TSG-RAN Working Group1 meeting #9 **TSGR1#8(99)l33**

Dresden, Germany, 30 November – 3 December 1999

Agenda Item:

Source: **Nokia**

Title: **Compressed mode by puncturing in downlink**

Document for: **Decision**

Introduction to the CR

The current scheme assumes certain limitations on the transmission gap pattern. It is assumed that transmission gaps repeat at integer intervals of a frame, i.e. N*10 ms. Also, it is assumed that within one TTI there are transmission gaps of only two lengths *z* and *z'* as shown in Figure 1. However, it is possible to generalize the combined algorithm to handle a larger number of transmission gap lengths.

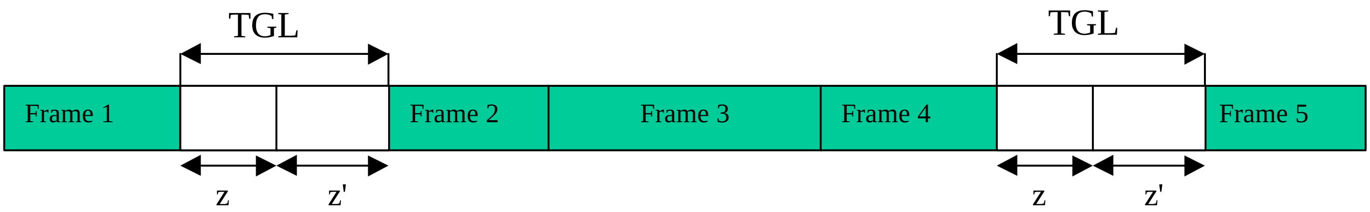

Figure 1. Example of transmission gaps within a TTI

Determining the rate matching parameters takes place as follows:

1) Calculate parameters assuming a full rate frame (e.g. Frame 3 above) -> output is ΔN_1 per frame; there are H_1 of these frames in the TTI

2) Re-calculate parameters assuming a compressed frame with TGL of *z* (e.g. Frame 1 above) -> output is ΔN_2 per frame; there are H_1 of these frames in the TTI

3) Re-calculate parameters assuming a compressed frame with TGL of *z'* (e.g. Frame 2 above) -> output is ΔN_3 per frame; there are H_1 of these frames in the TTI

Total amount of space available for data over the TTI is thus:

$\Delta N_1 * H_1 + \Delta N_2 * H_2 + \Delta N_3 * H_3$

After rate matching these bits are allocated to frames during radio frame segmentation:

$$y_{i,n_i k} = x_{i,\left(\sum_{m=0}^{n_i-1} Y_m\right) - Y_0 + k} \quad , \begin{cases} Y_m = Y_{u,i}, k = 1 \ldots Y_{u,i} & if\ TGL|_{n_i = m+1} = 0 \\ Y_m = Y_{cm,i}, k = 1 \ldots Y_{cm,i} & if\ TGL|_{n_i = m+1} = z \\ Y_m = Y_{cm',i}, k = 1 \ldots Y_{cm',i} & if\ TGL|_{n_i = m+1} = z' \end{cases}$$

where *k* is the number of bits that is allocated to a frame depending on whether there is a transmission gap during that frame in the TTI.

This scheme faces a QoS imbalance problem when there are TTIs of different lengths. The uncompressed frames of a TTI are mapped with as many bits as in normal mode. However, due to extra puncturing for the

TTI that has a TG, the Eb/N0 balance between the frames of the TTI in compressed mode and other full rate frames is lost. Figure 2 shows two traffic channels, one of which has a TTI of 40 ms and the other has a TTI of 10 ms. In this case all the frames over the TTI of 40 ms are punctured slightly because of the transmission gap. However, the 10 ms TTIs have the usual normal mode rate matching. Thus, Frames 1 – 3 have QoS imbalance.

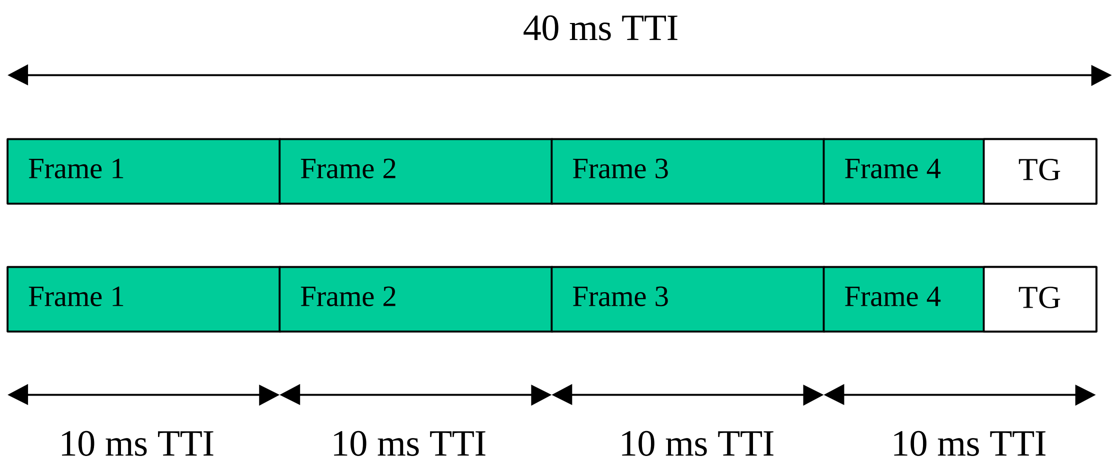

Figure 2. Example of different TTI lengths in compressed mode

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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**	**019rev1**	Current Version:	V3.0.0

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

For submission to:	TSG RAN#6	for approval	X	strategic		*(for SMG*
list expected approval meeting # here ↑		for information		non-strategic		*use only)*

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

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

Source: Nokia **Date:** 3 Dec 1999

Subject: Rate matching and multiplexing for compressed mode with puncturing (Method A)

Work item:

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

Reason for change: Description of compressed mode Method A for downlink is not adequately described in TS 25.212. This text proposal explains how multiplexing chain is modified in order to support Method A.

Clauses affected: 3.2, 3.3, 4.2, 4.2.5, 4.2.6, 4.2.7.2, 4.2.9

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

Other comments:

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

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*
N_{first}	The first slot in the *TG*.
N_{last}	The last slot in the *TG*. N_{last} is either a slot in the same radio frame as N_{first} or a slot in the radio frame immediately following the slot that contains N_{first}.

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*.
$F_{u,i}$	Number of uncompressed radio frames within one TTI of TrCH i when compressed mode by puncturing is employed.
$F_{cm,i}$, $F_{cm',i}$	Number of compressed radio frames within one TTI of TrCH i when compressed mode by puncturing is employed.
H_i	Maximum number of bits in a radio frame for any TrCH i.
$H_{u,i}$	Maximum number of bits in an uncompressed radio frame within a TTI for any TrCH i when compressed mode by puncturing is employed.
$H_{cm,i}$,$H_{cm',i}$	Maximum number of bits in a compressed radio frame within a TTI for any TrCH i when compressed mode by puncturing is employed.
M_i	Number of transport blocks in one TTI of TrCH *i*.
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)sections with different meaning.

x, X
y, Y
z, Z

3.3 Abbreviations

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

ACS	Add, Compare, Select
ARQ	Automatic Repeat Request
BCH	Broadcast Channel
BER	Bit Error Rate
BLER	Block Error Rate
BS	Base Station
CCPCH	Common Control Physical Channel
CCTrCH	Coded Composite Transport Channel
CRC	Cyclic Redundancy Code

DCH	Dedicated Channel
DL	Downlink (Forward link)
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DS-CDMA	Direct-Sequence Code Division Multiple Access
DSCH	Downlink Shared Channel
DTX	Discontinuous Transmission
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FER	Frame Error Rate
GF	Galois Field
MAC	Medium Access Control
Mcps	Mega Chip Per Second
MS	Mobile Station
OVSF	Orthogonal Variable Spreading Factor (codes)
PCCC	Parallel Concatenated Convolutional Code
PCH	Paging Channel
PRACH	Physical Random Access Channel
PhCH	Physical Channel
QoS	Quality of Service
RACH	Random Access Channel
RX	Receive
SCH	Synchronisation Channel
SF	Spreading Factor
SFN	System Frame Number
SIR	Signal-to-Interference Ratio
SNR	Signal to Noise Ratio
TF	Transport Format
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TG	Transmission Gap
TGL	Transmission Gap Length
TPC	Transmit Power Control
TrCH	Transport Channel
TTI	Transmission Time Interval
TX	Transmit
UL	Uplink (Reverse link)

4 Multiplexing, channel coding and interleaving

4.1 General

Data stream from/to MAC and higher layers (Transport block / Transport block set) is encoded/decoded to offer transport services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channels mapping onto/splitting from physical channels.

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 section 4.2.1)
- Transport block concatenation and code block segmentation (see section 4.2.2)
- Channel coding (see section 4.2.3)
- Rate matching (see section 4.2.7)
- Insertion of discontinuous transmission (DTX) indication bits (see section 4.2.9)
- Interleaving (two steps, see sections 4.2.4 and 4.2.11)
- Radio frame segmentation (see section 4.2.6)
- Multiplexing of transport channels (see section 4.2.8)
- Physical channel segmentation (see section 4.2.10)
- Mapping to physical channels (see section 4.2.12)

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

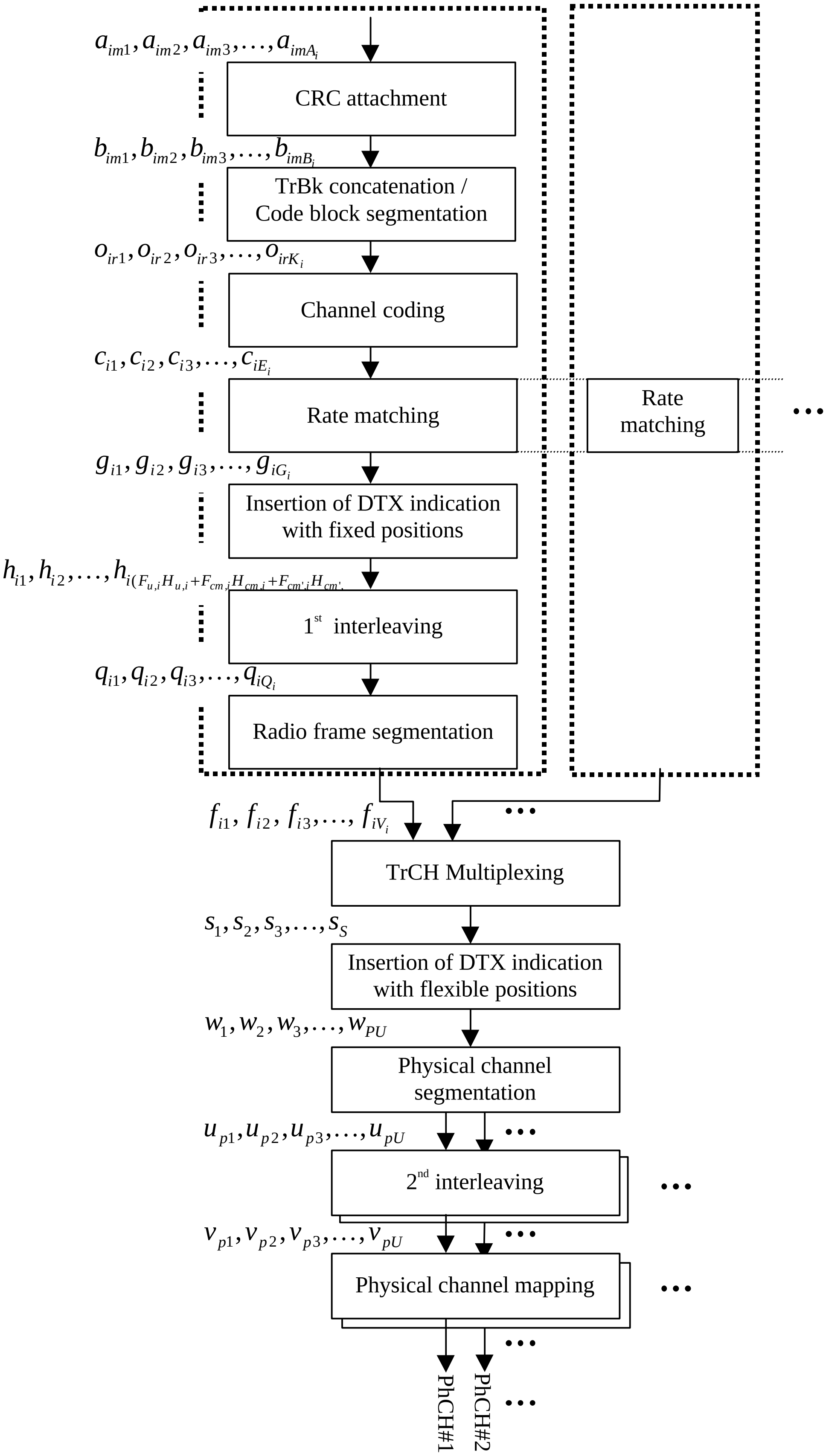

Figure 2: Transport channel multiplexing structure for downlink

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

Table 2: Table of prime p and associated primitive root

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

4.1.3.2.3.2 Definition of number of pruning bits

The output of the mother interleaver is pruned by deleting the l-bits in order to adjust the mother interleaver to the block length K, where the deleted bits are non-existent bits in the input sequence. The pruning bits number l is defined as:

$$l = R \times C - K,$$

where R is the row number and C is the column number defined in section 4.1.3.2.3.1.

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 section 4.1.6. Radio frame size equalisation is only performed in the UL (DL rate matching output block length 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

$t_{ik} = \{0 \mid 1\}$ for k= E_i +1… T_i, if $E_i < T_i$

where

$T_i = F_i * N_i$ and

$N_i = \lfloor (E_i - 1)/F_i \rfloor + 1$ is the number of bits per segment after size equalisation.

4.2.5 1st interleaving

The 1st interleaving is a block interleaver with inter-column permutations. The input bit sequence to the 1st interleaver is denoted by $x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$, 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).

Note: When compressed mode by puncturing is used, input bit sequence length X_i is not necessarily an integer multiple of F_i.

The output bit sequence is derived as follows:

(1) Select the number of columns C_I from table 3.

(2) Determine the number of rows R_I defined as

$R_I = \lceil X_i/C_I \rceil$

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

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

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

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

(5) Read the output bit sequence $y_{i1}, y_{i2}, y_{i3}, \ldots, y_{i,(C_I R_I)}$ of the 1st interleaving column by column from the inter-column permuted $R_I \times C_I$ matrix. Bit $y_{i,1}$ corresponds to the first row of the first column and bit $y_{i,(R_I C_I)}$ corresponds to row R_I of column C_I. In downlink, for TTIs using compressed mode by puncturing, the output is pruned by deleting bits that were not present in the input bit sequence, i.e. bits y_{ik} that corresponds to bits x_{ik} with $k>X_i$ are removed from the output.

Table 3

TTI	Number of columns C_I	Inter-column permutation patterns
10 ms	1	{0}
20 ms	2	{0,1}
40 ms	4	{0,2,1,3}
80 ms	8	{0,4,2,6,1,5,3,7}

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

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

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

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

If fixed positions of the TrCHs in a radio frame is used then the bits input to the 1st interleaving are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_{u,i}H_{u,i}+F_{cm,i}H_{cm,i})}$, where i is the TrCH number. Hence, $x_{ik} = h_{ik}$ and $X_i = F_i H_i$. When compressed mode by puncturing is used, $X_i = F_{u,i}H_{u,i}+F_{cm,i}H_{cm,i}+F_{cm',i}H_{cm',i}$

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

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. When compressed mode by puncturing is employed, $Q_i = F_{u,i}H_{u,i}+F_{cm,i}H_{cm,i}+F_{cm',i}H_{cm',i},$ if fixed 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 radio frames. Following rate matching in the DL and radio frame size equalisation in the UL the input bit sequence length is guaranteed to be an integer multiple of F_i.

4.2.6.1 Radio frame segmentation in case that compressed mode by puncturing is not used

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

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

where

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

x_{ik} is the kth bit of the input bit sequence and

y_{i,n_ik} is the kth bit of the output bit sequence corresponding to the nth radio frame

4.2.6.2 Radio frame segmentation in compressed mode by puncturing

Note: When compressed mode by puncturing is used, input bit sequence length is not necessarily an integer multiple of F_i. A TTI contains frames that do not have a TG and/or frames that have a TG.

In the case of compressed mode by puncturing in downlink, different numbers of bits are mapped to the frames n_i of the TTI of TrCH i depending on whether there is a transmission gap or not in frame n_i. The frames n_i that do not contain a transmission gap are mapped full of input bits x_i according to the calculations in section 4.2.7.2. Frames with a transmission gap are mapped with the rest of remaining X_i bits for TrCH i. In section 4.2.7.2 it is made sure that by completely filling the frames without a transmission gap, a long enough transmission gap is left for the frames in compressed mode.

The input bit sequence is denoted by $x_{i1,}, x_{i,2}, x_{i,3}, \ldots, x_{i,X_i}$ where i is the TrCH number and X_i is the number of bits. The $F_{u,i}$ output bit sequences per TTI to be mapped into frames without a TG are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_{u,i}}$ where n_i is the radio frame number in current TTI and $Y_{u,i}$ is the number of bits per radio frame for TrCH i. The $F_{cm,i}$ output bit sequences per TTI to be mapped into frames with a TGL z are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_{cm,i}}$ where n_i is the radio frame number in current TTI and $Y_{cm,i}$ is the number of bits per radio frame for TrCH i. In similar fashion, the $F_{cm',i}$ output bit sequences per TTI to be mapped into frames with a TGL z' are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_{cm',i}}$ where n_i is the radio frame number in current TTI and $Y_{cm',i}$ is the number of bits per radio frame for TrCH i. Thus, the output sequences are defined as follows.

$$y_{i,n_ik} = x_{i,\left(\sum_{m=0}^{n_i-1} Y_m\right) - Y_0 + k} \quad , \begin{cases} Y_m = Y_{u,i}, k = 1 \ldots Y_{u,i} & if\ TGL\big|_{n_i=m+1} = 0 \\ Y_m = Y_{cm,i}, k = 1 \ldots Y_{cm,i} & if\ TGL\big|_{n_i=m+1} = z \\ Y_m = Y_{cm',i}, k = 1 \ldots Y_{cm',i} & if\ TGL\big|_{n_i=m+1} = z' \end{cases}$$

where

Y_m is the number of bits per segment,

$x_{i,k}$ is the k[th] bit of the input bit sequence and

$y_{i,n_i k}$ is the k[th] bit of the output bit sequence corresponding to the n[th] radio frame

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

4.2.6.3 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 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, $e_{i,k} = y_{i,n_i k}$ and $N_i = Y_i$.

4.2.6.4 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, $f_{i,k} = y_{i,n_i k}$ and $V_i = Y_i$.

In downlink compressed mode by puncturing, the output bit sequence corresponding to radio frame n_i that does not have a TG is denoted by $f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_{u,i}}$, where i is the TrCH number and $V_{u,i}$ is the number of bits. Hence, $f_{i,k} = y_{i,n_i k}$ and $V_{u,i} = Y_{u,i}$. The output bit sequence corresponding to radio frame n_i that has a TGL of z is denoted by $f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_{cm,i}}$, where i is the TrCH number and $V_{cm,i}$ is the number of bits. Hence, $f_{i,k} = y_{i,n_i k}$ and $V_{cm,i} = Y_{cm,i}$. Finally, the output bit sequence corresponding to radio frame n_i that has a TGL of z' is denoted by $f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_{cm',i}}$, where i is the TrCH number and $V_{cm',i}$ is the number of bits. Hence, $f_{i,k} = y_{i,n_i k}$ and $V_{cm',i} = Y_{cm',i}$.

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 second multiplexing is identical to the total channel bit rate of the allocated dedicated physical channels.

Notation used in section 4.2.7 and subsections:

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

For downlink : An intermediate calculation variable (not a 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 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.

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

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

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

I: Number of TrCHs in the CCTrCH.

Z_{ij}: Intermediate calculation variable.

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

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

q: Average puncturing distance. 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 pattern for radio frame n_i. Used in uplink only.

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

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

TFCS The set of transport format combination indexes j.

e_{ini} Initial value of variable e in the rate matching pattern determination algorithm of section 4.2.7.4.

e_{plus} Increment of variable e in the rate matching pattern determination algorithm of section 4.2.7.4.

e_{minus} Decrement of variable e in the rate matching pattern determination algorithm of section 4.2.7.4.

X: Systematic bit in section 4.1.3.2.1.

Y: 1st parity bit (from the upper Turbo constituent encoder) in section 4.1.3.2.1.

Y': 2nd parity bit (from the lower Turbo constituent encoder) in section 4.1.3.2.1.

NOTE: Time index t in section 4.1.3.2.1 is omitted for simplify the rate matching description.

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

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

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

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

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

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 used to avoid multicode or to enable the use of a higher spreading factor when this is needed because the UE does not support SF down to 4. The maximum amount of puncturing that can be applied is signalled from higher layers and denoted by PL. The number of available bits in the radio frames for all possible spreading factors is given in [2]. Denote these values by N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, and N_4, where the index refers to the spreading factor. The possible values of N_{data} then are $\{ N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2N_4, 3N_4, 4N_4, 5N_4, 6N_4\}$.Depending on the UE capabilities, the supported set of N_{data} , denoted SET0, can be a subset of $\{ N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2N_4, 3N_4, 4N_4, 5N_4, 6N_4\}$. $N_{data,j}$ for the transport format combination j is determined by executing the following algorithm:

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

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

$N_{data,j}$ = min SET1

else

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

Sort SET2 in ascending order

N_{data} = min SET2

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

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

End while

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

End if

$e_{plus} = a \cdot N$

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

puncturing for ΔN<0, repeating otherwise.

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.

For compressed mode by puncturing $N_{data,*}$ is replaced by $N^{cm}_{data,*}$ in determining rate matching parameters. $N^{cm}_{data,*}$ is given from the following relation:

$$N^{cm}_{data,*} = N_{data,*} - N_{TGL}$$

$$N_{TGL} = \begin{cases} \dfrac{TGL}{15} N_{data,*} & \text{,if } N_{first} \le 15 \\[2ex] \dfrac{15 - N_{first}}{15} N_{data,*} & \text{,in first frame if } N_{first} + TGL > 15 \\[2ex] \dfrac{TGL - (15 - N_{first})}{15} N_{data,*} & \text{, in second frame if } N_{first} + TGL > 15 \end{cases}$$

If first frame and second frame belong to the same TTI, the TGL is combined for calculation purposes in sections 4.2.7.2.1 and 4.2.7.2.2, i.e. $N_{TGL} = \dfrac{TGL}{15} N_{data,*}$.

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

4.2.7.2.1 Determination of rate matching parameters for fixed positions of TrCHs

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

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

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

$$\Delta N^{TTI}_{i,*} = F_i \cdot \Delta N_{i,*}$$

When compressed mode by puncturing is employed, $\Delta N^{TTI}_{i,*}$ is re-calculated for each transport channel. Let y be the number of frames with a transmission gap of z slots and y' the number of frames with transmission gap z' slots. Now, recalculate $\Delta N^{TTI}_{i,*}$ for all TrCH i by using $N^{cm}_{data,*}$ for frames with a TGL of z slots and $N^{cm'}_{data,*}$ for frames with a TGL of z' slots instead of $N_{data,*}$. Now the amount of rate matching for a TTI in compressed mode is written as $\Delta N^{TTI,cm}_{i,l}$ for frames with a TGL of z slots and $\Delta N^{TTI,cm'}_{i,l}$ for frames with a TGL of z' slots. Finally, the total amount of rate matching is calculated as follows:

$$\Delta N_{i,*}^{TTI} = \left\lfloor \frac{N_{i,l}^{TTI}}{F_i} \left(\Delta N_{i,l}^{TTI,normal} \times (F_i - y - y') + \Delta N_{i,l}^{TTI,cm} \times y + \Delta N_{i,l}^{TTI,cm'} \times y' \right) \right\rfloor - N_{i,l}^{TTI}$$

If $\Delta N_{i,*}^{TTI} = 0$ then, for TrCH *i*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.4 does not need to be executed.

Otherwise, for determining e_{ini}, e_{plus}, e_{minus}, and N the following parameters are needed:

For convolutional codes,

$$\Delta N = \Delta N_{i,*}^{TTI}$$

a=2

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

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.4. The following parameters are used as input:

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

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

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

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

Puncturing if $\Delta N < 0$, repetition otherwise.

For turbo codes, if repetition is to be performed, such as $\Delta N_{i,*}^{TTI} > 0$, parameters for turbo codes are the same as parameter for convolutional codes. If puncturing is to be performed, parameters are as follows.

a=2 for *Y* sequence,

a=1 for *Y'* sequence.

The X bits shall not be punctured.

$$\Delta N = \begin{cases} \lfloor DN_{i,*}^{TTI} / 2 \rfloor & \text{for Y sequence} \\ \lceil DN_{i,*}^{TTI} / 2 \rceil & \text{for Y' sequence} \end{cases}$$

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

For each transmission time interval of TrCH *i* with TF *l*, the rate-matching pattern is calculated with the algorithm in section 4.2.7.4. The following parameters are used as input:

$$N = \lfloor N_{il}^{TTI} / 3 \rfloor$$

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

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

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

Puncturing if $\Delta N < 0$, repetition otherwise.

4.2.7.2.2 Determination of rate matching parameters for flexible positions of TrCHs

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

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

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

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

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

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

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

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

The second phase is defined by the following algorithm:

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

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

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

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

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

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

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

end-if

end-for

end-if

end-for

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

When compressed mode by puncturing is employed, $\Delta N_{i,l}^{TTI}$ is re-calculated for each transport channel. Let *y* be the number of frames with a transmission gap of *z* slots and *y'* the number of frames with transmission gap *z'* slots. Now, recalculate $\Delta N_{i,l}^{TTI}$ for all TrCH *i* by using $N_{data,*}^{cm}$ for frames witrh a TGL of *z* slots and $N_{data,*}^{cm'}$ for frames with a TGL of *z'* slots instead of $N_{data,*}$. Now the amount of rate matching for a TTI in compressed mode is written as $\Delta N_{i,TF_i(j)}^{TTI,cm}$ for frames with a TGL of *z* slots and $\Delta N_{i,TF_i(j)}^{TTI,cm'}$ for frames with a TGL of *z'* slots. Finally, the total amount of rate matching is calculated as follows:

$$\Delta N_{i,TF_i(j)}^{TTI} = \left(\frac{N_{i,TF_i(j)}^{TTI} + \Delta N_{i,TF_i(j)}^{TTI,normal}}{F_i} \times \left(F_i - y - y' \right) + \left\lfloor \frac{N_{i,TF_i(j)}^{TTI}}{F_i} \left(\Delta N_{i,TF_i(j)}^{TTI,cm} \times y + \Delta N_{i,TF_i(j)}^{TTI,cm'} \times y' \right) \right\rfloor \right) - N_{i,TF_i(j)}^{TTI}$$

If $\Delta N_{i,l}^{TTI} = 0$ then, for TrCH *i* at TF *l*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.4 does not need to be executed.

Otherwise, for determining e_{ini}, e_{plus}, e_{minus}, and N the following parameters are needed:

For convolutional codes,

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

multiplexing are denoted by $s_1, s_2, s_3, \ldots, s_S$, where S is the number of bits, i.e. $S = \sum_i V_i$. The TrCH multiplexing is defined by the following relations:

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

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

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

…

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

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 Insertion of DTX indication bits with fixed positions

4.2.9.1.1 Insertion of DTX in case that compressed mode by puncturing is not used

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 reserved for one radio frame of TrCH i by H_i, i.e. the maximum number of bits in a radio frame for any transport format of TrCH i. The number of radio frames in a TTI of TrCH i is denoted by F_i. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_iH_i)}$. Note that these bits are three valued. They are defined by the following relations:

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

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

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

4.2.9.1.2 Insertion of DTX during compressed mode by puncturing

When compressed mode by puncturing is employed, insertion of DTX indication bits proceeds as follows:

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 reserved for one radio frame of TrCH i without a TG by H_i, i.e. the maximum number of bits in a radio frame for any transport format of TrCH i. The number of radio frames within a TTI of TrCH i without TGs is denoted by $F_{u,i}$. Denote the number of bits reserved for one radio frame of TrCH i with a TGL of z slots by $H_{cm,i}$, i.e. the maximum number of bits in a compressed radio frame for any transport format of TrCH i. The number of radio frames in a TTI of TrCH i with a TGL of z slots is denoted by $F_{cm,i}$. Also, denote the number of bits reserved for one radio frame of TrCH i with a TGL of z' slots by $H_{cm',i}$, i.e. the maximum number of bits in a compressed radio frame for any transport format of TrCH i. The number of radio frames in a TTI of TrCH i with a TGL of z' slots is denoted by $F_{cm',i}$. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_{u,i}H_{u,i}+F_{cm,i}H_{cm,i}+F_{cm',i}H_{cm',i})}$. Note that these bits are three valued. They are defined by the following relations:

$h_{ik} = g_{ik}$ k = 1, 2, 3, …, G_i

$h_{ik} = d$ $k = G_i+1, G_i+2, G_i+3, \ldots, F_{u,i}H_{u,I}+F_{cm,i} H_{cm,i}$

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

4.2.9.2 Insertion of DTX indication bits with flexible positions

NOTE: Below, it is assumed that all physical channels belonging to the same CCTrCH use the same SF. Hence, U_p=U=constant.

This step of inserting DTX indication bits is used only if the positions of the TrCHs in the radio frame are flexible. The DTX indication bits shall be placed at the end of the radio frame. Note that the DTX will be distributed over all slots after 2[nd] 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 *U*.

The bits output from the DTX insertion block are denoted by $w_1, w_2, w_3, \ldots, w_{(PU)}$. Note that these bits are threevalued. 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, …, PU

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

4.2.10 Physical channel segmentation

NOTE: Below, it is assumed that all physical channels belonging to the same CCTrCH use the same SF. Hence, U_p=U=constant.

When more than one PhCH is used, physical channel segmentation divides the bits among the different PhCHs. The bits input to the physical channel segmentation are denoted by $x_1, x_2, x_3, \ldots, x_Y$, where *Y* is the number of bits input to the physical channel segmentation block. The number of PhCHs is denoted by *P*.

The bits after physical channel segmentation are denoted $u_{p1}, u_{p2}, u_{p3}, \ldots, u_{pU}$, where *p* is PhCH number and *U* is the number of bits in one radio frame for each PhCH, i.e. $U = \frac{Y}{P}$. The relation between x_k and u_{pk} is given below.

Bits on first PhCH after physical channel segmentation:

$u_{1k} = x_k$ k = 1, 2 , …, U

Bits on second PhCH after physical channel segmentation:

$u_{2k} = x_{(k+U)}$ k = 1, 2 , …, U

…

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

$u_{Pk} = x_{(k+(P-1)U)}$ k = 1, 2 , …, 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 $Y = S$.