TSG-RAN Working Group1 meeting #10 TSGR1#10(00)0174

Beijing, China, January 18-21, 2000

Agenda Item : **AH04 + AH08**

Source : **Nortel Networks**

Title : **Downlink Compressed Mode by Puncturing, update**

Document for : **Decision**

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1. Introduction

This document presents a CR, which is the result of a merge between CR 25.212–042, and the suggestion to describe the insertion of the bits marked p, for compressed mode, before the first interleaver as presented in Tdoc R1-00139, plus a proposal for the location of the removal of the bits p.

2. Description of insertion of bits p in the multiplexing chain

This description has been removed from the rate matching step and put to the input of the first interleaver, using the algorithm proposed in Tdoc R1-00139, with notations adapted to the current specifications for the relations between output and input bits of a block in the multiplexing chain.

Moreover, the calculation of the number of bits p to insert in each segment of the TTI has been a little bit updated and detailed for clarity and consistency with the current specification: it is better explained how the formula (1) is used to calculate $\Delta N_{cm,i,max}$ and $\Delta^{NTTI}{}_{cm,il}$, and these values are negative to show that they correspond to removal of more bits in the rate matching step, to allow insertion of bits p.

3. Description of removal of bits p in the multiplexing chain

Discussion is still on going on the location of the removal of the p bits in the chain. However, some pros and cons for different places can already be listed.

One proposal was to remove the bits p just after the first interleaver. However, this leads to the need for an inequal Radio Frame Segmentation, and modification of the current Radio Frame Segmentation block for the purpose of Compressed Mode. This leads also to the need to modify the Transport Multiplexing block for Compressed Mode, since the number of bits per frame would not be the same for all the frames of one TTI. Thus it seems more straight forward and simple not to eliminate the p bits at this stage of the chain.

The other proposal was to remove the p bits at the physical segmentation step. This modifies a little only the Physical Channel Segmentation block. It consists in processing the input flow the same way as in the normal Physical Channel Segmentation, but not writing the bits p on the physical channels.

Actually, the number of bits p has been calculated to create exactly a gap of N_{TGL} bits on each physical channel. Thus by writing U bits from the input flow on each physical channel while ignoring (or “jumping over”) the bits p of the input flow, these bits p are removed which creates a gap of length N_{TGL} on each code. This can be described as simply as the removal of the δ in the output flow of the rate matching in the current specification. For this reason, this change is proposed in the following CR.

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Document R1-00174
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.

25.212	**CR**	**042r2**	Current Version: 3.1.0

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

For submission to:	WG1 # 10	for approval	X	strategic	(for SMG use only)
list expected approval meeting # here ↑		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: *(at least one should be marked with an X)*	(U)SIM		ME	X	UTRAN / Radio	X	Core Network

Source: Nortel Networks

Date: 17 January, 2000

Subject: Downlink Compressed Mode by puncturing

Work item: TS 25.212

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	X		Release 98	
D	Editorial modification			Release 99	X
				Release 00	

Reason for change: Introduction of a method for compressed mode by puncturing, which requires minimal changes to the multiplexing chain.

Clauses affected: 4.2.7 and 4.2.12.2

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:

help.doc

<---------- 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 $x_{i1}, x_{i2}, x_{i3}, \dots, x_{iX_i}$, 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 C_I from table 3.

(2) Determine the number of rows R_I defined as

$R_I = X_i/C_I$

(3) Write the input bit sequence into the $R_I \times C_I$ rectangular matrix row by row starting with bit $x_{i,1}$ in the first column of the first row and ending with bit $x_{i,(R_I C_I)}$ in column C_I of row R_I:

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

(4) Perform the inter-column permutation based on the pattern $\{P_1(j)\}$ (j=0,1, ..., C-1) shown in table 3, where $P_1(j)$ is the original column position of the *j*-th permuted column. After permutation of the columns, the bits are denoted by y_{ik}:

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

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

Table 3

TTI	Number of columns C_I	Inter-column permutation patterns
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}

4.2.5.1 Relation between input and output of 1st interleaving in uplink

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

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

4.2.5.2 Relation between input and output of 1st interleaving in downlink

If fixed positions of the TrCHs in a radio frame is used then the bits input to the 1st interleaving are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_iH_i)}$, where *i* is the TrCH number. Hence, $x_{ik} = h_{ik}$ and $X_i = F_iH_i$.

If flexible positions of the TrCHs in a radio frame is used then the bits input to the 1st interleaving are denoted by $g_{i1}, g_{i2}, g_{i3}, \ldots, g_{iG_i}$, where *i* is the TrCH number. Hence, $x_{ik} = h_{ik}$ and $X_i = G_i$.

In Compressed Mode by puncturing, the following is applied instead of the previous relations:

The sequence $x_{i,k}$ which will be input to first interleaver is built from bits $h_{i,k}$, $k=1, F_iH_i + \Delta N_{cm,i,max}$, plus $|\Delta N_{cm,i,max}|$ bits marked p if fixed positions are used, and from bits $g_{i,k}$ $k=1, G_i + \Delta N_{cm,il}$, plus $|\Delta N_{cm,il}|$ bits marked p if flexible positions are used, as is described thereafter:

Define:

$BR_F[x]$: the inter column permutation function for a TTI of length Fi *10ms, as defined in Table 3 above. $BR_F[x]$ is the Bit Reversal function of x on $\log_2(F)$ bits.

Note:

- C[x], x= 0 to Fi – 1, the number of bits p which have to be inserted in each of the Fi segments of the TTI, i.e. in each column of the first interleaver. C[x] is equal to $|\Delta N_{cm,i,max}[x]|$ for x equal 0 to Fi –1 if fixed positions are used. . C[x] is equal to $|\Delta N_{cm,i,l}[x]|$ for x equal 0 to Fi –1 if flexible positions are used. Both are noted $|\Delta N_{cm,i}[x]|$ in the following initialisation step.
- cbi[x], x=0 to Fi – 1, the counter of the number of bits p inserted in each of the Fi segments of the TTI, i.e. in each column of the first interleaver.
- $w_{i,k} = h_{i,k}$, for k = 1 to $F_iH_i + \Delta N_{cm,i,max}$, if fixed positions are used; $w_{i,k} = g_{i,k}$, for k = 1 to $G_i + \Delta N_{cm,il}$, if flexible positions are used
- Note that Ri Ci is equal to F_iH_i in case of fixed positions, and Ri Ci is equal to *Gi* in case of flexible positions

```
col = 0
while col < Fi do
    C[col] = |ΔN cm, i [col] |   -- initialisation of number of bits p  to be inserted in each of the Fi segments of the TTI
    cbi[col] = 0                 -- initialisation of counter of number of bits p inserted in each of the Fi segments of the TTI
end do


n = 0, m = 0
while n < Ri · Ci do
    col = n mod Fi
    if cbi[col] < C[BRFi (col)] do
        xi,n = p                     -- insert one p bit
        cbi[col] = cbi[col]+1        -- update counter of number of bits p inserted
    else                             -- no more p bit to insert in this segment
        xi,n  = wi,m
        m = m+1
    endif
    n = n +1
```

end do

The bits output from the 1st interleaving are denoted by $q_{i1}, q_{i2}, q_{i3}, \ldots, q_{iQ_i}$, where i is the TrCH number and Q_i is the number of bits. Hence, $q_{ik} = y_{ik}$, $Q_i = F_i H_i$ if fixed positions are used, and $Q_i = G_i$ if flexible positions are used.

4.2.7 Rate matching

Rate matching means that bits on a transport channel are repeated or punctured. Higher layers assign a rate-matching attribute for each transport channel. 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 transport channel can vary between different transmission time intervals. In the downlink the transmission is interrupted if the number of bits is lower than maximum. When the number of bits between different transmission time intervals in uplink is changed, bits are repeated or punctured to ensure that the total bit rate after TrCH multiplexing is identical to the total channel bit rate of the allocated dedicated 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 and no uplink DPDCH will be selected in the case of uplink rate matching.

Notation used in section 4.2.7 and subsections:

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

For downlink : An intermediate calculation variable (not an integer but a multiple of 1/8).

N_{il}^{TTI} : Number of bits in a transmission time interval before rate matching on TrCH *i* with transport format *l*. Used in downlink only.

ΔN_{ij} : For uplink: If positive - number of bits that should be repeated in each radio frame on TrCH *i* with transport format combination *j*.

If negative - number of bits that should be punctured in each radio frame on TrCH *i* with transport format combination *j*.

For downlink : An intermediate calculation variable (not an integer but a multiple of 1/8).

ΔN_{il}^{TTI} : If positive - number of bits to be repeated in each transmission time interval on TrCH *i* with transport format *j*.

If negative - number of bits to be punctured in each transmission time interval on TrCH *i* with transport format *j*.

Used in downlink only.

$\Delta N^{TTI}_{cm,ij}$:Negative or null: number of bits to be removed in one Transmission Time Interval, to create the required gaps in the compressed frames of this TTI, in case of compressed mode for TrCH *i* with transport format *j*.

Used in downlink only.

$\Delta N_{cm,ij}[k]$, k=0 to F_i -1:Negative or null: number of bits, in each frame of the TTI corresponding to the gap for compressed mode in this frame, for TrCH *i* with transport format *j*. The value will be null for the un-compressed frames.

Used in downlink only.

$N_{TGL}[k]$, k=0 to F_i -1 : Positive or null: number of bits in each frame of the TTI of a Transport Channel, corresponding to the gap for compressed mode in a radio frame for the CCTrCh.

RM_i: Semi-static rate matching attribute for transport channel *i*. Signalled from higher layers.

PL: Puncturing limit for uplink. This value limits the amount of puncturing that can be applied in order to avoid multicode or to enable the use of a higher spreading factor. Signalled from higher layers.

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

I: Number of TrCHs in the 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* £ $n_i < F_i$).

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

$I_F(n_i)$: 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). Used in uplink only.

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

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

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

TFCS The set of transport format combination indexes *j*.

e_{ini} Initial value of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.5.

e_{plus} Increment of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.5.

e_{minus} Decrement of variable *e* in the rate matching pattern determination algorithm of section 4.2.7.5.

b: Indicates systematic and parity bits

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

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

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

The * (star) notation is used to replace an index *x* when the indexed variable X_x does not depend on the index *x*. In the left wing of an assignment the meaning is that "$X_* = Y$" is equivalent to "**for all** $\underline{x}$ **do** $X_x = Y$ ". In the right wing of an assignment, the meaning is that "$Y = X_*$ " is equivalent to "**take any** $\underline{x}$ **and do** $Y = X_x$ "

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

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

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

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

4.2.7.1 Determination of rate matching parameters in uplink

4.2.7.1.1 Determination of SF and number of PhCHs needed

In uplink, puncturing can be applied to match the CCTrCH bit rate to the PhCH bit rate. The bit rate of the PhCH(s) is limited by the UE capability and restrictions imposed by UTRAN, through limitations on the PhCH spreading factor. The maximum amount of puncturing that can be applied is signalled from higher layers and denoted by *PL*. The number of available bits in the radio frames for all possible spreading factors is given in [2]. Denote these values by N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, and N_4, where the index refers to the spreading factor. The possible values of N_{data} then are $\{ N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2N_4, 3N_4, 4N_4, 5N_4, 6N_4\}$.Depending on the UE capability and the restrictions from UTRAN, the allowed set of N_{data} , denoted SET0, can be a subset of $\{ N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2N_4, 3N_4, 4N_4, 5N_4, 6N_4\}$. $N_{data,j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} in SET0 such that $N_{data} - \sum_{x=1}^{I} \frac{RM_{x,}}{\min_{1 \le y \le I}\{RM_y\}} \cdot N_{x,j}$ is non negative }

If SET1 is not empty and the smallest element of SET1 requires just one PhCH then

$N_{data,j}$ = min SET1

else

SET2 = { N_{data} in SET0 such that $N_{data} - PL \cdot \sum_{x=1}^{I} \frac{RM_x}{\min_{1 \le y \le I}\{RM_y\}} \cdot N_{x,j}$ is non negative }

Sort SET2 in ascending order

N_{data} = min SET2

While N_{data} is not the max of SET2 and the follower of N_{data} requires no additional PhCH do

N_{data} = follower of N_{data} in SET2

End while

$N_{data,j} = N_{data}$

End if

4.2.7.1.2 Determination of parameters needed for calculating the rate matching pattern

The number of bits to be repeated or punctured, DN_{ij}, within one radio frame for each TrCH i is calculated with equation 1 for all possible transport format combinations j and selected every radio frame. $N_{data,j}$ is given from section 4.2.7.1.1. In compressed mode $N_{data,j}$ is replaced by $N_{data,j}^{cm}$ in Equation 1. $N_{data,j}^{cm}$ is given from the following relation:

$N_{data,j}^{cm} = 2N_{data,j} - 2N_{TGL}$, for compressed mode by spreading factor reduction

$N_{data,j}^{cm} = N_{data,j} - N_{TGL}$, for compressed mode by higher layer scheduling

$$N_{TGL} = \begin{cases} \frac{TGL}{15} N_{data,j}, \text{ if } N_{first} + TGL \le 15 \\ \frac{15 - N_{first}}{15} N_{data,j}, \text{ in first frame if } N_{first} + TGL > 15 \\ \frac{TGL - (15 - N_{first})}{15} N_{data,j}, \text{ in second frame if } N_{first} + TGL > 15 \end{cases}$$

N_{first} and TGL are defined in section 4.4.

If $DN_{ij} = 0$ then the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed.

If $DN_{ij} \neq 0$ the parameters listed in sections 4.2.7.1.2.1 and 4.2.7.1.2.2 shall be used for determining e_{ini}, e_{plus}, and e_{minus} (regardless if the radio frame is compressed or not).

4.2.7.1.2.1 Uncoded and convolutionally encoded TrCHs

$R = DN_{ij} \bmod N_{ij}$ -- note: in this context $DN_{ij} \bmod N_{ij}$ is in the range of 0 to N_{ij}-1 i.e. -1 mod 10 = 9.

if $R \neq 0$ and $2R \le N_{ij}$

then $q = \lceil N_{ij} / R \rceil$

else

$q = \lceil N_{ij} / (R - N_{ij}) \rceil$

endif

-- note: *q* is a signed quantity.

if q is even

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

-- note that *q'* is not an integer, but a multiple of 1/8

else

q' = q

endif

for x = 0 to F_i-1

$S(I_F(|\lfloor x*q' \rfloor| \bmod F_i)) = (|\lfloor x*q' \rfloor| \text{ div } F_i)$

end for

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

a = 2

For each radio frame, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5, where :

$X_i = N_{i,j}$., and

$e_{ini} = (a \cdot S(n_i) \cdot |\Delta N_i| + 1) \bmod (a \cdot N_{ij})$.

$e_{plus} = a \cdot N_{ij}$

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

puncturing for *DN*<0, repetition otherwise.

4.2.7.1.2.2 Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. $DN_{i,j} > 0$, the parameters in section 4.2.7.1.2.1 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

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

$X_i = \lfloor N_{i,j} / 3 \rfloor$,

$q = \lfloor X_i / |\Delta N_i| \rfloor$

if($q \le 2$)

for *x*=0 to F_i-1

$S[I_F[(3x+b-1) \bmod F_i]] = x \bmod 2$;

end for

else

if q is even

then $q' = q - gcd(q, F_i)/ F_i$ -- where $gcd (q, F_i)$ means greatest common divisor of q and F_i
-- note that q' is not an integer, but a multiple of 1/8

else q' = q

endif

for x=0 to F_i -1

r = $\lceil x*q' \rceil$ mod F_i;

$S[I_F[(3r+b-1) \bmod F_i]] = \lceil x*q' \rceil \operatorname{div} F_i$;

endfor

endif

For each radio frame, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5, where:

X_i is as above,

$e_{ini} = (a \cdot S(n_i) \cdot |\Delta N_i| + X_i) \bmod (a \cdot X_i)$, if e_{ini} =0 then $e_{ini} = a \cdot X_i$.

$e_{plus} = a \cdot X_i$

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

4.2.7.2 Determination of rate matching parameters in downlink

For downlink $N_{data,j}$ does not depend on the transport format combination j. $N_{data,*}$ is given by the channelization code(s) assigned by higher layers.

When compressed mode by puncturing is used, the number of bits corresponding to the gap for TrCh i, in each frame of its TTI is calculated using the number of bits to remove on each Physical Channel $N_{TGL}[k]$, where k is the frame number in the TTI.

For each frame k of the TTI, $N_{TGL}[k]$ is given by the relation:

$$N_{TGL} = \begin{cases} \frac{TGL}{15} N_{data,j}, & \text{if } N_{first} + TGL \le 15 \\ \frac{15 - N_{first}}{15} N_{data,j}, & \text{in first frame if } N_{first} + TGL > 15 \\ \frac{TGL - (15 - N_{first})}{15} N_{data,j}, & \text{in second frame if } N_{first} + TGL > 15 \end{cases}$$

N_{first} and TGL are defined in section 4.4.

Note that $N_{TGL}[k]$ = 0 if frame k is not compressed.

4.2.7.2.1 Determination of rate matching parameters for fixed positions of TrCHs

First an intermediate calculation variable $N_{i,*}$ is calculated for all transport channels i by the following formula:

$$N_{i,*} = \frac{1}{F_i} \cdot \max_{l \in TFS(i)} N_{i,l}^{TTI}$$

The computation of the $\Delta N_{i,l}^{TTI}$ parameters is then performed in for all TrCH *i* and all TF *l* by the following formula, where $\Delta N_{i,*}$ is derived from $N_{i,*}$ by the formula given at section 4.2.7:

$$\Delta N_{max} = F_i \cdot \Delta N_{i,*}$$

In other modes than compressed mode by puncturing, If $\Delta N_{max} = 0$ then, for TrCH *i*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed. In this case we have :

$$\forall l \in TFS(i)\ \Delta N_{i,l}^{TTI} = 0$$

If $\Delta N_{max} \neq 0$ the parameters listed in sections 4.2.7.2.1.1 and 4.2.7.2.1.2 shall be used for determining e_{ini}, e_{plus}, and e_{minus}.

For compressed mode by puncturing:

Let $|\Delta N_{cm,\,i,\,max}[k]|$ be the number of bits to eliminate on TrCH i to create the gap for compressed mode, in each frame k of the TTI, calculated for the Transport Format Combination of TrChi, in which the number of bits of TrChi is maximum.

$\Delta N_{cm,\,i,\,max}[k]$ is calculated for each frame k of the TTI, for each TrCh i present, for the Transport Format Combination of TrChi, in which its number of bits is maximum, as follows:

Intermediate variables Z_i for i = 1 to I are calculated using the formula (1) in 4.2.7, by replacing $N_{data,j}$ by $P*N_{TGL}[k]$, where P is the number of physical channels on which the CCTrCh will be mapped.

Then $\Delta N_{cm,\,i,\,max}[k] = -(Z_i - Z_{i-1})$ for i = 1 to I

The total number of bits $\Delta N^{TTI}_{cm,\,i,\,max}$ corresponding to the gaps for compressed mode for TrCh i in the TTI is calculated as:

$$\Delta N^{TTI}_{cm,\,i,\,max} = \Sigma_{k=0}^{Fi-1}\ \Delta N_{cm,\,i,\,max}[k]$$

If $\Delta N_{max} = |\Delta N^{TTI}_{cm,\,i,\,max}|$, then, for TrCH *i*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed. If $\Delta N_{max} <> |\Delta N^{TTI}_{cm,\,i,\,max}|$, then, for TrCH *i*, the rate matching algorithm of section 4.2.7.5 needs to be executed.

4.2.7.2.1.1 Uncoded and convolutionally encoded TrCHs

$$\Delta N_i = \Delta N_{max}$$

For compressed mode by puncturing, ΔN_i is defined as: $\Delta N_i = \Delta N_{max} + \Delta N^{TTI}_{cm,\,i,\,max}$, instead of as the previous relation.

a=2

$$N_{max} = \max_{l \in TFS(i)} N_{il}^{TTI}$$

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5. The following parameters are used as input:

$$X_i = N_{il}^{TTI}$$

$$e_{ini} = 1$$

$$e_{plus} = a \cdot N_{max}$$

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

Puncturing if $\Delta N_i < 0$, repetition otherwise. The values of $\Delta N_{i,l}^{TTI}$ may be computed by counting repetitions or puncturing when the algorithm of section 4.2.7.5 is run.

4.2.7.2.1.2 Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. $\Delta N_{max} > 0$, the parameters in section 4.2.7.2.1.1 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

The bits indicated by *b*=1 shall not be punctured.

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

In Compressed Mode by puncturing, the following relations are used instead of the previous ones:

$\Delta N_i = \lfloor \Delta N_{max}/2 \rfloor + \lceil \Delta N^{cm}_{max}/2 \rceil$, b=2

$\Delta N_i = \lceil \Delta N_{max}/2 \rceil + \lfloor \Delta N^{cm}_{max}/2 \rfloor$, b=3

$$N_{max} = \max_{l \in TFS(i)} (N_{il}^{TTI} / 3)$$

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5. The following parameters are used as input:

$$X_i = N_{il}^{TTI} / 3$$

$$e_{ini} = N_{max}$$

$$e_{plus} = a \cdot N_{max}$$

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

The values of $\Delta N_{i,l}^{TTI}$ may be computed by counting repetitions or puncturing when the algorithm of section 4.2.7.5 is run.

4.2.7.2.2 Determination of rate matching parameters for flexible positions of TrCHs

First an intermediate calculation variable N_{ij} is calculated for all transport channels *i* and all transport format combinations *j* by the following formula:

$$N_{i,j} = \frac{1}{F_i} \cdot N_{i,TF_i(j)}^{TTI}$$

Then rate matching ratios RF_i are calculated for each the transport channel i in order to minimise the number of DTX bits when the bit rate of the CCTrCH is maximum. The RF_i ratios are defined by the following formula:

$$RF_i = \frac{N_{data,*}}{\max\limits_{j \in TFCS} \sum\limits_{i=1}^{i=I} \left(RM_i \cdot N_{i,j}\right)} \cdot RM_i$$

The computation of $\Delta N_{i,l}^{TTI}$ parameters is then performed in two phases. In a first phase, tentative temporary values of $\Delta N_{i,l}^{TTI}$ are computed, and in the second phase they are checked and corrected. The first phase, by use of the RF_i ratios, ensures that the number of DTX indication bits inserted is minimum when the CCTrCH bit rate is maximum, but it does not ensure that the maximum CCTrCH bit rate is not greater than $N_{data,*}$. per 10ms. The latter condition is ensured through the checking and possible corrections carried out in the second phase.

At the end of the second phase, the latest value of $\Delta N_{i,l}^{TTI}$ is the definitive value.

The first phase defines the tentative temporary $\Delta N_{i,l}^{TTI}$ for all transport channel i and any of its transport format l by use of the following formula:

$$\Delta N_{i,l}^{TTI} = F_i \cdot \left\lceil \frac{RF_i \cdot N_{i,l}^{TTI}}{F_i} \right\rceil - N_{i,l}^{TTI}$$

The second phase is defined by the following algorithm:

for all j in *TFCS* do -- for all TFC

$$D = \sum_{i=1}^{i=I} \frac{N_{i,TF_i(j)}^{TTI} + \Delta N_{i,TF_i(j)}^{TTI}}{F_i}$$ -- CCTrCH bit rate (bits per 10ms) for TFC *l*

  if $D > N_{data,*}$ then

    for i = 1 to I do -- for all TrCH

      $\Delta N = F_i \cdot \Delta N_{i,j}$ -- $\Delta N_{i,j}$ is derived from $N_{i,j}$ by the formula given at section 4.2.7.

      if $\Delta N_{i,TF_i(j)}^{TTI} > \Delta N$ then

        $\Delta N_{i,TF_i(j)}^{TTI} = \Delta N$

      end-if

    end-for

  end-if

end-for

NOTE: The order in which the transport format combinations are checked does not change the final result.

For other modes than compressed mode by puncturing, ~~I~~if $\Delta N_{i,l}^{TTI} = 0$ then, for TrCH i at TF l, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed.

If $\Delta N_{i,l}^{TTI} \neq 0$ the parameters listed in sections 4.2.7.2.2.1 and 4.2.7.2.2.2 shall be used for determining e_{ini}, e_{plus}, and e_{minus}.

For compressed mode by puncturing:

The number of bits for TrCh i corresponding to the gap for compressed mode in frame k of the TTI, noted $|\Delta N_{cm,\,il}[k]|$, is calculated for each frame k of the TTI and for each TrCh of transport format combination l, as follows:

Intermediate variables Z_i for i = 1 to I are calculated using the formula (1) in 4.2.7, by replacing $N_{data,j}$ by $P*N_{TGL}[k]$, where P is the number of physical channels on which the CCTrCh will be mapped.

Then $\Delta N_{cm,\,il}[k] = -(Z_i - Z_{i-1})$ for i = 1 to I

The total number of bits $\Delta N^{TTI}_{cm,\,il}$ corresponding to the gaps for compressed mode for TrCh i in the whole TTI is calculated as:

$\Delta N^{TTI}_{cm,\,il} = \Sigma_{k=0}^{Fi-1} \Delta N_{cm,\,il}[k]$

If $\Delta N^{TTI}_{il} = |\Delta N^{TTI}_{cm,\,il}|$, then, for TrCH *i* at TF *l*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed. If ΔN^{TTI}_{il} <> $|\Delta N^{TTI}_{cm,\,il}|$, the parameters listed in sections 4.2.7.2.2.1 and 4.2.7.2.2.2 shall be used for determining e_{ini}, e_{plus}, and e_{minus}

4.2.7.2.2.1 Uncoded and convolutionally encoded TrCHs

$$\Delta N_i = \Delta N_{il}^{TTI}$$

In Compressed Mode by puncturing, the following relation is used instead of the previous one:

$$DN_i = DN^{TTI}_{il} + DN^{TTI}_{cm,\,il}$$

a=2

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5. The following parameters are used as input:

$$X_i = N_{il}^{TTI}$$

$$e_{ini} = 1$$

$$e_{plus} = a \cdot N_{il}^{TTI}$$

$$e_{\min us} = a \cdot |\Delta N_i|$$

puncturing for $\Delta N_i < 0$, repetition otherwise.

4.2.7.2.2.2 Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. $\Delta N_{il}^{TTI} > 0$, the parameters in section 4.2.7.2.2.1 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

The bits indicated by *b*=1 shall not be punctured.

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

In Compressed Mode by puncturing, the following relations are used instead of the previous ones:

$\Delta N_i = \lfloor \Delta N^{TTI}_{il}/2 \rfloor + \lceil \Delta N^{TTI}_{cm,il}/2 \rceil$, b=2

$\Delta N_i = \lceil \Delta N^{TTI}_{il}/2 \rceil + \lfloor \Delta N^{TTI}_{cm,il}/2 \rfloor$, b=3

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.5. The following parameters are used as input:

$$X_i = N_{il}^{TTI} / 3\text{N},$$

$$e_{ini} = X_i ,$$

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

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

4.2.7.3 Bit separation and collection in uplink

The systematic bits (excluding bits for trellis termination) of turbo encoded TrCHs shall not be punctured. The systematic bit, first parity bit, and second parity bit in the bit sequence input to the rate matching block are therefore separated from each other. Puncturing is only applied to the parity bits and systematic bits used for trellis termination.

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 6 and 7.

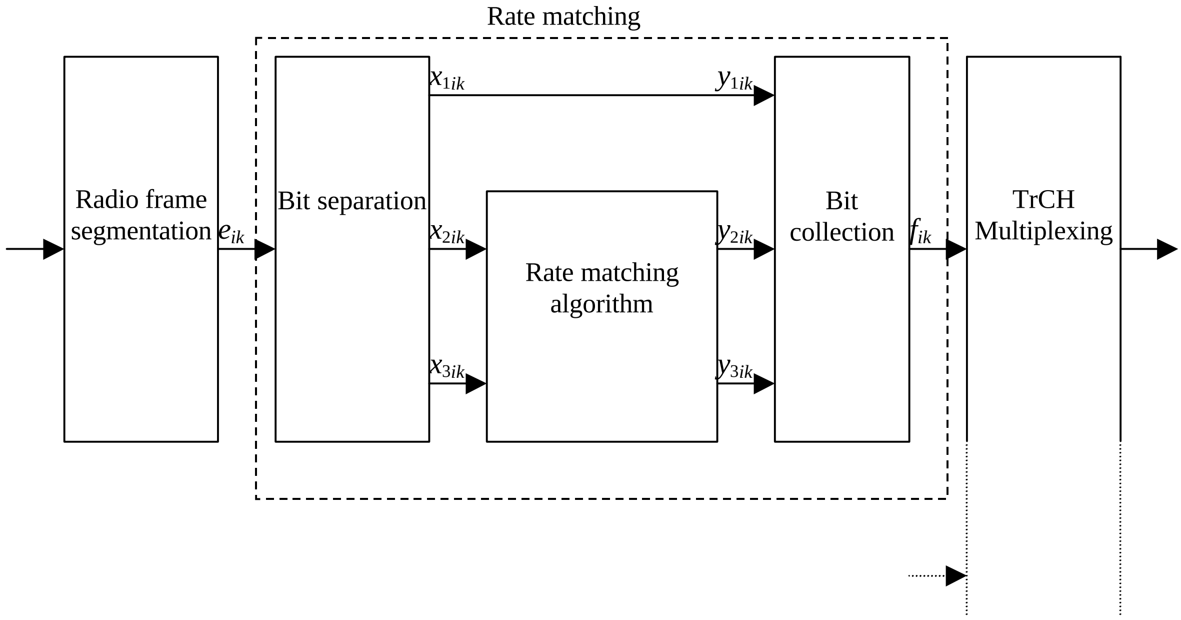

Figure 6: Puncturing of turbo encoded TrCHs

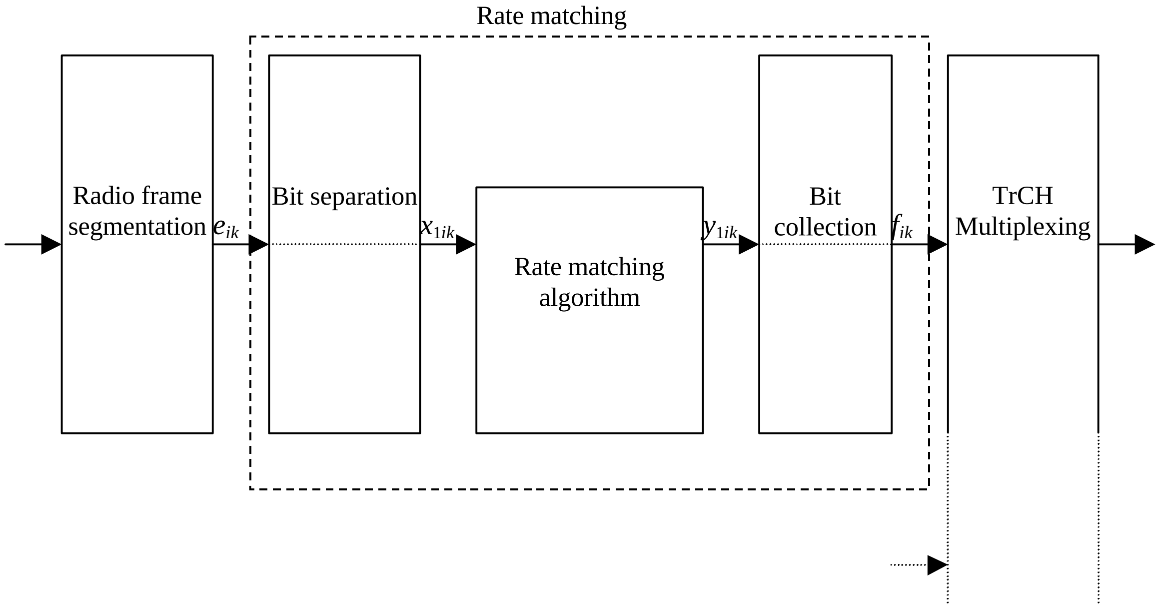

Figure 7: Rate matching for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition.

The bit separation is dependent on the 1st interleaving and offsets are used to define the separation for different TTIs. The offsets a_b for the systematic (b=1) and parity bits ($b \in \{2, 3\}$) are listed in table 4.

Table 4: TTI dependent offset needed for bit separation

TTI (ms)	a_1	a_2	a_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 b_{n_i} .

Table 5: Radio frame dependent offset needed for bit separation

TTI (ms)	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_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

4.2.7.3.1 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 systematic, first parity, or second parity bit. 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:

$x_{1,i,k} = e_{i,3(k-1)+1+(a_1+b_{n_i}) \bmod 3}$ 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.

$$x_{2,i,k} = e_{i,3(k-1)+1+(a_2+b_{n_i}) \bmod 3} \qquad k = 1, 2, 3, \ldots, X_i \qquad X_i = \lfloor N_i / 3 \rfloor$$

$$x_{3,i,k} = e_{i,3(k-1)+1+(a_3+b_{n_i}) \bmod 3} \qquad k = 1, 2, 3, \ldots, X_i \qquad X_i = \lfloor N_i / 3 \rfloor$$

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

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

4.2.7.3.2 Bit collection

The bits x_{bik} are input to the rate matching algorithm described in section 4.2.7.5. The bits output from the rate matching algorithm are denoted $y_{bi1}, y_{bi2}, y_{bi3}, \ldots, y_{biY_i}$.

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

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

$$z_{i,3(k-1)+1+(a_1+b_{n_i}) \bmod 3} = y_{1,i,k} \qquad k = 1, 2, 3, \ldots, Y_i$$

$$z_{i,3\lfloor N_i/3 \rfloor + k} = y_{1,i,\lfloor N_i/3 \rfloor + k} \qquad k = 1, \ldots, N_i \bmod 3$$

Note: When (N_i mod 3) = 0 this row is not needed.

$$z_{i,3(k-1)+1+(a_2+b_{n_i}) \bmod 3} = y_{2,i,k} \qquad k = 1, 2, 3, \ldots, Y_i$$

$$z_{i,3(k-1)+1+(a_3+b_{n_i}) \bmod 3} = y_{3,i,k} \qquad k = 1, 2, 3, \ldots, Y_i$$

After the bit collection, bits $z_{i,k}$ with value d, where $d \notin \{0, 1\}$, 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:

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

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 d, where $d \notin \{0, 1\}$, 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.

4.2.7.4 Bit separation and collection in downlink

The systematic bits (excluding bits for trellis termination) of turbo encoded TrCHs shall not be punctured. The systematic bit, first parity bit, and second parity bit in the bit sequence input to the rate matching block are therefore separated from each other. Puncturing is only applied to the parity bits and systematic bits used for trellis termination.

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 8 and 9.

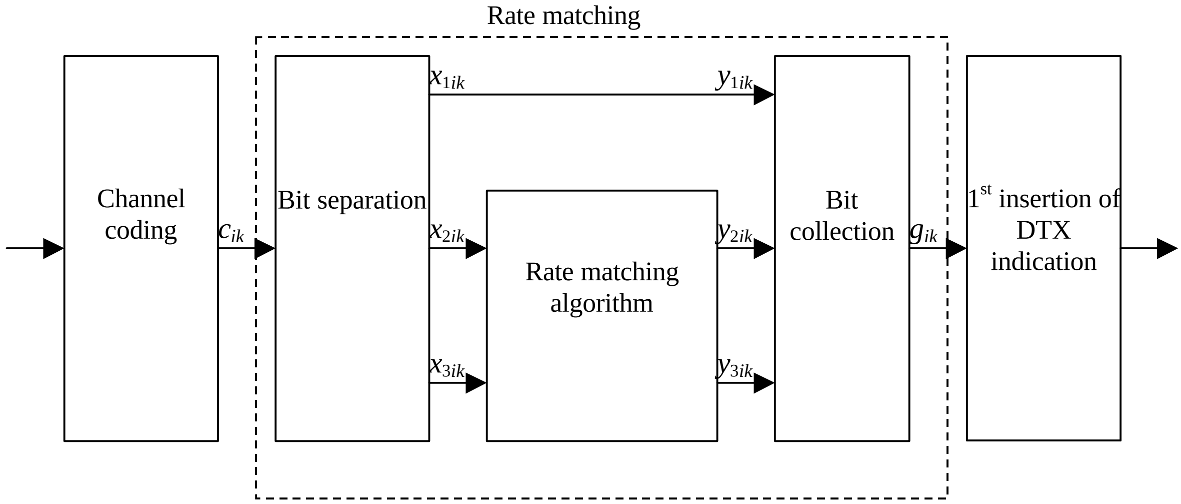

Figure 8: Puncturing of turbo encoded TrCHs

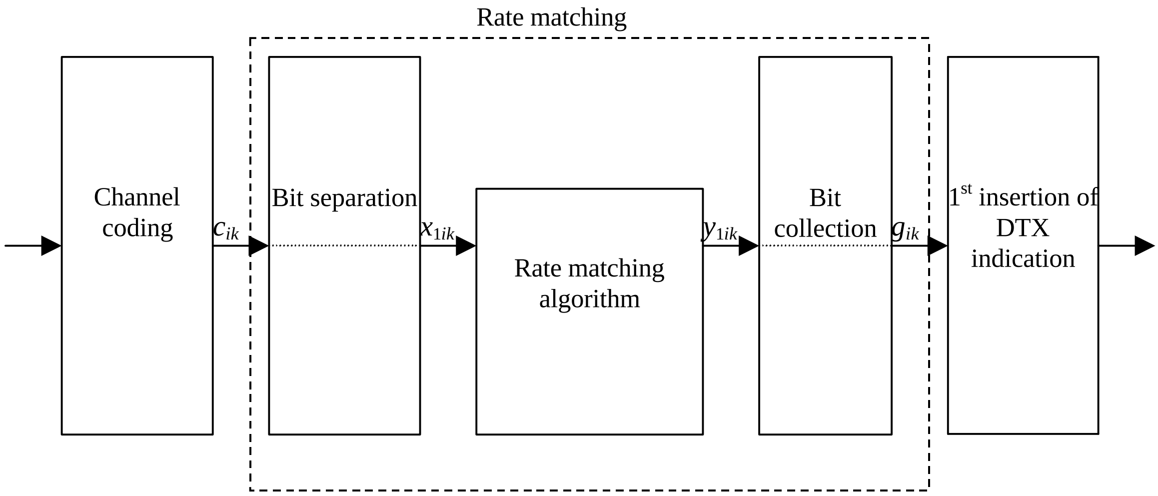

Figure 9: Rate matching for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition.

4.2.7.4.1 Bit separation

The bits input to the rate matching are denoted by $c_{i1}, c_{i2}, c_{i3}, \ldots, c_{iE_i}$, where i is the TrCH number and E_i is the number of bits input to the rate matching block. Note that E_i is a multiple of 3 for turbo encoded TrCHs and that the transport format combination number j for simplicity has been left out in the bit numbering, i.e. E_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 systematic, first parity, or second parity bit. 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 c_{ik} and x_{bik} is given below.

For turbo encoded TrCHs with puncturing:

$x_{1,i,k} = c_{i,3(k-1)+1}$ k = 1, 2, 3, …, X_i $X_i = E_i /3$

$x_{2,i,k} = c_{i,3(k-1)+2}$ k = 1, 2, 3, …, X_i $X_i = E_i /3$

$x_{3,i,k} = c_{i,3(k-1)+3}$ k = 1, 2, 3, …, X_i $X_i = E_i /3$

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

$x_{1,i,k} = c_{i,k}$ k = 1, 2, 3, …, X_i $X_i = E_i$

4.2.7.4.2 Bit collection

The bits x_{bik} are input to the rate matching algorithm described in section 4.2.7.5. The bits output from the rate matching algorithm are denoted $y_{bi1}, y_{bi2}, y_{bi3}, \ldots, y_{biY_i}$.

Bit collection is the inverse function of the separation. The bits after collection are denoted by $z_{bi1}, z_{bi2}, z_{bi3}, \ldots, z_{biY_i}$. After bit collection, the bits indicated as punctured are removed and the bits are then denoted by $g_{i1}, g_{i2}, g_{i3}, \ldots, g_{iG_i}$, where i is the TrCH number and $G_i = N_{ij} + \Delta N_{ij}$. The relations between y_{bik}, z_{bik}, and g_{ik} are given below.

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

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

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

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

After the bit collection, bits $z_{i,k}$ with value δ, where $\delta \notin \{0, 1\}$, are removed from the bit sequence. Bit $g_{i,1}$ corresponds to the bit $z_{i,k}$ with smallest index k after puncturing, bit $g_{i,2}$ 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, $g_{i,k} = z_{i,k}$ and $Y_i = G_i$.

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 $g_{i,1}$ corresponds to the bit $z_{i,k}$ with smallest index k after puncturing, bit $g_{i,2}$ corresponds to the bit $z_{i,k}$ with second smallest index k after puncturing, and so on.

4.2.7.5 Rate matching pattern determination

Denote the bits before rate matching by:

$x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$, where i is the TrCH number and X_i is the parameter given in sections 4.2.7.1 and 4.2.7.2.

The rate matching rule is as follows:

```
if puncturing is to be performed
    e = e_ini         -- initial error between current and desired puncturing ratio
    m = 1             -- index of current bit
    do while m <= X_i
        e = e – e_minus         -- update error
        if e <= 0 then          -- check if bit number m should be punctured
            set bit x_i,m to δ where δ ∉ {0, 1}
            e = e + e_plus   -- update error
        end if
        m = m + 1               --  next bit
    end do
```

```
else
    e = e_ini              -- initial error between current and desired puncturing ratio
    m = 1                  -- index of current bit
    do while m <= X_i
        e = e – e_minus        -- update error
        do while e <= 0        -- check if bit number m should be repeated
            repeat bit x_i,m
            e = e + e_plus   -- update error
        end do
        m = m + 1                -- next bit
    end do
end if
```

A repeated bit is placed directly after the original one.

4.2.10 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 $x_1, x_2, x_3, \ldots, x_Y$, where Y 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 $u_{p1}, u_{p2}, u_{p3}, \ldots, u_{pU}$, where p is PhCH number and U is the number of bits in one radio frame for each PhCH, i.e. $U = \frac{Y}{P}$. The relation between x_k and u_{pk} is given below.

Bits on first PhCH after physical channel segmentation:

$$u_{1k} = x_k \quad k = 1, 2, \ldots, U$$

Bits on second PhCH after physical channel segmentation:

$$u_{2k} = x_{(k+U)} \quad k = 1, 2, \ldots, U$$

…

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

$$u_{Pk} = x_{(k+(P-1)U)} \quad k = 1, 2, \ldots, U$$

In Downlink Compressed Mode by puncturing, the following is used instead of the previous relation between input and output bits:

The bits of the input flow not corresponding to bits p are mapped to each code until the number of bits on the code is U, each bit p is removed to ensure creation the gap required by the compressed mode on each code, as described below:

Bits on first PhCH after physical channel segmentation:

$u_{1,k} = x_{i,f(k)}$ $k = 1, 2, \ldots, U,$

Bits on second PhCH after physical channel segmentation:

$u_{2,k} = x_{i,f(k+U)}$ $k = 1, 2, \ldots, U$

…

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

$u_{P,k} = x_{i,f(k+(P-1)U)}$ $k = 1, 2, \ldots, U$

where f is such that bit $u_{1,1}$ corresponds to the bit $x_{i,k}$ with smallest index k when the bits p are not counted, bit $u_{1,2}$ corresponds to the bit $x_{i,k}$ with second smallest index k when the bits p are not counted, and so on for bits $u_{1,3}, \ldots u_{1,U}, u_{2,1}, u_{2,2}, \ldots u_{2,U}, \ldots u_{P,1}, u_{P,2}, \ldots u_{P,U}$.

4.2.10.1 Relation between input and output of the physical segmentation block in uplink

The bits input to the physical segmentation are denoted by $s_1, s_2, s_3, \ldots, s_S$. Hence, $x_k = s_k$ and $Y = S$.

4.2.10.2 Relation between input and output of the physical segmentation block in downlink

In compressed mode by puncturing, the bits input to the physical segmentation are denoted by $w_1, w_2, w_3, \ldots w_{P*Ndata}$. Hence, $x_k = w_k$ and $Y = P*Ndata$

In all other cases, ~~T~~the bits input to the physical segmentation are denoted by $w_1, w_2, w_3, \ldots, w_{(PU)}$. Hence, $x_k = w_k$ and $Y = PU$.