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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

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

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1 Scope

The present document specifies the coding, multiplexing and mapping to physical channels for 5G NR.

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 38.201: "NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.211: "NR; Physical channels and modulation"

[5] 3GPP TS 38.213: "NR; Physical layer procedures for control"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[9] 3GPP TS 38.331: "NR; 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 TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

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

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

BCH	Broadcast channel
CBG	Code block group
CBGTI	Code block group transmission information

CORESET	Control resource set
CQI	Channel quality indicator
CRC	Cyclic redundancy check
CRI	CSI-RS resource indicator
CSI	Channel state information
CSI-RS	CSI reference signal
DAI	Downlink assignment index
DCI	Downlink control information
DL	Downlink
DL-SCH	Downlink shared channel
DMRS	Dedicated demodulation reference signal
HARQ	Hybrid automatic repeat request
HARQ-ACK	Hybrid automatic repeat request acknowledgement
LDPC	Low density parity check
LI	Layer indicator
MCS	Modulation and coding scheme
OFDM	Orthogonal frequency division multiplex
PBCH	Physical broadcast channel
PCH	Paging channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PMI	Precoding matrix indicator
PRB	Physical resource block
PRACH	Physical random access channel
PTRS	Phase-tracking reference signal
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
RACH	Random access channel
RI	Rank indicator
RSRP	Reference signal received power
SFN	System frame number
SR	Scheduling request
SRS	Sounding reference signal
SS	Synchronisation signal
SUL	Supplementary uplink
TPC	Transmit power control
TrCH	Transport channel
UCI	Uplink control information
UE	User equipment
UL	Uplink
UL-SCH	Uplink shared channel
VRB	Virtual resource block
ZP CSI-RS	Zero power CSI-RS

4 Mapping to physical channels

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

Table 4.2-2

Control information	Physical Channel
DCI	PDCCH

5 General procedures

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 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 $p_0, p_1, p_2, p_3, ..., p_{L-1}$, where 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:

- $g_{\text{CRC24A}}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1]$ for a CRC length $L = 24$;
- $g_{\text{CRC24B}}(D) = [D^{24} + D^{23} + D^6 + D^5 + D + 1]$ for a CRC length $L = 24$;
- $g_{\text{CRC24C}}(D) = [D^{24} + D^{23} + D^{21} + D^{20} + D^{17} + D^{15} + D^{13} + D^{12} + D^8 + D^4 + D^2 + D + 1]$ for a CRC length $L = 24$;
- $g_{\text{CRC16}}(D) = [D^{16} + D^{12} + D^5 + 1]$ for a CRC length $L = 16$;
- $g_{\text{CRC11}}(D) = [D^{11} + D^{10} + D^9 + D^5 + 1]$ for a CRC length $L = 11$;
- $g_{\text{CRC6}}(D) = [D^6 + D^5 + 1]$ for a CRC length $L = 6$.

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

$$a_0 D^{A+L-1} + a_1 D^{A+L-2} + ... + a_{A-1} D^L + p_0 D^{L-1} + p_1 D^{L-2} + ... + p_{L-2} D^1 + p_{L-1}$$

yields a remainder equal to 0 when divided by the corresponding CRC generator polynomial.

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 $k = A, A+1, A+2,..., A+L-1$.

5.2 Code block segmentation and code block CRC attachment

5.2.1 Polar coding

The input bit sequence to the code block segmentation is denoted by $a_0, a_1, a_2, a_3,..., a_{A-1}$, where $A > 0$.

if $I_{seg} = 1$

Number of code blocks: $C = 2$;

else

Number of code blocks: $C = 1$

end if

$A' = \lceil A/C \rceil \cdot C$;

for $i = 0$ to $A' - A - 1$

$a'_i = 0$;

end for

for $i = A' - A$ to $A' - 1$

$a'_i = a_{i-(A'-A)}$;

end for

$s = 0$;

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

for $k = 0$ to $A'/C - 1$

$c_{rk} = a'_s$;

$s = s + 1$;

end for

The sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3},..., c_{r(A'/C-1)}$ is used to calculate the CRC parity bits $p_{r0}, p_{r1}, p_{r2},..., p_{r(L-1)}$ according to Clause 5.1 with a generator polynomial of length L.

for $k = A'/C$ to $A'/C + L - 1$

$c_{rk} = p_{r(k-A'/C)}$;

end for

end for

The value of A is no larger than 1706.

5.2.2 Low density parity check coding

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 K_{cb}, segmentation of the input bit sequence is performed and an additional CRC sequence of $L = 24$ bits is attached to each code block.

For LDPC base graph 1, the maximum code block size is:

- $K_{cb} = 8448$.

For LDPC base graph 2, the maximum code block size is:

- $K_{cb} = 3840$.

Total number of code blocks C is determined by:

if $B \le K_{\mathbf{cb}}$

$L = 0$

Number of code blocks: $C = 1$

$B' = B$

else

$L = 24$

Number of code blocks: $C = \lceil B/(K_{cb} - L) \rceil$.

$B' = B + C \cdot L$

end if

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

The number of bits K in each code block is calculated as:

$K' = B'/C$;

For LDPC base graph 1,

$K_b = 22$.

For LDPC base graph 2,

if $B > 640$

$K_b = 10$;

elseif $B > 560$

$K_b = 9$;

elseif $B > 192$

$K_b = 8$;

else

$K_b = 6$;

end if

find the minimum value of Z in all sets of lifting sizes in Table 5.3.2-1, denoted as Z_c, such that $K_b \cdot Z_c \geq K'$, and set $K = 22Z_c$ for LDPC base graph 1 and $K = 10Z_c$ for LDPC base graph 2;

The bit sequence c_{rk} is calculated as:

$s = 0$;

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

for $k = 0$ to $K'-L-1$

$c_{rk} = b_s$;

$s = s+1$;

end for

if $C > 1$

The sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K'-L-1)}$ is used to calculate the CRC parity bits $p_{r0}, p_{r1}, p_{r2}, ..., p_{r(L-1)}$ according to Clause 5.1 with the generator polynomial $g_{\text{CRC24B}}(D)$.

for $k = K'-L$ to $K'-1$

$c_{rk} = p_{r(k+L-K')}$;

end for

end if

for $k = K'$ to $K-1$ -- Insertion of filler bits

$c_{rk} = <NULL>$;

end for

end for

5.3 Channel coding

Usage of coding scheme for the different types of TrCH is shown in table 5.3-1. Usage of coding scheme for the different control information types is shown in table 5.3-2.

Table 5.3-1: Usage of channel coding scheme for TrCHs

TrCH	Coding scheme
UL-SCH	LDPC
DL-SCH	
PCH	
BCH	Polar code

Table 5.3-2: Usage of channel coding scheme for control information

Control Information	Coding scheme
DCI	Polar code
UCI	Block code
	Polar code

5.3.1 Polar 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 $d_0, d_1, d_2, ..., d_{N-1}$, where $N = 2^n$ and the value of n is determined by the following:

Denote by E the rate matching output sequence length as given in Clause 5.4.1;

If $E \le (9/8) \cdot 2^{(\lceil \log_2 E \rceil - 1)}$ and $K/E < 9/16$

$n_1 = \lceil \log_2 E \rceil - 1$;

else

$n_1 = \lceil \log_2 E \rceil$;

end if

$R_{\min} = 1/8$;

$n_2 = \lceil \log_2 (K/R_{\min}) \rceil$;

$n = \max\{\min\{n_1, n_2, n_{\max}\}, n_{\min}\}$

where $n_{\min} = 5$.

UE is not expected to be configured with $K + n_{PC} > E$, where n_{PC} is the number of parity check bits defined in Clause 5.3.1.2.

5.3.1.1 Interleaving

The bit sequence $c_0, c_1, c_2, c_3, ..., c_{K-1}$ is interleaved into bit sequence $c'_0, c'_1, c'_2, c'_3, ..., c'_{K-1}$ as follows:

$c'_k = c_{\Pi(k)}$, $k = 0,1,...,K-1$

where the interleaving pattern $\Pi(k)$ is given by the following:

if $I_{IL} = 0$

$\Pi(k) = k$, $k = 0,1,...,K-1$

else

$k = 0$;

for $m = 0$ to $K_{IL}^{\max} - 1$

if $\Pi_{IL}^{\max}(m) \ge K_{IL}^{\max} - K$

$\Pi(k) = \Pi_{IL}^{\max}(m) - (K_{IL}^{\max} - K)$;

$k = k + 1$;

        end if

      end for

  end if

where $\Pi_{IL}^{\max}(m)$ is given by Table 5.3.1.1-1 and $K_{IL}^{\max} = 164$.

Table 5.3.1.1-1: Interleaving pattern $\Pi_{IL}^{\max}(m)$

m	$\Pi_{IL}^{\max}(m)$	m	$\Pi_{IL}^{\max}(m)$	m	$\Pi_{IL}^{\max}(m)$	m	$\Pi_{IL}^{\max}(m)$	m	$\Pi_{IL}^{\max}(m)$	m	$\Pi_{IL}^{\max}(m)$
0	0	28	67	56	122	84	68	112	33	140	38
1	2	29	69	57	123	85	73	113	36	141	144
2	4	30	70	58	126	86	78	114	44	142	39
3	7	31	71	59	127	87	84	115	47	143	145
4	9	32	72	60	129	88	90	116	64	144	40
5	14	33	76	61	132	89	92	117	74	145	146
6	19	34	77	62	134	90	94	118	79	146	41
7	20	35	81	63	138	91	96	119	85	147	147
8	24	36	82	64	139	92	99	120	97	148	148
9	25	37	83	65	140	93	102	121	100	149	149
10	26	38	87	66	1	94	105	122	103	150	150
11	28	39	88	67	3	95	107	123	117	151	151
12	31	40	89	68	5	96	109	124	125	152	152
13	34	41	91	69	8	97	112	125	131	153	153
14	42	42	93	70	10	98	114	126	136	154	154
15	45	43	95	71	15	99	116	127	142	155	155
16	49	44	98	72	21	100	121	128	12	156	156
17	50	45	101	73	27	101	124	129	17	157	157
18	51	46	104	74	29	102	128	130	23	158	158
19	53	47	106	75	32	103	130	131	37	159	159
20	54	48	108	76	35	104	133	132	48	160	160
21	56	49	110	77	43	105	135	133	75	161	161
22	58	50	111	78	46	106	141	134	80	162	162
23	59	51	113	79	52	107	6	135	86	163	163
24	61	52	115	80	55	108	11	136	137		
25	62	53	118	81	57	109	16	137	143		
26	65	54	119	82	60	110	22	138	13		
27	66	55	120	83	63	111	30	139	18		

5.3.1.2 Polar encoding

The Polar sequence $\mathbf{Q}_0^{N_{\max}-1} = \{Q_0^{N_{\max}}, Q_1^{N_{\max}}, ..., Q_{N_{\max}-1}^{N_{\max}}\}$ is given by Table 5.3.1.2-1, where $0 \le Q_i^{N_{\max}} \le N_{\max} - 1$ denotes a bit index before Polar encoding for $i = 0,1,..., N_{\max} - 1$ and $N_{\max} = 1024$. The Polar sequence $\mathbf{Q}_0^{N_{\max}-1}$ is in ascending order of reliability $W(Q_0^{N_{\max}}) < W(Q_1^{N_{\max}}) < ... < W(Q_{N_{\max}-1}^{N_{\max}})$, where $W(Q_i^{N_{\max}})$ denotes the reliability of bit index $Q_i^{N_{\max}}$.

For any code block encoded to N bits, a same Polar sequence $\mathbf{Q}_0^{N-1} = \{Q_0^N, Q_1^N, Q_2^N, ..., Q_{N-1}^N\}$ is used. The Polar sequence $\mathbf{Q}_0^{N-1}$ is a subset of Polar sequence $\mathbf{Q}_0^{N_{\max}-1}$ with all elements $Q_i^{N_{\max}}$ of values less than N, ordered in ascending order of reliability $W(Q_0^N) < W(Q_1^N) < W(Q_2^N) < ... < W(Q_{N-1}^N)$.

Denote $\overline{\mathbf{Q}}_I^N$ as a set of bit indices in Polar sequence $\mathbf{Q}_0^{N-1}$, and $\overline{\mathbf{Q}}_F^N$ as the set of other bit indices in Polar sequence $\mathbf{Q}_0^{N-1}$, where $\overline{\mathbf{Q}}_I^N$ and $\overline{\mathbf{Q}}_F^N$ are given in Clause 5.4.1.1, $|\overline{\mathbf{Q}}_I^N| = K + n_{PC}$, $|\overline{\mathbf{Q}}_F^N| = N - |\overline{\mathbf{Q}}_I^N|$, and n_{PC} is the number of parity check bits.

Denote $\mathbf{G}_N = (\mathbf{G}_2)^{\otimes n}$ as the n-th Kronecker power of matrix $\mathbf{G}_2$, where $\mathbf{G}_2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$.

For a bit index j with $j = 0,1,..., N-1$, denote $\mathbf{g}_j$ as the j-th row of $\mathbf{G}_N$ and $w(\mathbf{g}_j)$ as the row weight of $\mathbf{g}_j$, where $w(\mathbf{g}_j)$ is the number of ones in $\mathbf{g}_j$. Denote the set of bit indices for parity check bits as $\mathbf{Q}_{PC}^N$, where $|\mathbf{Q}_{PC}^N| = n_{PC}$. A number of $(n_{PC} - n_{PC}^{wm})$ parity check bits are placed in the $(n_{PC} - n_{PC}^{wm})$ least reliable bit indices in $\overline{\mathbf{Q}}_I^N$. A number of n_{PC}^{wm} other parity check bits are placed in the bit indices of minimum row weight in $\tilde{\mathbf{Q}}_I^N$, where $\tilde{\mathbf{Q}}_I^N$ denotes the $(|\overline{\mathbf{Q}}_I^N| - n_{PC})$ most reliable bit indices in $\overline{\mathbf{Q}}_I^N$; if there are more than n_{PC}^{wm} bit indices of the same minimum row weight