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Technical Specification

China Wireless Telecommunication Standard (CWTS);
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Multiplexing and channel coding;

CWTS

Contents

1 Intellectual Property Rights

<Editor’s note: this section will be completed when an official format for the document is agreed>

2 Foreword

This Technical Specification has been produced by the CWTS, Working Group 1 (CWTS WG1).

The contents of this TS may be subject to continuing work within the CWTS WG1and may change following formal TSG approval. Should the TSG modify the contents of this TS, it will be re-released with an identifying change of release date and an increase in version number as follows:

Version m.x.y

where:

m indicates [major version number]

x the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

y the third digit is incremented when editorial only changes have been incorporated into the specification.

3 Scope

This CWTS Report describes multiplexing, channel coding and interleaving for CWTS Physical Layer TD-SCDMA mode.

4 References

[1] CWTS TS C102 (V1.3.0): “Physical channels and mapping of transport channels onto physical channels

[2] CWTS TS C103 (V1.1.0): “Multiplexing and channel coding ”

[3] CWTS TS C104 (V1.1.0): “Spreading and modulation ”

[4] CWTS TS C105 (V1.2.0): “Physical layer procedures ”

[5] CWTS TS 25222 (V2.0.2): “Multiplexing and channel coding ”

[6] CWTS TS C002 (V2.0.0): “Service provided by physical layer”

5 Definitions, symbols and abbreviations

5.1 Definitions

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

<defined term>: <definition>.

5.2 Symbols

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

<symbol> <Explanation>

5.3 Abbreviations

ARQ Automatic Repeat on Request

BCH Broadcast Channel
BER Bit Error Rate
BPSK Binary Phase Shift Keying
BS Base Station
BSS Base Station Subsystem

CA Capacity Allocation
CAA Capacity Allocation Acknowledgement
CBR Constant Bit Rate
CCCH Common Control Channel
CCTrCH Coded Composite Transport Channel
CD Capacity Deallocation
CDA Capacity Deallocation Acknowledgement
CDMA Code Division Multiple Access
CTDMA Code Time Division Multiple Access
CRC Cyclic Redundancy Check

DCA Dynamic Channel Allocation
DCCH Dedicated Control Channel
DL Downlink
DRX Discontinuous Reception
DSCH Downlink Shared Channel
DTX Discontinuous Transmission

FACH Forward Access Channel
FDD Frequency Division Duplex
FDMA Frequency Division Multiple Access
FEC Forward Error Control
FER Frame Error Rate

GF Galois Field

HCS Hierarchical Cell Structure

JD Joint Detection

L1 Layer 1
L2 Layer 2

LLC	Logical Link Control
MA	Multiple Access
MAC	Medium Access Control
MAHO	Mobile Assisted Handover
MO	Mobile Originated
MOHO	Mobile Originated Handover
MS	Mobile Station
MT	Mobile Terminated
NRT	Non-Real Time
PC	Power Control
PCCC	Parallel Concatenated Convolutional Code
PCH	Paging Channel
ODMA	Opportunity Driven Multiple Access
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
RACH	Random Access Channel
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
RRM	Radio Resource Management
RT	Real Time
RU	Resource Unit
SCCC	Serial Concatenated Convolutional Code
SCH	Synchronisation Channel
SDCCH	Stand-alone Dedicated Control Channel
SFN	System Frame Number
SNR	Signal to Noise Ratio
SP	Switching Point
TCH	Traffic channel
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TFCI	Transport Format Combination Indicator
TrCH	Transport Channel
UL	Uplink
UMTS	Universal Mobile Telecommunications System
VBR	Variable Bit Rate

6 Multiplexing, channel coding and interleaving

6.1 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 (including rate matching), and interleaving and transport channels mapping onto/splitting from physical channels.

In the TD-SCDMA mode, the total number of basic physical channels (a certain time slot one spreading code on a certain carrier frequency) per subframe is given by the maximum number of time slots and the maximum number of CDMA codes per time slot.

6.2 Transport-channel coding/multiplexing

Figure 6-1 illustrates the overall concept of transport-channel coding and 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 6.2.1)
- Channel coding (see section 6.2.3)
- Rate matching (see section 6.2.5)
- Interleaving (two steps, see sections 6.2.4 and 6.2.8)
- Radio frame segmentation
- Multiplexing of transport channels (two steps, see sections 6.2.2 and 6.2.6)
- Physical channel segmentation (see section 6.2.7)
- Mapping to physical channels (see section 6.2.9)

The coding/multiplexing steps for uplink and downlink are shown in Figure 6-1.

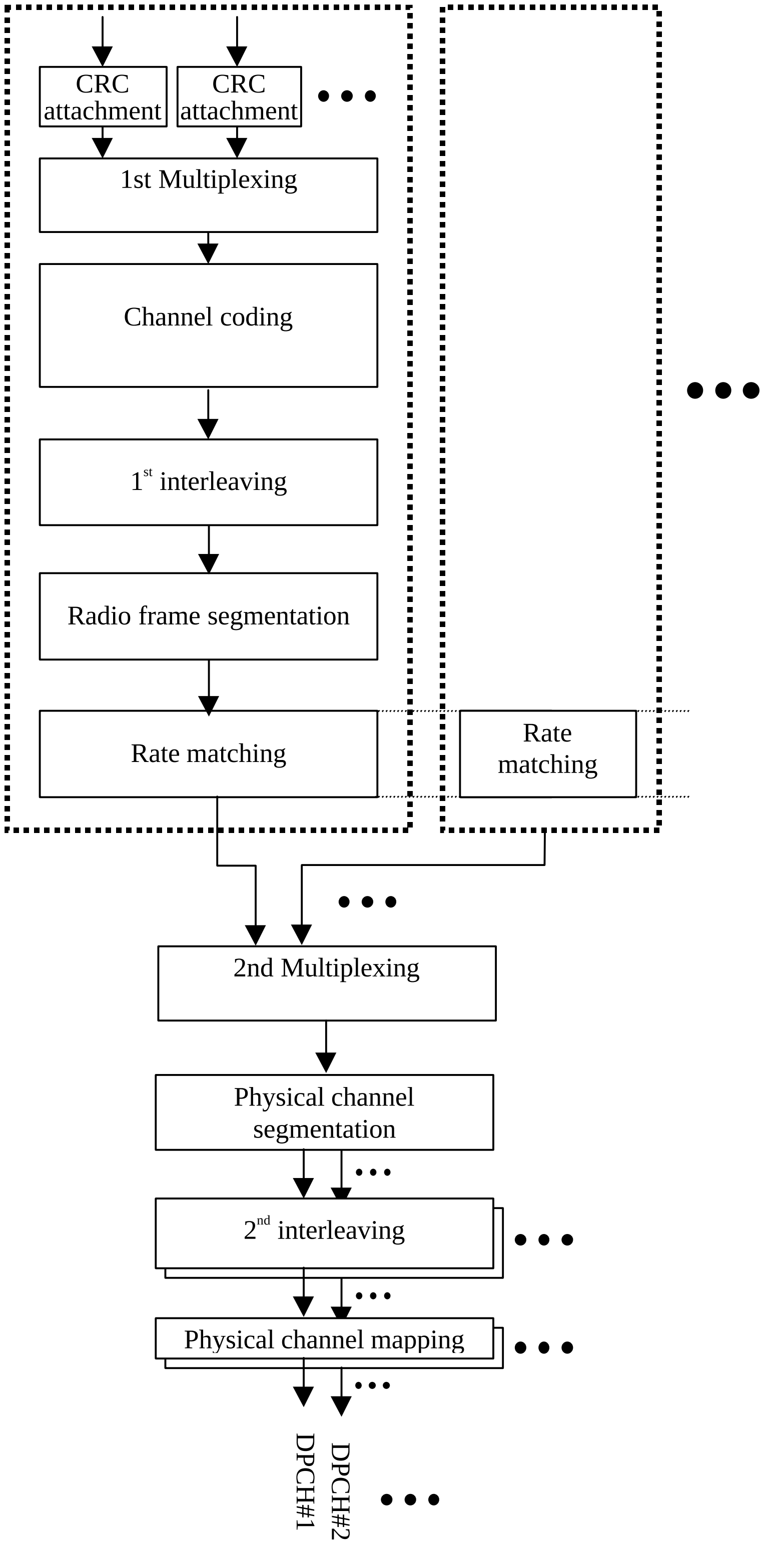


Figure 6~~1~~. Transport channel multiplexing structure for uplink and downlink

Primarily, transport channels are multiplexed as described above, i.e. into one data stream mapped on one or several physical channels. However, an alternative way of multiplexing services is to use multiple CCTrCHs (Coded

Composite Transport Channels), which corresponds to having several parallel multiplexing chains as in Figure 6-1, resulting in several data streams, each mapped to one or several physical channels.

6.2.1 Error detection

Error detection is provided on transport blocks through a Cyclic Redundancy Check. The CRC is 16, 8 or 0 bits and it is signalled from higher layers what CRC length that should be used for each transport channel.

6.2.1.1 CRC calculation

The entire transport block is used to calculate the CRC parity bits for each transport block. The parity bits are generated by one of the following cyclic generator polynomials:

$g_{CRC16}(D) = D^{16} + D^{12} + D^{5} + 1$

$g_{CRC8}(D) = D^{8} + D^{7} + D^{4} + D^{3} + D + 1$

Denote the bits in a transport block delivered to layer 1 by $b_1, b_2, b_3, \dots b_N$, and the parity bits by $p_1, p_2, \dots p_L$. N is the length of the transport block and L is 16, 8, or 0 depending on what is signalled from higher layers.The encoding is performed in a systematic form, which means that in GF(2), the polynomial

$b_1D^{N+15} + b_2D^{N+14} + \dots + b_ND^{16} + p_1D^{15} + p_2D^{14} + \dots + p_{15}D^{1} + p_{16}$

yields a remainder equal to 0 when divided by $g_{CRC16}(D)$. Similarly,

$b_1D^{N+7} + b_2D^{N+6} + \dots + b_ND^{8} + p_1D^{7} + p_2D^{6} + \dots + p_7D^{1} + p_8$

yields a remainder equal to 0 when divided by $g_{CRC8}(D)$.

6.2.1.2 Relation between input and output of the Cyclic Redundancy Check

Bits delivered to layer 1 are denoted $b_1, b_2, b_3, \dots b_N$, where N is the length of the transport block. The bits after CRC attachment are denoted by $w_1, w_2, w_3, \dots w_{N+L}$, where L is 16, 8, or 0. The relation between b and w is:

$w_k = b_k$ $\quad$ k = 1, 2, 3, ... N

$w_k = p_{(L+1-(k-N))}$ $\quad$ k = N+1, N+2, N+3, ... N+L

6.2.2 1st multiplexing

Fixed rate transport channels that are characterised by the same transport format attributes (as defined in [6]) can be multiplexed before coding. When this multiplexing step is present, the transport blocks from different transport channels are serially concatenated. Denote the number of transport channels (TrCHs) by R, the number of transport blocks on each TrCH by P, and the number of bits in each transport block, including CRC bits, by K. The bits before multiplexing can then be described as follows:

Bits from transport block 1 of transport channel 1: $w_{111}, w_{112}, w_{113}, \dots w_{11K}$

Bits from transport block 2 of transport channel 1: $w_{121}, w_{122}, w_{123}, \dots w_{12K}$

…

Bits from transport block P of transport channel 1: $w_{1P1}, w_{1P2}, w_{1P3}, \dots w_{1PK}$

Bits from transport block 1 of transport channel 2: $w_{211}, w_{212}, w_{213}, \dots w_{21K}$

…

Bits from transport block P of transport channel 2: $w_{2P1}, w_{2P2}, w_{2P3}, \dots w_{2PK}$

...

Bits from transport block 1 of transport channel R: w_{R11}, w_{R12}, w_{R13}, … w_{R1K}

…

Bits from transport block P of transport channel R: w_{RP1}, w_{RP2}, w_{RP3}, … w_{RPK}

The bits after first multiplexing are denoted by d_1, d_2, d_3, … d_M, and defined by the following relations:

$$\left.\begin{array}{ll} d_k = w_{11k} & k = 1, 2, \ldots, K \\ d_k = w_{12(k-K)} & k = K + 1, K + 2, \ldots, 2K \\ \ldots & \\ d_k = w_{1P(k-(P-1)K)} & k = (P - 1)K + 1, \ldots, PK \end{array}\right\} \text{TrCH 1}$$

$$\left.\begin{array}{ll} d_k = w_{21(k-PK)} & k = PK + 1, \ldots, (P + 1)K \\ \ldots & \\ d_k = w_{2P(k-(2P-1)K)} & k = (2P - 1)K + 1, \ldots, 2PK \end{array}\right\} \text{TrCH 2}$$

…

$$\left.\begin{array}{ll} d_k = w_{R1(k-(R-1)PK)} & k = (R - 1)PK + 1, \ldots, ((R - 1)P + 1)K \\ & \\ d_k = w_{RP(k-(RP-1)K)} & k = (RP - 1)K + 1, \ldots, RPK \end{array}\right\} \text{TrCH R}$$

<Note: Above it is assumed that all transport blocks have the same size. There are cases when the total number of bits that are sent during a transmission time interval is not a multiple of the number of transport blocks. A few padding bits are then needed but the exact insertion point (in the multiplexing chain) of these bits is for further study.>

6.2.3 Channel coding

The following channel coding schemes can be applied to transport channels.

- Convolutional coding
- Turbo coding
- No channel coding

The maximum encoding segment length for turbo coding is 5120 bits. In Real Time (RT) services a FEC coding is used, instead Non Real Time (NRT) services could be well managed with a proper combination of FEC and ARQ.

Table 6.2.3-1 Error Correction Coding Parameters

Transport channel type (Maximum coding unit size)	Coding scheme (constraint length)	Coding rate
BCH	Convolutional code (K=9)	1/2
PCH		
FACH		
RACH		1/2, [2/3, 7/8] *<Editor's note: the values in square brackets have not yet been approved.>*
DCH		1/2 ,1/3 or no coding
DCH	Turbo code	

Note 1: The exact physical layer encoding/decoding capabilities for different code types are FFS.

Note 2: In the UE the channel coding capability should be linked to the terminal class.

6.2.3.1 Convolutional Coding

- Constraint length K=9. Coding rates 1/2, 1/3 and [2/3, 7/8].
- The configuration of the convolutional coder is presented in Fig. 6-2.
- The output from the convolutional coder shall be done in the order starting from output0, output1 and output2. (When coding rate is 1/2, output is done up to output 1).
- The initial value of the shift register of the coder shall be “all 0”.
- K-1 tail bits (value 0) shall be added to the end of the coding block.

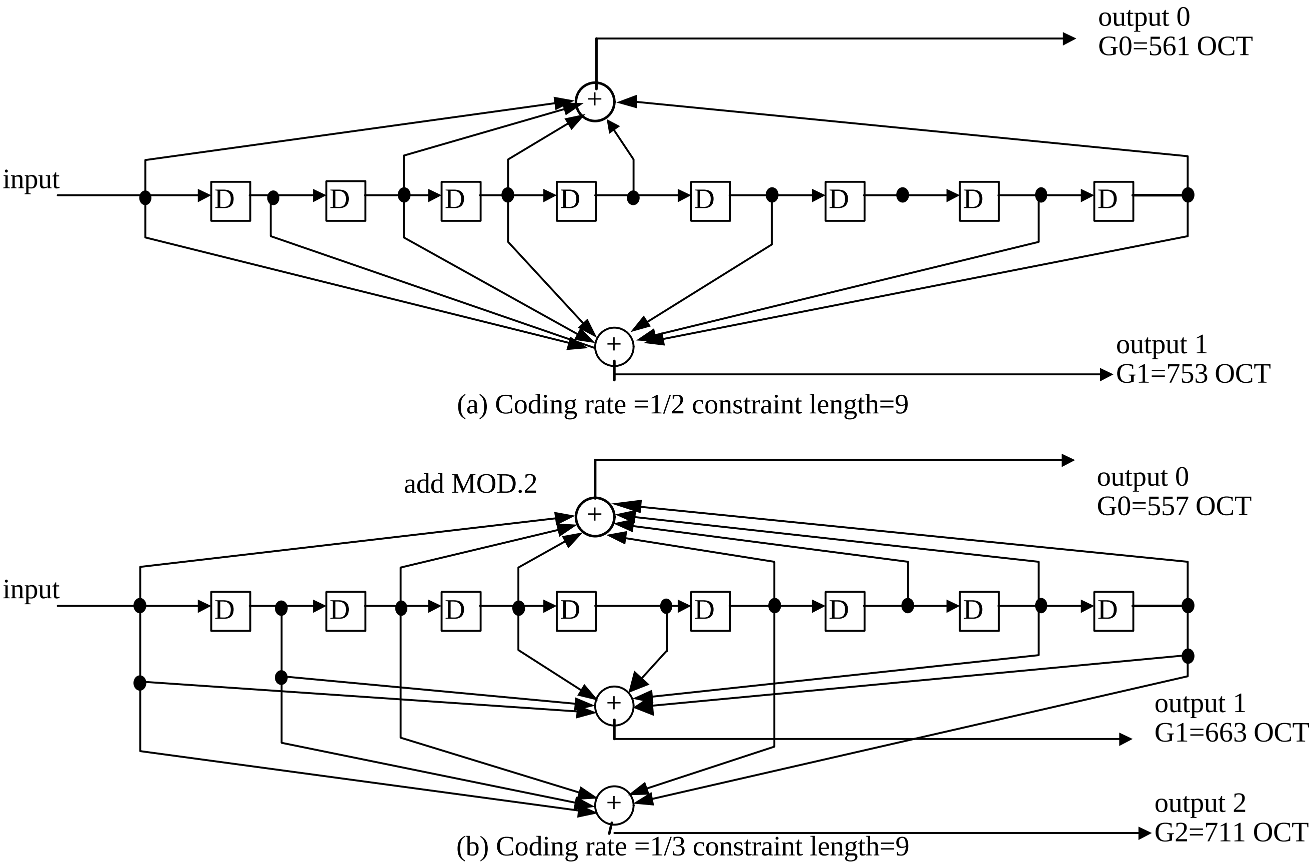


Fig. 6-2 Convolutional Coder

6.2.3.1.1 Segmentation into code blocks for convolutional coding

<Note: It is for further study if the maximum code block size is 504 or shorter.>

If the transport blocks or multiplexed transport blocks are longer than [504] bits (including CRC bits), they are segmented before convolutional encoding. Denote the number of transport blocks before coding by P and the number of bits in each transport block or the sum of the number of bits in the multiplexed blocks by M. Note that if first multiplexing is performed, all transport blocks of a transport channel in the same transmission time interval are multiplexed together, i.e. P=1. The bits before segmentation can then be described as follows:

Bits in transport block 1before segmentation: $d_{1,1}$, $d_{1,2}$, $d_{1,3}$, … $d_{1,M}$

Bits in transport block 2 before segmentation: $d_{2,1}$, $d_{2,2}$, $d_{2,3}$, … $d_{2,M}$

…

Bits in transport block P before segmentation: $d_{P,1}$, $d_{P,2}$, $d_{P,3}$, … $d_{P,M}$

If M ≤ [504], no segmentation is performed. If M > [504] the following parameters are calculated:

Number of code blocks: S = round_up(PM / [504])

Length of coded blocks: C = round_up(PM / S)

Remainder: R = PM – S round_down(PM / S)

Number of filler bits: F = S – R, if R≠0
F = 0, if R=0

round_up(x) means the smallest integer number larger or equal to x.

round_down(x) means the largest integer number smaller or equal to x.

The F filler bits are appended to the end of the last code block before tail insertion and channel encoding. They are denoted f_1, f_2, f_3, ... f_F. The bits after segmentation are denoted by $u_{1,1}$, $u_{1,2}$, $u_{1,3}$, … $u_{1,C}$, $u_{2,1}$, $u_{2,2}$, $u_{2,3}$, ... ,$u_{2,C}$, ... $u_{S,1}$, $u_{S,2}$, $u_{S,3}$, ... ,$u_{S,C}$, and defined by the following relations:

$u_{1,k} = d_{1,k}$ k = 1, 2, 3, ... C

$u_{2,(k-C)} = d_{1,k}$ k = C + 1, C + 2, C + 3, ... 2C

...

$u_{j,(k-(j-1)C)} = d_{1,k}$ k = (j-1)C + 1, (j-1)C + 2, (j-1)C + 3, ... M

$u_{j,(k-(j-1)C)} = d_{2,(k-M)}$ k = M + 1, M + 2, M + 3, ... jC

$u_{j+1,(k-jC)} = d_{2,(k-M)}$ k = jC + 1, jC + 2, jC + 3, ... (j+1)C

...

$u_{S,(k-(S-1)C)} = d_{P,(M-C+F+k-(S-1)C)}$ k = (S - 1)C + 1, (S - 1)C + 2, (S - 1)C + 3, ... SC - F

$u_{S,(k-(S-1)C)} = f_{k-SC+F}$ k = SC – F + 1, SC - F+ 2, SC – F +3, ... SC

<Note: Above it is assumed that all transport blocks have the same size. There are cases when the total number of bits that are sent during a transmission time interval is not a multiple of the number of transport blocks. A few padding bits are then needed but the exact insertion point (in the multiplexing chain) of these bits is for further study.>

6.2.3.2 Turbo coding

6.2.3.2.1 Turbo Coder

<Note: It needs to be clarified from TSG SA what are the service specifications with respect to different qualities of service. The performance below BER of 10^{-6} needs to be studied if there is a requirement for this quality of services over the physical layer.>

For data services requiring quality of service between 10^{-3} and 10^{-6} BER inclusive, parallel concatenated convolutional code (PCCC) with 8-state constituent encoders is used.

The transfer function of the 8-state constituent code for PCCC is

$$G(D)=\left[1, \frac{n(D)}{d(D)}\right]$$

where,

$$d(D)=1+D^2+D^3$$

$$n(D)=1+D+D^3.$$

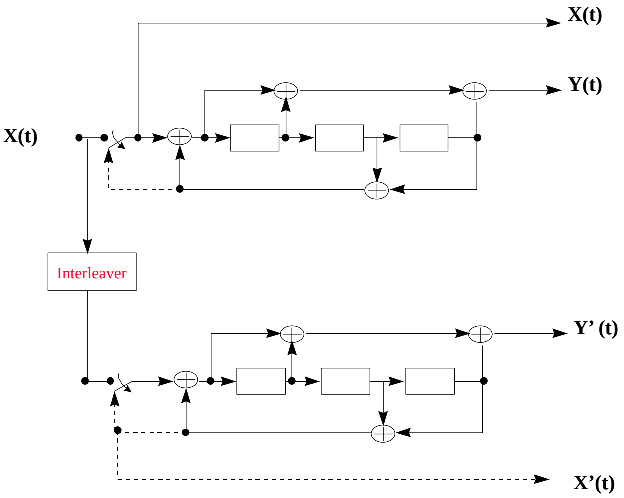


Figure 6-3. Structure of the 8 state PCCC encoder (dotted lines effective for trellis termination only)

The initial value of the shift registers of the PCCC encoder shall be all zeros.

The output of the PCCC encoder is punctured to produce coded bits corresponding to the desired code rate 1/3 or 1/2. For rate 1/3, none of the systematic or parity bits are punctured, and the output sequence is X(0), Y(0), Y'(0), X(1), Y(1), Y'(1), etc. For rate 1/2, the parity bits produced by the constituent encoders are alternately punctured to produce the output sequence X(0), Y(0), X(1), Y'(1), X(2), Y(2), X(3), Y'(3), etc.

The SCCC is a rate 1/3 SCCC, The outer code of the SCCC is a rate 2/3 obtained by puncturing a rate ½ code with generating matrix

$$G^{(o)}(Z) = (1, (1+Z^2)/(1+Z+Z^2))$$

The rate 2/3 is obtained by puncturing every other parity-check bit.
The inner code is a rate ½ systematic recursive convolutional code with the same previous generating matrix

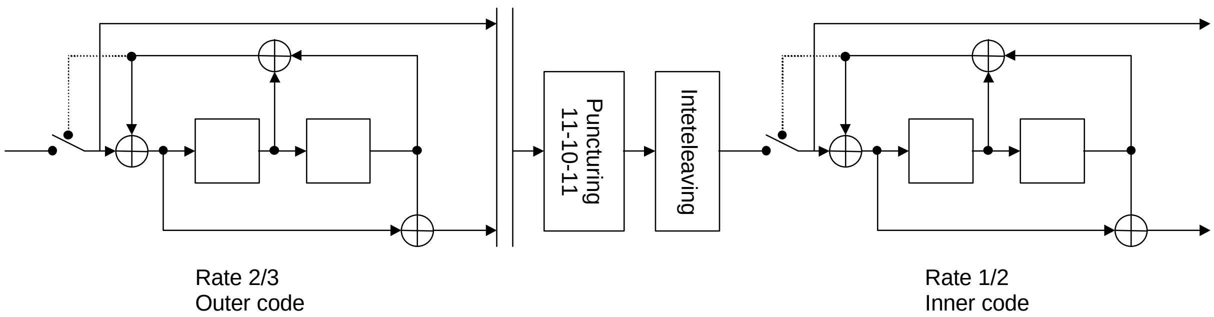


Figure 6-4. Structure of the 4 state SCCC encoder (dotted line effective for trellis termination only).

6.2.3.2.2 Trellis termination in Turbo code

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded . Tail bits are added after the encoding of information bits.

Trellis termination for PCCC

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of Figure 6-3 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of Figure 6-3 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be

X(t) Y(t) X(t+1) Y(t+1) X(t+2) Y(t+2) X'(t) Y'(t) X'(t+1) Y'(t+1) X'(t+2) Y'(t+2).

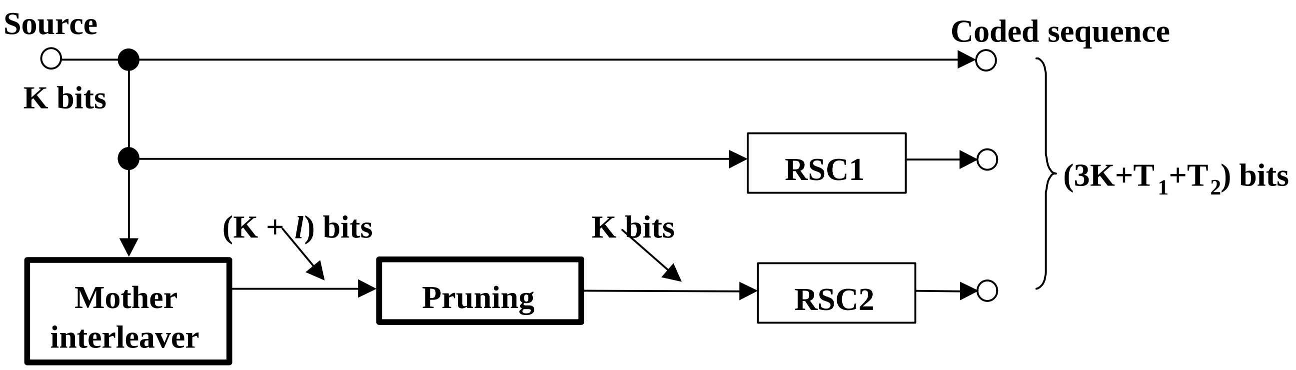
Trellis termination for SCCC

The conventional method of trellis termination is used also for SCCC in which the tail bits are taken from the shift register feedback after all bits are encoded (Figure 6-4). The tailing bits of the outer encoder are included in the interleaver. The outer code is terminated first with two additional input bits taken from the shift register feedback (dotted line), the outer code thus, after puncturing, outputs three additional bit that are feeded into the interleaver. After that all bits have been encoded from the inner encoder (included the interleaved tail bit of the outer encoder), two additional input bits are taken from the shift register feedback of the inner encoder producing four tail bits.

Thus the total overhead due to the tailing bits is 3*2+4 =10 bits.

6.2.3.2.3 Turbo code internal interleaver

Figure 6-5 depicts the overall 8 State PCCC Turbo coding scheme including Turbo code internal interleaver. The Turbo code internal interleaver consists of mother interleaver generation and pruning. For arbitrary given block length K, one mother interleaver is selected from the 207 mother interleavers set. The generation scheme of mother interleaver is described in section 6.2.3.2.3.1. After the mother interleaver generation, *l*-bits are pruned in order to adjust the mother interleaver to the block length K. The definition of *l* is shown in section 6.2.3.2.3.2..



If K=481 to 530 bits

$$K + l = 0 \pmod{10};$$
$$p-1 < (K + l) / 10 < p+2$$

else

$$K + l = 0 \pmod{20};$$
$$p-2 < (K + l) / 20 < p+2$$

where p is a prime number.

Figure 6-5. Overall 8 State PCCC Turbo Coding

6.2.3.2.3.1 Mother interleaver generation

The interleaving consists of three stages. In first stage, the input sequence is written into the rectangular matrix row by row. The second stage is intra-row permutation. The third stage is inter-row permutation. The three-stage permutations are described as follows, the input block length is assumed to be K (320 to 5120 bits).

<u>First Stage</u>:

(1) Determine a row number R such that

R=10 (K = 481 to 530 bits; Case-1)

R=20 (K = any other block length except 481 to 530 bits; Case-2)

(2) Determine a column number C such that

Case-1; C = p = 53

Case-2;

(i) find minimum prime p such that,

0 =< (p+1)-K/R

(ii) if (0 =< p-K/R) then go to (iii)

else C = p+1.

(iii) if (0 =< p-1-K/R) then C=p-1.

else C = p.

(3) The input sequence of the interleaver is written into the RxC rectangular matrix row by row.

Second Stage:

A. If C = p

(1) Select a primitive root g_0 from Table 6.2.2-2.

(2) Construct the base sequence c(i) for intra-row permutation as:

$c(i) = [g_0 \times c(i-1)] \bmod p$, i =1,2,…(p-2)., c(0) = 1.

(3) Select the minimum prime integer set $\{q_j\}$ (j=1,2,…R-1) such that

g.c.d$\{q_j, p\text{-}1\}$ =1

$q_j > 6$

$q_j > q_{(j-1)}$

where g.c.d. is greatest common divider. And $q_0 = 1$.

(4) The set $\{q_j\}$ is permuted to make a new set $\{p_j\}$ such that

$p_{P(j)} = q_j$, j = 0, 1, …. R-1,

where P(j) is the inter-row permutation pattern defined in the third stage.

(5) Perform the j-th (j = 0,1, 2, …, C-1) intra-row permutation as:

$c_j(i) = c([i \times p_j] \bmod (p-1))$, i =0,1,2,…, (p-2)., and $c_j(p\text{-}1) = 0$,

where $c_j(i)$ is the input bit position of i-th output after the permutation of j-th row.

B. If C = p+1(B-1) Same as case A-1.

(B-2) Same as case A-2.

(B-3) Same as case A-3.

(B-4) Same as case A-4.

(B-5) Perform the j-th (j = 0,1, 2, …, R-1) intra-row permutation as:

$$c_j(i) = c([i \times p_j] \bmod (p-1)), \quad i = 0,1,2,\ldots,(p-2).,\ c_j(p-1) = 0, \text{ and } c_j(p) = p,$$

where $c_j(i)$ is the input bit position of i-th output after the permutation of j-th row.

(B-6) If (K = C x R) then exhange $c_{R-1}(p)$ with $c_{R-1}(0)$.

C. If C = p-1

(1) Same as case A-1.

(2) Same as case A-2.

(3) Same as case A-3.

(4) Same as case A-4.

(5) Perform the j-th (j = 0,1, 2, …, R-1) intra-row permutation as:

$$c_j(i) = c([i \times p_j] \bmod (p-1)) - 1, \quad i = 0,1,2,\ldots,(p-2).,$$

where $c_j(i)$ is the input bit position of i-th output after the permutation of j-th row.

Third Stage:

Perform the inter-row permutation based on the following P(j) (j=0,1, ..., R-1) patterns, where P(j) is the original row position of the j-th permuted row.

P_A: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11} for R=20

P_B: {19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10} for R=20

P_C: {9, 8, 7, 6, 5, 4, 3, 2, 1, 0} for R=10

The usage of these patterns is as follows:

Block length K:	P(j)
320 to 480-bit:	P_A
481 to 530-bit:	P_C
531 to 2280-bit:	P_A
2281 to 2480-bit:	P_B
2481 to 3160-bit:	P_A
3161 to 3210-bit:	P_B
3211 to 5120-bit:	P_A

(2) The output of the mother interleaver is the sequence read out column by column from the permuted R × C matrix.

Table 6.2.2-2. Table of prime *p* and associated primitive root

p	g_o	p	g_o	p	g_o	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	269	2	331	3	389	2
19	2	61	2	107	2	163	2	223	3	271	6	337	10	397	5
23	5	67	2	109	6	167	5	227	2	277	5	347	2	401	3
29	2	71	7	113	3	173	2	229	6	281	3	349	2	409	21
31	3	73	5	127	3	179	2	233	3	283	3	353	3		
37	2	79	3	131	2	181	2	239	7	293	2	359	7		
41	6	83	2	137	3	191	19	241	7	307	5	367	6		
43	3	89	3	139	2	193	5	251	6	311	17	373	2		
47	5	97	5	149	2	197	2	257	3	313	10	379	2		
53	2	101	2	151	6	199	3	263	5	317	2	383	5		

6.2.3.2.3.2 Definition of the 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 6.2.3.2.3.1.

6.2.3.2.4 Encoding blocks for turbo code

<Editor's note: Segment length of 5120 is FFS.>

Input data blocks for a turbo encoder consist of the user data and possible extra data being appended to the user data before turbo encoding. The encoding segments for a turbo encoder are defined in terms of systematic bits. The segment includes the user data, a possible error detection field (CRC), possible filler bits, and the termination. The Algorithm for combining and segmentation is as follows:

Inputs:

N_{DATA} size of input data block to turbo encoder

N_{TAIL} number of tail bits to be appended to the encoding segments (termination)

Outputs:

N_{S} number of segments

N_{TB} number of bits in the turbo encoder input segments

N_{FILL} number of filler (zero) bits in the last turbo encoder input segment

Do:

1. Let N_S = round_up(N_{DATA} / (5120 – N_{TAIL}))
2. Let N_{TB} = round_up (N_{DATA} / N_S) + N_{TAIL};
3. Let N_{REM} = remainder of N_{DATA} / N_S;
4. If N_{REM} not equal to 0 then insert N_{FILL} = (N_S – N_{REM}) zero bits to the end of the input data else N_{FILL} = 0.
5. End.

Here *round_up(x)* stands for an smallest interger number being larger or equal to *x*.

All turbo encoder input segments are of equal size and therefore the same turbo interleaver can be used for all turbo segments. A number of systematic bits over an entire channel interleaving block at output of the encoder is

N_S * (round_up(N_{DATA} / N_S) + N_{TAIL}).

The N_{FILL} filler bits are padded to the end of the last encoding segment in order to make the last segment equal size to the precedent ones. The filler bits are encoded.

6.2.4 1st interleaving

The 1st interleaving of channel interleaving consists of two stage operations. In first stage, the input sequence is written into rectangular matrix row by row. The second stage is inter-column permutation. The two-stage operations are described as follows, the input block length is assumed to be K_1.

<u>First Stage</u>:

(1) Select a column number C_1 from Table 6.2.4-1.

(2) Determine a row number R_1 by finding minimum integer R_1 such that,

$$K_1 <= R_1 \times C_1.$$

(3) The input sequence of the 1st interleaving is written into the $R_1 \times C_1$ rectangular matrix row by row.

<u>Second Stage</u>:

(1) Perform the inter-column permutation based on the pattern $\{P_1\ (j)\}$ (j=0,1, ..., C-1) that is shown in Table 4-xx, where $P_1\ (j)$ is the original column position of the j-th permuted column.

(2) The output of the 1st interleaving is the sequence read out column by column from the inter-column permuted $R_1 \times C_1$ matrix and the output is pruned by deleting the non-existence bits in the input sequence, where the deleting bits number l_1 is defined as:

$$l_1 = R_1 \times C_1 – K_1.$$

Table 6.2.4-1

Interleaving span	Column number C_1	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}

6.2.5 Radio frame segmentation

Each transport channel with transmission time interval 10, 20, 40, or 80 ms is segmented into 10 ms equi-sized data blocks. Those segmented 1, 2, 4, or 8 blocks, depending on transmission time interval, are output to rate matching in block-wise order at every 10 ms.

Figure A-1 illustrates data flow from 1st interleaver down to 2nd interleaver in channel coding and multiplexing chain. In the figures, it is assumed that there are N different channel coding and multiplexing chains. The following subsections describe input-output relationship of radio frame segmentation in bit-wise manner, referring to the notation in Figure A-1, where the notations in each data block, for examples L_1, R_1, K_1, P/M, etc., indicate number of bits of the data block.

Define some notations:L_i = Size of i^{th} transport channel data in bits to radio frame segmentation

T_i = Transmission Time Interval of i^{th} channel coding and multiplexing chain (ms) / 10 (ms)

So, $T_i \in \{1, 2, 4, 8\}$ for $i = 0, 1, 2, \ldots, N$

6.2.5.1 Radio frame size equalization

i^{th} transport channel data of size L_i is segmented into radio frames of size L_i/T_i. Since the size of radio frame, L_i/T_i is not necessarily an integer, some of T_i the radio frames will contain one bit less than others. For systematic process of the proceeding functional blocks, the radio frame sizes are equalized to be one finite size by considering the number of proper filler bits. Note that maximum possible filler bits are 7 for transmission time interval of 80 ms. These filler bits are evenly distributed over the one-bit short radio frames. Following is the algorithm of radio frame size equalization.

t = radio frame index $(1, 2, 3, \ldots, T_i)$ for a given i^{th} channel coding and multiplexing chain

$r_i = T_i - (L_i \bmod T_i) \in \{0, 1, 2, \ldots, T_i\text{-}1\}$ *// number of filler bits*

$(L_i + r_i)/ T_i = R_i$ *// Target radio frame size for uplink*

If $r_i \neq 0$ *then*

For each t $(\geq T_i\text{-}r_i\text{+}1)$

Add one filler bit to the end of t^{th} *radio frame*

End
End If

6.2.5.2 Radio frame segmentation rule

Parameter r_i for segmentation are determined in radio frame size equalization.

The bits before radio frame segmentation for i^{th} channel coding and multiplexing chain are denoted by:

$b_{i1}, b_{i2}, \ldots b_{iL_i}$

Bits after radio frame segmentation block are 10 ms-based and denoted by:

$c_{i1}, \ldots c_{i,(L_i+r_i)/T_i}$

and related to the input bits to radio frame segmentation as follows.

Bits after radio frame segmentation in the first 10 ms time interval: *(t=1)*

$c_{ij} = b_{ij}$ $\quad j=1,2,\ldots, (L_i+r_i)/T_i$

$((L_i+ r_i)/T_i$ equals to R_i and K_i for uplink and downlink, respectively.)

Bits after radio frame segmentation in the second 10 ms time interval: $(t=2)$

$c_{ij} = b_{i,(j+(L_i+r_i)/T_i)}$ $\quad j=1,2, \ldots, (L_i+r_i)/T_i$

…

Bits after radio frame segmentation in the $(T_i - r_i)^{th}$ 10 ms time interval: $(t=T_i - r_i)$

$c_{ij} = b_{i,(j+(T_i-r_i-1)(L_i+r_i)/T_i)}$ $j=1,2, \ldots, (L_i+r_i)/T_i$

Bits after radio frame segmentation in the $(T_i - r_i+1)^{th}$ 10 ms time interval: $(t=T_i - r_i+1)$

$c_{ij} = b_{i,(j+(T_i-r_i)(L_i+r_i)/T_i)}$ $\quad j=1,2, \ldots, (L_i+r_i)/T_i-1$

$c_{ij} = filler\_bit(0/1)$ $\quad j= (L_i+r_i)/T_i$ $\quad$ *(filler bit)*

…

Bits after radio frame segmentation in the T_i^{th} 10 ms time interval: $(t=T_i)$

$c_{ij} = b_{i,(j+(T_i-1)(L_i+r_i)/T_i)}$ $\quad j=1,2, \ldots, (L_i+r_i)/T_i-1$

$c_{ij} = filler\_bit(0/1)$ $\quad j=(L_i+r_i)/T_i$ $\quad$ *(filler bit)*

6.2.6 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. When the number of bits between different transmission time intervals is changed, bits are repeated 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 6.2.6 and subsections:

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

ΔN_{ij} : If positive - number of bits to be repeated in each radio frame on transport channel i with transport format combination j.
If negative - number of bits to be punctured in each radio frame on transport channel i with transport format combination j.

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 minimise the number of dedicated physical channels. Signalled from higher layers.

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

T: Number of transport channels in a CCTrCH.

Z_{mj}: Intermediate calculation variable.

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

k: Radio frame number in the transmission time interval of transport channel i ($0 \leq k < F_i$).

q: Average puncturing distance.

$I_F(k)$: 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).

$S(k)$: The shift of the puncturing pattern for radio frame k.

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

6.2.6.1 Determination of rate matching parameters

The following relations are used when calculating the rate-matching pattern:

$$Z_0 = 0$$

$$Z_{mj} = \left\lfloor \frac{\sum_{i=1}^{m} RM_i \cdot N_{ij}}{\sum_{i=1}^{T} RM_i \cdot N_{ij}} \cdot N_{data} \right\rfloor$$ for all m = 1 .. E, *where ë û means round downwards*

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

Puncturing can be used to minimise the number of required transmission capacity. The maximum amount of puncturing that can be applied is signalled at connection setup from higher layers and denoted by *PL*. The possible values for N_{data} are always multiples of the dedicated physical channel with the smallest capacity, reduced by the amount of bits which carry the L1 control signals. The supported set of N_{data} , denoted SET0, depends on the UE capabilities. $N_{data,j}$ for the transport format combination *j* is determined by executing the following algorithm:

$$SET1 = \left\{ N_{data} in SET0 \ such\ that\ N_{data} - PL \sum_{i=1}^{T} \frac{RM_i}{\min_l \{RM_l\}} N_{ij}\ is\ non-negative \right\}$$

$N_{data,j}$ = *min SET1*

The number of bits to be repeated or punctured, DN_{ij}, within one radio subframe for each transport channel *i* is calculated with the relations given at the beginning of this section for all possible transport format combinations *j* and selected every radio subframe. For each radio subframe, the rate matching pattern is calculated with the algorithm in Section 6.2.5.2, where $DN = DN_{ij}$ and $N = N_{ij}$.

Additionally, the following parameters are needed:

$$q = \lfloor N_{ij} / (|\Delta N_{ij}|) \rfloor,\ where\ \lfloor\ \rfloor\ means\ round\ downwards,\ and\ |\ |\ means\ absolute\ value.$$

If *q* is even

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

Else

q' = q

endif

for *l=0* to F_I -1

$$S(I_F(\lceil l * q' \rceil \bmod F_i)) = (\lceil l * q' \rceil div F_i) - -where\ \lceil\ \rceil\ means\ rounding\ upwards.$$

end for

6.2.6.2 Rate matching algorithm

Denote the bits before rate matching by:

$c_1, c_2, c_3, \ldots c_N$

The rate matching rule is as follows:

```
if puncturing is to be performed

y = -ΔN
e = (2*S(k) * y +  N) mod 2N    -- initial error between current and desired puncturing ratio
m = 1           -- index of current bit
do while m <= N
e = e – 2 * y           -- update error
if e <= 0 then          -- check if bit number m should be punctured
puncture bit cm
e = e + 2*N     -- update error
end if
m = m + 1               --  next bit
end do
else
y = ΔN

e = (2*S(k) * y +  N) mod 2N    -- initial error between current and desired puncturing ratio
m = 1               -- index of current bit
do while m <= N
e = e – 2 * y           -- update error
do while e <= 0         -- check if bit number m should be repeated
repeat bit cm
e = e +  2*N    -- update error
enddo
m = m + 1               --  next bit
end do
end if
```

A repeated bit is placed directly after the original one.

6.2.7 Second multiplexing

For both uplink and downlink, radio frames in each channel coding and multiplexing chains are serially multiplexed into a 10 ms coded composite transport channel.

Figure A-1 illustrates data flow from 1st interleaver down to 2nd interleaver in channel coding and multiplexing chain. In the figure, it is assumed that there are N different channel coding and multiplexing chains. Following subsection describes the input-output relationship of 2nd multiplexing in bit-wise manner, referring to the notations in Figure A-1, where the notation in each data block, for examples L_1, R_1, K_1, P/M, etc., indicate number of bits of the data block.

The bits before second multiplexing in uplink are described as follows:

Bits from rate matching 1: $c_{11}, c_{12}, \ldots c_{1K_1}$

Bits from rate matching 2: $c_{21}, c_{22}, \ldots c_{2K_2}$

Bits from rate matching 3: $c_{31}, c_{32}, \ldots c_{3K_3}$

...

Bits from rate matching N: $c_{N1}, c_{N2}, \ldots c_{NK_N}$

The bits after second multiplexing are denoted by $d_1, d_2, \ldots, d_P$

and defined by the following relationships:

For $j=1,2,3 \ldots,P$ *where* $P=K_1+K_2+ \ldots +K_N$

$d_j = c_{1j}$ $\quad j=1,2,\dots K_1$

$d_j = c_{2,(j-K_1)}$ $\quad j= K_1+1, K_1+2, \dots, K_1+K_2$

$d_j = c_{3,(j-(K_1+K_2))}$ $\quad j=(K_1+K_2)+1, (K_1+K_2)+2, \dots, (K_1+K_2)+ K_3$

…

$d_j = c_{N,(j-(K_1+K_2+\dots+K_{N-1}))}$ $\quad j=(K_1+K_2+\dots+ K_{N-1})+1, (K_1+K_2+\dots+ K_{N-1})+2, \dots, (K_1+K_2+\dots+ K_{N-1})+K_N$

6.2.8 Physical channel segmentation

<Editor's note: Physical channel segmentation will depend upon the QoS parameters of the different transport channels in each CCTrCH. It will be necessary to specify what are the parameters expected from L2 for it.>

<Editor's note: for physical channel segmentation, it is assumed that the segmented physical channels use the same SF>

Data after multiplexing of transport channels with different QoS can get segmented into multiple physical channels which are transmitted in parallel during a 10ms interval.

Figure A-1 illustrates data flow from 1st interleaver down to 2nd interleaver in channel coding and multiplexing chain. In the figures, it is assumed that there are N different channel coding and multiplexing chains, and M physical channels. The following subsection describes input-output relationship of physical channel segmentation in bit-wise manner, referring to the notation in Figure A-1, where the notation in each data block, for examples $L_1, R_1, K_1, P/M$, etc., indicate number of bits of the data block.

The bits before physical channel segmentation are described as follows:

Bits from second multiplexing: $d_1, d_2, \dots , d_P$

M is the number of physical channel

The bits after physical channel segmentation are defined by the following relationship:

The first physical channel bits after physical channel segmentation:

$e_{1j} = d_j$ $\quad j=1,2,\dots,P/M$

The second physical channel bits after physical channel segmentation:

$e_{2j} = d_{(j+P/M)}$ $\quad j=1,2, \dots, P/M$

…

The M^{th} physical channel bits after physical channel segmentation:

$e_{Mj} = d_{(j+(M-1)P/M)}$ $\quad j=1,2, \dots, P/M$

6.2.9 2nd interleaving

The 2nd interleaving of channel interleaving consists of two stage operations. In first stage, the input sequence is written into rectangular matrix row by row. The second stage is inter-column permutation. The two-stage operations are described as follows, the input block length is assumed to be K_2.

First Stage:

(1) Set a column number $C_2 = 30$.

(2) Determine a row number R_2 by finding minimum integer R_2 such that,

$$K_2 <= R_2 \times C_2.$$

(3) The input sequence of the 2^{nd} interleaving is written into the $R_2 \times C_2$ rectangular matrix row by row.

Second Stage:

(1) Perform the inter-column permutation based on the pattern $\{P_2(j)\}$ (j=0,1, ..., C-1) that is shown in Table 4-yy, where $P_2(j)$ is the original column position of the j-th permuted column.

(2) The output of the 2nd interleaving is the sequence read out column by column from the inter-column permuted $R_2 \times C_2$ matrix and the output is pruned by deleting the non-existence bits in the input sequence, where the deleting bits number l_2 is defined as:

$$l_2 = R_2 \times C_2 - K_2.$$

Table 6.2.8-1

Column number C_2	Inter-column permutation pattern
30	{0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}

6.2.10 Physical channel mapping

- If transport data is less than the number of DPCH bits in a radio subframe, dynamic rate matching is applied to ensure that all resource units which belong to one user are either completely filled with data or empty.
- The transmission of the DPCH symbols shall be ON, only if there is data to transmit. If there is no data, the transmission shall be OFF.
- For transport channels not relying on TFCI for transport format detection (blind transport format detection or through higher layer signalling for transport format detection), the positions of the transport channels within the subframe should be fixed.
- For transport channels relying on TFCI for transport format detection, the positions of the transport channels should be non-fixed.

6.2.11 Multi-code Transmission

- For multi-code transmission several codes within one or several timeslots can be allocated for each user independently for uplink and downlink. Those resource units are negotiated by means of higher layers at the beginning of a transmission dependent on the individual services.

- For one user within a certain timeslot there is only one midamble code.

- Dependent on the actual amount of data to be transmitted not all resource units which are allocated to a certain link are used continuously. If no data is transmitted within a time slot during a subframe, then also the midamble will be omitted.

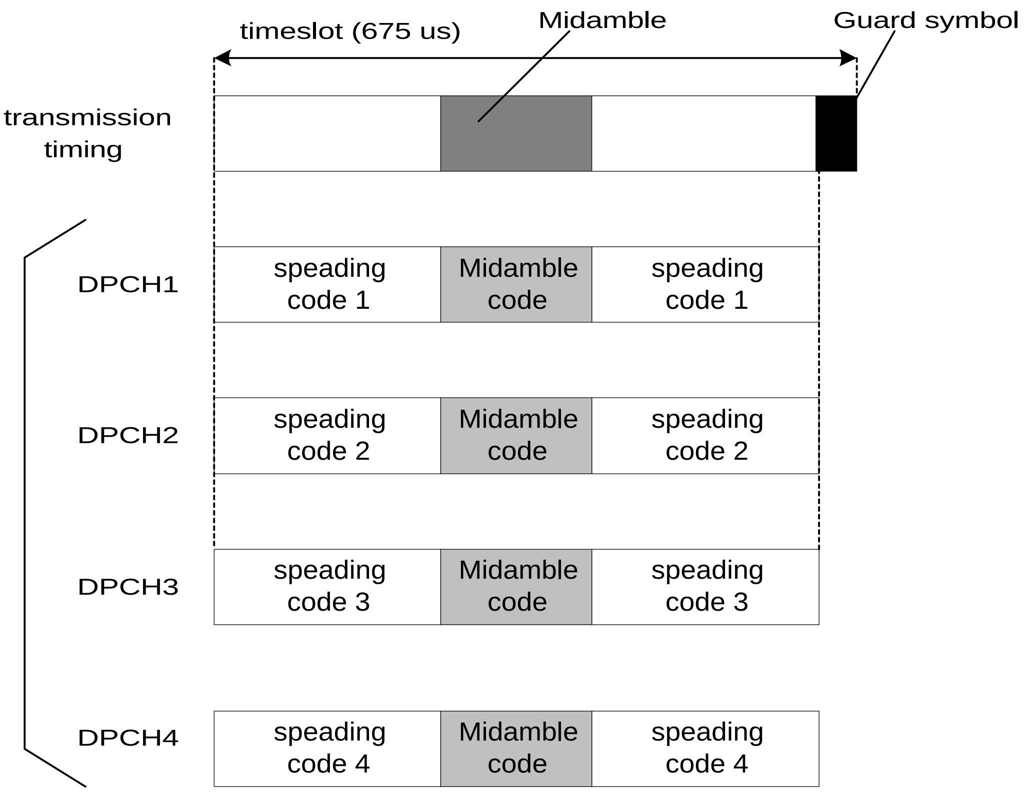


Fig. 6-7 Spreading code and midamble in multi-code transmission

6.2.12 Transport format detection

Transport format detection can be performed both with and without Transport Format Combination Indicator (TFCI). If a TFCI is transmitted, the receiver detects the transport format combination from the TFCI. When no TFCI is transmitted, so called blind transport format detection is used, i.e. the receiver side uses the possible transport format combinations as a priori information or the transport format is informed to the receiver side through higher layer signalling at connection setup.

6.2.12.1 Blind transport format detection

<Editor's note: The status of the support for blind transport format detection with more than one possible transport format in downlink is FFS. BRD may require high implementation complexity in UE.>

Blind transport format detection may be performed in the receiver by trying all possible combinations of the transport format.

6.2.12.2 Transport format detection based on TFCI

6.2.12.2.1 Transport Format Combination Indicator

Transport Format Combination Indicator (TFCI) informs the receiver of the number of bits in each subframe of each of the services currently in use. As soon as a certain bit-rate is known, the number of code channels, the spreading factor and the puncturing/repetition rate is immediately known from the rules described in section 6.2.5.

A connection may in general include the variable-rate services S_1, S_2, …, S_K. Each service S_i has a set of possible transport format combination indicators $TF_{i,1}$,$TF_{i,2}$,…$TF_{i,Li}$:

S_1: $TF_{1,1}$, … , $TF_{1,L1}$

S_2: $TF_{2,1}$, … , $TF_{2,L2}$

…

S_K: $TF_{K,1}$, … , $TF_{K,LK}$

This gives L=L1xL2x…xLK service rate combinations, and thus it is required that L is less than or equal to 64 with the default TFCI word or 1024 with the extended TFCI word.

These service rate combinations shall be mapped to a certain service rate combination number, *m*, in the following way:

For j=K:-1:1,

SRC[j]= m MOD L[j];

m = m DIV L[j];

End;

From this pseudo-code, given a service rate combination number, i.e. a certain combination of TFCI bits, *m*, SRC contains the rates of each of the K services. The integer values used for *m* shall be consecutive, starting from 0. Note that this code gives the mapping rule from *m* to SRC, i.e. the rule used in the receiving side. The mapping rule from SRC to *m*.

6.3 Coding for layer 1 control

6.3.1 Coding of transport format combination indicator (TFCI)

The number of TFCI bits is variable and is set at the beginning of the call via higher layer signalling. Encoding of the TFCI bits depends on the number of them. If there are at most 6 bits of TFCI the channel encoding is done as described in section 6.3.1.1. Correspondingly, if the TFCI word is extended to 7-10 bits the channel encoding is done as explained in the section 6.3.1.2. Also specific coding of less than 6 bits is possible as explained in 6.3.1.3. For improved TFCI detection reliability repetition is used to increase the number of TFCI bits. Additionally, with any TFCI coding scheme it is assumed that in the receiver combining of two successive TFCI words will be performed if the shortest transmission time interval of any TrCH is at least 20 ms.

6.3.1.1 Default TFCI word

If the number of TFCI bits is 6 a biorthogonal (32, 6) block code is used. The code words of the biorthogonal (32, 6) code are from two mutually biorthogonal sets, $S_{C_5} = \{C_5(0), C_5(1),.., C_5(31)\}$ and its binary complement, $\overline{S}_{C_5} = \{\overline{C}_5(0), \overline{C}_5(1),.., \overline{C}_5(31)\}$. Words of set S_{C5} are from the level 5 of the code three, which is generated, using the short code generation method defined in chapter 6.2 of 25.213. The mapping of information bits to code words is shown in the Table 6.3.1- 1

Table 6.3.1- 2 Mapping of information bits to code words for biorthogonal (32, 6) code.

Information bits	Code word
000000	$C_5(0)$
000001	$\overline{C_5(0)}$
000010	$C_5(1)$
...	...
111101	$\overline{C_5(30)}$
111110	$C_5(31)$
111111	$\overline{C_5(31)}$

6.3.1.2 Extended TFCI word

If the number of TFCI bits is 7-10 the TFCI information field is split into two words of length 5 bits as shown in the following formula:

$n := \lfloor \sqrt{TFCI} \rfloor$; n is the largest integer being smaller than or equal to the square root of the transmitted TFCI value.

if $TFCI < n^2 + n$

then $Word1 := n$; $Word2 := TFCI - n^2$

else $Word2 := n$; $Word1 := n^2 + 2n - TFCI$

Both of the words are encoded using biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_4} = \{C_4(0), C_4(1), \ldots, C_4(15)\}$ and its binary complement, $\overline{S}_{C_4} = \{\overline{C}_4(0), \overline{C}_4(1), \ldots, \overline{C}_4(15)\}$. Words of set S_{C_4} are from the level 4 of the code three, which is generated, using the short code generation method defined in TS C104. The mapping of information bits to code words is shown in theTable 6.3.1-2.

Table 6.3.1- 2 Mapping of information bits to code words for biorthogonal (16, 5) code.

Information bits	Code word
00000	$C_4(0)$
00001	$\overline{C_4(0)}$
00010	$C_4(1)$
...	...
11101	$\overline{C_4(14)}$
11110	$C_4(15)$
11111	$\overline{C_4(15)}$

6.3.1.3 Coding of short TFCI lengths

If the number of TFCI bits is 1 or 2, then repetition will be used for coding. In this case each bit is repeated 3 times giving 4-bit transmission for a single TFCI bit and 8-bit transmission for 2 TFCI bits.

If the number of TFCI bits is in the range of 3 to 5, then one word of the biorthogonal (16,5) block code, as described in section 6.3.1.2, will be used.

7 Annex

A.1 Data Flow from Radio Frame Segmentation to Physical Channel mapping

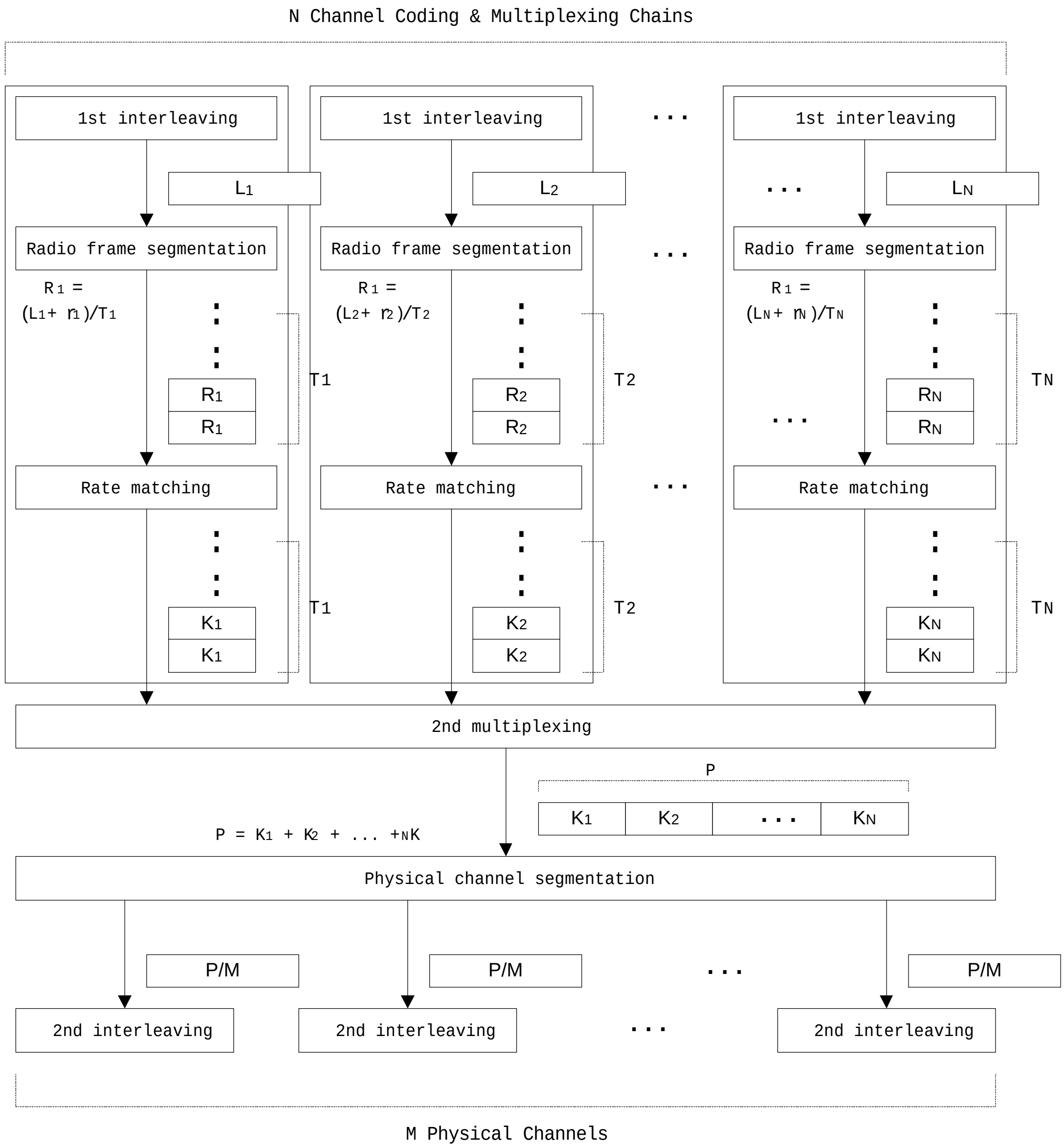


Figure A-1 Part of channel coding and multiplexing chains

8 History

Document history		
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