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Contents

Foreword

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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"

[7] 3GPP TS23.285, "Technical Specification Group Services and System Aspects; Architecture enhancements for V2X services"

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:

$N_{\mathrm{RB}}^{\mathrm{DL}}$ Downlink bandwidth configuration, expressed in number of resource blocks [2]

$N_{\mathrm{RB}}^{\mathrm{UL}}$ Uplink bandwidth configuration, expressed in number of resource blocks [2]

$N_{\mathrm{RB}}^{\mathrm{SL}}$	Sidelink bandwidth configuration, expressed in number of resource blocks [2]
$N_{\mathrm{subchannel}}^{\mathrm{SL}}$	Number of sidelink subchannels configured on the resource pool of a subcarrier [2]
$N_{\mathrm{sc}}^{\mathrm{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
$N_{\mathrm{symb}}^{\mathrm{PUSCH}}$	Number of SC-FDMA symbols carrying PUSCH in a subframe
$N_{\mathrm{symb}}^{\mathrm{PUSCH\text{-}initial}}$	Number of SC-FDMA symbols carrying PUSCH in the initial PUSCH transmission subframe
$N_{\mathrm{symb}}^{\mathrm{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\mathrm{symb}}^{\mathrm{SL}}$	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
MUST	Multiuser Superposition Transmission
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 $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. 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:

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

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

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

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

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

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

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

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

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

$b_k = a_k$ for k = 0, 1, 2, …, A-1

$b_k = p_{k-A}$ for k = A, A+1, A+2,..., 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 $b_0, b_1, b_2, b_3, ..., b_{B-1}$, 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 <*NULL*> at the input to the encoder.

Total number of code blocks C is determined by:

if $B \le Z$

$L = 0$

Number of code blocks: $C = 1$

$B' = B$

else

$L = 24$

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 $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, 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 $C \cdot K \ge B'$

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 $K < K_+$

$\Delta_K = K_+ - K_-$

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

Number of segments of size K_+: $C_+ = C - C_-$.

end if

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

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

$c_{0k} =< NULL >$

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 $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r - L - 1)}$ is used to calculate the CRC parity bits $p_{r0}, p_{r1}, p_{r2}, ..., p_{r(L-1)}$ according to subclause 5.1.1 with the generator polynomial $g_{CRC24B}(D)$. 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 $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits to encode. After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, 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.