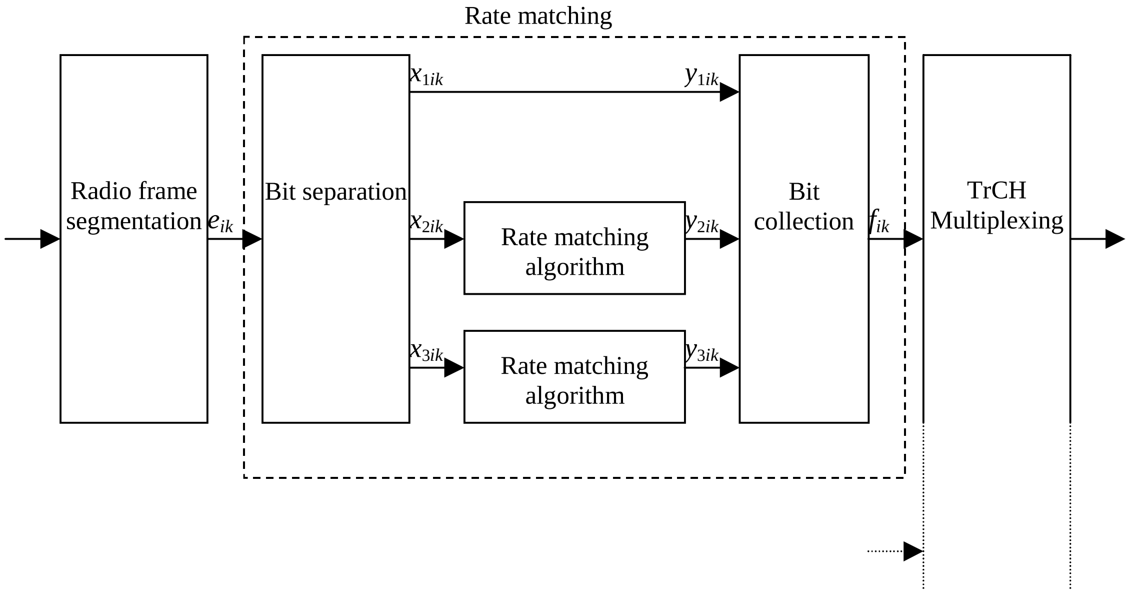


Figure 4: Puncturing of turbo encoded TrCHs

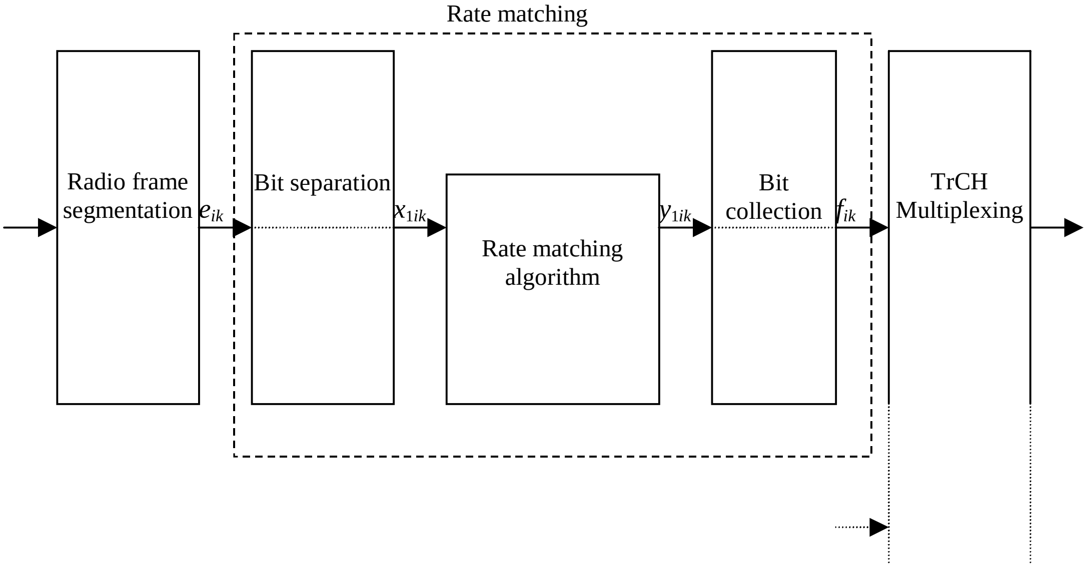


Figure 5: Rate matching for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition

The bit separation is dependent on the 1st interleaving and offsets are used to define the separation for different TTIs. The sequence denoted as b=1 contains all of the systematic bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=2 contains all of the first parity bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=3 contains all of the second parity bits and some systematic, first and second parity trellis termination bits. The offsets α_b for these sequences are listed in table 4.

Table 4: TTI dependent offset needed for bit separation

TTI (ms)	α_1	α_2	α_3
10, 40	0	1	2
20, 80	0	2	1

The bit separation is different for different radio frames in the TTI. A second offset is therefore needed. The radio frame number for TrCH *i* is denoted by n_i. and the offset by β_{n_i} .

Table 5: Radio frame dependent offset needed for bit separation

TTI (ms)	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7
10	0	NA	NA	NA	NA	NA	NA	NA
20	0	1	NA	NA	NA	NA	NA	NA
40	0	1	2	0	NA	NA	NA	NA
80	0	1	2	0	1	2	0	1

4.2.7.2.1 Bit separation

The bits input to the rate matching are denoted by $e_{i,1}, e_{i,2}, e_{i,3}, \ldots, e_{i,N_i}$ ~~$e_{i1}, e_{i2}, e_{i3}, \ldots, e_{iN_i}$~~, where *i* is the TrCH number and N_i is the number of bits input to the rate matching block. Note that the transport format combination number *j* for simplicity has been left out in the bit numbering, i.e. $N_i=N_{i,j}$. The bits after separation are denoted by $x_{b,i,1}, x_{b,i,2}, x_{b,i,3}, \ldots, x_{b,i,X_i}$ ~~$x_{bi1}, x_{bi2}, x_{bi3}, \ldots, x_{biX_i}$~~. For turbo encoded TrCHs with puncturing, *b* indicates the three sequences defined in section 4.2.7.2. The sequence denoted as b=1 contains all of the systematic bits and some systematic, first and second parity trellis termination bits; the sequence denoted as *b*~~b~~=2 contains all of the first parity bits and some systematic, first and second parity trellis termination bits; the sequence denoted as ~~b~~*b*=3 contains all of the second parity bits and some systematic, first and second parity trellis termination bits. For all other cases *b* is defined to be 1. X_i is the number of bits in each separated bit sequence. The relation between $e_{i,k}$ and $x_{b,i,k}$ is given below.

For turbo encoded TrCHs with puncturing:

$x_{1,i,k} = e_{i,3(k-1)+1+(\alpha_1+\beta_{n_i}) \bmod 3}$ $k = 1, 2, 3, \ldots, X_i$ $X_i = \lfloor N_i/3 \rfloor$

$x_{1,i,\lfloor N_i/3 \rfloor + k} = e_{i,3\lfloor N_i/3 \rfloor + k}$ $k = 1, \ldots, N_i \bmod 3$ Note: When (N_i mod 3) = 0 this row is not needed.

$x_{2,i,k} = e_{i,3(k-1)+1+(\alpha_2+\beta_{n_i}) \bmod 3}$ $k = 1, 2, 3, \ldots, X_i$ $X_i = \lfloor N_i/3 \rfloor$

$x_{3,i,k} = e_{i,3(k-1)+1+(\alpha_3+\beta_{n_i}) \bmod 3}$ $k = 1, 2, 3, \ldots, X_i$ $X_i = \lfloor N_i/3 \rfloor$

For uncoded TrCHs, convolutionally encoded TrCHs, and turbo encoded TrCHs with repetition:

$x_{1,i,k} = e_{i,k}$ $k = 1, 2, 3, \ldots, X_i$ $X_i = N_i$

4.2.7.2.2 Bit collection

The bits $x_{b,i,k}$ are input to the rate matching algorithm described in subclause 4.2.7.3. The bits output from the rate matching algorithm are denoted $y_{b,i,1}, y_{b,i,2}, y_{b,i,3}, \ldots, y_{b,i,Y_i}$ ~~$y_{bi1}, y_{bi2}, y_{bi3}, \ldots, y_{biY_i}$~~.

Bit collection is the inverse function of the separation. The bits after collection are denoted by $z_{b,i,1}, z_{b,i,2}, z_{b,i,3}, \ldots, z_{b,i,Y_i}$ ~~$z_{bi1}, z_{bi2}, z_{bi3}, \ldots, z_{biY_i}$~~. After bit collection, the bits indicated as punctured are removed and the bits are then denoted by $f_{i,1}, f_{i,2}, f_{i,3}, \ldots, f_{i,V_i}$ ~~$f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_i}$~~, where *i* is the TrCH number and V_i= $N_{i,j}+\Delta N_{i,j}$ ~~$N_{ij}+\Delta N_{ij}$~~. The relations between ~~y_{bik}, z_{bik}~~ $y_{b,i,k}$, $z_{b,i,k}$, and ~~f_{ik}~~ $f_{i,k}$ are given below.

For turbo encoded TrCHs with puncturing (Y_i=X_i):

$z_{i,3(k-1)+1+(\alpha_1+\beta_{n_i}) \bmod 3} = y_{1,i,k}$ $k = 1, 2, 3, \ldots, Y_I$

$z_{i,3\lfloor N_i/3 \rfloor + k} = y_{1,i,\lfloor N_i/3 \rfloor + k}$ $k = 1, \ldots, N_i \bmod 3$ Note: When (N_i mod 3) = 0 this row is not needed.

$z_{i,3(k-1)+1+(\alpha_2+\beta_{n_i}) \bmod 3} = y_{2,i,k}$ $k = 1, 2, 3, \ldots, Y_i$

$z_{i,3(k-1)+1+(\alpha_3+\beta_{n_i}) \bmod 3} = y_{3,i,k}$ $k = 1, 2, 3, \ldots, Y_i$

After the bit collection, bits $z_{i,k}$ with value δ, where $\delta \notin \{0, 1\}$, are removed from the bit sequence. Bit $f_{i,1}$ corresponds to the bit $z_{i,k}$ with smallest index *k* after puncturing, bit $f_{i,2}$ corresponds to the bit $z_{i,k}$ with second smallest index *k* after puncturing, and so on.

For uncoded TrCHs, convolutionally encoded TrCHs, and turbo encoded TrCHs with repetition:

$z_{i,k} = y_{1,i,k}$ $k = 1, 2, 3, \ldots, Y_i$

When repetition is used, $f_{i,k}$=$z_{i,k}$ and Y_i=V_i.

When puncturing is used, Y_i=X_i and bits $z_{i,k}$ with value δ, where $\delta \notin \{0, 1\}$, are removed from the bit sequence. Bit $f_{i,1}$ corresponds to the bit $z_{i,k}$ with smallest index *k* after puncturing, bit $f_{i,2}$ corresponds to the bit $z_{i,k}$ with second smallest index *k* after puncturing, and so on.

4.2.7.3 Rate matching pattern determination

The bits input to the rate matching are denoted by $x_{i,1}, x_{i,2}, x_{i,3}, \ldots, x_{i,X_i}$ ~~$x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$~~, where *i* is the TrCH and X_i is the parameter given in subclauses 4.2.7.1.1 and 4.2.7.1.2.

NOTE: The transport format combination number j for simplicity has been left out in the bit numbering.

The rate matching rule is as follows:

```
if puncturing is to be performed
    ~~e~~e = ~~eini~~$e_{ini}$        -- initial error between current and desired puncturing ratio
    m = 1            -- index of current bit
    do while m <= $X_i$
        ~~e~~e = ~~e~~e – $e_{minus}$~~eminus~~          -- update error
        if e <= 0 then          -- check if bit number m should be punctured
            set bit $x_{i,m}$ to $\delta$ where $\delta \notin \{0, 1\}$
            ~~e~~e = ~~e~~e + $e_{plus}$~~eplus~~     -- update error
        end if
        m = m + 1               --  next bit
    end do
else
    e = $e_{ini}$~~eini~~        -- initial error between current and desired puncturing ratio
    m = 1                 -- index of current bit
    do while m <= $X_i$
        ~~e~~e = ~~e~~e – $e_{minus}$~~eminus~~          -- update error
        do while e <= 0         -- check if bit number m should be repeated
            repeat bit $x_{i,m}$
            ~~e~~e = ~~e~~e + $e_{plus}$~~eplus~~ -- update error
        end do
        m = m + 1               --  next bit
    end do
end if
```

A repeated bit is placed directly after the original one.

4.2.8 TrCH multiplexing

Every 10 ms, one radio frame from each TrCH is delivered to the TrCH multiplexing. These radio frames are serially multiplexed into a coded composite transport channel (CCTrCH).

The bits input to the TrCH multiplexing are denoted by $f_{i,1}, f_{i,2}, f_{i,3}, \ldots, f_{i,V_i}$ ~~$f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_i}$~~, where i is the TrCH number and V_i is the number of bits in the radio frame of TrCH i. The number of TrCHs is denoted by I. The bits output from TrCH multiplexing are denoted by $s_1, s_2, s_3, \ldots, s_S$, where S is the number of bits, i.e. $S = \sum_i V_i$. The TrCH multiplexing is defined by the following relations:

$s_k = f_{1,k}$ ~~$s_k = f_{1k}$~~ $k = 1, 2, \ldots, V_1$

$s_k = f_{2,(k-V_1)}$ $k = V_1+1, V_1+2, \ldots, V_1+V_2$

$s_k = f_{3,(k-(V_1+V_2))}$ $k = (V_1+V_2)+1, (V_1+V_2)+2, \dots, (V_1+V_2)+V_3$

…

$s_k = f_{I,(k-(V_1+V_2+\dots+V_{I-1}))}$ $k = (V_1+V_2+\dots+V_{I-1})+1, (V_1+V_2+\dots+V_{I-1})+2, \dots, (V_1+V_2+\dots+V_{I-1})+V_I$

4.2.9 Physical channel segmentation

When more than one PhCH is used, physical channel segmentation divides the bits among the different PhCHs. The bits input to the physical channel segmentation are denoted by $s_1, s_2, s_3, \dots, s_S$, where S is the number of bits input to the physical channel segmentation block. The number of PhCHs is denoted by P.

The bits after physical channel segmentation are denoted $u_{p,1}, u_{p,2}, u_{p,3}, \dots, u_{p,U_p}$ ~~$u_{p1}, u_{p2}, u_{p3}, \dots, u_{pU_p}$~~, where p is PhCH number and U_p is the in general variable number of bits in the respective radio frame for each PhCH. The relation between s_k and ~~u_{pk}~~ $u_{p,k}$ is given below.

Bits on first PhCH after physical channel segmentation:

~~$u_{1k} = s_k$~~ $u_{1,k} = s_k$ $k = 1, 2, \dots, U_1$

Bits on second PhCH after physical channel segmentation:

~~$u_{2k} = s_{(k+U_1)}$~~ $u_{2,k} = s_{(k+U_1)}$ $k = 1, 2, \dots, U_2$

…

Bits on the P^{th} PhCH after physical channel segmentation:

~~$u_{Pk} = s_{(k+U_1+\dots+U_{P-1})}$~~ $u_{P,k} = s_{(k+U_1+\dots+U_{P-1})}$ $k = 1, 2, \dots, U_P$

4.2.10 2nd interleaving

The 2nd interleaving can be applied jointly to all data bits transmitted during one frame, or separately within each timeslot, on which the CCTrCH is mapped. The selection of the 2nd interleaving scheme is controlled by higher layer.

4.2.10.1 Frame related 2nd interleaving

In case of frame related interleaving, the bits input to the 2nd interleaver are denoted $x_1, x_2, x_3, \dots, x_U$, where U is the total number of bits after TrCH multiplexing transmitted during the respective radio frame with $S = U = \sum_p U_p$.

The relation between x_k and the bits $u_{p,k}$ in the respective physical channels is given below:

~~$x_k = u_{1k}$~~ $x_k = u_{1,k}$ $k = 1, 2, \dots, U_1$

~~$x_{(k+U_1)} = u_{2k}$~~ $x_{(k+U_1)} = u_{2,k}$ $k = 1, 2, \dots, U_2$

…

~~$x_{(k+U_1+\dots+U_{P-1})} = u_{Pk}$~~ $x_{(k+U_1+\dots+U_{P-1})} = u_{P,k}$ $k = 1, 2, \dots, U_P$

The following steps have to be performed once for each CCTrCH:

(1) Set the number of columns ~~C_2~~ C2 = 30. The columns are numbered 0, 1, 2, …, ~~C_2~~C2-1 from left to right.

(2) Determine the number of rows ~~R_2~~ R2 by finding minimum integer ~~R_2~~ R2 such that:

U ≤ ~~R_2C_2~~R2 X C2.

(3) The bits input to the 2nd interleaving are written into the ~~R_2~~ R2 × ~~C_2~~ C2 rectangular matrix row by row.

$$\begin{bmatrix} x_1 & x_2 & x_3 & \dots & x_{30} \\ x_{31} & x_{32} & x_{33} & \dots & x_{60} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ x_{(R2-1)\times 30+1} & x_{(R2-1)\times 30+2} & x_{(R2-1)\times 30+3} & \dots & x_{R2\times 30} \end{bmatrix} \begin{bmatrix} x_1 & x_2 & x_3 & \dots & x_{30} \\ x_{31} & x_{32} & x_{33} & \dots & x_{60} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ x_{(R_2-1)30+1} & x_{(R_2-1)30+2} & x_{(R_2-1)30+3} & \dots & x_{R_2\cdot 30} \end{bmatrix}$$

4) Perform the inter-column permutation based on the pattern {~~P_2~~P2(j)} (j = 0, 1, …, ~~C_2~~C2-1) that is shown in table 6, where ~~P_2~~P2(j) is the original column position of the j-th permuted column. After permutation of the columns, the bits are denoted by y_k.

$$\begin{bmatrix} y_1 & y_{R2+1} & y_{2\times R2+1} & \dots y_{29\times R2+1} \\ y_2 & y_{R2+2} & y_{2\times R2+2} & \dots y_{29\times R2+2} \\ \vdots & \vdots & \vdots & \dots \quad \vdots \\ y_{R2} & y_{2\times R2} & y_{3\times R2} & \dots \; y_{30\times R2} \end{bmatrix} \begin{bmatrix} y_1 & y_{R_2+1} & y_{2R_2+1} & \dots y_{29R_2+1} \\ y_2 & y_{R_2+2} & y_{2R_2+2} & \dots y_{29R_2+2} \\ \vdots & \vdots & \vdots & \dots \quad \vdots \\ y_{R_2} & y_{2R_2} & y_{3R_2} & \dots \; y_{30R_2} \end{bmatrix}$$

(5) The output of the 2nd interleaving is the bit sequence read out column by column from the inter-column permuted ~~R_2~~ R2 × ~~C_2~~ C2 matrix. The output is pruned by deleting bits that were not present in the input bit sequence, i.e. bits y_k that corresponds to bits x_k with k>U are removed from the output. The bits after 2nd interleaving are denoted by $v_1, v_2, \dots, v_U$, where v_1 corresponds to the bit y_k with smallest index k after pruning, v_2 to the bit y_k with second smallest index k after pruning, and so on.

4.2.10.2 Timeslot related 2nd interleaving

In case of timeslot related 2nd interleaving, the bits input to the 2nd interleaver are denoted $x_{t,1}, x_{t,2}, x_{t,3}, \dots, x_{t,U_t}$ ~~$x_{t1}, x_{t2}, x_{t3}, \dots, x_{tU_t}$~~, where *t* refers to a certain timeslot, and U_t is the number of bits transmitted in this timeslot during the respective radio frame.

In each timeslot *t* the relation between ~~x_{tk}~~ $x_{t,k}$ and ~~u_{tpk}~~ $u_{t,p,k}$ is given below with P_t refering to the number of physical channels within the respective timeslot:

~~$x_{tk} = u_{t1k}$~~ $x_{t,k} = u_{t,1,k}$ $k = 1, 2, \dots, U_{t1}$

~~$x_{t(k+U_{t1})} = u_{t2k}$~~ $x_{t,(k+U_{t1})} = u_{t,2,k}$ $k = 1, 2, \dots, U_{t2}$

…

~~$x_{t(k+U_{t1}+\dots+U_{t(P_t-1)})} = u_{tP_tk}$~~ $x_{t,(k+U_{t1}+\dots+U_{t(P_t-1)})} = u_{t,P_t,k}$ $k = 1, 2, \dots, U_{tP_t}$

The following steps have to be performed for each timeslot *t*, on which the respective CCTrCH is mapped:

(1) Set the number of columns ~~C_2~~ C2= 30. The columns are numbered 0, 1, 2, …, ~~C_2~~ C2 - 1 from left to right.

(2) Determine the number of rows ~~R_2~~ R2 by finding minimum integer ~~R_2~~ R2 such that:

U_t ≤ ~~R_2C_2~~R2×C2.

(3) The bits input to the 2nd interleaving are written into the ~~R_2~~ R2 × C2~~C_2~~ rectangular matrix row by row.

$$\begin{bmatrix} x_{t,1} & x_{t,2} & x_{t,3} & \cdots & x_{t,30} \\ x_{t,31} & x_{t,32} & x_{t,33} & \cdots & x_{t,60} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ x_{t,((R2-1)\times 30+1)} & x_{t,((R2-1)\times 30+2)} & x_{t,((R2-1)\times 30+3)} & \cdots & x_{t,(R2\times 30)} \end{bmatrix}$$

~~$\begin{bmatrix} x_{t1} & x_{t2} & x_{t3} & \cdots & x_{t30} \\ x_{t31} & x_{t32} & x_{t33} & \cdots & x_{t60} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ x_{t,((R_2-1)30+1)} & x_{t,((R_2-1)30+2)} & x_{t,((R_2-1)30+3)} & \cdots & x_{t,(R_2 30)} \end{bmatrix}$~~

(4) Perform the inter-column permutation based on the pattern ~~$\{P_2(j)\}$~~ P2(j) ~~(~~(j = 0, 1, …, ~~C_2~~C2-1)~~)~~ that is shown in table 6, where ~~$P_2(j)$~~ P2(j) is the original column position of the j-th permuted column. After permutation of the columns, the bits are denoted by $y_{t,k}$.

$$\begin{bmatrix} y_{t,1} & y_{t,(R2+1)} & y_{t,(2\times R2+1)} & \cdots & y_{t,(29\times R2+1)} \\ y_{t,2} & y_{t,(R2+2)} & y_{t,(2\times R2+2)} & \cdots & y_{t,(29\times R2+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y_{t,R2} & y_{t,(2\times R2)} & y_{t,(3\times R2)} & \cdots & y_{t,(30\times R2)} \end{bmatrix}$$

~~$\begin{bmatrix} y_{t1} & y_{t,(R_2+1)} & y_{t,(2R_2+1)} & \cdots & y_{t,(29R_2+1)} \\ y_{t2} & y_{t,(R_2+2)} & y_{t,(2R_2+2)} & \cdots & y_{t,(29R_2+2)} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y_{tR_2} & y_{t,(2R_2)} & y_{t,(3R_2)} & \cdots & y_{t,(30R_2)} \end{bmatrix}$~~

(5) The output of the 2nd interleaving is the bit sequence read out column by column from the inter-column permuted ~~R_2~~R2 $\times$C2 ~~C_2~~ matrix. The output is pruned by deleting bits that were not present in the input bit sequence, i.e. bits ~~y_{tk}~~ $y_{t,k}$ that corresponds to bits ~~x_{tk}~~ $x_{t,k}$ with $k>U_t$ are removed from the output. The bits after 2nd interleaving are denoted by $v_{t,1}, v_{t,2}, \ldots, v_{t,U_t}$ ~~$v_{t1}, v_{t2}, \ldots, v_{tU_t}$~~, where ~~$v_{t1}$~~ $v_{t,1}$ corresponds to the bit ~~y_{tk}~~ $y_{t,k}$ with smallest index k after pruning, ~~v_{t2}~~ $v_{t,2}$ to the bit ~~y_{tk}~~ $y_{t,k}$ with second smallest index k after pruning, and so on.

Table 6

Column number ~~C_2~~C2	Inter-column permutation pattern < P2(0), P2(1), …,P2(29) >
30	~~{~~<0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17~~}~~>

4.2.11 Physical channel mapping

The PhCH for both uplink and downlink is defined in [6]. The bits after physical channel mapping are denoted by $w_{p,1}, w_{p,2}, \ldots, w_{p,U_p}$ ~~$w_{p1}, w_{p2}, \ldots, w_{pU_p}$~~, where p is the PhCH number and U_p is the number of bits in one radio frame for the respective PhCH. The bits ~~w_{pk}~~ $w_{p,k}$ are mapped to the PhCHs so that the bits for each PhCH are transmitted over the air in ascending order with respect to k.

The mapping of the bits $v_{(t),1}, v_{(t),2}, \ldots, v_{(t),U_{(t)}}$ ~~$v_{(t)1}, v_{(t)2}, \ldots, v_{(t)U_{(t)}}$~~ is performed like block interleaving, writing the bits into columns, but a PhCH with an odd number is filled in forward order, were as a PhCH with an even number is filled in reverse order.

The mapping scheme, as described in the following subclause, shall be applied individually for each timeslot t used in the current frame. Therefore, the bits $v_{t,1}, v_{t,2}, \ldots, v_{t,U_t}$ ~~$v_{t1}, v_{t2}, \ldots, v_{tU_t}$~~ are assigned to the bits of the physical channels $w_{t,1,1\ldots U_{t1}}, w_{t,2,1\ldots U_{t2}}, \ldots, w_{t,P_t,1\ldots U_{tP_t}}$ ~~$w_{t1,1\ldots U_{t1}}, w_{t2,1\ldots U_{t2}}, \ldots, w_{tP_t,1\ldots U_{tP_t}}$~~ in each timeslot.

In uplink there are at most two codes allocated (P≤2). If there is only one code, the same mapping as for downlink is applied. Denote SF1 and SF2 the spreading factors used for code 1 and 2, respectively. For the number of consecutive bits to assign per code bs_k the following rule is applied:

```
if
    SF1 >= SF2  then $bs_1$ = 1  ; $bs_2$ =  SF1/SF2 ;
else
    SF2 > SF1  then $bs_1$ = SF2/SF1; $bs_2$ = 1 ;
end if
```

In the downlink case bs_p is 1 for all physical channels.

4.2.11.1 Mapping scheme

Notation used in this subclause:

P_t: number of physical channels for timeslot t , P_t = 1..2 for uplink ; P_t = 1...16 for downlink

$U_{t,p}$~~U_{tp}~~: capacity in bits for the physical channel p in timeslot t

$U_{t.}$: total number of bits to be assigned for timeslot t

bs_p: number of consecutive bits to assign per code

for downlink all bs_p = 1

for uplink if SF1 >= SF2 then bs_1 = 1 ; bs_2 = SF1/SF2 ;

if SF2 > SF1 then bs_1 = SF2/SF1; bs_2 = 1 ;

fb_p: number of already written bits for each code

pos: intermediate calculation variable

```
for  p=1  to $P_t$                          -- reset number of already written bits for every physical channel
    $fb_p$ = 0
end for
p = 1                                       -- start with PhCH #1
for k=1  to $U_{t.}$
    do while ($fb_p$ == ~~$U_{tp}$~~$U_{t,p}$)          -- physical channel filled up already ?
        p = (p mod $P_t$) + 1;
    end do
    if (p mod 2) == 0
        pos = ~~$U_{tp}$~~ $U_{t,p}$ - $fb_p$                -- reverse order
    else
        pos = $fb_p$ + 1                    -- forward order
    endif
    ~~$w_{tp,pos}$~~ $w_{t,p,pos}$ = $v_{t,k}$                   -- assignment
    $fb_p$ = $fb_p$ + 1                     -- Increment number of already written bits
```

```
if ($fb_p$ mod $bs_p$) == 0                    -- Conditional change to the next physical channel
    p = (p mod $P_t$) + 1;
```

4.3 Coding for layer 1 control

4.3.1 Coding of transport format combination indicator (TFCI)

Encoding of the TFCI ~~bits~~ depends on the ~~number of them~~its length. If there are 6-10 bits of TFCI the channel encoding is done as described in subclause 4.3.1.1. Also specific coding of less than 6 bits is possible as explained in subclause 4.3.1.2.

4.3.1.1 Coding of long TFCI lengths

The TFCI ~~bits are~~is encoded using a (32, 10) sub-code of the second order Reed-Muller code. The coding procedure is as shown in figure 6.

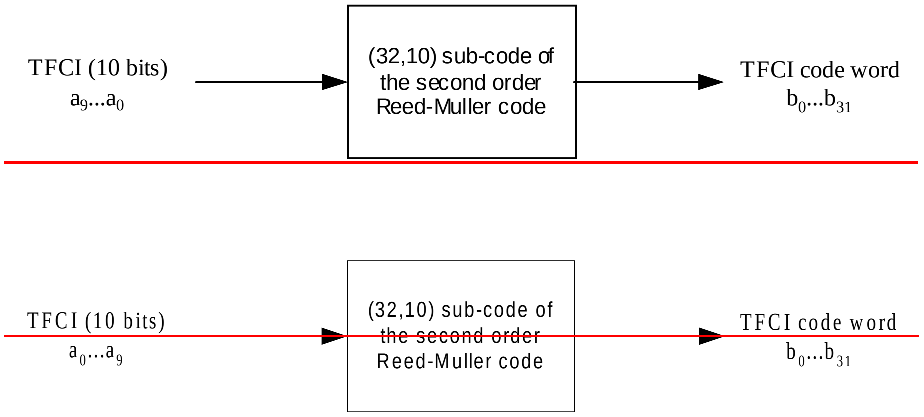


Figure 6: Channel coding of TFCI information bits

TFCI is encoded by the (32,10) sub-code of second order Reed-Muller code. The code words of the (32,10) sub-code of second order Reed-Muller code are linear combination of some among 10 basis sequences. The basis sequences are as follows in table 7.

Table 7: Basis sequences for (32,10) TFCI code

I	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{I,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$
0	1	0	0	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1	0	0	0
2	1	1	0	0	0	1	0	0	0	1
3	0	0	1	0	0	1	1	0	1	1
4	1	0	1	0	0	1	0	0	0	1
5	0	1	1	0	0	1	0	0	1	0
6	1	1	1	0	0	1	0	1	0	0
7	0	0	0	1	0	1	0	1	1	0
8	1	0	0	1	0	1	1	1	1	0
9	0	1	0	1	0	1	1	0	1	1
10	1	1	0	1	0	1	0	0	1	1
11	0	0	1	1	0	1	0	1	1	0
12	1	0	1	1	0	1	0	1	0	1
13	0	1	1	1	0	1	1	0	0	1
14	1	1	1	1	0	1	1	1	1	1
15	1	0	0	0	1	1	1	1	0	0
16	0	1	0	0	1	1	1	1	0	1
17	1	1	0	0	1	1	1	0	1	0
18	0	0	1	0	1	1	0	1	1	1
19	1	0	1	0	1	1	0	1	0	1
20	0	1	1	0	1	1	0	0	1	1
21	1	1	1	0	1	1	0	1	1	1
22	0	0	0	1	1	1	0	1	0	0
23	1	0	0	1	1	1	1	1	0	1
24	0	1	0	1	1	1	1	0	1	0
25	1	1	0	1	1	1	1	0	0	1
26	0	0	1	1	1	1	0	0	1	0
27	1	0	1	1	1	1	1	1	0	0
28	0	1	1	1	1	1	1	1	1	0
29	1	1	1	1	1	1	1	1	1	1
30	0	0	0	0	0	1	0	0	0	0
31	0	0	0	0	1	1	1	0	0	0

~~Let's define t~~The TFCI information bits ~~as~~ a_0 , a_1 , a_2 , a_3 , a_4 , a_5 , a_6 , a_7 , a_8 , a_9 (where a_0 is LSB and a_9 is MSB)~~. The TFCI information bits~~ shall correspond to the TFC index (expressed in unsigned binary form) defined by the RRC layer to reference the TFC of the CCTrCH in the associated DPCH radio frame.

The output code word bits b_i are given by:

$$b_i = \sum_{n=0}^{9} (a_n \times M_{i,n}) \bmod 2$$

where i~~i~~=0,…,31. N_{TFCI}=32.

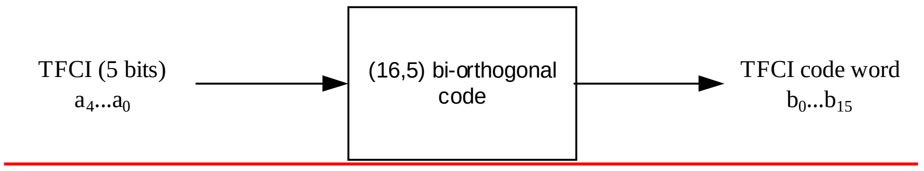
4.3.1.2 Coding of short TFCI lengths

4.3.1.2.1 Coding very short TFCIs by repetition

If the number of TFCI bits is 1 or 2, then repetition will be used for coding. In this case each bit is repeated to a total of 4 times giving 4-bit transmission (N_{TFCI}=4) for a single TFCI bit and 8-bit transmission (N_{TFCI}=8) for 2 TFCI bits.~~ Let's define the TFCI information bit(s) as b_0 (or b_0 and b_1).~~ The TFCI information bit(s) b_0 (or b_0 and b_1 where b_0 is the LSB) shall correspond to the TFC index (expressed in unsigned binary form) defined by the RRC layer to reference the TFC of the CCTrCH in the associated DPCH radio frame. In the case of two TFCI bits denoted b_0 and b_1 the TFCI word shall be { b_0, b_1, b_0, b_1, b_0, b_1, b_0, b_1 }.

4.3.1.2.2 Coding short TFCIs using bi-orthogonal codes

If the number of TFCI bits is in the range 3 to 5 the TFCI ~~bits are~~is encoded using a (16, 5) bi-orthogonal (or first order Reed-Muller) code. The coding procedure is as shown in figure 7.



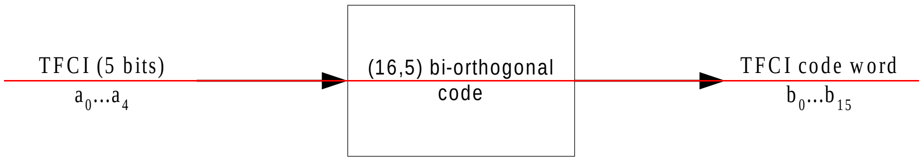


Figure 7: Channel coding of short length TFCI information bits

The code words of the (16,5) bi-orthogonal code are linear combinations of 5 basis sequences as defined in table 8.

Table 8: Basis sequences for (16,5) TFCI code

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$
0	1	0	0	0	1
1	0	1	0	0	1
2	1	1	0	0	1
3	0	0	1	0	1
4	1	0	1	0	1
5	0	1	1	0	1
6	1	1	1	0	1
7	0	0	0	1	1
8	1	0	0	1	1
9	0	1	0	1	1
10	1	1	0	1	1
11	0	0	1	1	1
12	1	0	1	1	1
13	0	1	1	1	1
14	1	1	1	1	1
15	0	0	0	0	1

~~Let's define t~~The TFCI information bits ~~as~~ a_0 , a_1 , a_2 , a_3 , a_4 (where a_0 is LSB and a_4 is MSB)~~. The TFCI information bits~~ shall correspond to the TFC index (expressed in unsigned binary form) defined by the RRC layer to reference the TFC of the CCTrCH in the associated DPCH radio frame.

The output code word bits b_j are given by:

$$b_i = \sum_{n=0}^{4} (a_n \times M_{i,n}) \bmod 2$$

where i~~i~~=0,…,15. N_{TFCI}=16.

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25.222 CR 041r1 Current Version: 3.3.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑ *↑ CR number as allocated by MCC support team*

For submission to: RAN #9 *list expected approval meeting # here ↑*	for approval	☒	Strategic	☐	*(for SMG use only)*
	For information	☐	non-strategic	☐	

Form: CR cover sheet, version 2 for 3GPP and SMG The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc

Proposed change affects: (U)SIM ☐ ME ☒ UTRAN / Radio ☒ Core Network ☐
(at least one should be marked with an X)

Source: TSG RAN WG1 **Date:** 24-August-2000

Subject: Editorial corrections in Turbo code internal interleaver section

Work item:

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

F Correction	☒	**Release:**	Phase 2	☐
A Corresponds to a correction in an earlier release	☐		Release 96	☐
B Addition of feature	☐		Release 97	☐
C Functional modification of feature	☐		Release 98	☐
D Editorial modification	☐		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 TS25.222

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.

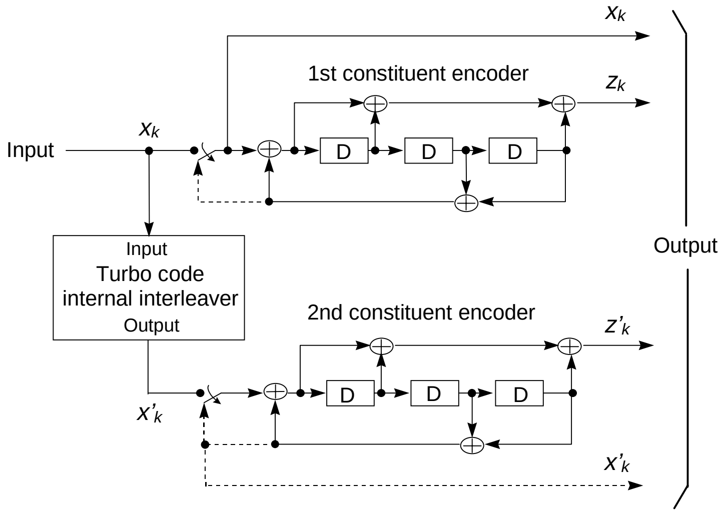

Figure 3: Structure of rate 1/3 Turbo coder (dotted lines apply for trellis termination only)

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:

$$x_{K+1}, z_{K+1}, x_{K+2}, z_{K+2}, x_{K+3}, z_{K+3}, x'_{K+1}, z'_{K+1}, x'_{K+2}, z'_{K+2}, x'_{K+3}, z'_{K+3}.$$

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 $40 \leq K \leq 5114$. The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by $x_k = o_{irk}$ 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~~K	Number of bits input to Turbo code internal interleaver
~~R~~R	Number of rows of rectangular matrix
~~C~~C	Number of columns of rectangular matrix
~~p~~p	Prime number
~~v~~v	Primitive root
~~s(i)~~$\langle s(j) \rangle_{j \in \{0,1,\cdots,p-2\}}$	Base sequence for intra-row permutation
~~q_j~~q_i	Minimum prime integers
~~r_j~~r_i	Permuted prime integers

~~T(j)~~ $\langle T(i)\rangle_{i\in\{0,1,\cdots,R-1\}}$ Inter-row permutation pattern

~~U~~ ~~$U_j(i)$~~ $\langle U_i(j)\rangle_{j\in\{0,1,\cdots,C-1\}}$ Intra-row permutation pattern of *i*-th row

~~i~~*i* Index of row number of rectangular matrix
~~j~~*j* Index of column number of rectangular matrix
~~k~~*k* Index of bit sequence

4.2.3.2.3.1 Bits-input to rectangular matrix with padding

The bit sequence $x_1, x_2, x_3, \ldots, x_K$ input to the Turbo code internal interleaver ~~x_k~~ is written into the rectangular matrix as follows:

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

$$R = \begin{cases} 5, \text{if } (40 \le K \le 159) \\ 10, \text{if } ((160 \le K \le 200) \text{ or } (481 \le K \le 530)) \\ 20, \text{if } (K = \text{any other value}) \end{cases} .$$

~~where t~~The rows of rectangular matrix are numbered 0, 1,~~ 2,~~ …, *R* - 1 from top to bottom.

(2) Determine the prime number to be used in the intra-permutation, *p*, and the number of columns ~~*C*~~ of rectangular matrix, *C*, such that:

```
if (481 ≤ $K$ ≤ 530) then
    $p$ = 53 and $C = p$.
else
    Find minimum prime number $p$ from table 2 such that
        ~~$(p + 1) - K/R \geq 0$~~ $K \le R\times(p+1)$,
    and determine $C$ such that
        $C = \begin{cases} p-1 & \text{if } K \le R\times(p-1) \\ p & \text{if } R\times(p-1) < K \le R\times p \\ p+1 & \text{if } R\times p < K \end{cases}.$
    ~~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~~
end if
```

~~where t~~The columns of rectangular matrix are numbered 0, 1,~~ 2,~~ …, *C* - 1 from left to right.

Table 2: List of prime number *p* and associated primitive root *v*

p	*v*	*p*	*v*	*p*	*v*	*p*	*v*	*p*	*v*
7	3	47	5	101	2	157	5	223	3
11	2	53	2	103	5	163	2	227	2
13	2	59	2	107	2	167	5	229	6
17	3	61	2	109	6	173	2	233	3
19	2	67	2	113	3	179	2	239	7
23	5	71	7	127	3	181	2	241	7
29	2	73	5	131	2	191	19	251	6
31	3	79	3	137	3	193	5	257	3
37	2	83	2	139	2	197	2		
41	6	89	3	149	2	199	3		
43	3	97	5	151	6	211	2		

(3) Write the input bit sequence ~~x_k~~ $x_1, x_2, x_3, \ldots, x_K$ into the $R\times C$ rectangular matrix row by row starting with bit ~~x~~y_1 in column 0 of row 0:

$$\cancel{\begin{bmatrix} x_1 & x_2 & x_3 & \cdots\ x_C \\ x_{(C+1)} & x_{(C+2)} & x_{(C+3)} & \cdots x_{2C} \\ \vdots & \vdots & \vdots & \cdots\ \vdots \\ x_{((R-1)C+1)} & x_{((R-1)C+2)} & x_{((R-1)C+3)} & \cdots x_{RC} \end{bmatrix}} \begin{bmatrix} y_1 & y_2 & y_3 & \cdots\ y_C \\ y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \cdots\ y_{2C} \\ \vdots & \vdots & \vdots & \cdots\ \vdots \\ y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \cdots y_{R\times C} \end{bmatrix}$$

where $y_k = x_k$ for k = 1, 2, …, K and 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 stepwise by using the following algorithm with steps (1) – (6).

(1) Select a primitive root *v* from table 2 in section 4.2.3.2.3.1, which is indicated on the right side of the prime number *p*.

(2) Construct the base sequence ~~$s(i)$~~ $\langle s(j)\rangle_{j\in\{0,1,\cdots,p-2\}}$ for intra-row permutation as:

~~$s(i) = [v \times s(i-1)] \bmod p$~~ $s(j) = (v\times s(j-1)) \bmod p$, $\cancel{i}j$ = 1, 2,…, (p - 2)~~.~~, and $s(0)$ = 1.

(3) ~~Let~~Assign q_0 = 1 to be the first prime integer in ~~$\{q_j\}$~~the sequence $\langle q_i\rangle_{i\in\{0,1,\cdots,R-1\}}$, and ~~select~~determine the ~~consecutive minimum~~ prime integer~~s~~ ~~$\{q_j\}$~~ in the sequence $\langle q_i\rangle_{i\in\{0,1,\cdots,R-1\}}$ ~~(j = 1, 2, …, R – 1)~~ to be a least prime integer such that~~:~~

g.c.d~~{~~$(q_{\cancel{j}i}, p - 1$~~}~~$)$ = 1, $q_{\cancel{j}i} > 6$, and $q_{\cancel{j}i} > q_{(\cancel{j}i-1)}$~~,~~ for each i = 1, 2, …, R – 1.

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

(4) Permute ~~$\{q_j\}$~~the sequence $\langle q_i\rangle_{i\in\{0,1,\cdots,R-1\}}$ to make ~~$\{r_j\}$~~the sequence $\langle r_i\rangle_{i\in\{0,1,\cdots,R-1\}}$ such that

$r_{T(\cancel{j}i)} = q_{\cancel{j}i}$, $\cancel{j}i$ = 0, 1, …, R - 1, where ~~$T(j)$ (j = 0, 1, 2, …, R - 1)~~ $\langle T(i) \rangle_{i \in \{0,1,\cdots,R-1\}}$ 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.

~~$\{T(0),T(1),T(2),\ldots,T(R-1)\} =$~~

$$\begin{cases} Pat_4 & \text{if}\,(40 \le K \le 159) \\ Pat_3 & \text{if}\,(160 \le K \le 200) \\ Pat_1 & \text{if}\,(201 \le K \le 480) \\ Pat_3 & \text{if}\,(481 \le K \le 530) \\ \cancel{Pat_1} & \cancel{\text{if}\,(531 \le K \le 2280)} \\ Pat_2 & \text{if}\,(2281 \le K \le 2480) \\ Pat_1 & \text{if}\,(2481 \le K \le 3160) \\ Pat_2 & \text{if}\,(3161 \le K \le 3210) \\ Pat_1 & \text{if}\,(3211 \le K \le 5114) \end{cases}$$ ~~,~~

~~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

Number of input bits K	Number of rows R	Inter-row permutation patterns <$T(0)$, $T(1)$, …, $T(R - 1)$>
($40 \le K \le 159$)	5	<4, 3, 2, 1, 0>
($160 \le K \le 200$) or ($481 \le K \le 530$)	10	<9, 8, 7, 6, 5, 4, 3, 2, 1, 0>
($2281 \le K \le 2480$) or ($3161 \le K \le 3210$)	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10>
K = any other value	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11>

(5) Perform the ~~j~~i-th (~~j~~i = 0, 1,~~2,~~ …, R - 1) intra-row permutation as:

if ($C = p$) then

~~$U_j(i) = s([i \times r_j] \bmod (p-1))$~~ $U_i(j) = s((j \times r_i) \bmod (p-1))$, ~~$i$~~$j$ = 0, 1,~~2,~~ …, (p - 2)~~., ,~~, and $U_{i}(p - 1) = 0$,

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

end if

if ($C = p + 1$) then

~~$U_j(i) = s([i \times r_j] \bmod (p-1))$~~ $U_i(j) = s((j \times r_i) \bmod (p-1))$, ~~$i$~~$j$ = 0, 1,~~2,~~ …, (p - 2).~~,~~ $U_{i}(p - 1) = 0$, and $U_{i}(p) = p$,

where $U_{i}(j)$ is the ~~input~~original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row, and

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

Exchange $U_{R-1}(p)$ with $U_{R-1}(0)$.

end if

end if

if ($C = p - 1$) then

~~$U_j(i) = s([i \times r_j]\bmod(p-1)) - 1$~~ $U_i(j) = s((j \times r_i)\bmod(p-1)) - 1$, ~~$i$~~$j$ = 0, 1,~~ 2,~~ …, (p - 2),

where $U_{\sout{j}i}$(~~i~~j) is the ~~input~~ original bit position of ~~i~~j-th ~~output after the permutation~~permuted bit of ~~j~~i-th row.

end if

(6) Perform the inter-row permutation for the rectangular matrix based on the pattern ~~$T(j)$ (j = 0, 1, 2, …, R - 1)~~ $\langle T(i) \rangle_{i\in\{0,1,\cdots,R-1\}}$,

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

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

~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~v~~	~~p~~	~~V~~	~~p~~	~~V~~
~~7~~	~~3~~	~~47~~	~~5~~	~~101~~	~~2~~	~~157~~	~~5~~	~~223~~	~~3~~
~~11~~	~~2~~	~~53~~	~~2~~	~~103~~	~~5~~	~~163~~	~~2~~	~~227~~	~~2~~
~~13~~	~~2~~	~~59~~	~~2~~	~~107~~	~~2~~	~~167~~	~~5~~	~~229~~	~~6~~
~~17~~	~~3~~	~~61~~	~~2~~	~~109~~	~~6~~	~~173~~	~~2~~	~~233~~	~~3~~
~~19~~	~~2~~	~~67~~	~~2~~	~~113~~	~~3~~	~~179~~	~~2~~	~~239~~	~~7~~
~~23~~	~~5~~	~~71~~	~~7~~	~~127~~	~~3~~	~~181~~	~~2~~	~~241~~	~~7~~
~~29~~	~~2~~	~~73~~	~~5~~	~~131~~	~~2~~	~~191~~	~~19~~	~~251~~	~~6~~
~~31~~	~~3~~	~~79~~	~~3~~	~~137~~	~~3~~	~~193~~	~~5~~	~~257~~	~~3~~
~~37~~	~~2~~	~~83~~	~~2~~	~~139~~	~~2~~	~~197~~	~~2~~		
~~41~~	~~6~~	~~89~~	~~3~~	~~149~~	~~2~~	~~199~~	~~3~~		
~~43~~	~~3~~	~~97~~	~~5~~	~~151~~	~~6~~	~~211~~	~~2~~		

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:

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

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 ~~in~~to 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~~y_k with $k > K$ are removed from the output. The bits output from Turbo code internal interleaver are denoted by x'_1, x'_2, …, x'_K, where x'_1 corresponds to the bit y'_k with smallest index k after pruning, x'_2 to the bit y'_k 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:

$$R \times C - K.$$

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Form: CR cover sheet, version 2 for 3GPP and SMG *The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc*

Proposed change affects: (U)SIM ☐ ME ☒ UTRAN / Radio ☒ Core Network ☐
(at least one should be marked with an X)

Source: TSG RAN WG1 **Date:** 2000-07-05

Subject: Paging Indicator Terminology

Work item:

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

F	Correction	☒	**Release:**	Phase 2	☐
A	Corresponds to a correction in an earlier release	☐		Release 96	☐
B	Addition of feature	☐		Release 97	☐
C	Functional modification of feature	☐		Release 98	☐
D	Editorial modification	☐		Release 99	☒
				Release 00	☐

Reason for change: The Abbreviation PI is used for the value calculated by higher layers and should not be mixed with the physical layer paging indicator

Clauses affected:

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:

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3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

<ACRONYM>	<Explanation>
ARQ	Automatic Repeat on Request
BCH	Broadcast Channel
BER	Bit Error Rate
BS	Base Station
BSS	Base Station Subsystem
CBR	Constant Bit Rate
CCCH	Common Control Channel
CCTrCH	Coded Composite Transport Channel
CDMA	Code Division Multiple Access
CFN	Connection Frame Number
CRC	Cyclic Redundancy Check
DCA	Dynamic Channel Allocation
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DL	Downlink
DRX	Discontinuous Reception
DSCH	Downlink Shared Channel
DTX	Discontinuous Transmission
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Control
FER	Frame Error Rate
GF	Galois Field
JD	Joint Detection
L1	Layer 1
L2	Layer 2
LLC	Logical Link Control
MA	Multiple Access
MAC	Medium Access Control
MS	Mobile Station
MT	Mobile Terminated
NRT	Non-Real Time
OVSF	Orthogonal Variable Spreading Factor
PC	Power Control
PCCC	Parallel Concatenated Convolutional Code
PCH	Paging Channel
PhCH	Physical Channel
PI	Paging Indicator (value calculated by higher layers)
P_q	Paging Indicator (indicator set by physical layer)
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
RACH	Random Access Channel
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
RRM	Radio Resource Management
RSC	Recursive Systematic Convolutional Coder
RT	Real Time
RU	Resource Unit
SCCC	Serial Concatenated Convolutional Code
SCH	Synchronization Channel
SNR	Signal to Noise Ratio
TCH	Traffic channel
TDD	Time Division Duplex
TDMA	Time Division Multiple Access

TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TPC	Transmit Power Control
TrBk	Transport Block
TrCH	Transport Channel
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
USCH	Uplink Shared Channel
UTRA	UMTS Terrestrial Radio Access
VBR	Variable Bit Rate

4.3.2 Coding of Paging Indicator~~ (PI)~~

The paging indicator P_q~~PI~~ is an identifier to instruct the UE whether there is a paging message for the groups of mobiles that are associated to the PI, calculated by higher layers, and the associated paging indicator P_q. The length L_{PI} of the paging indicator~~PI~~ is L_{PI}=2, L_{PI}=4 or L_{PI}=8 symbols. The coding of the paging indicator~~PI~~ is shown in table 9.

Table 9: Coding of the paging indicator~~PI~~

Bits	Paging Indicator~~PI~~	Content
All '0'	Not set, P_q='0'	There is no necessity to receive PCH
All '1'	Set, P_q='1'	There is necessity to receive PCH~~.~~

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25.222 CR 043r1 Current Version: 3.3.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑ *↑ CR number as allocated by MCC support team*

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Proposed change affects: (U)SIM ☐ ME ☐ UTRAN / Radio ☒ Core Network ☐
(at least one should be marked with an X)

Source: TSG RAN WG1 **Date:** August 23,2000

Subject: Bit separation and collection for rate matching

Work item: TS25.222

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

- 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: In the section describing the bit separation there was an error in the description: it was omitted that, when the number of bits is not a multiple of 3, some of the second and third parity bits from the turbo encoded TrCHs can go to the 1st sequence instead of to the 2nd and 3rd sequences.

Clauses affected: 4.2.7.2, 4.2.7.2.1

Other specs affected:

Other 3G core specifications	☐	→ List of CRs:	25.212 CR -092
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:

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4.2.7.2 Bit separation and collection for rate matching

The systematic bits of turbo encoded TrCHs shall not be punctured, the other bits ~~however systematic bits for trellis termination~~ may be punctured. The systematic bits, first parity bits, and second parity bits in the bit sequence input to the rate matching block are therefore separated into three sequences.

The first sequence contains:

- All of the systematic bits that are from turbo encoded TrCHs.
- From 0 to 2 first and/or second parity bits that are from turbo encoded TrCHs. These bits come into the first sequence when the total number of bits in a block after radio frame segmentation is not a multiple of three.
- Some of the systematic, first parity and second parity bits that are for trellis termination.

The second sequence contains:

- All of the first parity bits that are from turbo encoded TrCHs, except those that go into the first sequence when the total number of bits is not a multiple of three.
- Some of the systematic, first parity and second parity bits that are for trellis termination.

The third sequence contains:

- All of the second parity bits that are from turbo encoded TrCHs, except those that go into the first sequence when the total number of bits is not a multiple of three.
- Some of the systematic, first parity and second parity bits that are for trellis termination.

~~, one sequence containing all of the systematic bits and some systematic, first and second parity trellis termination bits; the second sequence containing all of the first parity bits and some systematic, first and second parity trellis termination bits and the third sequence containing all of the second parity bits and some systematic, first and second parity trellis termination bits.~~ The second and third sequences shall be of equal length, whereas the first sequence can contain from 0 to 2 more bits. Puncturing is ~~only~~ applied only to the second and third sequences.

The bit separation function is transparent for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition. The bit separation and bit collection are illustrated in figures 4 and 5.

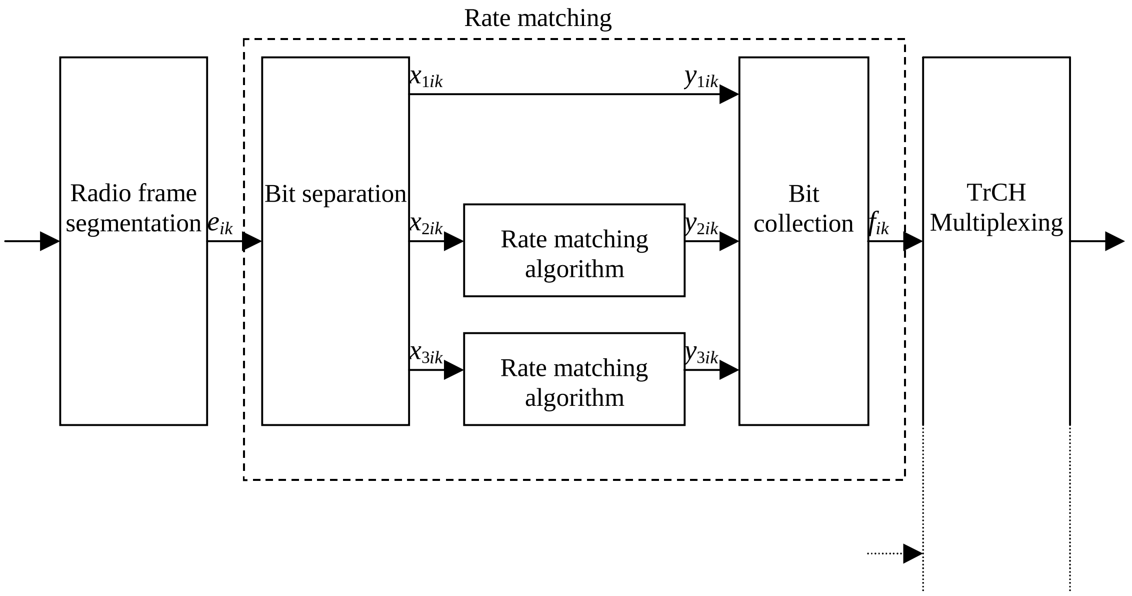

Figure 4: Puncturing of turbo encoded TrCHs

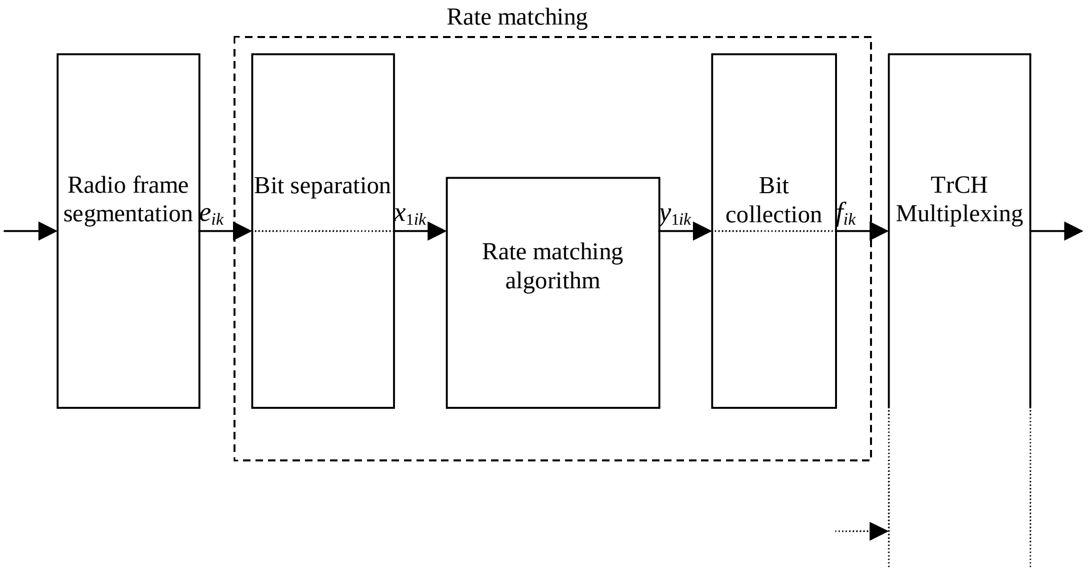

Figure 5: Rate matching for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition

The bit separation is dependent on the 1st interleaving and offsets are used to define the separation for different TTIs. *b* indicates the three sequences defined in this section, with *b*=1 indicating the first sequence, *b* = 2 the second one, and *b* = 3 the third one. ~~The sequence denoted as b=1 contains all of the systematic bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=2 contains all of the first parity bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=3 contains all of the second parity bits and some systematic, first~~

~~and second parity trellis termination bits.~~ The offsets α_b for these sequences are listed in table 4.

Table 4: TTI dependent offset needed for bit separation

TTI (ms)	α_1	α_2	α_3
10, 40	0	1	2
20, 80	0	2	1

The bit separation is different for different radio frames in the TTI. A second offset is therefore needed. The radio frame number for TrCH *i* is denoted by n_i. and the offset by β_{n_i}.

Table 5: Radio frame dependent offset needed for bit separation

TTI (ms)	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7
10	0	NA	NA	NA	NA	NA	NA	NA
20	0	1	NA	NA	NA	NA	NA	NA
40	0	1	2	0	NA	NA	NA	NA
80	0	1	2	0	1	2	0	1

4.2.7.2.1 Bit separation

The bits input to the rate matching are denoted by $e_{i1}, e_{i2}, e_{i3}, \ldots, e_{iN_i}$, where *i* is the TrCH number and N_i is the number of bits input to the rate matching block. Note that the transport format combination number *j* for simplicity has been left out in the bit numbering, i.e. N_i=N_{ij}. The bits after separation are denoted by $x_{bi1}, x_{bi2}, x_{bi3}, \ldots, x_{biX_i}$. For turbo encoded TrCHs with puncturing, *b* indicates the three sequences defined in section 4.2.7.2, with *b*=1 indicating the first sequence, and so forth.~~.~~ ~~The sequence denoted as b=1 contains all of the systematic bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=2 contains all of the first parity bits and some systematic, first and second parity trellis termination bits; the sequence denoted as b=3 contains all of the second parity bits and some systematic, first and second parity trellis termination bits.~~ For all other cases *b* is defined to be 1. X_i is the number of bits in each separated bit sequence. The relation between e_{ik} and x_{bik} is given below.

For turbo encoded TrCHs with puncturing:

$x_{1,i,k} = e_{i,3(k-1)+1+(\alpha_1+\beta_{n_i}) \bmod 3}$ k = 1, 2, 3, …, X_i $X_i = \lfloor N_i/3 \rfloor$

$x_{1,i,\lfloor N_i/3 \rfloor + k} = e_{i,3\lfloor N_i/3 \rfloor + k}$ k = 1, …, N_i mod 3 Note: When (N_i mod 3) = 0 this row is not needed.

$x_{2,i,k} = e_{i,3(k-1)+1+(\alpha_2+\beta_{n_i}) \bmod 3}$ k = 1, 2, 3, …, X_i $X_i = \lfloor N_i/3 \rfloor$

$x_{3,i,k} = e_{i,3(k-1)+1+(\alpha_3+\beta_{n_i}) \bmod 3}$ k = 1, 2, 3, …, X_i $X_i = \lfloor N_i/3 \rfloor$

For uncoded TrCHs, convolutionally encoded TrCHs, and turbo encoded TrCHs with repetition:

$x_{1,i,k} = e_{i,k}$ k = 1, 2, 3, …, X_i $X_i = N_i$

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Hawaii, USA, 20-22 September 2000

Document *R1-00-1104*
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CHANGE REQUEST

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Form: CR cover sheet, version 2 for 3GPP and SMG *The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc*

Proposed change affects: (U)SIM ☐ ME ☐ UTRAN / Radio ☒ Core Network ☐
(at least one should be marked with an X)

Source: TSG RAN WG1 **Date:** August 22, 2000

Subject: Puncturing Limit definition in WG1 specification

Work item: TS25.222

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

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: The definition of PL signalled by higher layers is not well defined in the current specification.

Clauses affected: 4.2.7, 4.2.7.1

Other specs affected:

Other 3G core specifications	☐	→ List of CRs:	25.212 CR-93
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:

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4.2.7 Rate matching

Rate matching means that bits on a TrCH are repeated or punctured. Higher layers assign a rate-matching attribute for each TrCH. This attribute is semi-static and can only be changed through higher layer signalling. The rate-matching attribute is used when the number of bits to be repeated or punctured is calculated.

The number of bits on a TrCH can vary between different transmission time intervals. When the number of bits between different transmission time intervals is changed, bits are repeated to ensure that the total bit rate after TrCH multiplexing is identical to the total channel bit rate of the allocated physical channels.

If no bits are input to the rate matching for all TrCHs within a CCTrCH, the rate matching shall output no bits for all TrCHs within the CCTrCH.

Notation used in subclause 4.2.7 and subclauses:

N_{ij}: Number of bits in a radio frame before rate matching on TrCH i with transport format combination j.

ΔN_{ij} : If positive – number of bits to be repeated in each radio frame on TrCH i with transport format

If negative – number of bits to be punctured in each radio frame on TrCH i with transport format combination j.

RM_i: Semi-static rate matching attribute for TrCH i. Signalled from higher layers.

PL: Puncturing limit. This value limits the amount of puncturing that can be applied in order to minimise the number of physical channels. Signalled from higher layers. The allowed puncturing in % is actually equal to (1-PL)*100.

$N_{data,j}$: Total number of bits that are available for a CCTrCH in a radio frame with transport format combination j.

P: number of physical channels used in the current frame.

P_{max}: maximum number of physical channels allocated for a CCTrCH.

U_p: Number of data bits in the physical channel p with p = 1...P.

I: Number of TrCHs in a CCTrCH.

Z_{ij}: Intermediate calculation variable.

F_i: Number of radio frames in the transmission time interval of TrCH i.

n_i: Radio frame number in the transmission time interval of TrCH i ($0 \leq n_i < F_i$).

q: Average puncturing or repetition distance(normalised to only show the remaining rate matching on top of an integer number of repetitions).

$I_F(n_i)$: The inverse interleaving function of the 1st interleaver (note that the inverse interleaving function is identical to the interleaving function itself for the 1st interleaver).

$S(n_i)$: The shift of the puncturing or repetition pattern for radio frame n_i.

$TF_i(j)$: Transport format of TrCH i for the transport format combination j.

TFS(i): The set of transport format indexes *l* for TrCH i.

e_{ini}: Initial value of variable e in the rate matching pattern determination algorithm of subclause 4.2.7.3.

e_{plus} Increment of variable *e* in the rate matching pattern determination algorithm of subclause 4.2.7.3.

e_{minus} Decrement of variable *e* in the rate matching pattern determination algorithm of subclause 4.2.7.3.

b: Indicates systematic and parity bits.

b=1: Systematic bit. *X(t)* in subclause 4.2.3.2.1.

b=2: 1st parity bit (from the upper Turbo constituent encoder). *Y(t)* in subclause 4.2.3.2.1.

b=3: 2nd parity bit (from the lower Turbo constituent encoder). *Y'(t)* in subclause 4.2.3.2.1.

4.2.7.1 Determination of rate matching parameters

The following relations, defined for all TFC *j*, are used when calculating the rate matching pattern:

$$Z_{0,j} = 0$$

$$Z_{ij} = \left\lfloor \frac{\left\{ \left(\sum_{m=1}^{i} RM_m \cdot N_{mj} \right) \cdot N_{data,j} \right\}}{\sum_{m=1}^{I} RM_m \cdot N_{mj}} \right\rfloor \qquad \text{for all i = 1 .. I}$$

$$\Delta N_{ij} = Z_{ij} - Z_{i-1,j} - N_{ij} \qquad \text{for all i = 1 .. I}$$

Puncturing can be used to minimise the required transmission capacity. The maximum amount of puncturing that can be applied is 1-Pl, PL is signalled from higher layers~~ and denoted by PL~~. The possible values for N_{data} depend on the number of physical channels P_{max} , allocated to the respective CCTrCH, and on their characteristics (spreading factor, length of midamble and TFCI, usage of TPC and multiframe structure), which is given in [7].

Denote the number of data bits in each physical channel by $U_{p,Sp}$, where *p* refers to the sequence number $1 \le p \le P_{max}$ of this physical channel in the allocation message, and the second index *Sp* indicates the spreading factor with the possible values {*16, 8, 4, 2, 1*}, respectively. For each physical channel an individual minimum spreading factor Sp_{min} is transmitted by means of the higher layer. Then, for N_{data} one of the following values in ascending order can be chosen:

$$\left\{ U_{1,16}, \ldots, U_{1,S1_{\min}}, U_{1,S1_{\min}} + U_{2,16}, \ldots, U_{1,S1_{\min}} + U_{2,S2_{\min}}, \ldots, U_{1,S1_{\min}} + U_{2,S2_{\min}} + \ldots + U_{P_{\max},16}, \ldots, U_{1,S1_{\min}} + U_{2,S2_{\min}} + \ldots + U_{P_{\max},(SP_{\max})_{\min}} \right\}$$

$N_{data,\ j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} such that $\min\limits_{1 \le y \le I} \{RM_y\} \cdot N_{data} - PL \cdot \sum\limits_{x=1}^{I} RM_x \cdot N_{x,j}$ is non negative }

$N_{data,j}$ = min SET1

The number of bits to be repeated or punctured, ΔN_{ij}, within one radio frame for each TrCH i is calculated with the relations given at the beginning of this subclause for all possible transport format combinations j and selected every radio frame.
If $\Delta N_{ij} = 0$ then the output data of the rate matching is the same as the input data and the rate matching algorithm of subclause 4.2.7.3 does not need to be executed.
Otherwise, the rate matching pattern is calculated with the algorithm described in subclause 4.2.7.3. For this algorithm the parameters e_{ini}, e_{plus}, e_{minus}, and X_i are needed, which are calculated according to the equations in subclauses 4.2.7.1.1 and 4.2.7.1.2.