TSG-RAN Working Group1 meeting #12 TSGR1#12(00)570

Seoul, Korea., April 10 ~ April 13, 2000 (this is a rev. of 461)

Agenda Item	:	**AH04 + AH08**
Source	:	**Mitsubishi Electric (Trium-RD)**
Title	:	**Downlink Compressed Mode by Puncturing, revision 3**
Document for	:	**Discussion and Decision**

Introduction

Compressed mode by puncturing has been intensively discussed in RAN WG1 #11. As a matter of fact it was agreed that Nortel's proposal [1] contained some problems regarding the flexible position case. Also, it was decided to introduce into 25.212 sufficient hooks so that the method proposed by Mitsubishi in the revision 1 [3] of this paper, based on segmentation coefficients, has a chance to be introduced later.

The method proposed in [3] was incomplete as it was not explained how to determine the segmentation coefficient. In [4] we proposed a very simple method. We are currently evaluating other methods, that will be proposed in future papers for release 2000.

The method proposed for fixed position in Nortel's proposal [1] was complete, and so accepted by RAN #7 and incorporated into 25.212 [6].

In this paper we propose that :

- The method for fixed position proposed in the previous revision [4] of this paper replace the method currently in 25.212 [6]
- The description of the 1st IL and the p-bits be such that p-bits are removed immediately after the 1st IL.

References

[1] TSGR1#11(00)272 Downlink Compressed Mode by Puncturing, update, source Nortel Networks

[2] R1#10-00-139 Discussion on De-shuffling in place of 1st IL in the context of Compressed Mode by puncturing, source Mitsubisi Electric.

[3] TSGR1#11(00)445 Downlink Compressed Mode by Puncturing (revision 1), source Mitsubishi Electric,

[4] TSGR1#11(00)461 Downlink Compressed Mode by Puncturing (revision 2), source Mitsubishi Electric,

[5] TSGR1#11(00)0571 UL multiframe Compressed mode (release 2000), source Mitsubishi Electric,

[6] TS 25.212 ver 3.2.0 Multiplexing and channel coding (FDD) (Release 1999), source RAN

[7] R1#11(00)444 Compressed mode terminology, and R'00 new items, source Mitsubishi Electric

Abbreviations used in this paper

UL	Uplink
RM	Rate Matching

Difference from previous revision [4] of this paper

The previous revision of this paper was proposing a method both for flexible and for fixed position, so it was concerned both with release 1999 and release 2000. This paper is concerned only with fixed position, that is release 99.

Moreover, contrary to this paper, [4] is not based on the latest version of 25.212.

Motivation for the proposal

What we are proposing is completely equivalent from the functional point of view to what there is in the current 25.212 [6] as for the 1st IL thing, and is almost equivalent for the segment size parameter determination (the result might slightly differ due to a different rounding method).

So, in term of function, there is very little change compared with what we have. Besides, if things were going to stop with release '99 we would be satisfied with what there is currently in 25.212 [6].

However, considering the decision by RAN #7 that enhancement of compressed mode is one of the work item of release 2000 and considering the possible ways to evolve 25.212, we consider that the description given in the CR hereinafter is more evolvable that the current one.

The reason for that are the following :

- As shown in [5], in order to form a multiframe compressed mode in UL, there would be a need make unequal segmentation also. Since RM is immediately following radio frame segmentation in UL, the p-bits removal needs to be before RM to ensure that the correct amount of data bits is punctured or repeated without changing the RM pattern algorithm. So, if we want the spec to evolve smoothly, there are only two places left for the p-bits removal, either immediately after radio frame segmentation, or immediately after 1st IL. Having it immediately after the 1st IL seems more consistent, as their insertion is made immediately before, and the p-bit are therefore some kind of particular IL pruning technique.

- As shown in [7], in the future we may well want to combine CM by rate matching and CM by SF division by 2. The reason why we say CM by rate matching and not CM by puncturing is that in this case the RM is used to repeat more, or puncture less the data, because the SF division by 2 provided to much gap space, and we want to fill it. One of the motivation of having the p-bit removal as low as possible in the chain was that these p-bits are supposed to be used to form the gap, that is to say they are kind of gap bits removed to form the gap. Clearly this kind of description is inadequate as in the case of combining CM by rate matching and CM by SF division by 2, the p-bits correspond to the radio frames where there is not transmission gap as said in [6] " *This allows 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.*". So, in fact, p-bits are better understood as an interleaving thing rather than as a gap formation thing. It is not the p-bits that are forming the gap but the ability to make unequal segmentation to change the rate matching ratios.

- As we showed in [2], the main advantage of the p-bits is to solve some potential problem with the 1st interleaving function that could occur when unequal radio frame segmentation is used. The quality of a specification is not relying in the number of lines, but in the relevance of the function split. This is why we should not hide by removing these p-bits later in the chain that we are making an *unequal* segmentation, while this is precisely what we want to do, we should not hide either that we are impacting the 1st IL whereas this is also the goal pursued.

- Finally, as we have stated several times there are several ways of determining the segmentation coefficients. Using the segmentation coefficient method for the determination of block size in DL fixed position would allow less impact on the spec the day when a new segmentation coefficient method is proposed, as the usage of the segmentation coefficient itself would remain unchanged. Furthermore, the method being more general, as it also applied to UL and to DL in flexible position, we simply obtain a more elegant description.

Conclusion

In this paper we propose several changes to 25.212 for release 99. These changes do not impact very much the function that we currently have (no change for 1st IL, little change to segment size), but on the other hand they provide better evolvability of the spec and better clarity of the functional description.

3GPP/SMG Meeting RAN WG1#12
Seoul, Korea, April 2000

Document ***R1-000570***
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**	**063rev1**	Current Version:	3.2.0

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

For submission to:	RAN#8	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: (U)SIM [ ] ME [X] UTRAN / Radio [X] Core Network [ ]
(at least one should be marked with an X)

Source:	Mitsubishi Electric	**Date:**	11th April 2000
Subject:	Downlink Compressed Mode by puncturing		
Work item:	TS 25.212		

Category:				**Release:**		
	F	Correction			Phase 2	
	A	Corresponds to a correction in an earlier release			Release 96	
(only one category shall be marked with an X)	B	Addition of feature			Release 97	
	C	Functional modification of feature	X		Release 98	
	D	Editorial modification	X		Release 99	X
					Release 00	

Reason for change: Clarifying the spec in terms of functional split. Making the description more evolvable for release 2000

Clauses affected: To be completed

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:

R_I and C_I have been renamed *RI* and *CI* because C_I interferes with C_i when $i = I$.

In DL the meaning of H_i has been changed, it is now the block size after 1st IL, the radio frame segment size being denoted FS_i.

3.2 Symbols

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

éxù	round towards ¥, i.e. integer such that *x* £ *éxù* < *x*+1
ëxû	round towards -¥, i.e. integer such that *x*-1 < *ëxû* £ *x*
çxç	absolute value of *x*
sgn(*x*)	signum function, i.e. $\mathrm{sgn}(x) = \begin{cases} 1; & x \geq 0 \\ -1; & x < 0 \end{cases}$
N_{first}	The first slot in the *TG*.
N_{last}	The last slot in the *TG*.
N_{tr}	Number of transmitted slots in a radio frame.

Unless otherwise is explicitly stated when the symbol is used, the meaning of the following symbols is:

i	TrCH number
j	TFC number
k	Bit number
l	TF number
m	Transport block number
n_i	Radio frame number of TrCH *i*.
p	PhCH number
r	Code block number
I	Number of TrCHs in a CCTrCH.
C_i	Number of code blocks in one TTI of TrCH *i*.
F_i	Number of radio frames in one TTI of TrCH *i*.
F_{max}	Number of radio frames in the longest TTI within the CCTrCH.
$FS_{i,l}^{cm,n}$	DL radio frame segment size for TrCH *i*, for TF *l*, and for radio frame number *n* within longest TTI, when compressed mode by puncturing is in use. This notation can be replaced by $FS_i^{cm,n}$ by dropping the TF index when this does not lead to an ambiguity.
$FS_{i,l}$	DL radio frame segment size for TrCH *i*, and for TF *l* when compressed mode by puncturing is not in use. This notation can be alleviated to FS_i by dropping the TF index when this does not lead to an ambiguity.
M_i	Number of transport blocks in one TTI of TrCH *i*.
$N_{data,j}$	Number of data bits that are available for the CCTrCH in a radio frame with TFC *j*.
$N_{data,j}^{cm}$	Number of data bits that are available for the CCTrCH in a compressed radio frame with TFC *j* (UL).
$N_{data,j}^{cm,n}$	Number of data bits that are available for the CCTrCH in a compressed radio frame with TFC *j* and radio frame number *n* within the longest TTI ($0 \leq n \leq F_{max}$) (DL compressed mode by puncturing).
P	Number of PhCHs used for one CCTrCH.
PL	Puncturing Limit for the uplink. Signalled from higher layers
RM_i	Rate Matching attribute for TrCH *i*. Signalled from higher layers.

Temporary variables, i.e. variables used in several (sub)clauses with different meaning.

x, X
y, Y
z, Z
x', X'
y', Y'

4.2 Transport-channel coding/multiplexing

Data arrives to the coding/multiplexing unit in form of transport block sets once every transmission time interval. The transmission time interval is transport-channel specific from the set {10 ms, 20 ms, 40 ms, 80 ms}.

The following coding/multiplexing steps can be identified:

- add CRC to each transport block (see subclause 4.2.1);
- transport block concatenation and code block segmentation (see subclause 4.2.2);
- channel coding (see subclause 4.2.3);
- rate matching (see subclause 4.2.7);
- insertion of discontinuous transmission (DTX) indication bits (see subclause 4.2.9);
- interleaving (two steps, see subclauses 4.2.4 and 4.2.11);
- radio frame segmentation (see subclause 4.2.6);
- multiplexing of transport channels (see subclause 4.2.8);
- physical channel segmentation (see subclause 4.2.10);
- mapping to physical channels (see subclause 4.2.12).

The coding/multiplexing steps for uplink and downlink are shown in figure 1 and figure 2 respectively.

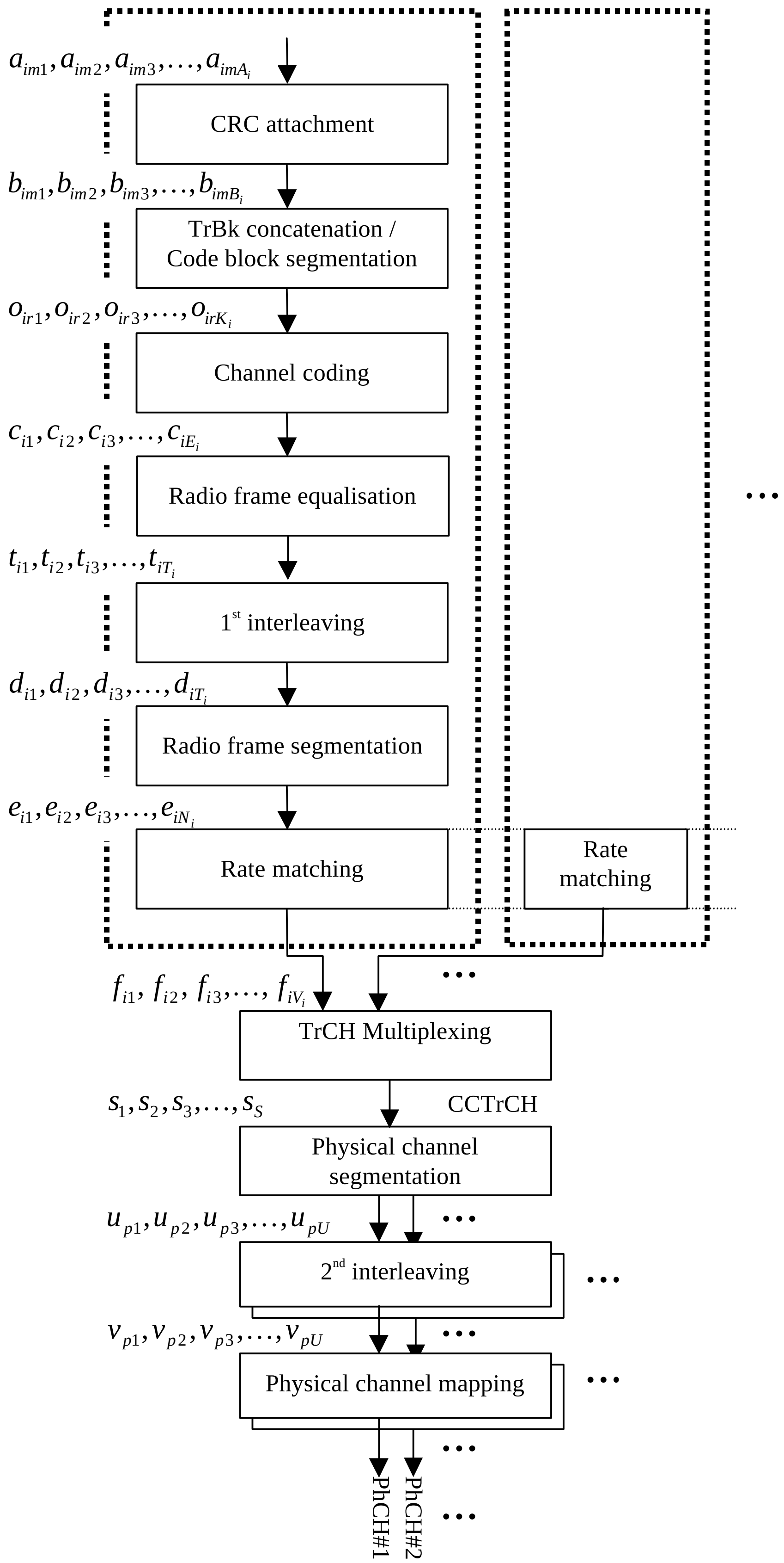

Figure 1: Transport channel multiplexing structure for uplink

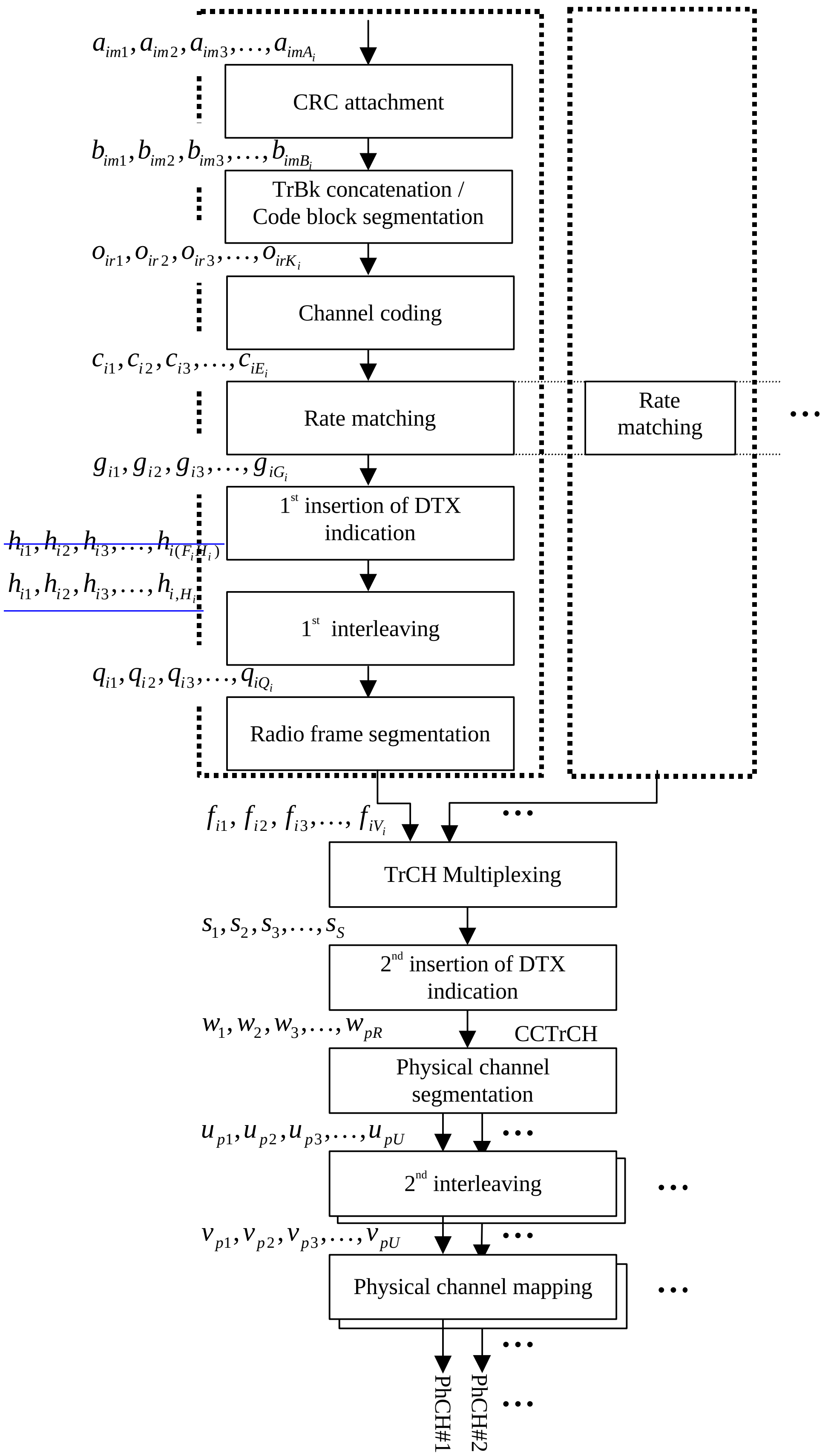

Figure 2: Transport channel multiplexing structure for downlink

The single output data stream from the TrCH multiplexing, including DTX indication bits in downlink, is denoted *Coded Composite Transport Channel (CCTrCH)*. A CCTrCH can be mapped to one or several physical channels.

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:

$x_{ik} = z_{ik}$ and $X_i = Z_i$.

In case of compressed mode by puncturing and fixed positions, sequence $x_{i,k}$ which will be input to first interleaver for TrCh *i* and TTI *m* within largest TTI, is built from bits $z_{i,k}$, $k=1,..Z_i$, plus $Np^{TTI,m}_{i,max}$ bits marked p and $X_i = Z_i + Np^{TTI,m}_{i,max}$, as is described thereafter.

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

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

NOTE 1: 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 $Np^{*}_{i,max}$ for x equal 0 to Fi –1 for fixed positions . It is noted Np^{*}_{i} in the following initialisation step.

NOTE 2: 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.

col = 0

while col < F_i **do**

C[col] = Np^{col}_{i} -- 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 < X_i **do**

col = *n* mod F_i

if cbi[col] < C[P_{Fi}(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 $x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$, 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 denoted by $y_{i1}, y_{i2}, y_{i3}, \ldots, y_{iY_i}$, where i is TrCH number and Y_i the number of bits.

Two intermediate bit sequences are respectively denoted by $x'_{i1}, x'_{i2}, x'_{i3}, \ldots, x'_{iX'_i}$ or $y'_{i1}, y'_{i2}, y'_{i3}, \ldots, y'_{iY'_i}$, where i is TrCH number and X'_i or Y'_i the respective number of bits. The $x'_{i1}, x'_{i2}, x'_{i3}, \ldots, x'_{iX'_i}$ is hereinafter called the intermediate input bit sequence, while the $y'_{i1}, y'_{i2}, y'_{i3}, \ldots, y'_{iY'_i}$ is called the intermediate ouptu bit sequence.

The output bit sequence is derived as follows:

4.2.5.1 Operation of the 1st interleaver on the intermediate bit sequences

At this stage X'_i is assumed and guaranteed to be an integer multiple of F_i.

(1) Select the number of columns CI ~~C_I~~ to F_i as in ~~from~~ table 3.

(2) Determine the number of rows RI ~~R_I~~ defined as:

$$RI = X'_i / CI$$ ~~$R_I = X_i/C_I$~~

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

$$\begin{bmatrix} x'_{i,1} & x'_{i,2} & x'_{i,3} & \ldots & x'_{i,CI} \\ x'_{i,(CI+1)} & x'_{i,(CI+2)} & x'_{i,(CI+3)} & \ldots & x'_{i,(2CI)} \\ \vdots & \vdots & \vdots & \ldots & \vdots \\ x'_{i,((RI-1)CI+1)} & x'_{i,((RI-1)CI+2)} & x'_{i,((RI-1)CI+3)} & \ldots & x'_{i,(RI \cdot CI)} \end{bmatrix}$$

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

(4) Perform the inter-column permutation based on the pattern $\{P1_{CI}(j)\}$ (j=0,1, ..., CI-1) shown in table 3, where $P1_{CI}(j)$ is the original column position of the j-th permuted column. After permutation of the columns, the bits are denoted by $y'_{i,k}$, $Y'_i = X'_i$, and constitute the intermediate output sequence ~~y_{ik}~~:

$$\begin{bmatrix} y'_{i,1} & y'_{i,(RI+1)} & y'_{i,(2RI+1)} & \ldots & y'_{i,((CI-1)RI+1)} \\ y'_{i,2} & y'_{i,(RI+2)} & y'_{i,(2RI+2)} & \ldots & y'_{i,((CI-1)RI+2)} \\ \vdots & \vdots & \vdots & \ldots & \vdots \\ y'_{i,RI} & y'_{i,(2RI)} & y'_{i,(3RI)} & \ldots & y'_{i,(CI \cdot RI)} \end{bmatrix}$$

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

(5) Read the intermediate output bit sequence $y'_{i1}, y'_{i2}, y'_{i3}, \ldots, y'_{i,(CI \cdot RI)}$ ~~$y_{i1}, y_{i2}, y_{i3}, \ldots, y_{i,(C_I R_I)}$~~ of the 1st interleaving column by column from the inter-column permuted $RI \times CI$ ~~$R_I \times C_I$~~ matrix. Bit $y'_{i,1}$ ~~$y_{i,1}$~~

corresponds to the first row of the first column and bit $y'_{i,(R_I C_I)}$ ~~$y_{i,(R_I C_I)}$~~ corresponds to row R_I ~~R_I~~ of column C_I ~~C_I~~.

Table 3

TTI	Number of columns C_I ~~C_I~~	Inter-column permutation patterns $\{P_{1,C_I}(0), P_{1,C_I}(1), \ldots, P_{1,C_I}(C_I-1)\}$
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}

4.2.5.2 Relation between input or output and intermediate bit sequence in other case than DL compressed mode by puncturing

In other cases than DL compressed mode by puncturing, the input bit sequence and the intermediate input bit sequence are identical, that is to say :

$$X'_i = X_i$$

$x'_{i,k} = x_{i,k}$ for $k = 1,2,\ldots,X_i$.

Moreover, the intermediate output bit sequence and the output bit sequence are identical, that is to say :

$$Y_i = Y'_i$$

$y_{i,k} = y'_{i,k}$ for $k = 1,2,\ldots,Y'_i$.

4.2.5.3 Relation between input or output and intermediate bit sequence in the case of DL compressed mode by puncturing

In this section we use dummy bits called p-bits, that take a fourth value on top of the 3 bit values {0,δ,1}.

The number of bits in the intermediate bit sequence is defined as follows :

$$Y'_i = X'_i = F_i \cdot \left(\max_{\substack{m \cdot F_i \le n \\ n < (m+1) \cdot F_i}} FS_i^{cm,n} \right)$$

Moreover we have also the following relations :

$$Y_i = X_i = \sum_{n = m \cdot F_i}^{n = (m+1) \cdot F_i - 1} FS_i^{cm,n}$$

The intermediate input bit sequence $x'_{i1}, x'_{i2}, x'_{i3}, \ldots, x'_{iX'_i}$ is obtained from the input bit sequence $x_{i,1}, x_{i,2}, x_{i,3}, \ldots, x_{i,X_i}$ by inserting p-bits into it. The p-bits are inserted so that they are grouped in the beginning of each interleaver matrix column.

To that purpose we use a F_i p-bit count-downs $pbcd_0$, $pbcd_1$, …, $pbcd_{F_i-1}$, counting the number of p-bits still to be inserted in the beginning of the respective column.

-- initialisation of $pbcd_n$ p-bit count downs

for n = 0 to F_i-1 do

$n' = P_{1,F_i}(n)$

cbi[n] = $X_i'/F_i - FS_i^{cm,m \cdot F_i + n'}$

end for

-- p-bit insertion

n = 0

k = 1

l = 1

while l = 1 to X_i' do

if cbi[n] ≠ 0 then

$x_{i,l}'$ = p-bit

else

$x_{i,l}' = x_{i,k}$

k = k+1

cbi[n] = cbi[n]-1

end if

n = n+1 mod F_i

end for

The output bit sequence $y_{i,1}, y_{i,2}, y_{i,3}, \ldots, y_{i,Y_i}$ is obtained from the intermediate output bit sequence $y_{i,1}', y_{i,2}', y_{i,3}', \ldots, y_{i,Y_i'}'$ by removing the p-bits from it. In other words, the following algorithm is applied :

k = 1

l = 1

for l = 1 to Y_i'

if $y_{i,l}'$ ≠ p-bit then

$y_{i,k} = y'_{i,l}$

$k = k+1$

end-if

end-for

Note : In this description the p-bits are removed in the 1st interleaver. However, alternative descriptions, equivalent from the point of view of the CCTrCH output, would remove them in any other step after the 1st interleaver and before the 2nd interleaver : if for instance they are removed after the radio frame segmentation, the segments, including p-bits, are all of equal size over a TTI, like in normal mode.

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

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

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

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 $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i,H_i}$ $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_iH_i)}$, where i is the TrCH number. Hence, z_{ik} X_{ik} = h_{ik} and $Z_i = F_i * H_i - Np_{TTI, m}$ $_{i,max}$ in compressed mode by puncturing, and Z_i X_i = F_iH_i otherwise.

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$$X_{ik} = g_{ik}$ and Z_i X_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.

4.2.6 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 rate matching in the DL not in compressed mode by puncturing and radio frame size equalisation in the UL in compressed or normal mode, the input bit sequence length is guaranteed to be an integer multiple of F_i.

In the DL in compressed mode by puncturing the input bit sequence is not necessarily an integer multiple of F_i. A TrCH TTI is concerned by this when the largest TTI containing it is overlapping with at least one transmission gap.

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 $y_{i,n_i,1}, y_{i,n_i,2}, y_{i,n_i,3}, \ldots, y_{i,n_i,Y_{i,n_i}}$ $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_i}$ where n_i is the radio frame number in current TTI and Y_{i,n_i} Y_i is the number of bits per in radio frame number n_i of the considered TTI for TrCH i. The output sequences are defined as follows:

$y_{i,n_i,k} = x_{i,l}$ where n_i = 0, …, F_i-1, k = 1, 2, …., Y_{i,n_i}, and $l = \left(\sum_{x=0}^{x=n_i-1} Y_{i,x}\right) + k$ $y_{i,n_ik} = x_{i,((n_i-1)Y_i)+k}$, n_i = 1…F_i, k = 1…Y_i

where

Y_{i,n_i} ~~$Y_i = (X_i / F_i)$~~ 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.

In DL compressed mode by puncturing :

$Y_{i,n} = FS_{i,*}^{cm,m\cdot F_i+n}$ for frame number n = 0, 1, …, F_i-1 within the TTI, and TTI number *m* within the longest TTI.

$FS_{i,*}^{cm,m\cdot F_i+n}$ is determined in section 4.2.7.2.

Otherwise

$Y_{i,n} = X_i / F_i$ for all frame number n = 0, 1, …, F_i-1 within the TTI.

4.2.6.1 Relation between input and output of the radio frame segmentation block in uplink

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,n_i} ~~Y_i~~.

4.2.6.2 Relation between input and output of the radio frame segmentation block in downlink

The bits input to the radio frame segmentation are denoted by $q_{i1}, q_{i2}, q_{i3}, \ldots, q_{iQ_i}$, where *i* is the TrCH number and Q_i the number of bits. Hence, $x_{ik} = q_{ik}$ and $X_i = Q_i$.

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

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 subcaluse 4.2.7 and subclauses:

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.

~~$Np^{TTI,m}_{i,l}$, $m=0$ 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 $Np^{TTI,m}_{i,max}$ 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.~~

~~$Np^{n}_{i,l}$ $n=0$ 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 un-compressed radio frames. In case of fixed positions and compressed mode by puncturing, this value is noted $Np^{n}_{i,max}$ 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_i-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*. 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*.

$N^{cm}_{data,j}$ Number of data bits that are available for the CCTrCH in a compressed radio frame with TFC *j* (UL).

$N^{cm,n}_{data,j}$ Number of data bits that are available for the CCTrCH in a compressed radio frame with TFC *j* and radio frame number *n* within the longest TTI ($0 \le n \le F_{max}$) (DL compressed mode by puncturing).

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*.

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 ($0 £ n_i < F_i$).

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.

$SC_{F,n}$ DL compressed mode by puncturing Segmentation coefficient for TTI duration F in radio frame count, and radio frame number n within largest TTI ($0 \le n \le F_{max}$).

$TF_i(j)$: 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. $X(t)$ in subclause 4.2.3.2.1.

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

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:

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

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

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

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 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 $\{ N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2N_4, 3N_4, 4N_4, 5N_4, 6N_4\}$. 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 $\min_{1 \le y \le I}\{RM_y\} \cdot N_{data} - \sum_{x=1}^{I} RMx \cdot N_{x,j}$ 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 $\min_{1 \le y \le I}\{RM_y\} \cdot N_{data} - PL \cdot \sum_{x=1}^{I} RMx \cdot N_{x,j}$ 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 subclause 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 as follows:

In compressed mode 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:

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

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

In compressed mode by spreading factor reduction, $N_{data,j}^{cm} = 2N_{data,j} - 2N_{TGL}$, where $N_{TGL} = \frac{15 - N_{tr}}{15} N_{data,j}$

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 subclause 4.2.7.5 does not need to be executed.

If $DN_{ij} \neq 0$ 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

$R = DN_{ij} \bmod N_{ij}$ -- 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 $2R \leq N_{ij}$

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 subclause 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 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

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

If ΔN_i is calculated as 0 for *b*=2 or *b*=3, then the following procedure and the rate matching algorithm of subclause 4.2.7.5 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($q \leq 2$)

for x=0 to F_i-1

S[I_F[(3x+b-1) mod F_i]] = x 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 = $\lceil x*q' \rceil$ mod F_i;

S[I_F[(3r+b-1) mod F_i]] = $\lceil x*q' \rceil$ 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:

$e_{ini} = (a \cdot S(n_i) \cdot |\Delta N_i| + X_i) \bmod (a \cdot X_i)$, 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. 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 $N_{data,*}=P(15N_{data1}+15N_{data2})$, where N_{data1} and N_{data2} are defined in [2]. Note that contrary to the uplink, the same rate matching patterns are used in normal and compressed mode 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 compressed mode by puncturing in case of fixed positions 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 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 $_i$. In case of fixed positions, it is calculated in addition to the amount of rate matching indicated by higher layers. It is noted $Np^{TTI,m}_{i,max}$.~~

In fixed positions case, to obtain the total rate matching $\Delta N_{i,\max}^{TTI,cm,m}$ to be performed on the TTI number m within the longest TTI, the size of each radio frame segment $FS_{i,*}^{cm,n}$, $n \in \{m \cdot F_i, m \cdot F_i + 1, \ldots, (m+1) \cdot F_i - 1\}$, within TTI number m is computed by replacing $N_{data,*}$ by $N_{data,*}^{cm,n}$ and $\frac{1}{F_i}$ by $SC_{F_i,n}$ in the formulas. $SC_{F_i,n}$ denotes the segmentation coefficient in compressed mode by puncturing and so differs from $\frac{1}{F_i}$ in case of unequal segmentation.

$\Delta N_{i,\max}^{TTI,cm,m}$ is then simply computed as the difference between the block size before radio frame segmentation and that before rate matching:

$$\Delta N_{i,\max}^{TTI,cm,m} = \left(\sum_{n=m \cdot F_i}^{n=(m+1) \cdot F_i - 1} FS_{i,*}^{cm,n} \right) - N_{i,\max}^{TTI}$$

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

~~$Np^{TTI,m}_{i,max}$ is sub-stracted from $DN^{TTI,m}_{i,max}$ (calculated based on higher layers RM parameters as for normal rate matching). This allows to create room for the $Np^{TTI,m}_{i,max}$ 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, $N_{data,*}^{cm,n}$ ~~$N'_{data,*}$~~ is used for radio frames with gap instead of $N_{data,*}$, where $N_{data,*}^{cm,n} = P \cdot N_{Tr} \cdot (N'_{Data1} + N'_{Data2})$ ~~$N'_{data,*} = P(15N'_{data1} + 15N'_{data2})$~~.

~~N'_{data1}~~ N'_{Data1} and ~~N'_{data2}~~ 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 N_{Tr} of transmitted slots in use. For radio frames not overlapping a transmission gap, but within a longest TTI overlapping with a transmission gap we have $N_{data,*}^{cm,n} = N_{data,*}$ as usual.

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

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

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

~~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 each Physical Channel $N_{TGL}[k]$, where k is the radio frame number in the TTI.~~

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

$$N_{TGL} = \begin{cases} \frac{TGL}{15} N'_{data,*}, & \text{if } N_{first} + TGL \le 15 \\ \frac{15 - N_{first}}{15} N'_{data,*}, & \text{in first radio frame of the gap if } N_{first} + TGL > 15 \\ \frac{TGL - (15 - N_{first})}{15} N'_{data,*}, & \text{in second radio frame of the gap if } N_{first} + TGL > 15 \end{cases}$$

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

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

4.2.7.2.1 Determination of rate matching parameters for fixed positions of TrCHs

4.2.7.2.1.1 Calculation of DN_{max} for normal mode and compressed mode by higher layer scheduling and spreading factor reduction

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

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

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 subclause 4.2.7:

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

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 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 $\Delta N_{max} \neq 0$ the parameters listed in subclauses 4.2.7.2.1.~~3~~ 4 and 4.2.7.2.1.~~4~~5 shall be used for determining e_{ini}, e_{plus}, and e_{minus}.

4.2.7.2.1.2 Calculations for compressed mode by puncturing

Calculations of ~~$DN^{TTI,m}_{i,max}$~~ $\Delta N_{i,\max}^{TTI,cm,m}$, for all TTI *m* within l~~ar~~ongest TTI, for all TrC~~h~~H *i*

First an intermediate calculation variable $N_{i,\max}^{cm,n}$ ~~$N^n_{i,*}$~~ is calculated for all transport channels *i* and all frames *n* in TTI *m* within the l~~ar~~ongest TTI, using the ~~same formula as for normal mode above by replacing $N^{TTI}_{i,l}$ by $N^{TTI,m}_{i,l}$, the number of bits in TTI *m*.~~ following formula:

$$N_{i,\max}^{cm,n} = SC_{F_i,n} \cdot \max_{l \in TFS(i)} N_{i,l}^{TTI}$$

$SC_{F_i,n}$ denotes the the segmentation coefficient for TTI duration F_i and is determined like in section 4.2.7.2.1.3.

The computation of the ~~$\Delta N^{TTI,m}_{i,max}$~~ $\Delta N_{i,\max}^{TTI,cm,m}$ parameters is then performed for all TrCH *i* by the following formula,

~~$DN^{TTI,m}_{i,max} = S_{n=0}^{n=Fi} DN^n_{i,*}$~~

$$\Delta N_{i,\max}^{TTI,cm,m} = \left(\sum_{n=m \cdot F_i}^{n=(m+1) \cdot F_i - 1} FS_{i,*}^{cm,n} \right) - \left(\max_{l \in TFS(i)} N_{i,l}^{TTI} \right)$$

where all ~~$\Delta N^n_{i,*}$~~ $FS_{i,*}^{cm,n}$ are derived from $N_{i,\max}^{cm,n}$ ~~$N^n_{i,*}$~~ for all TrC~~h~~H *i* and all frames *n* in TTI *m* , from the formula

$$FS_{i,*}^{cm,n} = Z_{i,*} - Z_{i-1,*}$$

where $Z_{i,*}$ is defined by the formula (1) given at subclause 4.2.7 using $N_{data,*}^{cm,n}$ instead of $N_{data,*}$, for the non compressed frames of TTI *m* and using $N'_{data,*}$ instead of $N_{data,*}$, for the compressed frames of TTI *m* and using $N_{i,\max}^{cm,n}$ instead of $N_{i,j}$.

Calculations of $Np^{n}_{i,max}$ and $Np^{TTI,m}_{i,max}$

Let $Np^{n}_{i,max}$ be the number of bits to eliminate on TrCh *i* to create the gap for compressed mode, in each radio frame k 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 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 $N_{TGL}[k]$.

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:

$Np^{TTI,m}_{i,max} = S_{n=0}^{Fi-1} Np^{n}_{i,max}$

If $DN_{max} = Np^{TTI,m}_{i,max}$, then, for TrCH *i*, the output data of the rate matching is the same as the input data and the rate matching algorithm of subclause 4.2.7.5 does not need to be executed. If $DN_{max} \neq Np^{TTI,m}_{i,max}$, then, for TrCH *i*, the rate matching algorithm of subclause 4.2.7.5 needs to be executed.

$\Delta N_{i,\max}^{TTI,cm,m} = DN^{TTI,m}_{i,max} - Np^{TTI,m}_{i,max}$

4.2.7.2.1.3 Determination of rate matching segmentation coefficients

$$\forall F \in \{1,2,4,\ldots,F_{\max}\}, \forall m \in \left\{0,1,\ldots,\frac{F_{\max}}{F}-1\right\} \forall n \in \{0,1,\ldots,F-1\}\ SC_{F,m\cdot F+n} = 2^{-18} \cdot \left\lfloor \frac{2^{18} \cdot N_{data,*}^{cm,n}}{\sum_{u=m\cdot F}^{m\cdot F+F-1} N_{data,*}^{cm,u}} \right\rfloor$$

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

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

For compressed mode by puncturing, DN_i is defined as: $DN_i = \Delta N_{i,\max}^{TTI,cm,m}$, instead of 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 subclause 4.2.7.5. The following parameters are used as input:

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

$$e_{ini} = 1$$

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

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

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

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

4.2.7.2.1.~~4~~5 Determination of rate matching parameters for Turbo encoded TrCHs

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

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

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

DN_i = ë $\Delta N_{i,\max}^{TTI,cm,m}$ /2 û , $b=2$

DN_i = é $\Delta N_{i,\max}^{TTI,cm,m}$ /2 ù , $b=3$

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

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:

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

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

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

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

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.

$$\Delta N_{i,l}^{TTI} = -\left\lfloor \frac{|\lfloor \Delta N_{max}/2 \rfloor| \times X_i}{N_{max}} + 0.5 \right\rfloor - \left\lfloor \frac{|\lceil \Delta N_{max}/2 \rceil| \times X_i}{N_{max}} \right\rfloor$$

b=2 and the second

b=3.

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 $_i$, $_i$, $_i$,

i $\sum_{n=m\cdot F}^{n=(m+1)\cdot}$ $_{i,*}^{cm,n}$ $FS_{i,*}^{cm,n}$

h_{i,H_i} ~~h_{iDi}~~ Note that these bits are three valued. They are defined by the following relations:

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

$h_{ik} = d$ $k = G_i+1, G_i+2, G_i+3, \ldots,$ ~~D_i~~ H_i

where DTX indication bits are denoted by d. Here $g_{ik} \in \{0, 1\}$ and $d \notin \{0, 1\}$.

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 normal mode $R = \frac{N_{data,*}}{P} = 15N_{data1} + 15N_{data2}$, where N_{data1} and N_{data2} are defined in [2].

For compressed mode by puncturing, ~~$N'_{data,*}$~~ in radio frames overlapping with a transmission gap $N_{data,*}^{cm,n}$ is defined as

$N_{data,*}^{cm,n} = P \cdot N_{Tr} \cdot (N'_{Data1} + N'_{Data2})$. N'_{Data1} ~~N'_{data1}~~ and N'_{Data2} ~~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 N_{Tr} of transmitted slots in use. In radio frames not overlapping with a transmission gap $N_{data,*}^{cm,n}$ is equal to $N_{data,*}$ like in normal mode. n denotes the radio frame number within the longest TTI.

~~In case of compressed mode by puncturing and fixed positions,~~ DTX shall be inserted up to $N_{data,*}^{cm,n}$ ~~until $N'_{data,*}$~~, bits, ~~since the exact room for the gap is already reserved thanks to the earlier insertion of the p-bits~~. Therefore R is defined as ~~$R = N'_{data,*} / P$~~ $R = \frac{N_{data,*}^{cm,n}}{P}$.

In compressed mode by SF reduction and by higher layer scheduling, additional DTX shall be inserted if the transmission time reduction method does not exactly create a transmission gap of the desired TGL. The number of bits available to the CCTrCH in one radio frame in compressed mode by SF reduction and by higher layer scheduling is denoted by $N_{data,*}^{cm}$ and $R = \frac{N_{data,*}^{cm}}{P}$. The exact value of $N_{data,*}^{cm}$ is dependent on the *TGL* and the transmission time reduction method, which are signalled from higher layers. For transmission time reduction by SF/2 method in compressed mode $N_{data,*}^{cm} = \frac{N'_{data,*}}{2}$, and for other methods it can be calculated as $N_{data,*}^{cm} = N'_{data,*} - N_{TGL}$. For every transmission time reduction method $N'_{data,*} = P(15N'_{data1} + 15N'_{data2})$, where N'_{data1} and N'_{data2} are the number of bits in the data fields of a slot for slot format A or B as defined in [2]. N_{TGL} is the number of bits that are located within the transmission gap and defined as:

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

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

NOTE : In compressed mode by SF/2 method DTX is also added in physical channel mapping stage (subclause 4.2.12.2). During 2nd DTX insertion the number of CCTrCH bits is kept the same as in normal mode.

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

$w_k = d$ k = S+1, S+2, S+3, …, $P \cdot R$

where DTX indication bits are denoted by *d*. Here $s_k \in \{0,1, p\}$ and $d \notin \{0,1\}$.

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 $x_1, x_2, x_3, \ldots, x_Y$, 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. ~~$U = (Y - N_{TGL}) / P$ for compressed mode by puncturing, and~~ $U = \frac{Y}{P}$ ~~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 ~~V~~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:

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

Bits on second PhCH after physical channel segmentation:

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

…

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

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

~~where *f* is such that :~~

- ~~for modes other than compressed mode by puncturing, $x_{i,f(k)} = x_{i,k}$, i.e. $f(k) = k$, for all k.~~
- ~~for compressed mode by puncturing, 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 $u_{1,3}, \ldots u_{1,V}, u_{2,1}, u_{2,2}, \ldots u_{2,V}, \ldots u_{P,1}, u_{P,2}, \ldots u_{P,V}$.~~

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 $Y = S$.