TSG-RAN Working Group 1 meeting #10
Beijing, China
January 18 – 21, 2000

TSGR1#10(00)0015

Agenda item:

Source: Nokia

Title: Further methods for DL compressed mode by puncturing

Document for: Decision

This CR contains two methods for introducing downlink compressed mode by puncturing.

25212-CR031 is based on 25212-CR019 that was presented in the previous WG1 meeting in Dresden. This method was described in TSGR1#09(99)L33 and combines puncturing and rate matching over a TTI. The CR in this document introduces a new version with some clarifications and generalizations in notation.

25212-CR032 is another way of doing compressed mode by puncturing. In this case, rate matching is not done over the whole TTI but the TTI is segmented into frames. In this context, radio frame equalization is done also in downlink in order to facilitate even splitting of the data into frames. After individual rate matching steps the frames F_i are again joined into one TTI and 1st multiplexing, radio frame segmentation and the rest of the process is done as in CR031.

In Nokia contribution R1-00-0020 CR 25.215-023 it is argued that compressed mode by puncturing is better to be done by the first method, i.e. over the TTI. The other method is presented as an alternative; it does not have the problem with QoS balance with different length TTIs that was pointed out as a problem with the first method in the Dresden meeting.

3GPP TSG RAN WG1 (Radio) meeting #10
Beijing, China, 18 - 21 Jan 2000

***Document* R1-000015**
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 031 Current Version: V3.1.0

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

For submission to: TSG RAN#7	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: Nokia **Date:** 14 Jan 2000

Subject: Further methods for compressed mode by puncturing (I)

Work item:

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

F	Correction		
A	Corresponds to a correction in an earlier release		
B	Addition of feature	X	
C	Functional modification of feature		
D	Editorial modification		

Release:

Phase 2	
Release 96	
Release 97	
Release 98	
Release 99	X
Release 00	

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

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.

1 Scope

The present document describes the characteristics of the Layer 1 multiplexing and channel coding in the FDD mode of UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] 3G TS 25.201: "Physical layer – General Description"

[2] 3G TS 25.211: "Physical channels and mapping of transport channels onto physical channels (FDD)"

[3] 3G TS 25.213: "Spreading and modulation (FDD)"

[4] 3G TS 25.214: "Physical layer procedures (FDD)"

[5] 3G TS 25.215: "Measurements (FDD)"

[6] 3G TS 25.221: "Physical channels and mapping of transport channels onto physical channels (TDD)"

[7] 3G TS 25.222: "Multiplexing and channel coding (TDD)"

[8] 3G TS 25.223: "Spreading and modulation (TDD)"

[9] 3G TS 25.224: "Physical layer procedures (TDD)"

[10] 3G TS 25.225: "Measurements (TDD)"

[11] 3G TS 25.302: "Services Provided by the Physical Layer"

[12] 3G TS 25.402: "Synchronisation in UTRAN, Stage 2"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

TG: Transmission Gap is consecutive empty slots that have been obtained with a transmission time reduction method. The transmission gap can be contained in one or two consecutive radio frames.

TGL: Transmission Gap Length is the number of consecutive empty slots that have been obtained with a transmission time reduction method. $0 \leq TGL \leq 14$.

TrCH number: Transport channel number represents a TrCH ID assigned to L1 by L2. Transport channels are multiplexed to the CCTrCH in the ascending order of these IDs.

$\sum_{f \in CM} z_f$: The sum is calculated over those z_f for which f belongs to a specified group C. In this specification CM is used to represent a set of frames with different TGLs. Within the set CM, individual members of a property z are enumerated by f.

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.
$F_{f,i}$	Number of compressed radio frames of type f 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.
$H_{f,i}$	Maximum number of bits in a compressed radio frame of type f 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:

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
RACH	Random Access Channel
RSC	Recursive Systematic Convolutional Coder
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
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

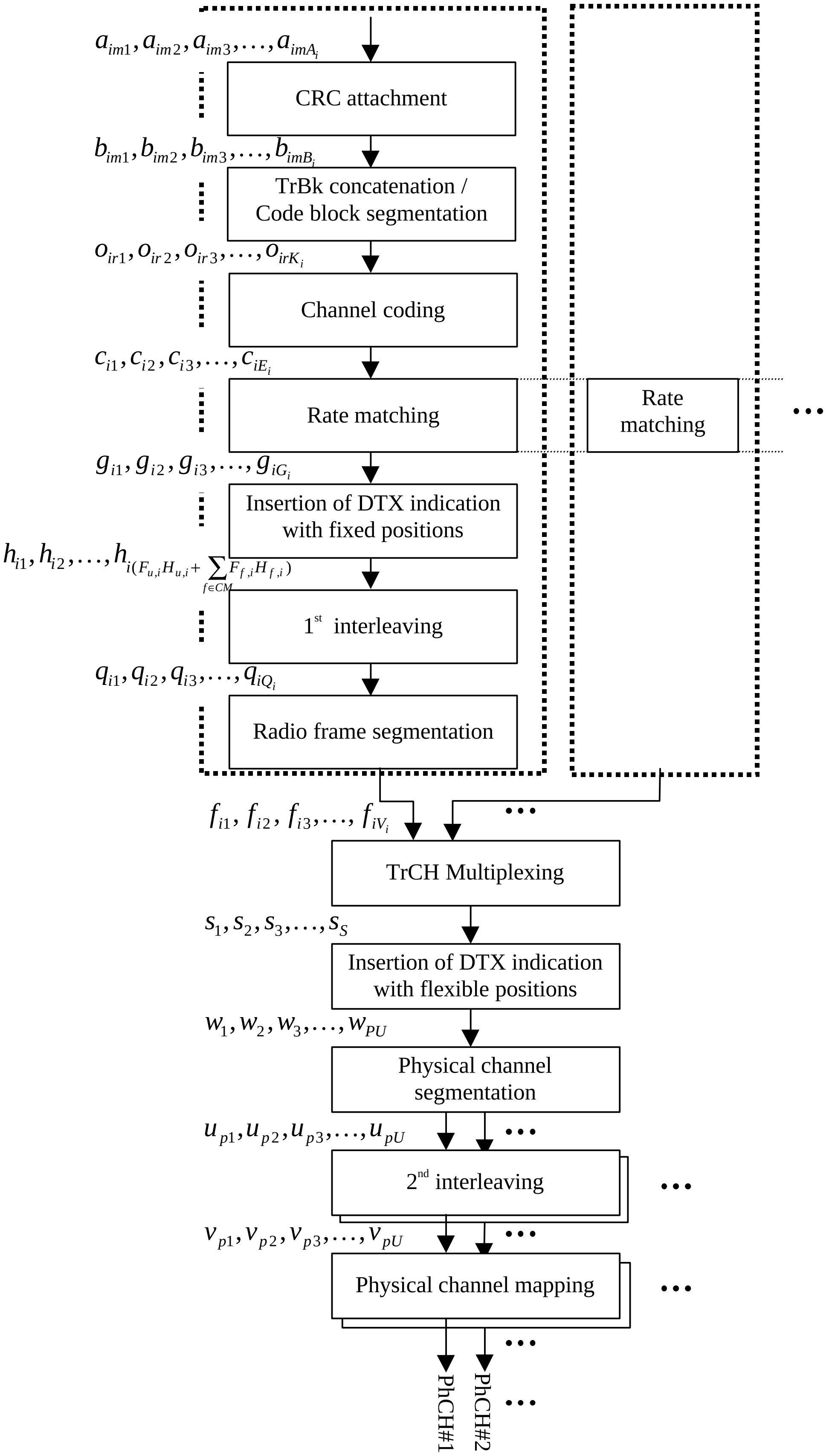
Data arrives to the coding/multiplexing unit in form of transport block sets once every transmission time interval. The transmission time interval is transport-channel specific from the set {10 ms, 20 ms, 40 ms, 80 ms}.

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.


$a_{im1}, a_{im2}, a_{im3}, \ldots, a_{imA_i}$
CRC attachment
$b_{im1}, b_{im2}, b_{im3}, \ldots, b_{imB_i}$
TrBk concatenation / Code block segmentation
$o_{ir1}, o_{ir2}, o_{ir3}, \ldots, o_{irK_i}$
Channel coding
$c_{i1}, c_{i2}, c_{i3}, \ldots, c_{iE_i}$
Rate matching
Rate matching
$g_{i1}, g_{i2}, g_{i3}, \ldots, g_{iG_i}$
Insertion of DTX indication with fixed positions
$h_{i1}, h_{i2}, \ldots, h_{i(F_{u,i}H_{u,i}+\sum_{f\in CM} F_{f,i}H_{f,i})}$
1st interleaving
$q_{i1}, q_{i2}, q_{i3}, \ldots, q_{iQ_i}$
Radio frame segmentation
$f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_i}$
TrCH Multiplexing
$s_1, s_2, s_3, \ldots, s_S$
Insertion of DTX indication with flexible positions
$w_1, w_2, w_3, \ldots, w_{PU}$
Physical channel segmentation
$u_{p1}, u_{p2}, u_{p3}, \ldots, u_{pU}$
2nd interleaving
$v_{p1}, v_{p2}, v_{p3}, \ldots, v_{pU}$
Physical channel mapping
PhCH#1
PhCH#2

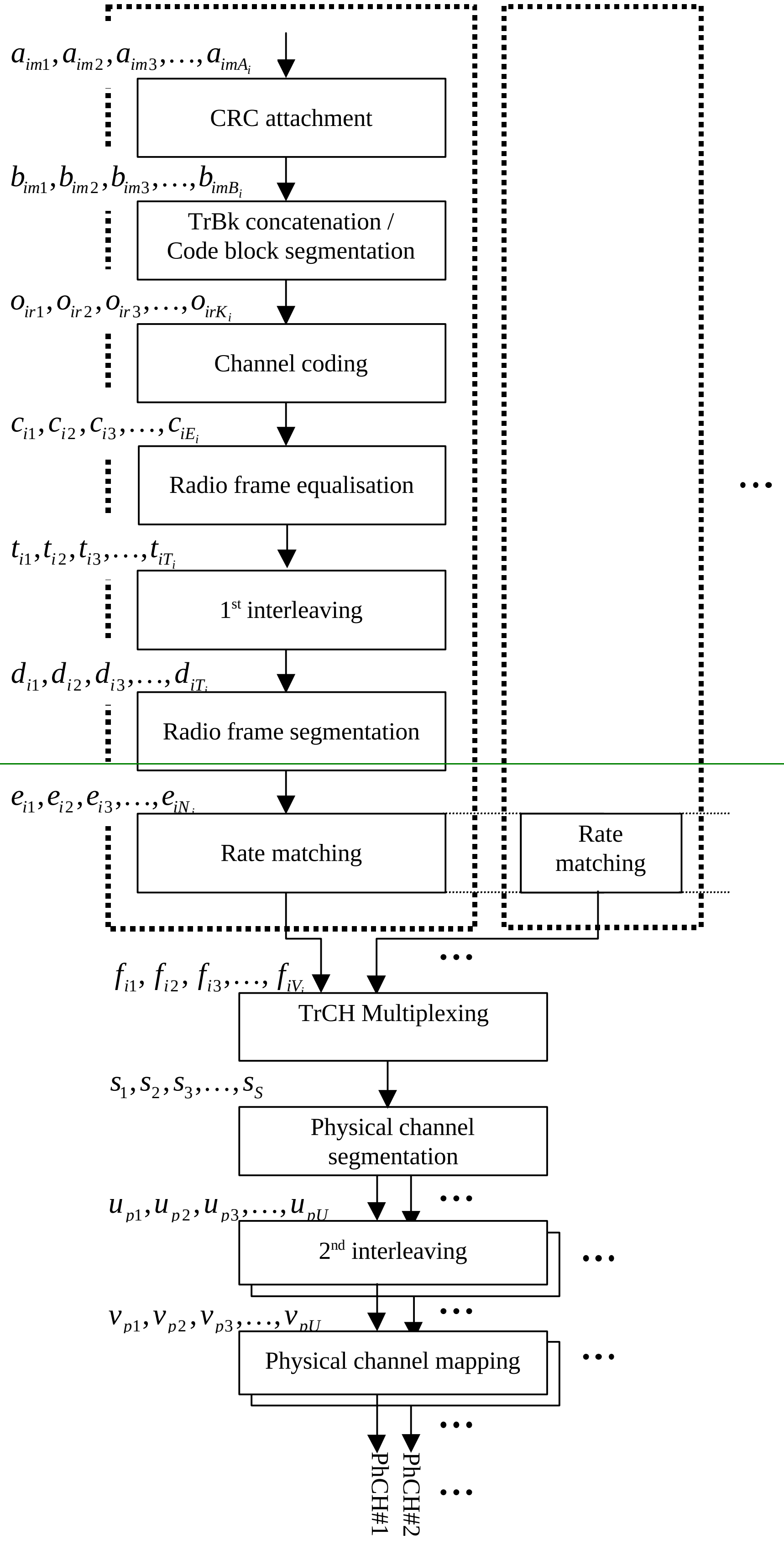


Figure 1: Transport channel multiplexing structure for uplink

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		

4.2.3.2.3.2 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 4.2.3.2.3.1.

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 | 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:

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

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

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

(5) Read the output bit sequence $y_{i1}, y_{i2}, y_{i3}, \dots, y_{i,(C_I R_I)}$ of the 1st interleaving column by column from the inter-column permuted $R_I \times C_I$ matrix. Bit $y_{i,1}$ corresponds to the first row of the first column and bit $y_{i,(R_I C_I)}$ corresponds to row R_I of column C_I. 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 $t_{i1}, t_{i2}, t_{i3}, \dots, t_{iT_i}$, where i is the TrCH number and T_i the number of bits. Hence, $x_{ik} = t_{ik}$ and $X_i = T_i$.

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

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

If fixed positions of the TrCHs in a radio frame is used then the bits input to the 1st interleaving are denoted by $h_{i1}, h_{i2}, h_{i3}, \dots, h_{i(F_i H_i)}$, 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, $X_i = F_{u,i} H_{u,i} + \sum_{f \in CM} F_{f,i} H_{f,i}$.

If flexible positions of the TrCHs in a radio frame is used then the bits input to the 1st interleaving are denoted by $g_{i1}, g_{i2}, g_{i3}, \dots, g_{iG_i}$, 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, $Q_i = F_{u,i} H_{u,i} + \sum_{f \in CM} F_{f,i} H_{f,i}$.

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 $x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$ 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 = 0~~1~~…F_i-1, $k = 1 \ldots Y_i$

where

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

x_{ik} is the k^th bit of the input bit sequence and

y_{i,n_ik} 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.

4.2.6.2 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. For frames with different TGs $f \in CM$ within the TTI the $F_{f,i}$ output bit sequences per TTI to be mapped into frames with a TGL z_f are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_{c,i}}$ where n_i is the radio frame number in current TTI and $Y_{f,i}$ is the number of bits per radio frame for TrCH i. Thus, the output sequences are defined as follows.

$$y_{i,n_ik} = x_{i,\left(\sum_{m=0}^{n_i-1} Y_m\right)+k}, \quad \begin{cases} Y_0 = 0 \\ Y_m = Y_{u,i}, k = 1 \ldots Y_{u,i} \quad \text{if radio frame } n_i = m \text{ has no TG} \\ Y_m = Y_{f,i}, k = 1 \ldots Y_{f,i} \quad \text{if radio frame } n_i = m \text{ has a TG of } z_f \text{ slots} \end{cases}$$

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~~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 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~~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, $f_{i,k} = y_{i,n_i k}$ 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_f is denoted by $f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_{c,i}}$, where i is the TrCH number and $V_{f,i}$ is the number of bits. Hence, $f_{i,k} = y_{i,n_i k}$ and $V_{f,i} = Y_{f,i}$.

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.

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:

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

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

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. $N_{TGL} = \frac{TGL}{15} N_{data,*}$.

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:

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

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

$$\Delta N_{\max} = \left\lfloor \frac{1}{F_i} \left(\left(\max_{l \in TFS(i)} N^{TTI}_{i,l} + \Delta N^{TTI,normal}_{\max} \right) \times \left(F_i - \sum_{f \in CM} y_f \right) + \sum_{f \in CM} \left(\max_{l \in TFS(i)} N^{TTI}_{i,l} + \Delta N^{TTI,f}_{\max} \right) \times y_f \right) \right\rfloor - \max_{l \in TFS(i)} N^{T}_{i,l}$$

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

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

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

4.2.7.2.1.1 Uncoded and convolutionally encoded TrCHs

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

a=2

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

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

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

$$e_{ini} = 1$$

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

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

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

4.2.7.2.1.2 Turbo encoded TrCHs

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

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

a=2 when *b*=2

a=1 when *b*=3

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

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

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

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

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

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

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

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

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

4.2.7.2.2 Determination of rate matching parameters for flexible positions of TrCHs

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

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

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

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

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 frames with different TGLs make a set *C*. Let y_f be the number of frames with a transmission gap of z_f slots. Now, recalculate $\Delta N_{i,l}^{TTI}$ for all TrCH *i* by using $N_{data,*}^{cm}$ for frames witrh a TGL of z_f slots instead of $N_{data,*}$. Now the amount of rate matching for a TTI in compressed mode is written as $\Delta N_{i,TF_i(j)}^{TTI,f}$ for frames with a TGL of z_f slots. Finally, the total amount of rate matching is calculated as follows:

$$\Delta N_{i,TF_i(j)}^{TTI} = \left\lfloor \frac{1}{F_i}\left(\left(N_{i,TF_i(j)}^{TTI} + \Delta N_{i,TF_i(j)}^{TTI,normal}\right)\times\left(F_i - \sum_{f\in CM} y_f\right) + \sum_{f\in CM}\left(N_{i,TF_i(j)}^{TTI} + \Delta N_{i,TF_i(j)}^{TTI,f}\right)\times y_f \right)\right\rfloor - N_{i,TF_i(j)}^{TTI}$$

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 4.2.7.5 does not need to be executed.

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

4.2.7.2.2.1 Uncoded and convolutionally encoded TrCHs

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

a=2

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

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

$$e_{ini} = 1$$

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

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

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

4.2.7.2.2.2 Turbo encoded TrCHs

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

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

a=2 when *b*=2

a=1 when *b*=3

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

A repeated bit is placed directly after the original one.

4.2.8 TrCH multiplexing

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

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

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

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

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

…

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

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 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.

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

The bits from rate matching are denoted by $g_{i1}, g_{i2}, g_{i3}, \ldots, g_{iG_i}$, where G_i is the number of bits in one TTI of TrCH i. Denote the number of bits in one radio frame of TrCH i by H_i. In normal or compressed mode by spreading factor reduction, H_i is constant and corresponds to the maximum number of bits from TrCH i in one radio frame for any transport format of TrCH i. In compressed mode by higher layer scheduling, only a subset of the TFC Set is allowed. From this subset it is possible to derive which TFs on each TrCH that are allowed. The maximum number of bits belonging to one TTI of TrCH i for the allowed TFs is denoted by X_i. H_i is then calculated as $H_i = \left\lceil \frac{X_i}{F_i} \right\rceil$, where F_i is the number of radio frames in a TTI of TrCH i. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_i H_i)}$. Note that these bits are three valued. They are defined by the following relations:

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

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

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

4.2.9.1.2 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 $F_{u,i}$. For different TGs $f Î CM$, denote the number of bits reserved for one radio frame of TrCH i with a TGL of z_f slots by $H_{f,i}$, 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_f slots is denoted by $F_{f,i}$. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_{u,i}H_{u,i} + \sum_{f \in CM} F_{f,i}H_{f,i})}$. Note that these bits are three valued. They are defined by the following relations:

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

$$h_{ik} = d \quad k = G_i+1, G_i+2, G_i+3, \ldots, F_{u,i}H_{u,I} + \sum_{f \in CM} F_{f,i} H_{f,i}$$

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 U. The number of available bits on the PhCH is denoted by N_{data} and $N_{data}=15N_{data1}+15N_{data2}$, where N_{data1} and N_{data2} are defined in [25.211]. In normal mode $U=N_{data}$. In compressed mode N_{data} is changed from the value in normal node. The exact value of N_{data} is dependent on the TGL and the transmission time reduction method, which are signalled from higher layers. The number of bits that are located within the transmission gap is denoted N_{TGL} and defined as:

$$N_{TGL} = \begin{cases} \frac{TGL}{15} N_{data}, & \text{if } N_{first} + TGL \le 15 \end{cases}$$

$\frac{15 - N_{first}}{15} N_{data}$, in first frame if N_{first} + TGL > 15

$\frac{TGL - (15 - N_{first})}{15} N_{data}$, in second frame if N_{first} + TGL > 15

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

In compressed mode $U=N_{data}-N_{TGL}$..

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

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 $Y = S$.

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

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

3GPP/SMG Meeting #10
Beijing, China, 18-21 Jan 2000

***Document* R1-00015**
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**	**032**	Current Version:	V3.1.0

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

For submission to:	RAN #7	for approval	X	strategic		(for SMG use only)
list expected approval meeting # here ↑		for information		non-strategic		

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

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

Source: Nokia **Date:** Jan 12, 2000

Subject: Further methods for compressed mode by puncturing (II)

Work item:

Category:	F	Correction		**Release:**	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: 3.1, 3.2, 4.2, 4.2.4, 4.2.5, 4.2.6, 4.2.7.2, 4.9

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:

1 Scope

The present document describes the characteristics of the Layer 1 multiplexing and channel coding in the FDD mode of UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] 3G TS 25.201: "Physical layer – General Description"

[2] 3G TS 25.211: "Physical channels and mapping of transport channels onto physical channels (FDD)"

[3] 3G TS 25.213: "Spreading and modulation (FDD)"

[4] 3G TS 25.214: "Physical layer procedures (FDD)"

[5] 3G TS 25.215: "Measurements (FDD)"

[6] 3G TS 25.221: "Physical channels and mapping of transport channels onto physical channels (TDD)"

[7] 3G TS 25.222: "Multiplexing and channel coding (TDD)"

[8] 3G TS 25.223: "Spreading and modulation (TDD)"

[9] 3G TS 25.224: "Physical layer procedures (TDD)"

[10] 3G TS 25.225: "Measurements (TDD)"

[11] 3G TS 25.302: "Services Provided by the Physical Layer"

[12] 3G TS 25.402: "Synchronisation in UTRAN, Stage 2"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

TG: Transmission Gap is consecutive empty slots that have been obtained with a transmission time reduction method. The transmission gap can be contained in one or two consecutive radio frames.

TGL: Transmission Gap Length is the number of consecutive empty slots that have been obtained with a transmission time reduction method. $0 \le TGL \le 14$.

TrCH number: Transport channel number represents a TrCH ID assigned to L1 by L2. Transport channels are multiplexed to the CCTrCH in the ascending order of these IDs.

$\sum_{f \in CM} z_f$: The sum is calculated over those z_f for which *f* belongs to a specified group *C*. In this specification *CM* is used to represent a set of frames with different TGLs. Within the set *CM*, individual members of a property *z* are enumerated by *f*.

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.
$F_{f,i}$	Number of compressed radio frames of type *f* 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.
$H_{f,i}$	Maximum number of bits in a compressed radio frame of type *f* 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.

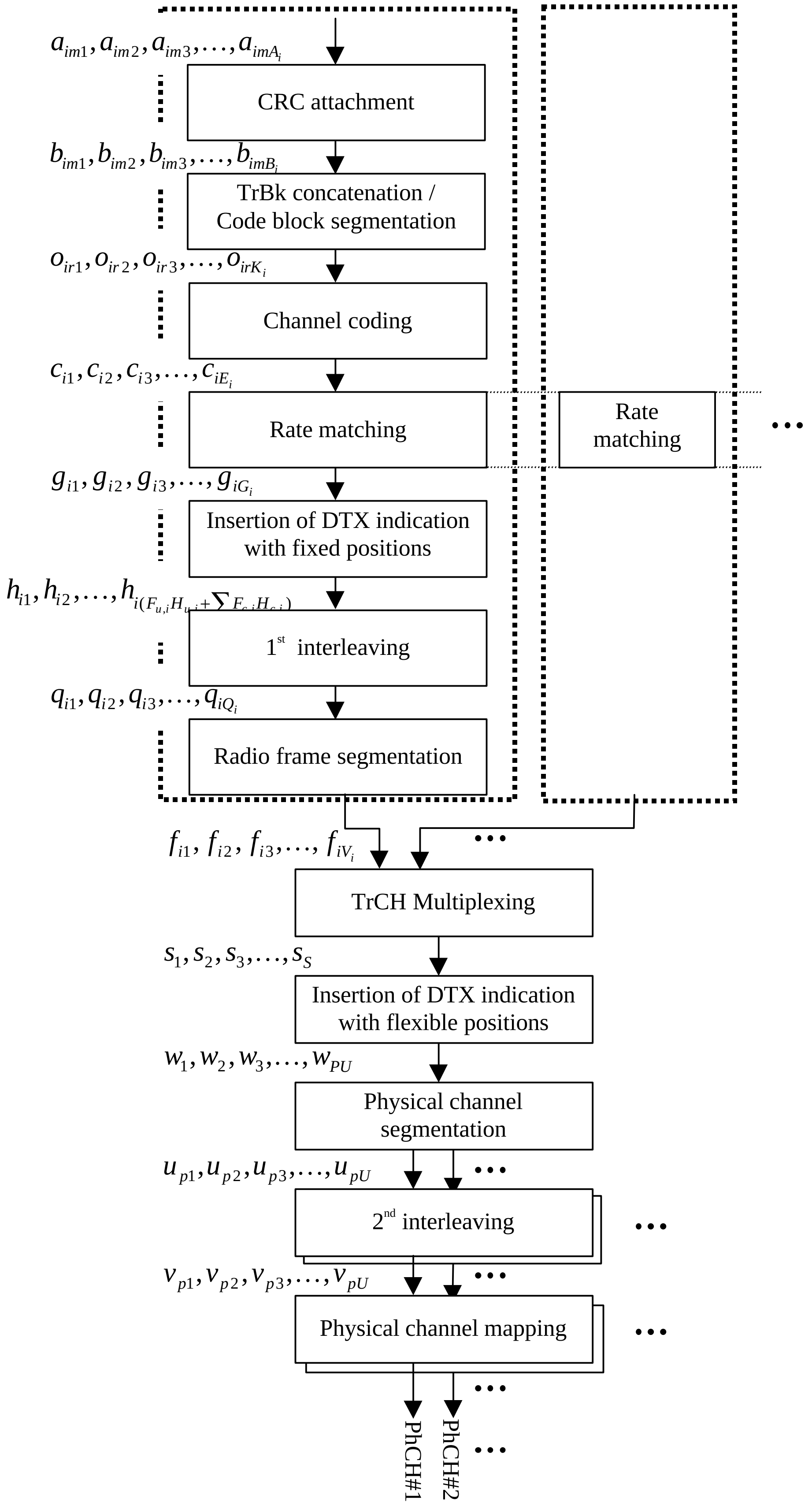
x, X
y, Y
z, Z

3.3 Abbreviations

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

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
RACH	Random Access Channel
RSC	Recursive Systematic Convolutional Coder
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
TPC	Transmit Power Control
TrCH	Transport Channel
TTI	Transmission Time Interval
TX	Transmit
UL	Uplink (Reverse link)



CRC attachment
TrBk concatenation /
Code block segmentation
Channel coding
Rate matching
Rate
matching
Insertion of DTX indication
with fixed positions
1st interleaving
Radio frame segmentation
TrCH Multiplexing
Insertion of DTX indication
with flexible positions
Physical channel
segmentation
2nd interleaving
Physical channel mapping
PhCH#1
PhCH#2

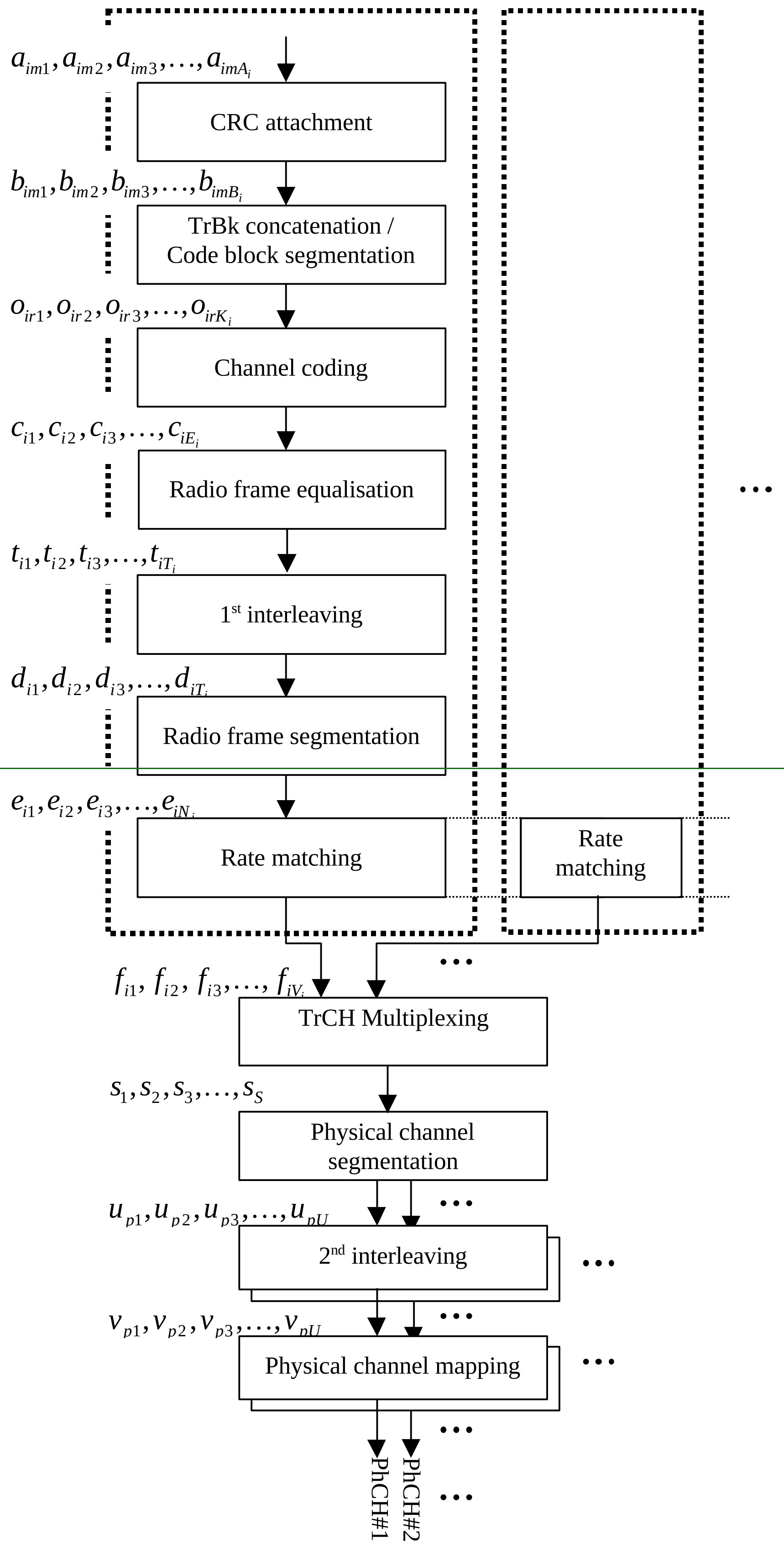


Figure 1: Transport channel multiplexing structure for uplink

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		

4.2.3.2.3.2 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 4.2.3.2.3.1.

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 alwaysonly performed in the UL, and in DL when compressed mode with puncturing is employed (in other cases 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 T_i the number of bits. Hence, $x_{ik} = t_{ik}$ and $X_i = T_i$.

The bits output from the 1st interleaving are denoted by $d_{i1}, d_{i2}, d_{i3}, \ldots, d_{iT_i}$, 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 $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_i H_i)}$, 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, $X_i = F_{u,i} H_{u,i} + \sum_{f \in CM} F_{f,i} H_{f,i}$.

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, $Q_i = F_{u,i} H_{u,i} + \sum_{f \in CM} F_{f,i} H_{f,i}$ 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 $x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iX_i}$ 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

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

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 input bits x_i according to the calculations in section 4.2.7.2.1.1 and 4.2.7.2.2.1. Frames with a transmission gap are mapped input bits y_i according to the calculations in section 4.2.7.2.1.2 and 4.2.7.2.2.2.

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. For frames with different TGs $f Î CM$ within the TTI the $F_{f,i}$ output bit sequences per TTI to be mapped into frames with a TGL z_f are denoted by $y_{i,n_i1}, y_{i,n_i2}, y_{i,n_i3}, \ldots, y_{i,n_iY_{c,i}}$ where n_i is the radio frame number in current TTI and $Y_{f,i}$ is the number of bits per radio frame for TrCH i. Thus, the output sequences are defined as follows.

$$y_{i,n_ik} = x_{i,\left(\sum_{m=0}^{n_i-1} Y_m\right)+k}, \begin{cases} Y_0 = 0 \\ Y_m = Y_{u,i}, k = 1\ldots Y_{u,i} \quad if \; radio \; frame \; n_i = m \; has \, no \, TG \\ Y_m = Y_{f,i}, k = 1\ldots Y_{f,i} \quad if \; radio \; frame \; n_i = m \; has \, a \, TG \, of \; z_f \; slots \end{cases}$$

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

z_c is the transmission gap length in a radio frame

$\Delta N_{il,c}$ is the amount of puncturing calculated for the n^{th} radio frame during rate matching

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

4.2.6.31 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 $N_i = Y_i$.

4.2.6.42 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_c is denoted by $f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iV_{c,i}}$, where i is the TrCH number and $V_{c,i}$ is the number of bits. Hence, $f_{i,k} = y_{i,n_i k}$ and $V_{c,i} = Y_{c,i}$.

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.

4.2.7.2 Determination of rate matching parameters in downlink

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

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

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

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

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. $N_{TGL} = \frac{TGL}{15} N_{data,*}$.

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

4.2.7.2.1.1 Rate matching parameters in case that compressed mode by puncturing is not used

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:

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

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 section 4.2.7.5 does not need to be executed. In this case we have :

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

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

4.2.7.2.1.1 Uncoded and convolutionally encoded TrCHs

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

a=2

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

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

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

$$e_{ini} = 1$$

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

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

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

4.2.7.2.1.2 Turbo encoded TrCHs

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

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

a=2 when *b*=2

a=1 when *b*=3

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

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

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

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

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

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

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

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

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

4.2.7.2.1.2 Rate matching parameters in compressed mode by puncturing

For TTIs that have a frame with a transmission gap in them, rate matching is done frame by frame. For this purpose, the incoming bits $c_{i1}, c_{i2}, c_{13}, \ldots, c_{iE_i}$ are segmented into F_i groups of equal size.

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

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

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 section 4.2.7.5 does not need to be executed. In this case we have :

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

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

4.2.7.2.1.1 Uncoded and convolutionally encoded TrCHs

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

a=2

$$N_{max} = \frac{1}{F_i} \max_{l \in TFS(i)} N_{il}^{TTI}$$

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

$$X_i = \frac{1}{F_i} N_{il}^{TTI}$$

$$e_{ini} = 1$$

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

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

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

4.2.7.2.1.2 Turbo encoded TrCHs

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

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

a=2 when *b*=2

a=1 when *b*=3

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

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

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

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

$$X_i = N_{il}^{TTI} / (3F_i)$$

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

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

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

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

4.2.7.2.2 Determination of rate matching parameters for flexible positions of TrCHs

4.2.7.2.2.1 Rate matching parameters in case that compressed mode by puncturing is not used

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:

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

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.

If $\Delta N_{i,l}^{TTI} = 0$ then, for TrCH *i* at TF *l*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed.

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

4.2.7.2.2.1 Uncoded and convolutionally encoded TrCHs

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

a=2

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

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

$e_{ini} = 1$

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

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

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

4.2.7.2.2.2 Turbo encoded TrCHs

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

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

a=2 when *b*=2

a=1 when *b*=3

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

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

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

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

$e_{ini} = X_i$,

$e_{plus} = a \cdot X_i$

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

4.2.7.2.2.2 Rate matching parameters in compressed mode by puncturing

For TTIs that have a frame with a transmission gap in them, rate matching is done frame by frame. For this purpose, the incoming bits $c_{i1}, c_{i2}, c_{13}, \ldots, c_{iE_i}$ are segmented into F_i groups of equal size.

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:

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

The computation of $\Delta N_{i,l}$ parameters is then performed in two phases. In a first phase, tentative temporary values of $\Delta N_{i,l}$ 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 $\Delta N_{i,l}$ is the definitive value.

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

$$\Delta N_{i,l} = \lceil RF_i \cdot N_{i,l} \rceil - N_{i,l}$$

The second phase is defined by the following algorithm:

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

$$D = \sum_{i=1}^{i=I} \frac{N_{i,TF_i(j)} + \Delta N_{i,TF_i(j)}}{F_i}$$ -- 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 $\Delta N_{i,TF_i(j)} > \Delta N$ then

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

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.

If $\Delta N_{i,l} = 0$ then, for TrCH *i* at TF *l*, the output data of the rate matching is the same as the input data and the rate matching algorithm of section 4.2.7.5 does not need to be executed.

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

4.2.7.2.2.1 Uncoded and convolutionally encoded TrCHs

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

a=2

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

$$X_i = N_{il}$$

$$e_{ini} = 1$$

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

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

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

4.2.7.2.2.2 Turbo encoded TrCHs

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

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

a=*2* when *b*=2

a=*1* when *b*=3

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

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

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

$X_i = N_{il} / 3$N,

$e_{ini} = X_i$,

$e_{plus} = a \cdot X_i$

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

4.2.7.3 Bit separation and collection in uplink

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

The bit separation function is transparent for uncoded TrCHs, convolutionally encoded TrCHs, and for turbo encoded TrCHs with repetition. The bit separation and bit collection are illustrated in figures 6 and 7.

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

A repeated bit is placed directly after the original one.

4.2.8 TrCH multiplexing

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

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

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

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

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

…

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

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 ~~4.2.9.1~~ 1st insertion of DTX indication bits

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 in one radio frame of TrCH i by H_i. In normal or compressed mode by spreading factor reduction, H_i is constant and corresponds to the maximum number of bits from TrCH i in one radio frame for any transport format of TrCH i. In compressed mode by higher layer scheduling, only a subset of the TFC Set is allowed. From this subset it is possible to derive which TFs on each TrCH that are allowed. The maximum number of bits belonging to one TTI of TrCH i for the allowed TFs is denoted by X_i. H_i is then calculated as $H_i = \left\lceil \frac{X_i}{F_i} \right\rceil$, where F_i is the number of radio frames in a TTI of TrCH i. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_i H_i)}$. Note that these bits are three valued. They are defined by the following relations:

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

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

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

4.2.9.1.2 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 $H_{u,i}$, 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 $F_{u,i}$. For different TGs f Î CM, denote the number of bits reserved for one radio frame of TrCH i with a TGL of z_f slots by $H_{f,i}$, 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_f slots is denoted by $F_{f,i}$. The bits output from the DTX insertion are denoted by $h_{i1}, h_{i2}, h_{i3}, \ldots, h_{i(F_{u,i}H_{u,i} + \sum_{f \cup CM} F_{f,i}H_{f,i})}$ where C is the set of compressed frames within the TTI).

Note that these bits are three valued. They are defined by the following relations:

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

$$h_{ik} = d \quad k = G_i+1, G_i+2, G_i+3, \ldots, F_{u,i} H_{u,i} + \sum_{f \in CM} F_{f,i} H_{f,i}$$

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 U. The number of available bits on the PhCH is denoted by N_{data} and N_{data}=15N_{data1}+15N_{data2}, where N_{data1} and N_{data2} are defined in [25.211]. In normal mode U=N_{data}. In compressed mode N_{data} is changed from the value in normal node. The exact value of N_{data} is dependent on the TGL and the transmission time reduction method, which are signalled from higher layers. The number of bits that are located within the transmission gap is denoted N_{TGL} and defined as:

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

$$\frac{TGL-(15-N_{first})}{15}N_{data}$$, in second frame if N_{first} + TGL > 15

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

In compressed mode $U=N_{data}-N_{TGL}$..

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

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 $Y = S$.

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

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