TSG-RAN Working Group 1 meeting #16 **_TSGR1#16(00)1227_**

Pusan, Korea

October 10 – 13, 2000

Agenda item:

Source: Nortel Networks, Interdigital

Title: CR 25.212-096: Corrections for compressed mode by puncturing

Document for: Decision

In this document, some mistakes left in the text for compressed mode by puncturing method are corrected. Some modifications correct formulas in the rate matching calculations section, some other are purely editorial, and one is a clarification.

Corrections of formulas:

In compressed mode, due to slot format change, the number of data bits available on the physical channel(s) in compressed frames is sometimes reduced compared to normal frames. It is reduced if the slot format for compressed frames contains fewer data bits than the corresponding one for normal frames. This fact had not been completely taken into account in operations for compressed mode by puncturing.

In fact, the reduction of the number of available data bits had been taken into account in the calculation of the total rate matching amount for each TrCh. But the calculation of the number of p-bits introduced did not cover this reduction. This lead to an inconsistent number of bits input to the first interleaver after p-bits insertion.

In this document, a correction is proposed. It the correction which leads to the minimum calculations for compressed mode by puncturing compared to normal mode.

It is proposed that the calculation of $Np_{i,\max}^{TTI,m}$, which is the total number of p-bits to insert, includes both the creation of the gap(s), and the reduction of available data bits in compressed frames. In this case, the calculation of the amount of rate matching due to static rate matching parameters, $?N_{i,\max}^{m}$, should not take this reduction into account. Thus calculation of $?N_{i,\max}^{m}$ should be identical to what it is in normal mode, i.e. use $N_{data,*}$ in the calculation with the "Z formula", instead of $N'_{data,*}$.

This leads to the following modifications in section 4.2.7.2, determination of rate matching parameters in downlink.

On one hand, the amount of rate matching due to static rate matching parameters, $?N_{i,\max}^{m}$, is now calculated identically as for normal mode, i.e. it uses $N_{data,*}$ in the calculation with the "Z formula", instead of $N'_{data,*}$.

On the other hand, $Np_{i,\max}^{TTI,m}$ is now the sum of the number of bits of the gap, plus the difference of number of data bits available on the physical channel, due to usage of a different slot in normal and compressed frames. Thus it uses the "Z formula" by replacing $N_{data,*}$ by $N_{TGL} + (N_{data,*} - N'_{data,*})$.

Then, as in the current specifications, $Np_{i,\max}^{TTI,m}$ is substracted from $?N_{i,\max}^{m}$.

Also, in section 4.2.10, physical channel segmentation, in compressed frames, the number of bits in one radio frame for each PhCH is corrected to take also into account the potential reduction of data bits. Thus $U= (X - N_{TGL} - (N_{data,*} - N'_{data,*})) / P$ instead of $U= (X - N_{TGL}) / P$.

Editorial modifications:

In section 4.2.5.4, relation between input and output of 1st interleaving in downlink, input bits are indexed from 1 to $FiHi$, while it should be from 1 to Di to respect the current notations.

In section 4.2.7.2.1.2, two notational mistakes are corrected. In two places, the index for frame number is using ‘n’ but the text says ‘for each frame k’. This is corrected to ‘for each frame n’.

In section 4.2.9.1, 1st insertion of DTX indication bits, in the formula to calculate D_i , $H_{i,*}$ is written, while it should be written H_i to be consistent with the rest of the notations.

Clarification:

In section , radio frame equalisation, it is written “DL rate matching output block length is always an integer multiple of *F* ”. However, in case of compressed mode by puncturing, the block length is an integer multiple of *Fi* after insertion of p-bits at the input of first interleaver. This is clarified in the present proposal.

3GPP TSG RAN WG1#16
Pusan, Korea

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e.g. for 3GPP use the format TP-99xxx
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CHANGE REQUEST

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25.212 CR 096 Current Version: 3.4.0

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

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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 [X] UTRAN / Radio [X] Core Network [ ]
(at least one should be marked with an X)

Source: Nortel Networks **Date:** 2000-10

Subject: Compressed mode by puncturing

Work item:

Category:
(only one category Shall be marked With an X)

F	Correction	X
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	X
Release 00	

Reason for change: Some mistakes had been left in some calculations for compressed mode by puncturing. Corrections of formulas for rate matching calculations to cope with the slot format change in compressed frames, plus editorial mistakes, plus one clarification are proposed.

Clauses affected: 4.2.4, 4.2.5.4, 4.2.7.2, 4.2.9.1, 4.2.10

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:

4.2.4 Radio frame size equalisation

Radio frame size equalisation is padding the input bit sequence in order to ensure that the output can be segmented in F_i data segments of same size as described in subclause 4.2.7. Radio frame size equalisation is only performed in the UL (In normal mode and in compressed modes by SF reduction and by higher layer scheduling, DL rate matching output block length is always an integer multiple of F_i. In compressed mode by puncturing, first interleaver input block length after p-bits insertion is always an integer multiple of F_i).

The input bit sequence to the radio frame size equalisation is denoted by $c_{i1}, c_{i2}, c_{i3}, \ldots, c_{iE_i}$, where i is TrCH number and E_i the number of bits. The output bit sequence is denoted by $t_{i1}, t_{i2}, t_{i3}, \ldots, t_{iT_i}$, where T_i is the number of bits. The output bit sequence is derived as follows:

- $t_{ik} = c_{ik}$, for k = 1… E_i; and
- t_{ik} = {0, 1} for k= E_i +1… T_i, if $E_i < T_i$;

where

- $T_i = F_i * N_i$; and
- $N_i = \lceil E_i / F_i \rceil$ is the number of bits per segment after size equalisation.

4.2.5 1st interleaving

In Compressed Mode by puncturing, bits marked with a fourth value on top of {0, 1, δ} and noted p, are introduced in the radio frames to be compressed, in positions corresponding to the first bits of the radio frames. They will be removed in a later stage of the multiplexing chain to create the actual gap. Additional puncturing has been performed in the rate matching step, over the TTI containing the compressed radio frame, to create room for these p-bits. The following subclause describes this feature.

4.2.5.1 Insertion of marked bits in the sequence to be input in first interleaver

In normal mode, compressed mode by higher layer scheduling, and compressed mode by spreading factor reduction:

$x_{i,k} = z_{i,k}$ and $X_i = Z_i$

In case the TTI contains a radio frame that is compressed by puncturing and fixed positions are used, sequence $x_{i,k}$ which will be input to first interleaver for TrCH i and TTI m within largest TTI, is built from bits $z_{i,k}$, $k=1,\ldots, Z_i$, plus $Np_{i,\max}^{TTI,m}$ bits marked p and $X_i = Z_i + Np_{i,\max}^{TTI,m}$, as is described thereafter.

$Np_{i,\max}^{TTI,m}$ is defined in the Rate Matching subclause 4.2.7.

$P1_{Fi}(x)$ defines the inter column permutation function for a TTI of length F_i ? 10ms, as defined in Table 3 in section 4.2.5.2. $P1_{Fi}(x)$ is the Bit Reversal function of x on $\log_2(F_i)$ bits.

NOTE 1: C[x], x= 0 to $F_i - 1$, the number of bits p which have to be inserted in each of the F_i segments of the TTI, where x is the column number before permutation, i.e. in each column of the first interleaver. C[$P1_{Fi}(x)$] is equal to $Np_{i,\max}^{m?F_i?x}$ for x equal 0 to F_i-1 for fixed positions. It is noted $Np_i^{m?F_i?x}$ in the following initialisation step.

NOTE 2: cbi[x], x=0 to $F_i - 1$, the counter of the number of bits p inserted in each of the F_i segments of the TTI, i.e. in each column of the first interleaver x is the column number before permutation.

col = 0

while col < F_i **do** -- here col is the column number after column permutation

C[P1$_{Fi}$ (col)] = $Np_i^{m \times F_i + col}$ -- initialisation of number of bits p to be inserted in each of the F_i segments of the TTI number m

cbi[P1$_{Fi}$ (col)] = 0 -- initialisation of counter of number of bits p inserted in each of the F_i segments of the TTI

col = col +1

end do

n = 0, m = 0

while n < X_i **do** -- from here col is the column number before column permutation

col = n mod F_i

if cbi[col] < C[col] **do**

$x_{i,n}$ = 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

$x_{i,n} = z_{i,,m}$

m = m+1

endif

n = n +1

end do

4.2.5.2 1st interleaver operation

The 1st interleaving is a block interleaver with inter-column permutations. The input bit sequence to the 1st interleaver is denoted by $x_{i,1}, x_{i,2}, x_{i,3}, \ldots, x_{i,X_i}$, 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 from table 4.

(2) Determine the number of rows R1 defined as:

R1 = X_i / C1

(3) Write the input bit sequence into the R1 $\times$ C1 rectangular matrix row by row starting with bit $x_{i,1}$ in the first column of the first row and ending with bit $x_{i,(R1 \times C1)}$ in column C1 of row R1:

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

(4) Perform the inter-column permutation based on the pattern $\langle P1_{C1}(j) \rangle_{j \in \{0,1,\ldots,C1-1\}}$ shown in table 4, where $P1_{C1}$ (j) is the original column position of the j-th permuted column. After permutation of the columns, the bits are denoted by y_{ik}:

$$\begin{bmatrix} y_{i,1} & y_{i,(R1?1)} & y_{i,(2?R1?1)} & \cdots & y_{i,((C1?1)?R1?1)} \\ y_{i,2} & y_{i,(R1?2)} & y_{i,(2?R1?2)} & \cdots & y_{i,((C1?1)?R1?2)} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{i,R1} & y_{i,(2?R1)} & y_{i,(3?R1)} & \cdots & y_{i,(C1?R1)} \end{bmatrix}$$

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

Table 4 Inter-column permutation patterns for 1st interleaving

TTI	Number of columns 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>

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

The bits input to the 1st interleaving are denoted by $t_{i,1}, t_{i,2}, t_{i,3}, \ldots, t_{i,T_i}$, where i is the TrCH number and T_i the number of bits. Hence, $z_{i,k} = t_{i,k}$ and $Z_i = T_i$.

The bits output from the 1st interleaving are denoted by $d_{i,1}, d_{i,2}, d_{i,3}, \ldots, d_{i,T_i}$, and $d_{i,k} = y_{i,k}$.

4.2.5.4 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 $\cancel{h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_iH_i)}}$ $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{iD_i}$, where i is the TrCH number. Hence, $z_{ik} = h_{ik}$ and $Z_i = D_i$.

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, $z_{ik} = g_{ik}$ and $Z_i = G_i$.

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 mult iplexing 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 subcaluse 4.2.7 and subclauses:

$N_{i,j}$: 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).

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

? $N_{i,j}$: 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).

? $N_{i,l}^{TTI}$: If positive - number of bits to be repeated in each transmission time interval on TrCH *i* with transport format *l*.

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

Used in downlink only.

$Np_{i,l}^{TTI,m}$, $m=0$ *to* $(F_{max} / F_i) - 1$:Positive or null: number of bits to be removed in TTI number *m* within the largest TTI, to create the required gaps in the compressed radio frames of this TTI, in case of compressed mode by puncturing, for TrCH *i* with transport format *l*. In case of fixed positions and compressed mode by puncturing, this value is noted $Np_{i,\max}^{TTI,m}$ since it is calculated for all TrCH with their maximum number of bits; thus it is the same for all TFCs

Used in downlink only.

$Np_{i,l}^{n}$ $n=0$ *to* $F_{max} -1$:Positive or null: number of bits, in radio frame number *n* within the largest TTI, corresponding to the gap for compressed mode in this radio frame, for TrCH *i* with transport format *l*. The value will be null for the radio frames not overlapping with a transmission gap. In case of fixed positions and compressed mode by puncturing, this value is noted $Np_{i,\max}^{n}$ since it is calculated for all TrCHs with their maximum number of bits; thus it is the same for all TFCs

Used in downlink only.

$N_{TGL}[k]$, $k=0$ *to* $F_{\max}-1$: Positive or null: number of bits in each radio frame corresponding to the gap for compressed mode for the CCTrCH.

RM_i: Semi-static rate matching attribute for transport channel i. RM_i is provided by higher layers or takes a value as indicated in section 4.2.13.

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. The allowed puncturing in % is actually equal to (1-PL)*100.

$N_{data,j}$: 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.

$Z_{i,j}$: Intermediate calculation variable.

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

$F_{\max}$ Maximum number of radio frames in a transmission time interval used in the CCTrCH :

$$F_{\max} = \max_{1 \le i \le I} F_i$$

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). Used in uplink only.

$P1_F(n_i)$: The 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 4 of section 4.2.5.2 (note that the $P1_F$ is self-inverse). Used for rate matching in uplink only.

$S[n]$: The shift of the puncturing or repetition pattern for radio frame n_i when $n = P1_{F_i}(n_i)$. 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 subclause 4.2.7.5.

e_{plus} Increment of variable e in the rate matching pattern determination algorithm of subclause4.2.7.5.

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

b: Indicates systematic and parity bits

b=1: Systematic bit. x_k in subclause 4.2.3.2.1.

b=2: 1st parity bit (from the upper Turbo constituent encoder). z_k in subcaluse 4.2.3.2.1.

b=3: 2nd parity bit (from the lower Turbo constituent encoder). z'_k in subclause 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:

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

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

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

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 1-PL, PL is signalled from higher layers. The number of available bits in the radio frames of one PhCH 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 number of bits available to the CCTrCH on all PhCHs, N_{data}, then are { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2 \times N_4$, $3 \times N_4$, $4 \times N_4$, $5 \times N_4$, $6 \times N_4$}.

For a RACH CCTrCH SET0 represents the set of N_{data} values allowed by the UTRAN, as set by the minimum SF provided by higher layers. SET0 may be a sub-set of { N_{256}, N_{128}, N_{64}, N_{32} }. SET0 does not take into account the UE's capability.

For other CCTrCHs, SET0 denotes the set of N_{data} values allowed by the UTRAN and supported by the UE, as part of the UE's capability. SET0 can be a subset of { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2 \times N_4$, $3 \times N_4$, $4 \times N_4$, $5 \times N_4$, $6 \times N_4$}. $N_{data,j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} in SET0 such that $\left\{\min_{1 \le y \le I} \{RM_y\}\right\} \times N_{data} - \sum_{x=1}^{I} RM_x \times N_{x,j}$ 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 $\left\{\min_{1 \le y \le I} \{RM_y\}\right\} \times N_{data} \times PL - \sum_{x=1}^{I} RM_x \times N_{x,j}$ 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

For a RACH CCTrCH, if $N_{data,j}$ is not part of the UE's capability then the TFC j cannot be used.

4.2.7.1.2 Determination of parameters needed for calculating the rate matching pattern

The number of bits to be repeated or punctured, $\Delta N_{i,j}$, 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 subclause 4.2.7.1.1.

In a compressed radio frame, $N_{data,j}$ is replaced by $N_{data,j}^{cm}$ in Equation 1. $N_{data,j}^{cm}$ is given as follows:

In a radio frame compressed by higher layer scheduling, $N_{data,j}^{cm}$ is obtained by executing the algorithm in subclause 4.2.7.1.1 but with the number of bits in one radio frame of one PhCH reduced to $\frac{N_{tr}}{15}$ of the value in normal mode.

N_{tr} is the number of transmitted slots in a compressed radio frame and is defined by the following relation:

$$N_{tr} \,?\, \begin{cases} 15 \,?\, TGL\text{, if } N_{first} + TGL \,?\, 15 \\ N_{first}\text{, in first frame if } N_{first} + TGL > 15 \\ 30 \,?\, TGL \,?\, N_{first}\text{, in second frame if } N_{first} + TGL > 15 \end{cases}$$

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

In a radio frame compressed by spreading factor reduction, $N_{data,j}^{cm} \,?\, 2 ? ?N_{data,j} \,?\, N_{TGL} ?$, where

$$N_{TGL} \,?\, \frac{15 ? N_{tr}}{15} ? N_{data,j}$$

If $? N_{i,j} = 0$ then the output data of the rate matching is the same as the input data and the rate matching algorithm of subclause 4.2.7.5 does not need to be executed.

If $? N_{i,j} \,?\, 0$ the parameters listed in subclauses 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

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

if $R ? 0$ and $2?R ? N_{ij}$

then q = $? N_{i,j} / R ?$

else

q = $? N_{i,j} / (R - N_{i,j}) ?$

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[? ?x? q'? ? mod F_i] = (? ?x? q'? ? div F_i)

end for

$? N_i = ? N_{i,j}$

a = 2

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

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

e_{ini} = (a? S[P1$_{Fi}$(n_i)]? |? N_i | + 1) mod (a?N_{ij}).

e_{plus} = a? $N_{i,j}$

e_{minus} = a? |? N_i|

puncturing for ? N <0, repetition otherwise.

4.2.7.1.2.2 Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. ? $N_{i,j}$ >0, the parameters in subclause 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

$$? N_i \; ? \; \begin{matrix} ?\,?? N_{i,j}/2?, & b \; ? \; 2 \\ ?\,?? N_{i,j}/2?, & b \; ? \; 3 \end{matrix}$$

If $? N_i$ is calculated as 0 for b=2 or b=3, then the following procedure and the rate matching algorithm of subclause 4.2.7.5 don't need to be performed for the corresponding parity bit stream.

X_i = ?$N_{i,j}$ /3? ,

q = ?X_i /|? N_i| ?

if(q ? 2)

for r=0 to F_i-1

S[(3? r+b-1) mod F_I] = r mod 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 = ?x? q'? mod F_i;

S[(3? r+b-1) mod F_i] = ?x? q'? div F_i;

endfor

endif

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

X_i is as above:

e_{ini} = (a ? S[P1$_{Fi}(n_i)$] ? |? N_i| + X_i) mod (a ? X_i), if e_{ini} =0 then e_{ini} = a ? X_i

e_{plus} = a ? X_i

e_{minus} = a ? ?? 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. Denote the number of physical channels used for the CCTrCH by P. $N_{data,*}$ is the number of bits available to the CCTrCH in one radio frame and defined as $N_{data,*}=P ? 15 ? (N_{data1}+N_{data2})$, where N_{data1} and N_{data2} are defined in [2]. Note that contrary to the uplink, the same rate matching patterns are used in TTIs containing no compressed radio frames and in TTIs containing radio frames compressed by spreading factor reduction or higher layer scheduling.

In the following, the total amount of puncturing or repetition for the TTI is calculated.

Additional calculations for TTIs containing radio frames compressed by puncturing in case fixed positions are used, are performed to determine this total amount of rate matching needed.

For compressed mode by puncturing, in TTIs where some compressed radio frames occur, the puncturing is increased or the repetition is decreased compared to what is calculated according to the rate matching parameters provided by higher layers. This allows to cope with reduction of available data bits on the physical channel(s) if the slot format for the compressed frame(s) contains fewer data bits than for the normal frames(s), and to create room for later insertion of marked bits, noted p-bits, which will identify the positions of the gaps in the compressed radio frames.

The amount of additional puncturing corresponds to the number of bits to create the gap in the TTI for TrCH i, plus the difference between the number of data bits available in normal frames and in compressed frames, due to slot format change. In case of fixed positions, it is calculated in addition to the amount of rate matching indicated by higher layers. It is noted $Np_{i,\max}^{TTI,m}$.

In fixed positions case, to obtain the total rate matching $? N_{i,\max}^{TTI,cm,m}$ to be performed on the TTI m, $Np_{i,\max}^{TTI,m}$ is subtracted from $? N_{i,\max}^{TTI,m}$ (calculated based on higher layers RM parameters as for normal rate matching). This allows to create room for the $Np_{i,\max}^{TTI,m}$ bits p to be inserted later. If the result is null, i.e. the amount of repetition matches exactly the amount of additional puncturing needed, then no rate matching is necessary.

In case of compressed mode by puncturing and fixed positions, for some calculations, $N'_{data,*}$ is used for radio frames with gap instead of $N_{data,*}$, where $N'_{data,*} ? P ? 15 ? (N'_{data1} ? N'_{data2})$. N'_{data1} and N'_{data2} are the number of bits in the data fields of the slot format used for the current compressed mode, i.e. slot format A or B as defined in [2] corresponding to the Spreading Factor and the number of transmitted slots in use.

The number of bits corresponding to the gap for TrCH i, in each radio frame of its TTI is calculated using the number of bits to remove on all Physical Channels N_{TGL}[k], where k is the radio frame number in the largest TTI.

For each radio frame k of the largest TTI that is overlapping with a transmission gap, N_{TGL}[k] is given by the relation:

$$N_{TGL} ? \begin{cases} \dfrac{TGL}{15} ? N'_{data,*}\text{, if } N_{first} + TGL ? 15 \\[2ex] \dfrac{15 ? N_{first}}{15} ? N'_{data,*}\text{, in first radio frame of the gap if } N_{first} + TGL > 15 \\[2ex] \dfrac{TGL ? (15 ? N_{first})}{15} ? N'_{data,*}\text{, in second radio frame of the gap if } N_{first} + TGL > 15 \end{cases}$$

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

Note that N_{TGL} [k] = 0 if radio frame k is not overlapping with a transmission gap.

4.2.7.2.1 Determination of rate matching parameters for fixed positions of TrCHs

4.2.7.2.1.1 Calculation of $\Delta N_{i,\max}$ for normal mode and compressed mode by spreading factor reduction

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

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

In order to compute the $\Delta N_{i,l}^{TTI}$ parameters for all TrCH *i* and all TF *l*, we first compute an intermediate parameter $\Delta N_{i,\max}$ by the following formula, where $\Delta N_{i,*}$ is derived from $N_{i,*}$ by the formula given at subclause 4.2.7:

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

If $\Delta N_{i,max} = 0$ then, for TrCH *i*, the output data of the rate matching is the same as the input data and the rate matching algorithm of subclause 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 $\Delta N_{i,max} \neq 0$ the parameters listed in subclauses 4.2.7.2.1.3 and 4.2.7.2.1.4 shall be used for determining e_{ini}, e_{plus}, and e_{minus}, and $\Delta N_{i,l}^{TTI}$.

4.2.7.2.1.2 Calculations for compressed mode by puncturing

Calculations of $\Delta N_{i,\max}^{TTI,m}$ for all TTI *m* within largest TTI, for all TrCH *i*

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

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

Then an intermediate calculation variable $\cancel{\Delta N_{i,*}^{n}}$ $\Delta N_{i,*}$ is derived from $N_{i,*}$ by the formula given at subclause 4.2.7, for all TrCH *i* ~~and all frames *n* in the largest TTI, from the formula given at subclause 4.2.7 using $N_{data,*}$, when index *n* designates a radio frame of the largest TTI that is not overlapping with a transmission gap, and using $N'_{data,*}$ instead of $N_{data,*}$, when index *n* designate a frame that is overlapping with a transmission gap~~.

In order to compute the $\Delta N_{i,l}^{TTI,m}$ parameters for all TrCH *i*, all TF *l* and all TTI with number *m* in the largest TTI, we first compute an intermediate parameter $\Delta N_{i,\max}^{m}$ by the following formula :

$$\cancel{\Delta N_{i,\max}^{m} = \sum_{n = m \times F_i}^{(m+1) \times F_i - 1} \Delta N_{i,*}^{n}} \quad \Delta N_{i,\max}^{m} = F_i \times \Delta N_{i,*}$$

Calculations of $Np_{i,\max}^{n}$ and $Np_{i,\max}^{TTI,m}$

Let $Np^{n}_{i,\max}$ be the number of bits to eliminate on TrCH *i* to create the gap for compressed mode and to cope for the reduction of the number of available data bits in the compressed frame if the changed slot format contains fewer data bits than for normal frame, in each radio frame ~~k~~ n of the TTI, calculated for the Transport Format Combination of TrCH *i*, in which the number of bits of TrCH *i* is at its maximum.

$Np^{n}_{i,\max}$ is calculated for each radio frame ~~k~~ n of the TTI in the following way.

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 $(N_{TGL}[n] + (N_{data,*} - N'_{data,*}))$.

Then $Np^{n}_{i,\max}$ = $(Z_i - Z_{i-1})$ *for i = 1 to I*

The total number of bits $Np^{TTI,m}_{i,\max}$ corresponding to the gaps for compressed mode for TrCH i in the TTI is calculated as:

$$Np^{TTI,m}_{i,\max} ? \sum_{n ? m ? F_i}^{n ? (m?1) ? F_i ? 1} Np^{n}_{i,\max}$$

The amount of rate matching $?N^{TTI,cm,m}_{i,\max}$ for the highest TrCH bit rate is then computed by the following formula :

$$?N^{TTI,cm,m}_{i,\max} = ?N^{m}_{i,\max} - Np^{TTI,m}_{i,\max}$$

If $?N^{TTI,cm,m}_{i,\max}$ = 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 subclause 4.2.7.5 does not need to be executed.

If $?N^{TTI,cm,m}_{i,\max} ? 0$, then, for TrCH *i*, the rate matching algorithm of subclause 4.2.7.5 needs to be executed, and the parameters listed in subclauses 4.2.7.2.1.3 and 4.2.7.2.1.4 shall be used for determining e_{ini}, e_{plus}, and e_{minus}, and $?N^{TTI,m}_{i,l}$.

4.2.7.2.1.3 Determination of rate matching parameters for uncoded and convolutionally encoded TrCHs

$$?N_i ? ?N_{i,max}$$

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

a=2

$$N_{max} ? \max_{l ? TFS(i)} N^{TTI}_{il}$$

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

$$X_i ? N^{TTI}_{il}$$

$$e_{ini} ? 1$$

$$e_{plus} ? a ? N_{max}$$

$$e_{minus} ? a ? |?N_i|$$

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 subclause 4.2.7.5 is run. The resulting values of $\Delta N_{i,l}^{TTI}$ can be represented with following expression.

$$\Delta N_{i,l}^{TTI} = \left\lceil \frac{|\Delta N_i| \cdot X_i}{N_{max}} \right\rceil \cdot \mathrm{sgn}(\Delta N_i)$$

For compressed mode by puncturing, the above formula produces $\Delta N_{i,l}^{TTI,m}$ instead of $\Delta N_{i,l}^{TTI}$.

4.2.7.2.1.4 Determination of rate matching parameters for Turbo encoded TrCHs

If repetition is to be performed on turbo encoded TrCHs, i.e. $\Delta N_{i,max} > 0$, the parameters in subclause 4.2.7.2.1.3 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.

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

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

$\Delta N_i^b = \lfloor \Delta N_{i,\max}^{TTI,cm,m}/2 \rfloor$, for *b=2*

$\Delta N_{i\ I}^b = \lceil \Delta N_{i,\max}^{TTI,cm,m}/2 \rceil$, for *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 subcaluse 4.2.7.5. The following parameters are used as input:

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

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

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

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

The values of $\Delta N_{i,l}^{TTI}$ may be computed by counting puncturing when the algorithm of subclause 4.2.7.5 is run. The resulting values of $\Delta N_{i,l}^{TTI}$ can be represented with following expression.

$$\Delta N_{i,l}^{TTI} = -\left\lfloor \frac{|\Delta N_i^2| \cdot X_i}{N_{max}} + 0.5 \right\rfloor - \left\lfloor \frac{|\Delta N_i^3| \cdot X_i}{N_{max}} \right\rfloor$$

In the above equation, the first term of the right hand side represents the amount of puncturing for b=2 and the second term represents the amount of puncturing for b=3.

For compressed mode by puncturing, the above formula produces $?N_{i,l}^{TTI,m}$ instead of $?N_{i,l}^{TTI}$.

4.2.9 Insertion of discontinuous transmission (DTX) indication bits

In the downlink, DTX is used to fill up the radio frame with bits. The insertion point of DTX indication bits depends on whether fixed or flexible positions of the TrCHs in the radio frame are used. It is up to the UTRAN to decide for each CCTrCH whether fixed or flexible positions are used during the connection. DTX indication bits only indicate when the transmission should be turned off, they are not transmitted.

4.2.9.1 1st insertion of DTX indication bits

This step of inserting DTX indication bits is used only if the positions of the TrCHs in the radio frame are fixed. With fixed position scheme a fixed number of bits is reserved for each TrCH in the radio frame.

The bits from rate matching are denoted by $g_{i1}, g_{i2}, g_{i3}, \ldots, g_{iG_i}$, where G_i is the number of bits in one TTI of TrCH i. Denote the number of bits in one radio frame of TrCH i by H_i. Denote D_i the number of bits output of the first DTX insertion block.

In TTIs containing no compressed frames or frames compressed by spreading factor reduction, H_i is constant and corresponds to the maximum number of bits from TrCH i in one radio frame for any transport format of TrCH i and $D_i = F_i ? H_i$.

In TTIs containing frames compressed by puncturing, additional puncturing is performed in the rate matching block. The empty positions resulting from the additional puncturing are used to insert p-bits in the first interleaving block, the DTX insertion is therefore limited to allow for later insertion of p-bits. Thus DTX bits are inserted until the total number of bits is Di where $D_i = F_i ? H_{i,*} - Np^{TTI,m}_{i,max}$, and $H_i = N_{i,*} + ?N_{i,*}$.

The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{iDi}$ Note that these bits are three valued. They are defined by the following relations:

$$h_{ik} ? g_{ik} \quad k = 1, 2, 3, \ldots, G_i$$

$$h_{ik} ? ? \quad k = G_i+1, G_i+2, G_i+3, \ldots, D_i$$

where DTX indication bits are denoted by ?. Here g_{ik} ? {0, 1} and ? ? {0, 1}.

4.2.9.2 2nd insertion of DTX indication bits

The DTX indication bits inserted in this step shall be placed at the end of the radio frame. Note that the DTX will be distributed over all slots after 2nd interleaving.

The bits input to the DTX insertion block are denoted by $s_1, s_2, s_3, \ldots, s_S$, where S is the number of bits from TrCH multiplexing. The number of PhCHs is denoted by P and the number of bits in one radio frame, including DTX indication bits, for each PhCH by R..

In non-compressed frames, $R ? \frac{N_{data,*}}{P} ? 15 ? ?N_{data1} ? N_{data2} ?$, where N_{data1} and N_{data2} are defined in [2].

For compressed frames, $N'_{data,*}$ is defined as $N'_{data,*} ? P ? 15 ? (N'_{data1} ? N'_{data2})$. N'_{data1} and N'_{data2} are the number of bits in the data fields of the slot format used for the current compressed frame, i.e. slot format A or B as defined in [2] corresponding to the spreading factor and the number of transmitted slots in use.

In frames compressed by puncturing and when fixed positions are used, no DTX shall be inserted, since the exact room for the gap is already reserved thanks to the earlier insertion of the p-bits.

In frames compressed by higher layer scheduling, additional DTX with respect to normal mode shall be inserted if the transmission time reduction does not exactly create a transmission gap of the desired *TGL*.

The number of bits available to the CCTrCH in one radio frame compressed by spreading factor reduction or by higher layer scheduling is denoted by $N_{data,*}^{cm}$ and $R ? \frac{N_{data,*}^{cm}}{P}$.

For frames compressed by spreading factor reduction $N_{data,*}^{cm} ? \frac{N'_{data,*}}{2}$.

For frames compressed by higher layer scheduling the exact value of $N_{data,*}^{cm}$ is dependent on the *TGL* which is signalled from higher layers. It can be calculated as $N_{data,*}^{cm} ? N_{data,*}^{'} ? N_{TGL}$.

N_{TGL} is the number of bits that are located within the transmission gap and defined as:

$$N_{TGL} ? \begin{cases} \frac{TGL}{15} ? N_{data,*}^{'}, \text{ if } N_{first} + TGL ? 15 \\ \frac{15 ? N_{first}}{15} ? N_{data,*}^{'}, \text{ in first frame if } N_{first} + TGL > 15 \\ \frac{TGL ? (15 ? N_{first})}{15} ? N_{data,*}^{'}, \text{ in second frame if } N_{first} + TGL > 15 \end{cases}$$

N_{first} and *TGL* are defined in subclause 4.4.

The bits output from the DTX insertion block are denoted by $w_1, w_2, w_3, \ldots, w_{(PR)}$. Note that these bits are four valued in case of compressed mode by puncturing, and three valued otherwise. They are defined by the following relations:

$w_k ? s_k$ k = 1, 2, 3, …, S

$w_k ? ?$ k = S+1, S+2, S+3, …, *P*?*R*

where DTX indication bits are denoted by ?. Here s_k ? {0,1, p}and ? ? {0,1}.

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 $x_1, x_2, x_3, \ldots, x_X$, where *X* 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. $U = (X - N_{TGL} - (N_{data,*} - N'_{data,*})) / P$ for compressed mode by puncturing, and $U ? \frac{X}{P}$ otherwise. The relation between x_k and u_{pk} is given below.

For all modes, some bits of the input flow are mapped to each code until the number of bits on the code is *U*. For modes other than compressed mode by puncturing, all bits of the input flow are taken to be mapped to the codes. For compressed mode by puncturing, only the bits of the input flow not corresponding to bits p are taken to be mapped to the codes, each bit p is removed to ensure creation the gap required by the compressed mode, as described below.

Bits on first PhCH after physical channel segmentation:

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

Bits on second PhCH after physical channel segmentation:

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

…

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

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

where f is such that :

- for modes other than compressed mode by puncturing, $x_{f(k)} = x_k$, i.e. $f(k) = k$, for all k.
- for compressed mode by puncturing, bit $u_{1,1}$ corresponds to the bit x_k with smallest index k when the bits p are not counted, bit $u_{1,2}$ corresponds to the bit x_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

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 $Y = PU$.