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Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	6
1 Scope	7
2 References	7
3 Definitions, symbols and abbreviations	7
3.1 Definitions	7
3.2 Symbols.....	7
3.3 Abbreviations	8
4 Mapping to physical channels	9
4.1 Uplink.....	9
4.2 Downlink.....	9
4.3 Sidelink	9
5 Channel coding, multiplexing and interleaving.....	10
5.1 Generic procedures.....	10
5.1.1 CRC calculation.....	10
5.1.2 Code block segmentation and code block CRC attachment	11
5.1.3 Channel coding	12
5.1.3.1 Tail biting convolutional coding	13
5.1.3.2 Turbo coding	14
5.1.3.2.1 Turbo encoder.....	14
5.1.3.2.2 Trellis termination for turbo encoder.....	15
5.1.3.2.3 Turbo code internal interleaver.....	15
5.1.4 Rate matching	17
5.1.4.1 Rate matching for turbo coded transport channels	17
5.1.4.1.1 Sub-block interleaver.....	17
5.1.4.1.2 Bit collection, selection and transmission.....	18
5.1.4.2 Rate matching for convolutionally coded transport channels and control information.....	21
5.1.4.2.1 Sub-block interleaver.....	22
5.1.4.2.2 Bit collection, selection and transmission.....	22
5.1.5 Code block concatenation.....	23
5.2 Uplink transport channels and control information	23
5.2.1 Random access channel	24
5.2.2 Uplink shared channel	24
5.2.2.1 Transport block CRC attachment.....	25
5.2.2.2 Code block segmentation and code block CRC attachment.....	25
5.2.2.3 Channel coding of UL-SCH.....	26
5.2.2.4 Rate matching	26
5.2.2.5 Code block concatenation	26
5.2.2.6 Channel coding of control information	26
5.2.2.6.1 Channel quality information formats for wideband CQI reports.....	39
5.2.2.6.2 Channel quality information formats for higher layer configured subband CQI reports.....	48
5.2.2.6.3 Channel quality information formats for UE selected subband CQI reports.....	59
5.2.2.6.4 Channel coding for CQI/PMI information in PUSCH.....	67
5.2.2.6.5 Channel coding for more than 11 bits of HARQ-ACK information.....	68
5.2.2.7 Data and control multiplexing.....	69
5.2.2.8 Channel interleaver	69
5.2.3 Uplink control information on PUCCH.....	71
5.2.3.1 Channel coding for UCI HARQ-ACK	72
5.2.3.2 Channel coding for UCI scheduling request	78
5.2.3.3 Channel coding for UCI channel quality information.....	78
5.2.3.3.1 Channel quality information formats for wideband reports.....	79

5.2.3.3.2	Channel quality information formats for UE-selected sub-band reports	86
5.2.3.4	Channel coding for UCI channel quality information and HARQ-ACK	96
5.2.4	Uplink control information on PUSCH without UL-SCH data	97
5.2.4.1	Channel coding of control information	97
5.2.4.2	Control information mapping	98
5.2.4.3	Channel interleaver	98
5.3	Downlink transport channels and control information	98
5.3.1	Broadcast channel	98
5.3.1.1	Transport block CRC attachment	99
5.3.1.2	Channel coding	99
5.3.1.3	Rate matching	100
5.3.2	Downlink shared channel, Paging channel and Multicast channel	100
5.3.2.1	Transport block CRC attachment	101
5.3.2.2	Code block segmentation and code block CRC attachment	101
5.3.2.3	Channel coding	101
5.3.2.4	Rate matching	101
5.3.2.5	Code block concatenation	101
5.3.3	Downlink control information	102
5.3.3.1	DCI formats	102
5.3.3.1.1	Format 0	102
5.3.3.1.2	Format 1	104
5.3.3.1.3	Format 1A	105
5.3.3.1.3A	Format 1B	107
5.3.3.1.4	Format 1C	108
5.3.3.1.4A	Format 1D	109
5.3.3.1.5	Format 2	110
5.3.3.1.5A	Format 2A	114
5.3.3.1.5B	Format 2B	116
5.3.3.1.5C	Format 2C	117
5.3.3.1.5D	Format 2D	119
5.3.3.1.6	Format 3	120
5.3.3.1.7	Format 3A	121
5.3.3.1.8	Format 4	121
5.3.3.1.9	Format 5	123
5.3.3.1.10	Format 6-0A	123
5.3.3.1.11	Format 6-0B	124
5.3.3.1.12	Format 6-1A	125
5.3.3.1.13	Format 6-1B	126
5.3.3.1.14	Format 6-2	127
5.3.3.2	CRC attachment	128
5.3.3.3	Channel coding	128
5.3.3.4	Rate matching	129
5.3.4	Control format indicator	129
5.3.4.1	Channel coding	129
5.3.5	HARQ indicator (HI)	129
5.3.5.1	Channel coding	130
5.4	Sidelink transport channels and control information	130
5.4.1	Sidelink broadcast channel	130
5.4.1.1	Transport block CRC attachment	131
5.4.1.2	Channel coding	131
5.4.1.3	Rate matching	131
5.4.2	Sidelink shared channel	131
5.4.3	Sidelink control information	132
5.4.3.1	SCI formats	132
5.4.3.1.1	SCI format 0	132
5.4.4	Sidelink discovery channel	133
6	Narrowband IoT	133
6.1	Mapping to physical channels	133
6.2	Generic procedures	133
6.3	Uplink transport channels and control information	134
6.3.1	Random access channel	134

6.3.2	Uplink shared channel	134
6.3.3	Uplink control information on NPUSCH without UL-SCH data.....	135
6.4	Downlink transport channels and control information	135
6.4.1	Broadcast channel.....	135
6.4.2	Downlink shared channel and Paging channel.....	135
6.4.3	Downlink control information	136
6.4.3.1	DCI Format N0	136
6.4.3.2	DCI Format N1	137
6.4.3.3	DCI Format N2	137
Annex A (informative): Change history		139
History		145

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1 Scope

The present document specifies the coding, multiplexing and mapping to physical channels for E-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. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".
- [3] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".
- [4] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".
- [5] 3GPP TS36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"
- [6] 3GPP TS36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1].

BL/CE: A Bandwidth-reduced Low-complexity or Coverage Enhanced (BL/CE) UE is capable of coverage enhancement mode A support and intends to access a cell in a coverage enhancement mode or is configured in a coverage enhancement mode.

3.2 Symbols

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

N_{RB}^{DL}	Downlink bandwidth configuration, expressed in number of resource blocks [2]
N_{RB}^{UL}	Uplink bandwidth configuration, expressed in number of resource blocks [2]
N_{RB}^{SL}	Sidelink bandwidth configuration, expressed in number of resource blocks [2]

N_{sc}^{RB}	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{symb}^{PUSCH}	Number of SC-FDMA symbols carrying PUSCH in a subframe
$N_{symb}^{PUSCH-initial}$	Number of SC-FDMA symbols carrying PUSCH in the initial PUSCH transmission subframe
N_{symb}^{UL}	Number of SC-FDMA symbols in an uplink slot
N_{symb}^{SL}	Number of SC-FDMA symbols in a sidelink slot
N_{SRS}	Number of SC-FDMA symbols used for SRS transmission in a subframe (0 or 1).

3.3 Abbreviations

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

BCH	Broadcast channel
CFI	Control Format Indicator
CP	Cyclic Prefix
CSI	Channel State Information
DCI	Downlink Control Information
DL-SCH	Downlink Shared channel
EPDCCH	Enhanced Physical Downlink Control channel
FDD	Frequency Division Duplexing
HI	HARQ indicator
LAA	Licensed-Assisted Access
MCH	Multicast channel
MPDCCH	MTC Physical Downlink Control Channel
NPBCH	Narrowband Physical Broadcast channel
NPDCCH	Narrowband Physical Downlink Control channel
NPDSCH	Narrowband Physical Downlink Shared channel
NPRACH	Narrowband Physical Random Access channel
NPUSCH	Narrowband Physical Uplink Shared channel
PBCH	Physical Broadcast channel
PCFICH	Physical Control Format Indicator channel
PCH	Paging channel
PDCCH	Physical Downlink Control channel
PDSCH	Physical Downlink Shared channel
PHICH	Physical HARQ indicator channel
PMCH	Physical Multicast channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access channel
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel
PUCCH	Physical Uplink Control channel
PUSCH	Physical Uplink Shared channel
RACH	Random Access channel
RI	Rank Indication
SCI	Sidelink Control Information
SL-BCH	Sidelink Broadcast Channel
SL-DCH	Sidelink Discovery Channel
SL-SCH	Sidelink Shared Channel
SR	Scheduling Request
SRS	Sounding Reference Signal
TDD	Time Division Duplexing
TPMI	Transmitted Precoding Matrix Indicator
UCI	Uplink Control Information
UL-SCH	Uplink Shared channel

4 Mapping to physical channels

The mapping to physical channels for Narrowband IoT is provided in subclause 6.1.

4.1 Uplink

Table 4.1-1 specifies the mapping of the uplink transport channels to their corresponding physical channels. Table 4.1-2 specifies the mapping of the uplink control channel information to its corresponding physical channel.

Table 4.1-1

TrCH	Physical Channel
UL-SCH	PUSCH
RACH	PRACH

Table 4.1-2

Control information	Physical Channel
UCI	PUCCH, PUSCH

4.2 Downlink

Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel.

Table 4.2-1

TrCH	Physical Channel
DL-SCH	PDSCH
BCH	PBCH
PCH	PDSCH
MCH	PMCH

Table 4.2-2

Control information	Physical Channel
CFI	PCFICH
HI	PHICH
DCI	PDCCH, EPDCCH, MPDCCH

4.3 Sidelink

Table 4.3-1 specifies the mapping of the sidelink transport channels to their corresponding physical channels. Table 4.3-2 specifies the mapping of the sidelink control information to its corresponding physical channel.

Table 4.3-1

TrCH	Physical Channel
SL-SCH	PSSCH
SL-BCH	PSBCH
SL-DCH	PSDCH

Table 4.3-2

Control information	Physical Channel
SCI	PSCCH

5 Channel coding, multiplexing and interleaving

Data and control streams from/to MAC layer are encoded /decoded to offer transport and control services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto/splitting from physical channels.

5.1 Generic procedures

This subclause contains coding procedures which are used for more than one transport channel or control information type.

5.1.1 CRC calculation

Denote the input bits to the CRC computation by $a_0, a_1, a_2, a_3, \dots, a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, \dots, p_{L-1}$. A is the size of the input sequence and L is the number of parity bits. The parity bits are generated by one of the following cyclic generator polynomials:

- $g_{\text{CRC24A}}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1]$ and;
- $g_{\text{CRC24B}}(D) = [D^{24} + D^{23} + D^6 + D^5 + D + 1]$ for a CRC length $L = 24$ and;
- $g_{\text{CRC16}}(D) = [D^{16} + D^{12} + D^5 + 1]$ for a CRC length $L = 16$.
- $g_{\text{CRC8}}(D) = [D^8 + D^7 + D^4 + D^3 + D + 1]$ for a CRC length of $L = 8$.

The encoding is performed in a systematic form, which means that in GF(2), the polynomial:

$$a_0 D^{A+23} + a_1 D^{A+22} + \dots + a_{A-1} D^{24} + p_0 D^{23} + p_1 D^{22} + \dots + p_{22} D^1 + p_{23}$$

yields a remainder equal to 0 when divided by the corresponding length-24 CRC generator polynomial, $g_{\text{CRC24A}}(D)$ or $g_{\text{CRC24B}}(D)$, the polynomial:

$$a_0 D^{A+15} + a_1 D^{A+14} + \dots + a_{A-1} D^{16} + p_0 D^{15} + p_1 D^{14} + \dots + p_{14} D^1 + p_{15}$$

yields a remainder equal to 0 when divided by $g_{\text{CRC16}}(D)$, and the polynomial:

$$a_0 D^{A+7} + a_1 D^{A+6} + \dots + a_{A-1} D^8 + p_0 D^7 + p_1 D^6 + \dots + p_6 D^1 + p_7$$

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

The bits after CRC attachment are denoted by $b_0, b_1, b_2, b_3, \dots, b_{B-1}$, where $B = A + L$. The relation between a_k and b_k is:

$$b_k = a_k \quad \text{for } k = 0, 1, 2, \dots, A-1$$

$$b_k = p_{k-A} \quad \text{for } k = A, A+1, A+2, \dots, A+L-1.$$

5.1.2 Code block segmentation and code block CRC attachment

The input bit sequence to the code block segmentation is denoted by $b_0, b_1, b_2, b_3, \dots, b_{B-1}$, where $B > 0$. If B is larger than the maximum code block size Z , segmentation of the input bit sequence is performed and an additional CRC sequence of $L = 24$ bits is attached to each code block. The maximum code block size is:

- $Z = 6144$.

If the number of filler bits F calculated below is not 0, filler bits are added to the beginning of the first block.

Note that if $B < 40$, filler bits are added to the beginning of the code block.

The filler bits shall be set to $\langle NULL \rangle$ at the input to the encoder.

Total number of code blocks C is determined by:

if $B \leq Z$

$$L = 0$$

Number of code blocks: $C = 1$

$$B' = B$$

else

$$L = 24$$

$$\text{Number of code blocks: } C = \lceil B / (Z - L) \rceil$$

$$B' = B + C \cdot L$$

end if

The bits output from code block segmentation, for $C \neq 0$, are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits for the code block number r .

Number of bits in each code block (applicable for $C \neq 0$ only):

First segmentation size: K_+ = minimum K in table 5.1.3-3 such that $C \cdot K \geq B'$

if $C = 1$

the number of code blocks with length K_+ is $C_+ = 1$, $K_- = 0$, $C_- = 0$

else if $C > 1$

Second segmentation size: K_- = maximum K in table 5.1.3-3 such that $K < K_+$

$$\Delta_K = K_+ - K_-$$

$$\text{Number of segments of size } K_- : C_- = \left\lfloor \frac{C \cdot K_+ - B'}{\Delta_K} \right\rfloor$$

$$\text{Number of segments of size } K_+ : C_+ = C - C_-$$

end if

$$\text{Number of filler bits: } F = C_+ \cdot K_+ + C_- \cdot K_- - B'$$

for $k = 0$ to $F-1$ -- Insertion of filler bits

```

     $c_{0k} = \langle \text{NULL} \rangle$ 

end for

 $k = F$ 

 $s = 0$ 

for  $r = 0$  to  $C-1$ 

    if  $r < C_-$ 

         $K_r = K_-$ 

    else

         $K_r = K_+$ 

    end if

    while  $k < K_r - L$ 

         $c_{rk} = b_s$ 

         $k = k + 1$ 

         $s = s + 1$ 

    end while

    if  $C > 1$ 

        The sequence  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-L-1)}$  is used to calculate the CRC parity bits  $p_{r0}, p_{r1}, p_{r2}, \dots, p_{r(L-1)}$  according to subclause 5.1.1 with the generator polynomial  $g_{\text{CRC24B}}(D)$ . For CRC calculation it is assumed that filler bits, if present, have the value 0.

        while  $k < K_r$ 

             $c_{rk} = p_{r(k+L-K_r)}$ 

             $k = k + 1$ 

        end while

    end if

     $k = 0$ 

end for

```

5.1.3 Channel coding

The bit sequence input for a given code block to channel coding is denoted by $c_0, c_1, c_2, c_3, \dots, c_{K-1}$, where K is the number of bits to encode. After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, \dots, d_{D-1}^{(i)}$, where D is the number of encoded bits per output stream and i indexes the encoder output stream. The relation between c_k and $d_k^{(i)}$ and between K and D is dependent on the channel coding scheme.

The following channel coding schemes can be applied to TrCHs:

- tail biting convolutional coding;
- turbo coding.