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Foreword

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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"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP 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 3GPP 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 3GPP 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 3GPP TR 21.905 [1].

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

- $K_{\text{cb}} = 8448$.

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 .

Number of bits in each code block:

$K' = B' / C$;

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 $K_b \cdot Z_c \ge K'$, and set $K = 22 Z_c$ for LDPC base graph 1 and $K = 10 Z_c$ for LDPC base graph 2;

$s = 0$;

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 Subclause 5.1 with the generator polynomial $g_{\mathrm{CRC24B}}(D)$.

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 Subclause 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 $n_{\min} = 5$.

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

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

$k = k + 1$;

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 Subclause 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 in $\tilde{\mathbf{Q}}_I^N$, the n_{PC}^{wm} other parity check bits are placed in the n_{PC}^{wm} bit indices of the highest reliability and the minimum row weight in $\tilde{\mathbf{Q}}_I^N$.

Generate $\mathbf{u} = [u_0\ u_1\ u_2\ ...u_{N-1}]$ according to the following:

$k = 0$;

if $n_{PC} > 0$

$y_0 = 0$; $y_1 = 0$; $y_2 = 0$; $y_3 = 0$; $y_4 = 0$;

for $n = 0$ to $N-1$

$y_t = y_0$; $y_0 = y_1$; $y_1 = y_2$; $y_2 = y_3$; $y_3 = y_4$; $y_4 = y_t$;

if $n \in \overline{\mathbf{Q}}_I^N$

if $n \in \mathbf{Q}_{PC}^N$

$u_n = y_0$;

else

$u_n = c'_k$;

$k = k+1$;

$y_0 = y_0 \oplus u_n$;

end if

else

$u_n = 0$;

end if

end for

else

for $n = 0$ to $N-1$

if $n \in \overline{\mathbf{Q}}_I^N$

$u_n = c'_k$;

$k = k+1$;

else

$u_n = 0$;

end if

end for

end if

The output after encoding $\mathbf{d} = [d_0\ d_1\ d_2\ ...\ d_{N-1}]$ is obtained by $\mathbf{d} = \mathbf{u}\mathbf{G}_N$. The encoding is performed in GF(2).

Table 5.3.1.2-1: Polar sequence $\mathbf{Q}_0^{N_{\max}-1}$ and its corresponding reliability $W\left(Q_i^{N_{\max}}\right)$

$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$	$W(Q_i^{N_{max}})$	$Q_i^{N_{max}}$
0	0	128	518	256	94	384	214	512	364	640	414	768	819	896	966
1	1	129	54	257	204	385	309	513	654	641	223	769	814	897	755
2	2	130	83	258	298	386	188	514	659	642	663	770	439	898	859
3	4	131	57	259	400	387	449	515	335	643	692	771	929	899	940
4	8	132	521	260	608	388	217	516	480	644	835	772	490	900	830
5	16	133	112	261	352	389	408	517	315	645	619	773	623	901	911
6	32	134	135	262	325	390	609	518	221	646	472	774	671	902	871
7	3	135	78	263	533	391	596	519	370	647	455	775	739	903	639
8	5	136	289	264	155	392	551	520	613	648	796	776	916	904	888
9	64	137	194	265	210	393	650	521	422	649	809	777	463	905	479
10	9	138	85	266	305	394	229	522	425	650	714	778	843	906	946
11	6	139	276	267	547	395	159	523	451	651	721	779	381	907	750
12	17	140	522	268	300	396	420	524	614	652	837	780	497	908	969
13	10	141	58	269	109	397	310	525	543	653	716	781	930	909	508
14	18	142	168	270	184	398	541	526	235	654	864	782	821	910	861
15	128	143	139	271	534	399	773	527	412	655	810	783	726	911	757
16	12	144	99	272	537	400	610	528	343	656	606	784	961	912	970
17	33	145	86	273	115	401	657	529	372	657	912	785	872	913	919
18	65	146	60	274	167	402	333	530	775	658	722	786	492	914	875
19	20	147	280	275	225	403	119	531	317	659	696	787	631	915	862
20	256	148	89	276	326	404	600	532	222	660	377	788	729	916	758
21	34	149	290	277	306	405	339	533	426	661	435	789	700	917	948
22	24	150	529	278	772	406	218	534	453	662	817	790	443	918	977
23	36	151	524	279	157	407	368	535	237	663	319	791	741	919	923
24	7	152	196	280	656	408	652	536	559	664	621	792	845	920	972
25	129	153	141	281	329	409	230	537	833	665	812	793	920	921	761
26	66	154	101	282	110	410	391	538	804	666	484	794	382	922	877
27	512	155	147	283	117	411	313	539	712	667	430	795	822	923	952
28	11	156	176	284	212	412	450	540	834	668	838	796	851	924	495
29	40	157	142	285	171	413	542	541	661	669	667	797	730	925	703
30	68	158	530	286	776	414	334	542	808	670	488	798	498	926	935
31	130	159	321	287	330	415	233	543	779	671	239	799	880	927	978
32	19	160	31	288	226	416	555	544	617	672	378	800	742	928	883
33	13	161	200	289	549	417	774	545	604	673	459	801	445	929	762
34	48	162	90	290	538	418	175	546	433	674	622	802	471	930	503
35	14	163	545	291	387	419	123	547	720	675	627	803	635	931	925
36	72	164	292	292	308	420	658	548	816	676	437	804	932	932	878
37	257	165	322	293	216	421	612	549	836	677	380	805	687	933	735
38	21	166	532	294	416	422	341	550	347	678	818	806	903	934	993
39	132	167	263	295	271	423	777	551	897	679	461	807	825	935	885
40	35	168	149	296	279	424	220	552	243	680	496	808	500	936	939
41	258	169	102	297	158	425	314	553	662	681	669	809	846	937	994
42	26	170	105	298	337	426	424	554	454	682	679	810	745	938	980
43	513	171	304	299	550	427	395	555	318	683	724	811	826	939	926
44	80	172	296	300	672	428	673	556	675	684	841	812	732	940	764
45	37	173	163	301	118	429	583	557	618	685	629	813	446	941	941
46	25	174	92	302	332	430	355	558	898	686	351	814	962	942	967
47	22	175	47	303	579	431	287	559	781	687	467	815	936	943	886
48	136	176	267	304	540	432	183	560	376	688	438	816	475	944	831
49	260	177	385	305	389	433	234	561	428	689	737	817	853	945	947
50	264	178	546	306	173	434	125	562	665	690	251	818	867	946	507
51	38	179	324	307	121	435	557	563	736	691	462	819	637	947	889
52	514	180	208	308	553	436	660	564	567	692	442	820	907	948	984
53	96	181	386	309	199	437	616	565	840	693	441	821	487	949	751
54	67	182	150	310	784	438	342	566	625	694	469	822	695	950	942
55	41	183	153	311	179	439	316	567	238	695	247	823	746	951	996
56	144	184	165	312	228	440	241	568	359	696	683	824	828	952	971
57	28	185	106	313	338	441	778	569	457	697	842	825	753	953	890
58	69	186	55	314	312	442	563	570	399	698	738	826	854	954	509
59	42	187	328	315	704	443	345	571	787	699	899	827	857	955	949
60	516	188	536	316	390	444	452	572	591	700	670	828	504	956	973
61	49	189	577	317	174	445	397	573	678	701	783	829	799	957	1000
62	74	190	548	318	554	446	403	574	434	702	849	830	255	958	892
63	272	191	113	319	581	447	207	575	677	703	820	831	964	959	950
64	160	192	154	320	393	448	674	576	349	704	728	832	909	960	863
65	520	193	79	321	283	449	558	577	245	705	928	833	719	961	759
66	288	194	269	322	122	450	785	578	458	706	791	834	477	962	1008
67	528	195	108	323	448	451	432	579	666	707	367	835	915	963	510
68	192	196	578	324	353	452	357	580	620	708	901	836	638	964	979
69	544	197	224	325	561	453	187	581	363	709	630	837	748	965	953
70	70	198	166	326	203	454	236	582	127	710	685	838	944	966	763
71	44	199	519	327	63	455	664	583	191	711	844	839	869	967	974
72	131	200	552	328	340	456	624	584	782	712	633	840	491	968	954
73	81	201	195	329	394	457	587	585	407	713	711	841	699	969	879
74	50	202	270	330	527	458	780	586	436	714	253	842	754	970	981
75	73	203	641	331	582	459	705	587	626	715	691	843	858	971	982
76	15	204	523	332	556	460	126	588	571	716	824	844	478	972	927
77	320	205	275	333	181	461	242	589	465	717	902	845	968	973	995
78	133	206	580	334	295	462	565	590	681	718	686	846	383	974	765
79	52	207	291	335	285	463	398	591	246	719	740	847	910	975	956
80	23	208	59	336	232	464	346	592	707	720	850	848	815	976	887
81	134	209	169	337	124	465	456	593	350	721	375	849	976	977	985
82	384	210	560	338	205	466	358	594	599	722	444	850	870	978	997
83	76	211	114	339	182	467	405	595	668	723	470	851	917	979	986
84	137	212	277	340	643	468	303	596	790	724	483	852	727	980	943
85	82	213	156	341	562	469	569	597	460	725	415	853	493	981	891
86	56	214	87	342	286	470	244	598	249	726	485	854	873	982	998
87	27	215	197	343	585	471	595	599	682	727	905	855	701	983	766

88	97	216	116	344	299	472	189	600	573	728	795	856	931	984	511
89	39	217	170	345	354	473	566	601	411	729	473	857	756	985	988
90	259	218	61	346	211	474	676	602	803	730	634	858	860	986	1001
91	84	219	531	347	401	475	361	603	789	731	744	859	499	987	951
92	138	220	525	348	185	476	706	604	709	732	852	860	731	988	1002
93	145	221	642	349	396	477	589	605	365	733	960	861	823	989	893
94	261	222	281	350	344	478	215	606	440	734	865	862	922	990	975
95	29	223	278	351	586	479	786	607	628	735	693	863	874	991	894
96	43	224	526	352	645	480	647	608	689	736	797	864	918	992	1009
97	98	225	177	353	593	481	348	609	374	737	906	865	502	993	955
98	515	226	293	354	535	482	419	610	423	738	715	866	933	994	1004
99	88	227	388	355	240	483	406	611	466	739	807	867	743	995	1010
100	140	228	91	356	206	484	464	612	793	740	474	868	760	996	957
101	30	229	584	357	95	485	680	613	250	741	636	869	881	997	983
102	146	230	769	358	327	486	801	614	371	742	694	870	494	998	958
103	71	231	198	359	564	487	362	615	481	743	254	871	702	999	987
104	262	232	172	360	800	488	590	616	574	744	717	872	921	1000	1012
105	265	233	120	361	402	489	409	617	413	745	575	873	501	1001	999
106	161	234	201	362	356	490	570	618	603	746	913	874	876	1002	1016
107	576	235	336	363	307	491	788	619	366	747	798	875	847	1003	767
108	45	236	62	364	301	492	597	620	468	748	811	876	992	1004	989
109	100	237	282	365	417	493	572	621	655	749	379	877	447	1005	1003
110	640	238	143	366	213	494	219	622	900	750	697	878	733	1006	990
111	51	239	103	367	568	495	311	623	805	751	431	879	827	1007	1005
112	148	240	178	368	832	496	708	624	615	752	607	880	934	1008	959
113	46	241	294	369	588	497	598	625	684	753	489	881	882	1009	1011
114	75	242	93	370	186	498	601	626	710	754	866	882	937	1010	1013
115	266	243	644	371	646	499	651	627	429	755	723	883	963	1011	895
116	273	244	202	372	404	500	421	628	794	756	486	884	747	1012	1006
117	517	245	592	373	227	501	792	629	252	757	908	885	505	1013	1014
118	104	246	323	374	896	502	802	630	373	758	718	886	855	1014	1017
119	162	247	392	375	594	503	611	631	605	759	813	887	924	1015	1018
120	53	248	297	376	418	504	602	632	848	760	476	888	734	1016	991
121	193	249	770	377	302	505	410	633	690	761	856	889	829	1017	1020
122	152	250	107	378	649	506	231	634	713	762	839	890	965	1018	1007
123	77	251	180	379	771	507	688	635	632	763	725	891	938	1019	1015
124	164	252	151	380	360	508	653	636	482	764	698	892	884	1020	1019
125	768	253	209	381	539	509	248	637	806	765	914	893	506	1021	1021
126	268	254	284	382	111	510	369	638	427	766	752	894	749	1022	1022
127	274	255	648	383	331	511	190	639	904	767	868	895	945	1023	1023

5.3.2 Low density parity check 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 as defined in Subclause 5.2.2. After encoding the bits are denoted by $d_0, d_1, d_2, ..., d_{N-1}$, where $N = 66Z_c$ for LDPC base graph 1 and $N = 50Z_c$ for LDPC base graph 2, and the value of Z_c is given in Subclause 5.2.2.

For a code block encoded by LDPC, the following encoding procedure applies:

1) Find the set with index i_{LS} in Table 5.3.2-1 which contains Z_c.

2) for $k = 2Z_c$ to $K-1$

if $c_k \neq < NULL >$

$d_{k-2Z_c} = c_k$;

else

$c_k = 0$;

$d_{k-2Z_c} = < NULL >$;

end if

end for

3) Generate $N + 2Z_c - K$ parity bits $\mathbf{w} = \left[w_0, w_1, w_2, ..., w_{N+2Z_c-K-1}\right]^T$ such that $\mathbf{H} \times \begin{bmatrix} \mathbf{c} \\ \mathbf{w} \end{bmatrix} = \mathbf{0}$, where $\mathbf{c} = \left[c_0, c_1, c_2, ..., c_{K-1}\right]^T$; $\mathbf{0}$ is a column vector of all elements equal to 0. The encoding is performed in GF(2).

For LDPC base graph 1, a matrix of $\mathbf{H}_{\mathrm{BG}}$ has 46 rows with row indices $i = 0,1,2,...,45$ and 68 columns with column indices $j = 0,1,2,...,67$. For LDPC base graph 2, a matrix of $\mathbf{H}_{\mathrm{BG}}$ has 42 rows with row indices $i = 0,1,2,...,41$ and 52 columns with column indices $j = 0,1,2,...,51$. The elements in $\mathbf{H}_{\mathrm{BG}}$ with row and column indices given in Table 5.3.2-2 (for LDPC base graph 1) and Table 5.3.2-3 (for LDPC base graph 2) are of value 1, and all other elements in $\mathbf{H}_{\mathrm{BG}}$ are of value 0.

The matrix $\mathbf{H}$ is obtained by replacing each element of $\mathbf{H}_{\mathrm{BG}}$ with a $Z_c \times Z_c$ matrix, according to the following:

- Each element of value 0 in $\mathbf{H}_{\mathrm{BG}}$ is replaced by an all zero matrix $\mathbf{0}$ of size $Z_c \times Z_c$;
- Each element of value 1 in $\mathbf{H}_{\mathrm{BG}}$ is replaced by a circular permutation matrix $\mathbf{I}(P_{i,j})$ of size $Z_c \times Z_c$, where i and j are the row and column indices of the element, and $\mathbf{I}(P_{i,j})$ is obtained by circularly shifting the identity matrix $\mathbf{I}$ of size $Z_c \times Z_c$ to the right $P_{i,j}$ times. The value of $P_{i,j}$ is given by $P_{i,j} = \mathrm{mod}(V_{i,j}, Z_c)$. The value of $V_{i,j}$ is given by Tables 5.3.2-2 and 5.3.2-3 according to the set index i_{LS} and LDPC base graph.

4) for $k = K$ to $N + 2Z_c - 1$

$d_{k-2Z_c} = w_{k-K}$;

end for

Table 5.3.2-1: Sets of LDPC lifting size Z

Set index (i_{LS})	***Set of lifting sizes (Z)***
0	{2, 4, 8, 16, 32, 64, 128, 256}
1	{3, 6, 12, 24, 48, 96, 192, 384}
2	{5, 10, 20, 40, 80, 160, 320}
3	{7, 14, 28, 56, 112, 224}
4	{9, 18, 36, 72, 144, 288}
5	{11, 22, 44, 88, 176, 352}
6	{13, 26, 52, 104, 208}
7	{15, 30, 60, 120, 240}

Table 5.3.2-2: LDPC base graph 1 ($\mathbf{H}_{\mathrm{BG}}$) and its parity check matrices ($V_{i,j}$)

$\mathbf{H}_{BG}$		$V_{i,j}$							
Row index i	Column index j	Set index i_{LS} 0	1	2	3	4	5	6	7
0	0	250	307	73	223	211	294	0	135
	1	69	19	15	16	198	118	0	227
	2	226	50	103	94	188	167	0	126
	3	159	369	49	91	186	330	0	134
	5	100	181	240	74	219	207	0	84
	6	10	216	39	10	4	165	0	83
	9	59	317	15	0	29	243	0	53
	10	229	288	162	205	144	250	0	225
	11	110	109	215	216	116	1	0	205
	12	191	17	164	21	216	339	0	128
	13	9	357	133	215	115	201	0	75
	15	195	215	298	14	233	53	0	135
	16	23	106	110	70	144	347	0	217
	18	190	242	113	141	95	304	0	220
	19	35	180	16	198	216	167	0	90
	20	239	330	189	104	73	47	0	105
	21	31	346	32	81	261	188	0	137
	22	1	1	1	1	1	1	0	1
	23	0	0	0	0	0	0	0	0
1	0	2	76	303	141	179	77	22	96
	2	239	76	294	45	162	225	11	236
	3	117	73	27	151	223	96	124	136
	4	124	288	261	46	256	338	0	221
	5	71	144	161	119	160	268	10	128
	7	222	331	133	157	76	112	0	92
	8	104	331	4	133	202	302	0	172
	9	173	178	80	87	117	50	2	56
	11	220	295	129	206	109	167	16	11
	12	102	342	300	93	15	253	60	189
	14	109	217	76	79	72	334	0	95
	15	132	99	266	9	152	242	6	85
	16	142	354	72	118	158	257	30	153
	17	155	114	83	194	147	133	0	87
	19	255	331	260	31	156	9	168	163
	21	28	112	301	187	119	302	31	216
	22	0	0	0	0	0	0	105	0
	23	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0
2	0	106	205	68	207	258	226	132	189
	1	111	250	7	203	167	35	37	4
	2	185	328	80	31	220	213	21	225
	4	63	332	280	176	133	302	180	151
	5	117	256	38	180	243	111	4	236
	6	93	161	227	186	202	265	149	117
	7	229	267	202	95	218	128	48	179
	8	177	160	200	153	63	237	38	92
	9	95	63	71	177	0	294	122	24
	10	39	129	106	70	3	127	195	68
	13	142	200	295	77	74	110	155	6
	14	225	88	283	214	229	286	28	101
	15	225	53	301	77	0	125	85	33
	17	245	131	184	198	216	131	47	96
	18	205	240	246	117	269	163	179	125
	19	251	205	230	223	200	210	42	67
	20	117	13	276	90	234	7	66	230
	24	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0
3	0	121	276	220	201	187	97	4	128
	1	89	87	208	18	145	94	6	23
	3	84	0	30	165	166	49	33	162
	4	20	275	197	5	108	279	113	220
	6	150	199	61	45	82	139	49	43
	7	131	153	175	142	132	166	21	186
	8	243	56	79	16	197	91	6	96
	10	136	132	281	34	41	106	151	1
	11	86	305	303	155	162	246	83	216
	12	246	231	253	213	57	345	154	22
	13	219	341	164	147	36	269	87	24
	14	211	212	53	69	115	185	5	167
	16	240	304	44	96	242	249	92	200
	17	76	300	28	74	165	215	173	32
	18	244	271	77	99	0	143	120	235
	20	144	39	319	30	113	121	2	172
	21	12	357	68	158	108	121	142	219
	22	1	1	1	1	1	1	0	1
	25	0	0	0	0	0	0	0	0
4	0	157	332	233	170	246	42	24	64
	1	102	181	205	10	235	256	204	211
	26	0	0	0	0	0	0	0	0
5	0	205	195	83	164	261	219	185	2
	1	236	14	292	59	181	130	100	171
	3	194	115	50	86	72	251	24	47
	12	231	166	318	80	283	322	65	143
	16	28	241	201	182	254	295	207	210

$\mathbf{H}_{BG}$		$V_{i,j}$							
Row index i	Column index j	Set index i_{LS} 0	1	2	3	4	5	6	7
15	1	96	2	290	120	0	348	6	138
	10	65	210	60	131	183	15	81	220
	13	63	318	130	209	108	81	182	173
	18	75	55	184	209	68	176	53	142
	25	179	269	51	81	64	113	46	49
	37	0	0	0	0	0	0	0	0
16	1	64	13	69	154	270	190	88	78
	3	49	338	140	164	13	293	198	152
	11	49	57	45	43	99	332	160	84
	20	51	289	115	189	54	331	122	5
	22	154	57	300	101	0	114	182	205
	38	0	0	0	0	0	0	0	0
17	0	7	260	257	56	153	110	91	183
	14	164	303	147	110	137	228	184	112
	16	59	81	128	200	0	247	30	106
	17	1	358	51	63	0	116	3	219
	21	144	375	228	4	162	190	155	129
	39	0	0	0	0	0	0	0	0
18	1	42	130	260	199	161	47	1	183
	12	233	163	294	110	151	286	41	215
	13	8	280	291	200	0	246	167	180
	18	155	132	141	143	241	181	68	143
	19	147	4	295	186	144	73	148	14
	40	0	0	0	0	0	0	0	0
19	0	60	145	64	8	0	87	12	179
	1	73	213	181	6	0	110	6	108
	7	72	344	101	103	118	147	166	159
	8	127	242	270	198	144	258	184	138
	10	224	197	41	8	0	204	191	196
	41	0	0	0	0	0	0	0	0
20	0	151	187	301	105	265	89	6	77
	3	186	206	162	210	81	65	12	187
	9	217	264	40	121	90	155	15	203
	11	47	341	130	214	144	244	5	167
	22	160	59	10	183	228	30	30	130
	42	0	0	0	0	0	0	0	0
21	1	249	205	79	192	64	162	6	197
	5	121	102	175	131	46	264	86	122
	16	109	328	132	220	266	346	96	215
	20	131	213	283	50	9	143	42	65
	21	171	97	103	106	18	109	199	216
	43	0	0	0	0	0	0	0	0
22	0	64	30	177	53	72	280	44	25
	12	142	11	20	0	189	157	58	47
	13	188	233	55	3	72	236	130	126
	17	158	22	316	148	257	113	131	178
	44	0	0	0	0	0	0	0	0
23	1	156	24	249	88	180	18	45	185
	2	147	89	50	203	0	6	18	127
	10	170	61	133	168	0	181	132	117
	18	152	27	105	122	165	304	100	199
	45	0	0	0	0	0	0	0	0
24	0	112	298	289	49	236	38	9	32
	3	86	158	280	157	199	170	125	178
	4	236	235	110	64	0	249	191	2
	11	116	339	187	193	266	288	28	156
	22	222	234	281	124	0	194	6	58
	46	0	0	0	0	0	0	0	0
25	1	23	72	172	1	205	279	4	27
	6	136	17	295	166	0	255	74	141
	7	116	383	96	65	0	111	16	11
	14	182	312	46	81	183	54	28	181
	47	0	0	0	0	0	0	0	0
26	0	195	71	270	107	0	325	21	163
	2	243	81	110	176	0	326	142	131
	4	215	76	318	212	0	226	192	169
	15	61	136	67	127	277	99	197	98
	48	0	0	0	0	0	0	0	0
27	1	25	194	210	208	45	91	98	165
	6	104	194	29	141	36	326	140	232
	8	194	101	304	174	72	268	22	9
	49	0	0	0	0	0	0	0	0
28	0	128	222	11	146	275	102	4	32
	4	165	19	293	153	0	1	1	43
	19	181	244	50	217	155	40	40	200
	21	63	274	234	114	62	167	93	205
	50	0	0	0	0	0	0	0	0
29	1	86	252	27	150	0	273	92	232
	14	236	5	308	11	180	104	136	32
	18	84	147	117	53	0	243	106	118
	25	6	78	29	68	42	107	6	103
	51	0	0	0	0	0	0	0	0
30	0	216	159	91	34	0	171	2	170
	10	73	229	23	130	90	16	88	199

	21	123	51	267	130	79	258	161	180		13	120	260	105	210	252	95	112	26
	22	115	157	279	153	144	283	72	180		24	9	90	135	123	173	212	20	105
	27	0	0	0	0	0	0	0	0		52	0	0	0	0	0	0	0	0
	0	183	278	289	158	80	294	6	199		1	95	100	222	175	144	101	4	73
	6	22	257	21	119	144	73	27	22		7	177	215	308	49	144	297	49	149
	10	28	1	293	113	169	330	163	23	31	22	172	258	66	177	166	279	125	175
	11	67	351	13	21	90	99	50	100		25	61	256	162	128	19	222	194	108
6	13	244	92	232	63	59	172	48	92		53	0	0	0	0	0	0	0	0
	17	11	253	302	51	177	150	24	207		0	221	102	210	192	0	351	6	103
	18	157	18	138	136	151	284	38	52		12	112	201	22	209	211	265	126	110
	20	211	225	235	116	108	305	91	13	32	14	199	175	271	58	36	338	63	151
	28	0	0	0	0	0	0	0	0		24	121	287	217	30	162	83	20	211
	0	220	9	12	17	169	3	145	77		54	0	0	0	0	0	0	0	0
	1	44	62	88	76	189	103	88	146		1	2	323	170	114	0	56	10	199
	4	159	316	207	104	154	224	112	209		2	187	8	20	49	0	304	30	132
7	7	31	333	50	100	184	297	153	32	33	11	41	361	140	161	76	141	6	172
	8	167	290	25	150	104	215	159	166		21	211	105	33	137	18	101	92	65
	14	104	114	76	158	164	39	76	18		55	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0		0	127	230	187	82	197	60	4	161
	0	112	307	295	33	54	348	172	181		7	167	148	296	186	0	320	153	237
	1	4	179	133	95	0	75	2	105	34	15	164	202	5	68	108	112	197	142
	3	7	165	130	4	252	22	131	141		17	159	312	44	150	0	54	155	180
	12	211	18	231	217	41	312	141	223		56	0	0	0	0	0	0	0	0
8	16	102	39	296	204	98	224	96	177		1	161	320	207	192	199	100	4	231
	19	164	224	110	39	46	17	99	145		6	197	335	158	173	278	210	45	174
	21	109	368	269	58	15	59	101	199	35	12	207	2	55	26	0	195	168	145
	22	241	67	245	44	230	314	35	153		22	103	266	285	187	205	268	185	100
	24	90	170	154	201	54	244	116	38		57	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0		0	37	210	259	222	216	135	6	11
	0	103	366	189	9	162	156	6	169		14	105	313	179	157	16	15	200	207
	1	182	232	244	37	159	88	10	12	36	15	51	297	178	0	0	35	177	42
	10	109	321	36	213	93	293	145	206		18	120	21	160	6	0	188	43	100
	11	21	133	286	105	134	111	53	221		58	0	0	0	0	0	0	0	0
9	13	142	57	151	89	45	92	201	17		1	198	269	298	81	72	319	82	59
	17	14	303	267	185	132	152	4	212	37	13	220	82	15	195	144	236	2	204
	18	61	63	135	109	76	23	164	92		23	122	115	115	138	0	85	135	161
	20	216	82	209	218	209	337	173	205		59	0	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	0	0		0	167	185	151	123	190	164	91	121
	1	98	101	14	82	178	175	126	116		9	151	177	179	90	0	196	64	90
	2	149	339	80	165	1	253	77	151	38	10	157	289	64	73	0	209	198	26
	4	167	274	211	174	28	27	156	70		12	163	214	181	10	0	246	100	140
10	7	160	111	75	19	267	231	16	230		60	0	0	0	0	0	0	0	0
	8	49	383	161	194	234	49	12	115		1	173	258	102	12	153	236	4	115
	14	58	354	311	103	201	267	70	84		3	139	93	77	77	0	264	28	188
	32	0	0	0	0	0	0	0	0	39	7	149	346	192	49	165	37	109	168
	0	77	48	16	52	55	25	184	45		19	0	297	208	114	117	272	188	52
	1	41	102	147	11	23	322	194	115		61	0	0	0	0	0	0	0	0
	12	83	8	290	2	274	200	123	134		0	157	175	32	67	216	304	10	4
11	16	182	47	289	35	181	351	16	1	40	8	137	37	80	45	144	237	84	103
	21	78	188	177	32	273	166	104	152		17	149	312	197	96	2	135	12	30
	22	252	334	43	84	39	338	109	165		62	0	0	0	0	0	0	0	0
	23	22	115	280	201	26	192	124	107		1	167	52	154	23	0	123	2	53
	33	0	0	0	0	0	0	0	0		3	173	314	47	215	0	77	75	189
	0	160	77	229	142	225	123	6	186	41	9	139	139	124	60	0	25	142	215
	1	42	186	235	175	162	217	20	215		18	151	288	207	167	183	272	128	24
	10	21	174	169	136	244	142	203	124		63	0	0	0	0	0	0	0	0
12	11	32	232	48	3	151	110	153	180		0	149	113	226	114	27	288	163	222
	13	234	50	105	28	238	176	104	98	42	4	157	14	65	91	0	83	10	170
	18	7	74	52	182	243	76	207	80		24	137	218	126	78	35	17	162	71
	34	0	0	0	0	0	0	0	0		64	0	0	0	0	0	0	0	0
	0	177	313	39	81	231	311	52	220		1	151	113	228	206	52	210	1	22
	3	248	177	302	56	0	251	147	185		16	163	132	69	22	243	3	163	127
13	7	151	266	303	72	216	265	1	154	43	18	173	114	176	134	0	53	99	49
	20	185	115	160	217	47	94	16	178		25	139	168	102	161	270	167	98	125
	23	62	370	37	78	36	81	46	150		65	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0		0	139	80	234	84	18	79	4	191
	0	206	142	78	14	0	22	1	124		7	157	78	227	4	0	244	6	211
	12	55	248	299	175	186	322	202	144	44	9	163	163	259	9	0	293	142	187
	15	206	137	54	211	253	277	118	182		22	173	274	260	12	57	272	3	148
14	16	127	89	61	191	16	156	130	95		66	0	0	0	0	0	0	0	0
	17	16	347	179	51	0	66	1	72		1	149	135	101	184	168	82	181	177
	21	229	12	258	43	79	78	2	76	45	6	151	149	228	121	0	67	45	114
	36	0	0	0	0	0	0	0	0		10	167	15	126	29	144	235	153	93
15	0	40	241	229	90	170	176	173	39		67	0	0	0	0	0	0	0	0

Table 5.3.2-3: LDPC base graph 2 ($\mathbf{H}_{\mathrm{BG}}$) and its parity check matrices ($V_{i,j}$)

$\mathbf{H}_{BG}$		$V_{i,j}$								$\mathbf{H}_{BG}$		$V_{i,j}$							
Row index i	Column index j	Set index i_{LS}								Row index i	Column index j	Set index i_{LS}							
		0	1	2	3	4	5	6	7			0	1	2	3	4	5	6	7
0	0	9	174	0	72	3	156	143	145	16	26	0	0	0	0	0	0	0	0
	1	117	97	0	110	26	143	19	131	17	1	254	158	0	48	120	134	57	196
	2	204	166	0	23	53	14	176	71		5	124	23	24	132	43	23	201	173
	3	26	66	0	181	35	3	165	21		11	114	9	109	206	65	62	142	195
	6	189	71	0	95	115	40	196	23		12	64	6	18	2	42	163	35	218
	9	205	172	0	8	127	123	13	112		27	0	0	0	0	0	0	0	0
	10	0	0	0	1	0	0	0	1	18	0	220	186	0	68	17	173	129	128
	11	0	0	0	0	0	0	0	0		6	194	6	18	16	106	31	203	211
1	0	167	27	137	53	19	17	18	142		7	50	46	86	156	142	22	140	210
	3	166	36	124	156	94	65	27	174		28	0	0	0	0	0	0	0	0
	4	253	48	0	115	104	63	3	183	19	0	87	58	0	35	79	13	110	39
	5	125	92	0	156	66	1	102	27		1	20	42	158	138	28	135	124	84
	6	226	31	88	115	84	55	185	96		10	185	156	154	86	41	145	52	88
	7	156	187	0	200	98	37	17	23		29	0	0	0	0	0	0	0	0
	8	224	185	0	29	69	171	14	9	20	1	26	76	0	6	2	128	196	117
	9	252	3	55	31	50	133	180	167		4	105	61	148	20	103	52	35	227
	11	0	0	0	0	0	0	0	0		11	29	153	104	141	78	173	114	6
	12	0	0	0	0	0	0	0	0		30	0	0	0	0	0	0	0	0
2	0	81	25	20	152	95	98	126	74	21	0	76	157	0	80	91	156	10	238
	1	114	114	94	131	106	168	163	31		8	42	175	17	43	75	166	122	13
	3	44	117	99	46	92	107	47	3		13	210	67	33	81	81	40	23	11
	4	52	110	9	191	110	82	183	53		31	0	0	0	0	0	0	0	0
	8	240	114	108	91	111	142	132	155	22	1	222	20	0	49	54	18	202	195
	10	1	1	1	0	1	1	1	0		2	63	52	4	1	132	163	126	44
	12	0	0	0	0	0	0	0	0		32	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	23	0	23	106	0	156	68	110	52	5
3	1	8	136	38	185	120	53	36	239		3	235	86	75	54	115	132	170	94
	2	58	175	15	6	121	174	48	171		5	238	95	158	134	56	150	13	111
	4	158	113	102	36	22	174	18	95		33	0	0	0	0	0	0	0	0
	5	104	72	146	124	4	127	111	110	24	1	46	182	0	153	30	113	113	81
	6	209	123	12	124	73	17	203	159		2	139	153	69	88	42	108	161	19
	7	54	118	57	110	49	89	3	199		9	8	64	87	63	101	61	88	130
	8	18	28	53	156	128	17	191	43		34	0	0	0	0	0	0	0	0
	9	128	186	46	133	79	105	160	75	25	0	228	45	0	211	128	72	197	66
	10	0	0	0	1	0	0	0	1		5	156	21	65	94	63	136	194	95
	13	0	0	0	0	0	0	0	0		35	0	0	0	0	0	0	0	0
4	0	179	72	0	200	42	86	43	29	26	2	29	67	0	90	142	36	164	146
	1	214	74	136	16	24	67	27	140		7	143	137	100	6	28	38	172	66
	11	71	29	157	101	51	83	117	180		12	160	55	13	221	100	53	49	190
	14	0	0	0	0	0	0	0	0		13	122	85	7	6	133	145	161	86
5	0	231	10	0	185	40	79	136	121		36	0	0	0	0	0	0	0	0
	1	41	44	131	138	140	84	49	41	27	0	8	103	0	27	13	42	168	64
	5	194	121	142	170	84	35	36	169		6	151	50	32	118	10	104	193	181
	7	159	80	141	219	137	103	132	88		37	0	0	0	0	0	0	0	0
	11	103	48	64	193	71	60	62	207	28	1	98	70	0	216	106	64	14	7
	15	0	0	0	0	0	0	0	0		2	101	111	126	212	77	24	186	144
6	0	155	129	0	123	109	47	7	137		5	135	168	110	193	43	149	46	16
	5	228	92	124	55	87	154	34	72		38	0	0	0	0	0	0	0	0
	7	45	100	99	31	107	10	198	172	29	0	18	110	0	108	133	139	50	25
	9	28	49	45	222	133	155	168	124		4	28	17	154	61	25	161	27	57
	11	158	184	148	209	139	29	12	56		39	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	30	2	71	120	0	106	87	84	70	37
7	1	129	80	0	103	97	48	163	86		5	240	154	35	44	56	173	17	139
	5	147	186	45	13	135	125	78	186		7	9	52	51	185	104	93	50	221
	7	140	16	148	105	35	24	143	87		9	84	56	134	176	70	29	6	17
	11	3	102	96	150	108	47	107	172		40	0	0	0	0	0	0	0	0
	13	116	143	78	181	65	55	58	154	31	1	106	3	0	147	80	117	115	201
	17	0	0	0	0	0	0	0	0		13	1	170	20	182	139	148	189	46
8	0	142	118	0	147	70	53	101	176		41	0	0	0	0	0	0	0	0
	1	94	70	65	43	69	31	177	169	32	0	242	84	0	108	32	116	110	179
	12	230	152	87	152	88	161	22	225		5	44	8	20	21	89	73	0	14
	18	0	0	0	0	0	0	0	0		12	166	17	122	110	71	142	163	116
9	1	203	28	0	2	97	104	186	167		42	0	0	0	0	0	0	0	0
	8	205	132	97	30	40	142	27	238	33	2	132	165	0	71	135	105	163	46
	10	61	185	51	184	24	99	205	48		7	164	179	88	12	6	137	173	2
	11	247	178	85	83	49	64	81	68		10	235	124	13	109	2	29	179	106
	19	0	0	0	0	0	0	0	0		43	0	0	0	0	0	0	0	0
10	0	11	59	0	174	46	111	125	38	34	0	147	173	0	29	37	11	197	184
	1	185	104	17	150	41	25	60	217		12	85	177	19	201	25	41	191	135
	6	0	22	156	8	101	174	177	208		13	36	12	78	69	114	162	193	141
	7	117	52	20	56	96	23	51	232		44	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	35	1	57	77	0	91	60	126	157	85
11	0	11	32	0	99	28	91	39	178		5	40	184	157	165	137	152	167	225
	7	236	92	7	138	30	175	29	214		11	63	18	6	55	93	172	181	175
	9	210	174	4	110	116	24	35	168		45	0	0	0	0	0	0	0	0
	13	56	154	2	99	64	141	8	51	36	0	140	25	0	1	121	73	197	178
	21	0	0	0	0	0	0	0	0		2	38	151	63	175	129	154	167	112
12	1	63	39	0	46	33	122	18	124		7	154	170	82	83	26	129	179	106
	3	111	93	113	217	122	11	155	122		46	0	0	0	0	0	0	0	0
	11	14	11	48	109	131	4	49	72	37	10	219	37	0	40	97	167	181	154
	22	0	0	0	0	0	0	0	0		13	151	31	144	12	56	38	193	114
13	0	83	49	0	37	76	29	32	48		47	0	0	0	0	0	0	0	0
	1	2	125	112	113	37	91	53	57	38	1	31	84	0	37	1	112	157	42
	8	38	35	102	143	62	27	95	167		5	66	151	93	97	70	7	173	41

	13	222	166	26	140	47	127	186	219		11	38	190	19	46	1	19	191	105
	23	0	0	0	0	0	0	0	0		48	0	0	0	0	0	0	0	0
14	1	115	19	0	36	143	11	91	82	39	0	239	93	0	106	119	109	181	167
	6	145	118	138	95	51	145	20	232		7	172	132	24	181	32	6	157	45
	11	3	21	57	40	130	8	52	204		12	34	57	138	154	142	105	173	189
	13	232	163	27	116	97	166	109	162		49	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	40	2	0	103	0	98	6	160	193	78
15	0	51	68	0	116	139	137	174	38		10	75	107	36	35	73	156	163	67
	10	175	63	73	200	96	103	108	217		13	120	163	143	36	102	82	179	180
	11	213	81	99	110	128	40	102	157		50	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	41	1	129	147	0	120	48	132	191	53
16	1	203	87	0	75	48	78	125	170		5	229	7	2	101	47	6	197	215
	9	142	177	79	158	9	158	31	23		11	118	60	55	81	19	8	167	230
	11	8	135	111	134	28	17	54	175		51	0	0	0	0	0	0	0	0
	12	242	64	143	97	8	165	176	202										

5.3.3 Channel coding of small block lengths

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 $d_0, d_1, d_2, ..., d_{N-1}$.

5.3.3.1 Encoding of 1-bit information

For $K = 1$, the code block is encoded according to Table 5.3.3.1-1, where $N = Q_m$ and Q_m is the modulation order for the code block.

Table 5.3.3.1-1: Encoding of 1-bit information

Q_m	**Encoded bits** $d_0, d_1, d_2, ..., d_{N-1}$
1	$[c_0]$
2	$[c_0 \text{ y}]$
4	$[c_0 \text{ y x x}]$
6	$[c_0 \text{ y x x x x }]$
8	$[c_0 \text{ y x x x x x x }]$

The "x" and "y" in Table 5.3.3.1-1 are placeholders for Subclause 6.3.1.1 of [4, TS 38.211] to scramble the information bits in a way that maximizes the Euclidean distance of the modulation symbols carrying the information bits.

5.3.3.2 Encoding of 2-bit information

For $K = 2$, the code block is encoded according to Table 5.3.3-2, where $c_2 = (c_0 + c_1) \bmod 2$, $N = 3Q_m$, and Q_m is the modulation order for the code block.

Table 5.3.3.2-1: Encoding of 2-bit information

Q_m	**Encoded bits** $d_0, d_1, d_2, ..., d_{N-1}$
1	$[c_0\ c_1\ c_2]$
2	$[c_0\ c_1\ c_2\ c_0\ c_1\ c_2]$
4	$[c_0\ c_1 \text{ x x } c_2\ c_0 \text{ x x } c_1\ c_2 \text{ x x}]$
6	$[c_0\ c_1 \text{ x x x x } c_2\ c_0 \text{ x x x x } c_1\ c_2 \text{ x x x x}]$
8	$[c_0\ c_1 \text{ x x x x x x } c_2\ c_0 \text{ x x x x x x } c_1\ c_2 \text{ x x x x x x}]$

The "x" in Table 5.3.3.2-1 are placeholders for Subclause 6.3.1.1 of [4, TS 38.211] to scramble the information bits in a way that maximizes the Euclidean distance of the modulation symbols carrying the information bits.

5.3.3.3 Encoding of other small block lengths

For $3 \le K \le 11$, the code block is encoded by $d_i = \left(\sum_{k=0}^{K-1} c_k \cdot M_{i,k} \right) \bmod 2$, where $i = 0, 1, \cdots, N-1$, $N = 32$, and $M_{i,k}$ represents the basis sequences as defined in Table 5.3.3.3-1.

Table 5.3.3.3-1: Basis sequences for (32, K) code

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

5.4 Rate matching

5.4.1 Rate matching for Polar code

The rate matching for Polar code is defined per coded block and consists of sub-block interleaving, bit collection, and bit interleaving. The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$. The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

5.4.1.1 Sub-block interleaving

The bits input to the sub-block interleaver are the coded bits $d_0, d_1, d_2, ..., d_{N-1}$. The coded bits $d_0, d_1, d_2, ..., d_{N-1}$ are divided into 32 sub-blocks. The bits output from the sub-block interleaver are denoted as $y_0, y_1, y_2, ..., y_{N-1}$, generated as follows:

for $n = 0$ to $N-1$

$i = \lfloor 32n / N \rfloor$;

$J(n) = P(i) \times (N/32) + \mathrm{mod}(n, N/32)$;

$y_n = d_{J(n)}$;

end for

where the sub-block interleaver pattern $P(i)$ is given by Table 5.4.1.1-1.

Table 5.4.1.1-1: Sub-block interleaver pattern $P(i)$

i	$P(i)$	i	$P(i)$	i	$P(i)$	i	$P(i)$	i	$P(i)$	i	$P(i)$	i	$P(i)$	i	$P(i)$
0	0	4	3	8	8	12	10	16	12	20	14	24	24	28	27
1	1	5	5	9	16	13	18	17	20	21	22	25	25	29	29
2	2	6	6	10	9	14	11	18	13	22	15	26	26	30	30
3	4	7	7	11	17	15	19	19	21	23	23	27	28	31	31

The sets of bit indices $\overline{\mathbf{Q}}_I^N$ and $\overline{\mathbf{Q}}_F^N$ are determined as follows, where K, n_{PC}, and $\mathbf{Q}_0^{N-1}$ are defined in Subclause 5.3.1

$\overline{\mathbf{Q}}_{F,tmp}^N = \varnothing$

if $E < N$

  if $K/E \le 7/16$ -- puncturing

    for $n = 0$ to $N - E - 1$

      $\overline{\mathbf{Q}}_{F,tmp}^N = \overline{\mathbf{Q}}_{F,tmp}^N \cup \{J(n)\}$;

    end for

    if $E \ge 3N/4$

      $\overline{\mathbf{Q}}_{F,tmp}^N = \overline{\mathbf{Q}}_{F,tmp}^N \cup \{0,1,\ldots,\lceil 3N/4 - E/2 \rceil - 1\}$;

    else

      $\overline{\mathbf{Q}}_{F,tmp}^N = \overline{\mathbf{Q}}_{F,tmp}^N \cup \{0,1,\ldots,\lceil 9N/16 - E/4 \rceil - 1\}$;

    end if

  else -- shortening

    for $n = E$ to $N - 1$

      $\overline{\mathbf{Q}}_{F,tmp}^N = \overline{\mathbf{Q}}_{F,tmp}^N \cup \{J(n)\}$;

    end for

  end if

end if

$\overline{\mathbf{Q}}_{I,tmp}^N = \mathbf{Q}_0^{N-1} \setminus \overline{\mathbf{Q}}_{F,tmp}^N$;

$\overline{\mathbf{Q}}_I^N$ comprises $(K + n_{PC})$ most reliable bit indices in $\overline{\mathbf{Q}}_{I,tmp}^N$;

$\overline{\mathbf{Q}}_F^N = \mathbf{Q}_0^{N-1} \setminus \overline{\mathbf{Q}}_I^N$;

5.4.1.2 Bit selection

The bit sequence after the sub-block interleaver $y_0, y_1, y_2, ..., y_{N-1}$ from Subclause 5.4.1.1 is written into a circular buffer of length N.

Denoting by E the rate matching output sequence length, the bit selection output bit sequence e_k, $k = 0,1,2,...,E-1$, is generated as follows:

if $E \geq N$ -- repetition

for $k = 0$ to $E - 1$

$e_k = y_{\text{mod}(k,N)}$;

end for

else

if $K / E \leq 7/16$ -- puncturing

for $k = 0$ to $E - 1$

$e_k = y_{k+N-E}$;

end for

else -- shortening

for $k = 0$ to $E - 1$

$e_k = y_k$;

end for

end if

end if

5.4.1.3 Interleaving of coded bits

The bit sequence $e_0, e_1, e_2, ..., e_{E-1}$ is interleaved into bit sequence $f_0, f_1, f_2, ..., f_{E-1}$, as follows:

If $I_{BIL} = 1$

Denote T as the smallest integer such that $T(T+1)/2 \geq E$;

$k = 0$;

for $i = 0$ to $T - 1$

for $j = 0$ to $T - 1 - i$

if $k < E$

$v_{i,j} = e_k$;

else

$v_{i,j} = < NULL >$;

end if

$k = k + 1$;

end for

end for

$k = 0$;

for $j = 0$ to $T - 1$

for $i = 0$ to $T - 1 - j$

if $v_{i,j} \neq < NULL >$

$f_k = v_{i,j}$;

$k = k + 1$

end if

end for

end for

else

for $i = 0$ to $E - 1$

$f_i = e_i$;

end for

end if

The value of E is no larger than 8192.

5.4.2 Rate matching for LDPC code

The rate matching for LDPC code is defined per coded block and consists of bit selection and bit interleaving. The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$. The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

5.4.2.1 Bit selection

The bit sequence after encoding $d_0, d_1, d_2, ..., d_{N-1}$ from Subclause 5.3.2 is written into a circular buffer of length N_{cb} for the r-th coded block, where N is defined in Subclause 5.3.2.

For the r-th code block, let $N_{cb} = N$ if $I_{LBRM} = 0$ and $N_{cb} = \min(N, N_{ref})$ otherwise, where $N_{ref} = \left\lfloor \frac{TBS_{\text{LBRM}}}{C \cdot R_{\text{LBRM}}} \right\rfloor$, $R_{\text{LBRM}} = 2/3$, TBS_{LBRM} is determined according to Subclause 6.1.4.2 in [6, TS 38.214] for UL-SCH and Subclause 5.1.3.2 in [6, TS 38.214] for DL-SCH/PCH, assuming the following:

- maximum number of layers for one TB supported by the UE for the serving cell, if the UE has reported its corresponding capability; otherwise a maximum of 2 layers is assumed for DL-SCH;
- maximum modulation order configured for the serving cell, if configured by higher layers; otherwise a maximum modulation order $Q_m = 6$ is assumed for DL-SCH ;
- maximum coding rate of 948/1024;
- $n_{PRB} = n_{PRB,LBRM}$ is given by Table 5.4.2.1-1, where the value of $n_{PRB,LBRM}$ for DL-SCH is determined according to the initial bandwidth part if there is no other bandwidth part configured to the UE;
- $N_{RE} = 156 \cdot n_{PRB}$;
- C is the number of code blocks of the transport block determined according to Subclause 5.2.2.

Table 5.4.2.1-1: Value of $n_{PRB,LBRM}$

Maximum number of PRBs across all configured BWPs of a carrier	$n_{PRB,LBRM}$
Less than 33	32
33 to 66	66
67 to 107	107
108 to 135	135
136 to 162	162
163 to 217	217
Larger than 217	273

Denoting by E_r the rate matching output sequence length for the r -th coded block, where the value of E_r is determined as follows:

Set $j = 0$

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

if the r -th coded block is not scheduled for transmission as indicated by CBGTI according to Subclause 5.1.7.2 for DL-SCH and 6.1.5.2 for UL-SCH in [6, TS 38.214]

$E_r = 0$;

else

if $j \le C' - \mathrm{mod}\left(G/\left(N_L \cdot Q_m\right), C'\right) - 1$

$$E_r = N_L \cdot Q_m \cdot \left\lfloor \frac{G}{N_L \cdot Q_m \cdot C'} \right\rfloor;$$

else

$$E_r = N_L \cdot Q_m \cdot \left\lceil \frac{G}{N_L \cdot Q_m \cdot C'} \right\rceil;$$

end if

$j = j + 1$;

end if

end for

where

- N_L is the number of transmission layers that the transport block is mapped onto;
- Q_m is the modulation order;
- G is the total number of coded bits available for transmission of the transport block;
- $C' = C$ if CBGTI is not present in the DCI scheduling the transport block and C' is the number of scheduled code blocks of the transport block if CBGTI is present in the DCI scheduling the transport block.

Denote by rv_{id} the redundancy version number for this transmission (rv_{id} = 0, 1, 2 or 3), the rate matching output bit sequence e_k , $k = 0,1,2,...,E-1$, is generated as follows, where k_0 is given by Table 5.4.2.1-2 according to the value of rv_{id} and LDPC base graph:

$k = 0$;

$j = 0$;

while $k < E$

if $d_{(k_0+j)\bmod N_{cb}} \neq <NULL>$

$e_k = d_{(k_0+j)\bmod N_{cb}}$;

$k = k + 1$;

end if

$j = j + 1$;

end while

Table 5.4.2.1-2: Starting position of different redundancy versions, k_0

rv_{id}	k_0	
	LDPC base graph 1	LDPC base graph 2
0	0	0
1	$\left\lfloor \frac{17N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{13N_{cb}}{50Z_c} \right\rfloor Z_c$
2	$\left\lfloor \frac{33N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{25N_{cb}}{50Z_c} \right\rfloor Z_c$
3	$\left\lfloor \frac{56N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{43N_{cb}}{50Z_c} \right\rfloor Z_c$

5.4.2.2 Bit interleaving

The bit sequence $e_0, e_1, e_2, ..., e_{E-1}$ is interleaved to bit sequence $f_0, f_1, f_2, ..., f_{E-1}$, according to the following, where the value of Q_m is the modulation order.

for $j = 0$ to $E/Q_m - 1$

for $i = 0$ to $Q_m - 1$

$f_{i+j\cdot Q_m} = e_{i\cdot E/Q_m + j}$;

end for

end for

5.4.3 Rate matching for channel coding of small block lengths

The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$. The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$, where E is the rate matching output sequence length. The bit sequence $f_0, f_1, f_2, ..., f_{E-1}$ is obtained by the following:

for $k = 0$ to $E - 1$

$f_k = d_{k \bmod N}$;

end for

5.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences f_{rk}, for $r = 0,...,C-1$ and $k = 0,...,E_r - 1$, where E_r is the number of rate matched bits for the r-th code block. The output bit sequence from the code block concatenation block is the sequence g_k for $k = 0,...,G-1$.

The code block concatenation consists of sequentially concatenating the rate matching outputs for the different code blocks. Therefore,

Set $k = 0$ and $r = 0$

while $r < C$

Set $j = 0$

while $j < E_r$

$g_k = f_{rj}$

$k = k+1$

$j = j+1$

end while

$r = r+1$

end while

6 Uplink transport channels and control information

6.1 Random access channel

The sequence index for the random access channel is received from higher layers and is processed according to [4, TS 38.211].

6.2 Uplink shared channel

6.2.1 Transport block CRC attachment

Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 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 payload size and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in Subclause x.x of [TS38.321].

The parity bits are computed and attached to the UL-SCH transport block according to Subclause 5.1, by setting L to 24 bits and using the generator polynomial $g_{\mathrm{CRC24A}}(D)$ if $A > 3824$; and by setting L to 16 bits and using the generator polynomial $g_{\mathrm{CRC16}}(D)$ otherwise.

The bits after CRC attachment are denoted by $b_0, b_1, b_2, b_3,..., b_{B-1}$, where $B = A + L$.

6.2.2 LDPC base graph selection

For initial transmission of a transport block with coding rate R indicated by the MCS index according to Subclause 6.1.4.1 in [6, TS 38.214] and subsequent re-transmission of the same transport block, each code block of the transport block is encoded with either LDPC base graph 1 or 2 according to the following:

- if $A \le 292$, or if $A \le 3824$ and $R \le 0.67$, or if $R \le 0.25$, LDPC base graph 2 is used;
- otherwise, LDPC base graph 1 is used,

where A is the payload size as described in Subclause 6.2.1.

6.2.3 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to Subclause 5.2.2.

The bits after code block segmentation 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 code block number r according to Subclause 5.2.2.

6.2.4 Channel coding of UL-SCH

Code blocks are delivered to the channel coding block. The bits in a code block 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 in code block number r. The total number of code blocks is denoted by C and each code block is individually LDPC encoded according to Subclause 5.3.2.

After encoding the bits are denoted by $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$, where the values of N_r is given in Subclause 5.3.2.

6.2.5 Rate matching

Coded bits for each code block, denoted as $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$, are delivered to the rate match block, where r is the code block number, and N_r is the number of encoded bits in code block number r. The total number of code blocks is denoted by C and each code block is individually rate matched according to Subclause 5.4.2 by setting $I_{LBRM} = 1$ if higher layer parameter *LBRM-FBRM-selection = LBRM* and by setting $I_{LBRM} = 0$ if higher layer parameter *LBRM-FBRM-selection = FBRM* or if higher layer parameter *LBRM-FBRM-selection* is not configured.

After rate matching, the bits are denoted by $f_{r0}, f_{r1}, f_{r2}, f_{r3}, ..., f_{r(E_r-1)}$, where E_r is the number of rate matched bits for code block number r.

6.2.6 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences $f_{r0}, f_{r1}, f_{r2}, f_{r3}, ..., f_{r(E_r-1)}$, for $r = 0,...,C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to Subclause 5.5.

The bits after code block concatenation are denoted by $g_0, g_1, g_2, g_3, ..., g_{G-1}$, where G is the total number of coded bits for transmission.

6.2.7 Data and control multiplexing

Denote the coded bits for UL-SCH as $g_0^{\text{UL-SCH}}, g_1^{\text{UL-SCH}}, g_2^{\text{UL-SCH}}, g_3^{\text{UL-SCH}}, ..., g_{G^{\text{UL-SCH}}-1}^{\text{UL-SCH}}$.

Denote the coded bits for HARQ-ACK, if any, as $g_0^{\text{ACK}}, g_1^{\text{ACK}}, g_2^{\text{ACK}}, g_3^{\text{ACK}}, ..., g_{G^{\text{ACK}}-1}^{\text{ACK}}$.

Denote the coded bits for CSI part 1, if any, as $g_0^{\text{CSI-part1}}, g_1^{\text{CSI-part1}}, g_2^{\text{CSI-part1}}, g_3^{\text{CSI-part1}}, ..., g_{G^{\text{CSI-part1}}-1}^{\text{CSI-part1}}$.

Denote the coded bits for CSI part 2, if any, as $g_0^{\text{CSI-part2}}, g_1^{\text{CSI-part2}}, g_2^{\text{CSI-part2}}, g_3^{\text{CSI-part2}}, ..., g_{G^{\text{CSI-part2}}-1}^{\text{CSI-part2}}$.

Denote the multiplexed data and control coded bit sequence as $g_0, g_1, g_2, g_3, ..., g_{G-1}$.

Denote l as the OFDM symbol index of the scheduled PUSCH, starting from 0 to $N_{\text{symb,all}}^{\text{PUSCH}} - 1$, where $N_{\text{symb,all}}^{\text{PUSCH}}$ is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS.

Denote k as the subcarrier index of the scheduled PUSCH, starting from 0 to $M_{\text{sc}}^{\text{PUSCH}} - 1$, where $M_{\text{sc}}^{\text{PUSCH}}$ is expressed as a number of subcarriers.

Denote $\Phi_l^{\text{UL-SCH}}$ as the set of resource elements, in ascending order of indices k, available for transmission of data in OFDM symbol l, for $l = 0, 1, 2, ..., N_{\text{symb,all}}^{\text{PUSCH}} - 1$.

Denote $M_{\text{sc}}^{\text{UL-SCH}}(l) = \left|\Phi_l^{\text{UL-SCH}}\right|$ as the number of elements in set $\Phi_l^{\text{UL-SCH}}$. Denote $\Phi_l^{\text{UL-SCH}}(j)$ as the j-th element in $\Phi_l^{\text{UL-SCH}}$.

Denote Φ_l^{UCI} as the set of resource elements, in ascending order of indices k, available for transmission of UCI in OFDM symbol l, for $l = 0, 1, 2, ..., N_{\text{symb,all}}^{\text{PUSCH}} - 1$. Denote $M_{\text{sc}}^{\text{UCI}}(l) = \left|\Phi_l^{\text{UCI}}\right|$ as the number of elements in set Φ_l^{UCI}. Denote $\Phi_l^{\text{UCI}}(j)$ as the j-th element in Φ_l^{UCI}. For any OFDM symbol that carriers DMRS of the PUSCH, $\Phi_l^{\text{UCI}} = \varnothing$. For any OFDM symbol that does not carry DMRS of the PUSCH, $\Phi_l^{\text{UCI}} = \Phi_l^{\text{UL-SCH}}$.

If frequency hopping is configured for the PUSCH,

- denote $l^{(1)}$ as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS in the first hop;
- denote $l^{(2)}$ as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS in the second hop.
- denote $l_{\text{CSI}}^{(1)}$ as the OFDM symbol index of the first OFDM symbol that does not carry DMRS in the first hop;
- denote $l_{\text{CSI}}^{(2)}$ as the OFDM symbol index of the first OFDM symbol that does not carry DMRS in the second hop;
- if HARQ-ACK is present for transmission on the PUSCH with UL-SCH, let
    - $G^{\text{ACK}}(1) = N_L \cdot Q_m \cdot \left\lfloor G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \right\rfloor$ and $G^{\text{ACK}}(2) = N_L \cdot Q_m \cdot \left\lceil G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \right\rceil$;
- if CSI is present for transmission on the PUSCH with UL-SCH, let
    - $G^{\text{CSI-part1}}(1) = N_L \cdot Q_m \cdot \left\lfloor G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \right\rfloor$;
    - $G^{\text{CSI-part1}}(2) = N_L \cdot Q_m \cdot \left\lceil G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \right\rceil$;
    - $G^{\text{CSI-part2}}(1) = N_L \cdot Q_m \cdot \left\lfloor G^{\text{CSI-part2}} / (2 \cdot N_L \cdot Q_m) \right\rfloor$; and
    - $G^{\text{CSI-part2}}(2) = N_L \cdot Q_m \cdot \left\lceil G^{\text{CSI-part2}} / (2 \cdot N_L \cdot Q_m) \right\rceil$;
- if only HARQ-ACK and CSI part 1 are present for transmission on the PUSCH without UL-SCH, let
    - $G^{\text{ACK}}(1) = \min\left(N_L \cdot Q_m \cdot \left\lfloor G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \right\rfloor, M_1 \cdot N_L \cdot Q_m\right)$;

  - $G^{\text{ACK}}(2) = G^{\text{ACK}} - G^{\text{ACK}}(1)$;
  - $G^{\text{CSI-part1}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1)$; and
  - $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$;
- if HARQ-ACK, CSI part 1 and CSI part 2 are present for transmission on the PUSCH without UL-SCH, let
  - $G^{\text{ACK}}(1) = \min\left(N_L \cdot Q_m \cdot \left\lfloor G^{\text{ACK}} / \left(2 \cdot N_L \cdot Q_m\right)\right\rfloor, M_1 \cdot N_L \cdot Q_m\right)$;
  - $G^{\text{ACK}}(2) = G^{\text{ACK}} - G^{\text{ACK}}(1)$;
  - $G^{\text{CSI-part1}}(1) = \min\left(N_L \cdot Q_m \cdot \left\lfloor G^{\text{CSI-part1}} / \left(2 \cdot N_L \cdot Q_m\right)\right\rfloor, M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1)\right)$;
  - $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$;
  - $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(1)$ if the number of HARQ-ACK information bits is no more than 2, and $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1) - G^{\text{CSI-part1}}(1)$ otherwise; and
  - $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(2)$ if the number of HARQ-ACK information bits is no more than 2, and $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{ACK}}(2) - G^{\text{CSI-part1}}(2)$ otherwise;
- let $N_{\text{hop}}^{\text{PUSCH}} = 2$, and denote $N_{\text{symb,hop}}^{\text{PUSCH}}(1)$, $N_{\text{symb,hop}}^{\text{PUSCH}}(2)$ as the number of OFDM symbols of the PUSCH in the first and second hop, respectively;
- N_L is the number of transmission layers of the PUSCH;
- Q_m is the modulation order of the PUSCH;
- $M_1 = \sum_{l=0}^{N_{\text{symb,hop}}^{\text{PUSCH}}(1)-1} M_{\text{SC}}^{\text{UCI}}(l)$;
- $M_2 = \sum_{l=N_{\text{symb,hop}}^{\text{PUSCH}}(1)}^{N_{\text{symb,hop}}^{\text{PUSCH}}(1)+N_{\text{symb,hop}}^{\text{PUSCH}}(2)-1} M_{\text{SC}}^{\text{UCI}}(l)$.

If frequency hopping is not configured for the PUSCH,

- denote $l^{(1)}$ as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS;
- denote $l_{\text{CSI}}^{(1)}$ as the OFDM symbol index of the first OFDM symbol that does not carry DMRS;
- if HARQ-ACK is present for transmission on the PUSCH, let $G^{\text{ACK}}(1) = G^{\text{ACK}}$;
- if CSI is present for transmission on the PUSCH, let $G^{\text{CSI-part1}}(1) = G^{\text{CSI-part1}}$ and $G^{\text{CSI-part2}}(1) = G^{\text{CSI-part2}}$;
- let $N_{\text{hop}}^{\text{PUSCH}} = 1$ and $N_{\text{symb,hop}}^{\text{PUSCH}}(1) = N_{\text{symb,all}}^{\text{PUSCH}}$.

The multiplexed data and control coded bit sequence $g_0, g_1, g_2, g_3, ..., g_{G-1}$ is obtained according to the following:

Step 1:

Set $\bar{\Phi}_l^{\text{UL-SCH}} = \Phi_l^{\text{UL-SCH}}$ for $l = 0, 1, 2, ..., N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

Set $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = \left|\bar{\Phi}_l^{\text{UL-SCH}}\right|$ for $l = 0, 1, 2, ..., N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

Set $\bar{\Phi}_l^{\text{UCI}} = \Phi_l^{\text{UCI}}$ for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

Set $\bar{M}_{\text{sc}}^{\text{UCI}}(l) = \left|\bar{\Phi}_l^{\text{UCI}}\right|$ for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

if the number of HARQ-ACK information bits to be transmitted on PUSCH is 0, 1 or 2 bits

the number of reserved resource elements for potential HARQ-ACK transmission is calculated according to Subclause 6.3.2.4.1.1, by setting $O_{\text{ACK}} = 2$;

denote $G_{\text{rvd}}^{\text{ACK}}$ as the number of coded bits for potential HARQ-ACK transmission using the reserved resource elements;

if frequency hopping is configured for the PUSCH, let $G_{\text{rvd}}^{\text{ACK}}(1) = N_L \cdot Q_m \cdot \left\lfloor G_{\text{rvd}}^{\text{ACK}} / \left(2 \cdot N_L \cdot Q_m\right) \right\rfloor$ and $G_{\text{rvd}}^{\text{ACK}}(2) = N_L \cdot Q_m \cdot \left\lceil G_{\text{rvd}}^{\text{ACK}} / \left(2 \cdot N_L \cdot Q_m\right) \right\rceil$;

if frequency hopping is not configured for the PUSCH, let $G_{\text{rvd}}^{\text{ACK}}(1) = G_{\text{rvd}}^{\text{ACK}}$;

denote $\bar{\Phi}_l^{\text{rvd}}$ as the set of reserved resource elements for potential HARQ-ACK transmission, in OFDM symbol l, for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

Set $m_{\text{count}}^{\text{ACK}}(1) = 0$;

Set $m_{\text{count}}^{\text{ACK}}(2) = 0$;

$\bar{\Phi}_l^{\text{rvd}} = \varnothing$ for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

for $i = 1$ to $N_{\text{hop}}^{\text{PUSCH}}$

$l = l^{(i)}$;

while $m_{\text{count}}^{\text{ACK}}(i) < G_{\text{rvd}}^{\text{ACK}}(i)$

if $\bar{M}_{\text{sc}}^{\text{UCI}}(l) > 0$

if $G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$d = 1$;

$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UL-SCH}}(l)$;

end if

if $G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$d = \left\lfloor \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m \Big/ \left(G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) \right\rfloor$;

$m_{\text{count}}^{\text{RE}} = \left\lceil \left(G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) / \left(N_L \cdot Q_m\right) \right\rceil$;

end if

for $j = 0$ to $m_{\text{count}}^{\text{RE}} - 1$

$\bar{\Phi}_l^{\text{rvd}} = \bar{\Phi}_l^{\text{rvd}} \cup \left\{\bar{\Phi}_l^{\text{UL-SCH}}(j \cdot d)\right\}$

$m_{\text{count}}^{\text{ACK}}(i) = m_{\text{count}}^{\text{ACK}}(i) + N_L \cdot Q_m$;

end for

end if

$l = l + 1$;

end while

end for

else

$\bar{\Phi}_l^{\text{rvd}} = \varnothing$ for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$;

end if

Denote $\bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) = \left|\bar{\Phi}_l^{\text{rvd}}\right|$ as the number of elements in $\bar{\Phi}_l^{\text{rvd}}$.

Step 2:

if HARQ-ACK is present for transmission on the PUSCH and the number of HARQ-ACK information bits is more than 2,

Set $m_{\text{count}}^{\text{ACK}}(1) = 0$;

Set $m_{\text{count}}^{\text{ACK}}(2) = 0$;

Set $m_{\text{count,all}}^{\text{ACK}} = 0$;

for $i = 1$ to $N_{\text{hop}}^{\text{PUSCH}}$

$l = l^{(i)}$;

while $m_{\text{count}}^{\text{ACK}}(i) < G^{\text{ACK}}(i)$

if $\bar{M}_{\text{sc}}^{\text{UCI}}(l) > 0$

if $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$d = 1$;

$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UCI}}(l)$;

end if

if $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$d = \left\lfloor \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m \Big/ \left(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) \right\rfloor$;

$m_{\text{count}}^{\text{RE}} = \left\lceil \left(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) / \left(N_L \cdot Q_m\right) \right\rceil$;

end if

for $j = 0$ to $m_{\text{count}}^{\text{RE}} - 1$

$k = \bar{\Phi}_l^{\mathrm{UCI}}\left(j \cdot d\right)$;

for $v = 0$ to $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g^{\mathrm{ACK}}_{m^{\mathrm{ACK}}_{\mathrm{count,all}}}$;

$m^{\mathrm{ACK}}_{\mathrm{count,all}} = m^{\mathrm{ACK}}_{\mathrm{count,all}} + 1$;

$m^{\mathrm{ACK}}_{\mathrm{count}}(i) = m^{\mathrm{ACK}}_{\mathrm{count}}(i) + 1$;

end for

end for

for $j = 0$ to $m^{\mathrm{RE}}_{\mathrm{count}} - 1$

$\bar{\Phi}_l^{\mathrm{UCI}} = \bar{\Phi}_l^{\mathrm{UCI}} \setminus \left\{ \bar{\Phi}_l^{\mathrm{UCI}}\left(j \cdot d\right) \right\}$;

$\bar{\Phi}_l^{\mathrm{UL\text{-}SCH}} = \bar{\Phi}_l^{\mathrm{UL\text{-}SCH}} \setminus \left\{ \bar{\Phi}_l^{\mathrm{UCI}}\left(j \cdot d\right) \right\}$;

end for

$\bar{M}_{\mathrm{sc}}^{\mathrm{UCI}}\left(l\right) = \left| \bar{\Phi}_l^{\mathrm{UCI}} \right|$;

$\bar{M}_{\mathrm{sc}}^{\mathrm{UL\text{-}SCH}}\left(l\right) = \left| \bar{\Phi}_l^{\mathrm{UL\text{-}SCH}} \right|$;

end if

$l = l + 1$;

end while

end for

end if

Step 3:

if CSI is present for transmission on the PUSCH,

Set $m^{\mathrm{CSI\text{-}part1}}_{\mathrm{count}}(1) = 0$;

Set $m^{\mathrm{CSI\text{-}part1}}_{\mathrm{count}}(2) = 0$;

Set $m^{\mathrm{CSI\text{-}part1}}_{\mathrm{count,all}} = 0$;

for $i = 1$ to $N^{\mathrm{PUSCH}}_{\mathrm{hop}}$

$l = l^{(i)}_{\mathrm{CSI}}$;

while $\bar{M}_{\mathrm{sc}}^{\mathrm{UCI}}\left(l\right) - \bar{M}_{\mathrm{sc,\,rvd}}^{\bar{\Phi}}\left(l\right) \le 0$

$l = l + 1$;

end while

while $m_{\text{count}}^{\text{CSI-part1}}(i) < G^{\text{CSI-part1}}(i)$

if $\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l) > 0$

if $G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i) \geq \left(\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l)\right) \cdot N_L \cdot Q_m$

$d = 1$;

$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l)$;

end if

if $G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i) < \left(\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l)\right) \cdot N_L \cdot Q_m$

$d = \left\lfloor \left(\bar{M}_{\text{sc}}^{\text{UCI}}(l) - M_{\text{sc, rvd}}^{\bar{\Phi}}(l)\right) \cdot N_L \cdot Q_m \Big/ \left(G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i)\right) \right\rfloor$;

$m_{\text{count}}^{\text{RE}} = \left\lceil \left(G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i)\right) / \left(N_L \cdot Q_m\right) \right\rceil$;

end if

$\bar{\Phi}_l^{\text{temp}} = \bar{\Phi}_l^{\text{UCI}} \setminus \bar{\Phi}_l^{\text{rvd}}$;

for $j = 0$ to $m_{\text{count}}^{\text{RE}} - 1$

$k = \bar{\Phi}_l^{\text{temp}}(j \cdot d)$;

for $v = 0$ to $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{\text{count, all}}^{\text{CSI-part1}}}^{\text{CSI-part1}}$;

$m_{\text{count,all}}^{\text{CSI-part1}} = m_{\text{count,all}}^{\text{CSI-part1}} + 1$;

$m_{\text{count}}^{\text{CSI-part1}}(i) = m_{\text{count}}^{\text{CSI-part1}}(i) + 1$;

end for

end for

for $j = 0$ to $m_{\text{count}}^{\text{RE}} - 1$

$\bar{\Phi}_l^{\text{UCI}} = \bar{\Phi}_l^{\text{UCI}} \setminus \left\{\bar{\Phi}_l^{\text{temp}}(j \cdot d)\right\}$;

$\bar{\Phi}_l^{\text{UL-SCH}} = \bar{\Phi}_l^{\text{UL-SCH}} \setminus \left\{\bar{\Phi}_l^{\text{temp}}(j \cdot d)\right\}$

end for

$\bar{M}_{\text{sc}}^{\text{UCI}}(l) = \left|\bar{\Phi}_l^{\text{UCI}}\right|$;

$\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = \left|\bar{\Phi}_l^{\text{UL-SCH}}\right|$;

end if $l = l + 1$;

end while

end for

Set $m_{\text{count}}^{\text{CSI-part2}}(1)=0$;

Set $m_{\text{count}}^{\text{CSI-part2}}(2)=0$;

Set $m_{\text{count,all}}^{\text{CSI-part2}}=0$;

for $i=1$ to $N_{\text{hop}}^{\text{PUSCH}}$

$l=l_{\text{CSI}}^{(i)}$;

while $\bar{M}_{\text{sc}}^{\text{UCI}}(l)\le 0$

$l=l+1$;

end while

while $m_{\text{count}}^{\text{CSI-part2}}(i)<G^{\text{CSI-part2}}(i)$

if $\bar{M}_{\text{sc}}^{\text{UCI}}(l)>0$

if $G^{\text{CSI-part2}}(i)-m_{\text{count}}^{\text{CSI-part2}}(i)\ge \bar{M}_{\text{sc}}^{\text{UCI}}(l)\cdot N_L\cdot Q_m$

$d=1$;

$m_{\text{count}}^{\text{RE}}=\bar{M}_{\text{sc}}^{\text{UCI}}(l)$;

end if

if $G^{\text{CSI-part2}}(i)-m_{\text{count}}^{\text{CSI-part2}}(i)<\bar{M}_{\text{sc}}^{\text{UCI}}(l)\cdot N_L\cdot Q_m$

$d=\left\lfloor \bar{M}_{\text{sc}}^{\text{UCI}}(l)\cdot N_L\cdot Q_m \middle/ \left(G^{\text{CSI-part2}}(i)-m_{\text{count}}^{\text{CSI-part2}}(i)\right)\right\rfloor$;

$m_{\text{count}}^{\text{RE}}=\left\lceil \left(G^{\text{CSI-part2}}(i)-m_{\text{count}}^{\text{CSI-part2}}(i)\right)/\left(N_L\cdot Q_m\right)\right\rceil$;

end if

for $j=0$ to $m_{\text{count}}^{\text{RE}}-1$

$k=\bar{\Phi}_l^{\text{UCI}}(j\cdot d)$;

for $v=0$ to $N_L\cdot Q_m-1$

$\bar{g}_{l,k,v}=g_{m_{\text{count,all}}^{\text{CSI-part2}}}^{\text{CSI-part2}}$;

$m_{\text{count,all}}^{\text{CSI-part2}}=m_{\text{count,all}}^{\text{CSI-part2}}+1$;

$m_{\text{count}}^{\text{CSI-part2}}(i)=m_{\text{count}}^{\text{CSI-part2}}(i)+1$;

end for

end for

for $j=0$ to $m_{\text{count}}^{\text{RE}}-1$

$\bar{\Phi}_l^{\text{UCI}} = \bar{\Phi}_l^{\text{UCI}} \setminus \left\{ \bar{\Phi}_l^{\text{UCI}} \left(j \cdot d \right) \right\}$;

$\bar{\Phi}_l^{\text{UL-SCH}} = \bar{\Phi}_l^{\text{UL-SCH}} \setminus \left\{ \bar{\Phi}_l^{\text{UCI}} \left(j \cdot d \right) \right\}$;

end for

$\bar{M}_{\text{sc}}^{\text{UCI}}(l) = \left| \bar{\Phi}_l^{\text{UCI}} \right|$;

$\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = \left| \bar{\Phi}_l^{\text{UL-SCH}} \right|$;

end if

$l = l + 1$;

end while

end for

end if

Step 4:

if UL-SCH is present for transmission on the PUSCH,

Set $m_{\text{count}}^{\text{UL-SCH}} = 0$;

for $l = 0$ to $N_{\text{symb,all}}^{\text{PUSCH}} - 1$

if $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) > 0$

for $j = 0$ to $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) - 1$

$k = \bar{\Phi}_l^{\text{UL-SCH}}(j)$;

for $v = 0$ to $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{\text{count}}^{\text{UL-SCH}}}^{\text{UL-SCH}}$;

$m_{\text{count}}^{\text{UL-SCH}} = m_{\text{count}}^{\text{UL-SCH}} + 1$;

end for

end for

end if

end for

end if

Step 5:

if HARQ-ACK is present for transmission on the PUSCH and the number of HARQ-ACK information bits is no more than 2,

Set $m_{\text{count}}^{\text{ACK}}(1) = 0$;

Set $m_{\text{count}}^{\text{ACK}}(2) = 0$;

Set $m_{\text{count,all}}^{\text{ACK}} = 0$;

for $i = 1$ to $N_{\text{hop}}^{\text{PUSCH}}$

$l = l^{(i)}$;

while $m_{\text{count}}^{\text{ACK}}(i) < G^{\text{ACK}}(i)$

if $\bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l) > 0$

if $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m$

$d = 1$;

$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l)$;

end if

if $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m$

$d = \left\lfloor \bar{M}_{\text{sc, rvd}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m \big/ \left(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) \right\rfloor$;

$m_{\text{count}}^{\text{RE}} = \left\lceil \left(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)\right) / \left(N_L \cdot Q_m\right) \right\rceil$;

end if

for $j = 0$ to $m_{\text{count}}^{\text{RE}} - 1$

$k = \bar{\Phi}_l^{\text{rvd}}(j \cdot d)$;

for $v = 0$ to $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{\text{count,all}}^{\text{ACK}}}^{\text{ACK}}$;

$m_{\text{count,all}}^{\text{ACK}} = m_{\text{count,all}}^{\text{ACK}} + 1$;

$m_{\text{count}}^{\text{ACK}}(i) = m_{\text{count}}^{\text{ACK}}(i) + 1$;

end for

end for

end if

$l = l + 1$;

end while

end for

end if

<u>Step 6:</u>

Set $t = 0$;

for $l = 0$ to $N_{\text{symb,all}}^{\text{PUSCH}} - 1$

for $j = 0$ to $M_{\text{sc}}^{\text{UL-SCH}}(l) - 1$

$k = \Phi_l^{\text{UL-SCH}}(j)$;

for $v = 0$ to $N_L \cdot Q_m - 1$

$g_t = \bar{g}_{l,k,v}$;

$t = t + 1$;

end for

end for

end for

6.3 Uplink control information

6.3.1 Uplink control information on PUCCH

The procedure in this subclause applies to PUCCH formats 2/3/4.

6.3.1.1 UCI bit sequence generation

6.3.1.1.1 HARQ-ACK/SR only

If only HARQ-ACK bits are transmitted on a PUCCH, the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is determined by setting $a_i = \tilde{o}_i^{ACK}$ for $i = 0, 1, ..., O^{\text{ACK}} - 1$ and $A = O^{\text{ACK}}$, where the HARQ-ACK bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is given by Subclause 9.1 of [5, TS38.213].

If only HARQ-ACK and SR bits are transmitted on a PUCCH, the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is determined by setting $a_i = \tilde{o}_i^{ACK}$ for $i = 0, 1, ..., O^{\text{ACK}} - 1$, $a_i = \tilde{o}_i^{SR}$ for $i = O^{\text{ACK}}, O^{\text{ACK}} + 1, ..., O^{\text{ACK}} + O^{\text{SR}} - 1$, and $A = O^{\text{ACK}} + O^{\text{SR}}$, where the HARQ-ACK bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is given by Subclause 9.1 of [5, TS 38.213], and the SR bit sequence $\tilde{o}_0^{SR}, \tilde{o}_1^{SR}, ..., \tilde{o}_{O^{\text{SR}}-1}^{SR}$ is given by Subclause x.x of [5, TS 38.213].

6.3.1.1.2 CSI only

The bitwidth for PMI of *CodebookType=TypeI-SinglePanel* with 2 CSI-RS ports is 2 for Rank=1 and 1 for Rank=2, according to Subclause 5.2.2.2 in [6, TS 38.214].

The bitwidth for PMI of *CodebookType=TypeI-SinglePanel* with more than 2 CSI-RS ports is provided in Tables 6.3.1.1.2-1, where the values of (N_1, N_2) and (O_1, O_2) are given by Subclause 5.2.2.2.1 in [6, TS 38.214].

Table 6.3.1.1.2-1: PMI of *CodebookType=TypeI-SinglePanel*

<table>
<tr><th rowspan="3"></th><th colspan="3">Information field X_1 for wideband PMI</th><th colspan="2">Information field X_2 for wideband PMI
or per subband PMI</th></tr>
<tr><th colspan="2">$(i_{1,1}, i_{1,2})$</th><th rowspan="2">$i_{1,3}$</th><th colspan="2">i_2</th></tr>
<tr><th>CodebookMode=1</th><th>CodebookMode=2</th><th>CodebookMode=1</th><th>CodebookMode=2</th></tr>
</table>

Rank = 1 with >2 CSI-RS ports, $N_2 > 1$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{2} \cdot \frac{N_2O_2}{2}\right) \right\rceil$	N/A	2	4
Rank = 1 with >2 CSI-RS ports, $N_2 = 1$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{2}\right) \right\rceil$	N/A	2	4
Rank=2 with 4 CSI-RS ports, $N_2 = 1$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{2}\right) \right\rceil$	1	1	3
Rank=2 with >4 CSI-RS ports, $N_2 > 1$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{2} \cdot \frac{N_2O_2}{2}\right) \right\rceil$	2	1	3
Rank=2 with >4 CSI-RS ports, $N_2 = 1$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{2}\right) \right\rceil$	2	1	3
Rank=3 or 4, with 4 CSI-RS ports	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$		0	1	
Rank=3 or 4, with 8 or 12 CSI-RS ports	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$		2	1	
Rank=3 or 4 , with >=16 CSI-RS ports	$\left\lceil \log_2\left(\frac{N_1O_1}{2} \cdot N_2O_2\right) \right\rceil$		2	1	
Rank=5 or 6	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$		N/A	1	
Rank=7 or 8, $N_1 = 4, N_2 = 1$	$\left\lceil \log_2\left(\frac{N_1O_1}{2} \cdot N_2O_2\right) \right\rceil$		N/A	1	
Rank=7 or 8, $N_1 > 2, N_2 = 2$	$\left\lceil \log_2\left(N_1O_1 \cdot \frac{N_2O_2}{2}\right) \right\rceil$		N/A	1	
Rank=7 or 8, with $N_1 > 4, N_2 = 1$ or $N_1 = 2, N_2 = 2$ or $N_1 > 2, N_2 > 2$	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$		N/A	1	

The bitwidth for PMI of *CodebookType= TypeI-MultiPanel* is provided in Tables 6.3.1.1.2-2, where the values of (N_g, N_1, N_2) and (O_1, O_2) are given by Subclause 5.2.2.2.2 in [6, TS 38.214].

Table 6.3.1.1.2-2: PMI of *CodebookType= TypeI-MultiPanel*

	Information fields X_1 for wideband	Information fields X_2 for wideband or per subband

	$(i_{1,1}, i_{1,2})$	$i_{1,3}$	$i_{1,4,1}$	$i_{1,4,2}$	$i_{1,4,3}$	i_2	$i_{2,0}$	$i_{2,1}$	$i_{2,2}$
Rank=1 with $N_g = 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	N/A	2	N/A	N/A	2	N/A	N/A	N/A
Rank=1 with $N_g = 4$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	N/A	2	2	2	2	N/A	N/A	N/A
Rank=2 with $N_g = 2$, $N_1N_2 = 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	1	2	N/A	N/A	1	N/A	N/A	N/A
Rank=3 or 4 with $N_g = 2$, $N_1N_2 = 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	0	2	N/A	N/A	1	N/A	N/A	N/A
Rank=2 or 3 or 4 with $N_g = 2$, $N_1N_2 > 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	2	2	N/A	N/A	1	N/A	N/A	N/A
Rank=2 with $N_g = 4$, $N_1N_2 = 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	1	2	2	2	1	N/A	N/A	N/A
Rank=3 or 4 with $N_g = 4$, $N_1N_2 = 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	0	2	2	2	1	N/A	N/A	N/A
Rank=2 or 3 or 4 with $N_g = 4$, $N_1N_2 > 2$ *CodebookMode=1*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	2	2	2	2	1	N/A	N/A	N/A
Rank=1 with $N_g = 2$ *CodebookMode=2*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	N/A	2	2	N/A	N/A	2	1	1
Rank=2 with $N_g = 2$, $N_1N_2 = 2$ *CodebookMode=2*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	1	2	2	N/A	N/A	1	1	1
Rank=3 or 4 with $N_g = 2$, $N_1N_2 = 2$ *CodebookMode=2*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	0	2	2	N/A	N/A	1	1	1
Rank=2 or 3 or 4 with $N_g = 2$, $N_1N_2 > 2$ *CodebookMode=2*	$\lceil \log_2(N_1O_1 \cdot N_2O_2) \rceil$	2	2	2	N/A	N/A	1	1	1

The bitwidth for RI/LI/CQI of *CodebookType=TypeI-SinglePanel* is provided in Tables 6.3.1.1.2-3.

Table 6.3.1.1.2-3: RI, LI, and CQI of *CodebookType=TypeI-SinglePanel*

Field	Bitwidth			
	2 antenna ports	4 antenna ports	>4 antenna ports	
			Rank1~4	Rank5~8
Rank Indicator	$\min(1,\lceil \log_2 n_{\mathrm{RI}} \rceil)$	$\min(2,\lceil \log_2 n_{\mathrm{RI}} \rceil)$	$\lceil \log_2 n_{\mathrm{RI}} \rceil$	$\lceil \log_2 n_{\mathrm{RI}} \rceil$
Layer Indicator	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$
Wide-band CQI	4	4	4	8
Subband differential CQI	2	2	2	4
CRI	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$

If the higher layer parameter *Number_CQI* is not configured or *Number_CQI*=1, n_{RI} in Table 6.3.1.1.2-3 is the number of allowed rank indicator values in the 4 LSBs of the higher layer parameter *TypeI-SinglePanel-RI-Restriction* according to Subclause X.X [6, TS 38.214]; otherwise n_{RI} in Table 6.3.1.1.2-3 is the number of allowed rank indicator values according to Subclause X.X [6, TS 38.214]. The value of $K_s^{\mathrm{CSI-RS}}$ is the number of CSI-RS resources in the corresponding resource set.

The bitwidth for RI/LI/CQI of *CodebookType= TypeI-MultiPanel* is provided in Table 6.3.1.1.2-4.

Table 6.3.1.1.2-4: RI, LI, and CQI of *CodebookType=TypeI-MultiPanel*

Field	Bitwidth
Rank Indicator	$\min(2,\lceil \log_2 n_{\mathrm{RI}} \rceil)$
Layer Indicator	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$
Wide-band CQI	4
Subband differential CQI	2
CRI	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$

Where n_{RI} is the number of allowed rank indicator values according to Subclause X.X [6, TS 38.214], and $K_s^{\mathrm{CSI-RS}}$ is the number of CSI-RS resources in the corresponding resource set.

The bitwidth for RI/LI/CQI of *CodebookType= TypeII* is provided in Table 6.3.1.1.2-5.

Table 6.3.1.1.2-5: RI, LI, and CQI of *CodebookType=TypeII or TypeII-PortSelection*

Field	Bitwidth
Rank Indicator	$\min(1,\lceil \log_2 n_{\mathrm{RI}} \rceil)$
Layer Indicator	$\min(2,\lceil \log_2 \mathrm{RI} \rceil)$
Wide-band CQI	4
Subband differential CQI	2
Indicator of the number of non-zero wideband amplitude coefficients M_l for layer l	$\lceil \log_2 (2L-1) \rceil$
CRI	$\lceil \log_2 (K_s^{\mathrm{CSI-RS}}) \rceil$

Where n_{RI} is the number of allowed rank indicator values according to Subclause X.X [6, TS 38.214], and $K_s^{\mathrm{CSI-RS}}$ is the number of CSI-RS resources in the corresponding resource set.

The bitwidth for CRI, SSB index, RSRP, and differential RSRP are provided in Table 6.3.1.1.2-6.

Table 6.3.1.1.2-6: CRI, SSB index, and RSRP

Field	Bitwidth
CRI	$\left\lceil \log_2\left(K_s^{\text{CSI-RS}}\right)\right\rceil$
SSB index	$\left\lceil \log_2\left(K_s^{\text{SSB}}\right)\right\rceil$
RSRP	7
Differential RSRP	4

where $K_s^{\text{CSI-RS}}$ is the number of CSI-RS resources in the corresponding resource set, and K_s^{SSB} is the configured number of SS/PBCH blocks in the corresponding resource set for reporting 'SSBRI/RSRP'.

Table 6.3.1.1.2-7: Mapping order of CSI fields of one CSI report, *PMI-FormatIndicator=widebandPMI* and *CQI-FormatIndicator=widebandCQI*

CSI report number	CSI fields
CSI report #n	CRI as in Tables 6.3.1.1.2-3/4/5, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	Zero padding bits O_P, if needed
	PMI wideband information fields X_1, from left to right as in Tables 6.3.1.1.2-1/2, if reported
	PMI wideband information fields X_2, from left to right as in Tables 6.3.1.1.2-1/2, if reported
	Wideband CQI as in Tables 6.3.1.1.2-3/4/5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients M_l for layer l as in Table 6.3.1.1.2-5, if reported

The number of zero padding bits O_P in Table 6.3.1.1.2-7 is $O_P = N_{\max} - N_{\text{reported}}$, where

- $N_{\max} = \max_{r \in S_{\text{Rank}}} B(r)$ and S_{Rank} is the set of rank values r that are allowed to be reported;
- $N_{\text{reported}} = B(R)$, where R is the reported rank;
- For 2 CSI-RS ports, $B(r) = N_{\text{PMI}}(r) + N_{\text{CQI}}(r) + N_{\text{LI}}(r)$;
- For more than 2 CSI-RS ports, $B(r) = N_{\text{PMI,i1}}(r) + N_{\text{PMI,i2}}(r) + N_{\text{CQI}}(r) + N_{\text{LI}}(r)$;
- if PMI is reported, $N_{\text{PMI}}(1) = 2$ and $N_{\text{PMI}}(2) = 1$; otherwise, $N_{\text{PMI}}(r) = 0$;
- if PMI $i1$ is reported, $N_{\text{PMI,i1}}(r)$ is obtained according to Tables 6.3.1.1.2-1/2; otherwise, $N_{\text{PMI,i1}}(r) = 0$;
- if PMI $i2$ is reported, $N_{\text{PMI,i2}}(r)$ is obtained according to Tables 6.3.1.1.2-1/2; otherwise, $N_{\text{PMI,i2}}(r) = 0$;
- if CQI is reported, $N_{\text{CQI}}(r)$ is obtained according to Tables 6.3.1.1.2-3/4; otherwise, $N_{\text{CQI}}(r) = 0$;
- if LI is reported, $N_{\text{LI}}(r)$ is obtained according to Tables 6.3.1.1.2-3/4; otherwise, $N_{\text{LI}}(r) = 0$.

Table 6.3.1.1.2-8: Mapping order of CSI fields of one report for CRI/RSRP or SSB/RSRP reporting

CSI report number	CSI fields
CSI report #n	CRI or SSB index #1 as in Table 6.3.1.1.2-6, if reported
	CRI or SSB index #2 as in Table 6.3.1.1.2-6, if reported
	CRI or SSB index #3 as in Table 6.3.1.1.2-6, if reported
	CRI or SSB index #4 as in Table 6.3.1.1.2-6, if reported
	RSRP #1 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #2 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #3 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #4 as in Table 6.3.1.1.2-6, if reported

Table 6.3.1.1.2-9: Mapping order of CSI fields of one CSI report, CSI part 1, *PMI-FormatIndicator= subbandPMI* or *CQI-FormatIndicator=subbandCQI*

CSI report number	CSI fields
CSI report #n CSI part 1	CRI as in Tables 6.3.1.1.2-3/4/5, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	Wideband CQI for the first TB as in Tables 6.3.1.1.2-3/4/5, if reported
	Subband differential CQI for the first TB as in Tables 6.3.1.1.2-3/4/5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients M_l for layer l as in Table 6.3.1.1.2-5, if reported

Table 6.3.1.1.2-10: Mapping order of CSI fields of one CSI report, CSI part 2 wideband, *PMI-FormatIndicator= subbandPMI* or *CQI-FormatIndicator=subbandCQI*

CSI report number	CSI fields
CSI report #n CSI part 2 wideband	Wideband CQI for the second TB as in Tables 6.3.1.1.2-3/4/5, if present and reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	PMI wideband information fields X_1, from left to right as in Tables 6.3.1.1.2-1/2, if reported
	PMI wideband information fields X_2, from left to right as in Tables 6.3.1.1.2-1/2, if *PMI-FormatIndicator= widebandPMI* and if reported

Table 6.3.1.1.2-11: Mapping order of CSI fields of one CSI report, CSI part 2 subband, *PMI-FormatIndicator= subbandPMI* or *CQI-FormatIndicator=subbandCQI*

CSI report #n Part 2 subband	Subband differential CQI for the second TB of all even subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if *CQI-FormatIndicator=subbandCQI* and if reported
	PMI subband information fields X_2 of all even subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2, if *PMI-FormatIndicator= subbandPMI* and if reported
	Subband differential CQI for the second TB of all odd subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if *CQI-FormatIndicator=subbandCQI* and if reported
	PMI subband information fields X_2 of all odd subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2, if *PMI-FormatIndicator= subbandPMI* and if reported

If none of the CSI reports for transmission on a PUCCH is of two parts, the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-12, are mapped to the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ starting with a_0.

Table 6.3.1.1.2-12: Mapping order of CSI reports to UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$, without two-part CSI report(s)

UCI bit sequence	CSI report number
a_0 a_1 a_2 a_3 $\vdots$ a_{A-1}	CSI report #1 as in Table 6.3.1.1.2-7/8
	CSI report #2 as in Table 6.3.1.1.2-7/8
	…
	CSI report #n as in Table 6.3.1.1.2-7/8

If at least one of the CSI reports for transmission on a PUCCH is of two parts, two UCI bit sequences are generated, $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$ and $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$. The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-13, are mapped to the UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$ starting with $a_0^{(1)}$. The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-14, are mapped to the UCI bit sequence $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$ starting with $a_0^{(2)}$.

Table 6.3.1.1.2-13: Mapping order of CSI reports to UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$, with two-part CSI report(s)

UCI bit sequence	CSI report number
$a_0^{(1)}$ $a_1^{(1)}$ $a_2^{(1)}$ $a_3^{(1)}$ $\vdots$ $a_{A^{(1)}-1}^{(1)}$	CSI report #1 if CSI report #1 is not of two parts, or CSI report #1, CSI part 1, if CSI report #1 is of two parts, as in Table 6.3.1.1.2-7/8/9
	CSI report #2 if CSI report #2 is not of two parts, or CSI report #2, CSI part 1, if CSI report #2 is of two parts, as in Table 6.3.1.1.2-7/8/9
	…
	CSI report #n if CSI report #n is not of two parts, or CSI report #n, CSI part 1, if CSI report #n is of two parts, as in Table 6.3.1.1.2-7/8/9

Table 6.3.1.1.2-14: Mapping order of CSI reports to UCI bit sequence $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$, with two-part CSI report(s)

UCI bit sequence	CSI report number
$a_0^{(2)}$ $a_1^{(2)}$ $a_2^{(2)}$ $a_3^{(2)}$ $\vdots$ $a_{A^{(2)}-1}^{(2)}$	CSI report #1, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #2
	…
	CSI report #n, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #n
	CSI report #1, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #2
	…
	CSI report #n, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #n

6.3.1.1.3 HARQ-ACK/SR and CSI

If none of the CSI reports for transmission on a PUCCH is of two parts, the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is generated according to the following, where $A = O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI}}$:

- the HARQ-ACK bits are mapped to the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{O^{\text{ACK}}-1}$, where $a_i = \tilde{o}_i^{ACK}$ for $i = 0, 1, ..., O^{\text{ACK}} - 1$, the HARQ-ACK bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is given by Subclause 9.1 of [5, TS38.213], and O^{ACK} is number of HARQ-ACK bits;
- if SR is transmitted on the PUCCH, set $a_i = \tilde{o}_i^{SR}$ for $i = O^{\text{ACK}}, O^{\text{ACK}} + 1, ..., O^{\text{ACK}} + O^{\text{SR}} - 1$, where the SR bit sequence $\tilde{o}_0^{SR}, \tilde{o}_1^{SR}, ..., \tilde{o}_{O^{\text{SR}}-1}^{SR}$ is given by Subclause x.x of [5, TS 38.213];
- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-12, are mapped to the UCI bit sequence $a_{O^{\text{ACK}}+O^{\text{SR}}}, a_{O^{\text{ACK}}+O^{\text{SR}}+1}, ..., a_{O^{\text{ACK}}+O^{\text{SR}}+O^{\text{CSI}}-1}$ starting with $a_{O^{\text{ACK}}+O^{\text{SR}}}$, where O^{CSI} is the number of CSI bits.

If at least one of the CSI reports for transmission on a PUCCH is of two parts, two UCI bit sequences are generated, $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$ and $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$, according to the following, where $A^{(1)} = O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}}$ and $A^{(2)} = O^{\text{CSI-part2}}$:

- the HARQ-ACK bits are mapped to the UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{O^{\text{ACK}}-1}^{(1)}$, where $a_i^{(1)} = \tilde{o}_i^{ACK}$ for $i = 0, 1, ..., O^{\text{ACK}} - 1$, the HARQ-ACK bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is given by Subclause 9.1 of [5, TS38.213], and O^{ACK} is number of HARQ-ACK bits;
- if SR is transmitted on the PUCCH, set $a_i = \tilde{o}_i^{SR}$ for $i = O^{\text{ACK}}, O^{\text{ACK}} + 1, ..., O^{\text{ACK}} + O^{\text{SR}} - 1$, where the SR bit sequence $\tilde{o}_0^{SR}, \tilde{o}_1^{SR}, ..., \tilde{o}_{O^{\text{SR}}-1}^{SR}$ is given by Subclause x.x of [5, TS 38.213];

- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-13, are mapped to the UCI bit sequence $a^{(1)}_{O^{\text{ACK}}+O^{\text{SR}}}, a^{(1)}_{O^{\text{ACK}}+O^{\text{SR}}+1},..., a^{(1)}_{O^{\text{ACK}}+O^{\text{SR}}+O^{\text{CSI-part1}}-1}$ starting with $a^{(1)}_{O^{\text{ACK}}+O^{\text{SR}}}$, where $O^{\text{CSI-part1}}$ is the number of CSI bits in CSI part 1 of all CSI reports;
- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-14, are mapped to the UCI bit sequence $a^{(2)}_0, a^{(2)}_1, a^{(2)}_2, a^{(2)}_3,..., a^{(2)}_{A^{(2)}-1}$ starting with $a^{(2)}_0$, where $O^{\text{CSI-part2}}$ is the number of CSI bits in CSI part 2 of all CSI reports.

6.3.1.2 Code block segmentation and CRC attachment

The UCI bit sequence from subclause 6.3.1.1 is denoted by $a_0, a_1, a_2, a_3,..., a_{A-1}$, where A is the payload size. The procedure in 6.3.1.2.1 applies for $A \geq 12$ and the procedure in Subclause 6.3.1.2.2 applies for $A \leq 11$.

6.3.1.2.1 UCI encoded by Polar code

If the payload size $A \geq 12$, code block segmentation and CRC attachment is performed according to Subclause 5.2.1. If $A \geq 360$ and $E \geq 1088$, $I_{seg} = 1$; otherwise $I_{seg} = 0$, where E is the rate matching output sequence length as given in Subclause 6.3.1.4.

If $12 \leq A \leq 19$, the parity bits $p_{r0}, p_{r1}, p_{r2},..., p_{r(L-1)}$ in Subclause 5.2.1 are computed by setting L to 6 bits and using the generator polynomial $g_{\text{CRC6}}(D)$ in Subclause 5.1, resulting in the sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3},..., c_{r(K_r-1)}$ where r is the code block number and K_r is the number of bits for code block number r.

If $A \geq 20$, the parity bits $p_{r0}, p_{r1}, p_{r2},..., p_{r(L-1)}$ in Subclause 5.2.1 are computed by setting L to 11 bits and using the generator polynomial $g_{\text{CRC11}}(D)$ in Subclause 5.1, resulting in the sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3},..., c_{r(K_r-1)}$ where r is the code block number and K_r is the number of bits for code block number r.

6.3.1.2.2 UCI encoded by channel coding of small block lengths

If the payload size $A \leq 11$, CRC bits are not attached.

The output bit sequence is denoted by $c_0, c_1, c_2, c_3,..., c_{K-1}$, where $c_i = a_i$ for $i = 0,1,..., A-1$ and $K = A$.

6.3.1.3 Channel coding of UCI

6.3.1.3.1 UCI encoded by Polar code

Information bits are delivered to the channel coding block. They 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 in code block number r. The total number of code blocks is denoted by C and each code block is individually encoded by the following:

If $18 \leq K_r \leq 25$, the information bits are encoded via Polar coding according to Subclause 5.3.1, by setting $n_{\max} = 10$, $I_{IL} = 0$, $n_{PC} = 3$, $n^{wm}_{PC} = 1$ if $E_r - K_r + 3 > 192$ and $n^{wm}_{PC} = 0$ if $E_r - K_r + 3 \leq 192$, where E_r is the rate matching output sequence length as given in Subclause 6.3.1.4.1.

If $K_r > 30$, the information bits are encoded via Polar coding according to Subclause 5.3.1, by setting $n_{\max} = 10$, $I_{IL} = 0$, $n_{PC} = 0$, and $n^{wm}_{PC} = 0$.

After encoding the bits are denoted by $d_{r0}, d_{r1}, d_{r2}, d_{r3},..., d_{r(N_r-1)}$, where N_r is the number of coded bits in code block number r.

6.3.1.3.2 UCI encoded by channel coding of small block lengths

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3,..., c_{K-1}$, where K is the number of bits.

The information bits are encoded according to Subclause 5.3.3.

After encoding the bits are denoted by $d_0, d_1, d_2, d_3, ..., d_{N-1}$, where N is the number of coded bits.

6.3.1.4 Rate matching

For PUCCH formats 2/3/4, the total rate matching output sequence length E_{tot} is given by Table 6.3.1.4-1, where $N_{\text{symb,UCI}}^{\text{PUCCH, 2}}$, $N_{\text{symb,UCI}}^{\text{PUCCH, 3}}$, and $N_{\text{symb,UCI}}^{\text{PUCCH, 4}}$ are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively; $N_{\text{PRB}}^{\text{PUCCH, 2}}$ and $N_{\text{PRB}}^{\text{PUCCH, 3}}$ are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Subclause x.x of [5, TS38.213]; and $N_{\text{SF}}^{\text{PUCCH, 4}}$ is the spreading factor for PUCCH format 4.

Table 6.3.1.4-1: Total rate matching output sequence length E_{tot}

PUCCH format	***Modulation order***	
	QPSK	π/2-BPSK
PUCCH format 2	$16 \cdot N_{\text{symb,UCI}}^{\text{PUCCH, 2}} \cdot N_{\text{PRB}}^{\text{PUCCH, 2}}$	N/A
PUCCH format 3	$24 \cdot N_{\text{symb,UCI}}^{\text{PUCCH, 3}} \cdot N_{\text{PRB}}^{\text{PUCCH, 3}}$	$12 \cdot N_{\text{symb,UCI}}^{\text{PUCCH, 3}} \cdot N_{\text{PRB}}^{\text{PUCCH, 3}}$
PUCCH format 4	$24 \cdot N_{\text{symb,UCI}}^{\text{PUCCH, 4}} / N_{\text{SF}}^{\text{PUCCH, 4}}$	$12 \cdot N_{\text{symb,UCI}}^{\text{PUCCH, 4}} / N_{\text{SF}}^{\text{PUCCH, 4}}$

6.3.1.4.1 UCI encoded by Polar code

The input bit sequence to rate matching is $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$ where r is the code block number, and N_r is the number of coded bits in code block number r.

Table 6.3.1.4.1-1: Rate matching output sequence length E_{UCI}

UCI(s) for transmission on a PUCCH	**UCI for encoding**	**Value of E_{UCI}**
HARQ-ACK	HARQ-ACK	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, SR	HARQ-ACK, SR	$E_{\text{UCI}} = E_{\text{tot}}$
CSI (CSI not of two parts)	CSI	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, CSI (CSI not of two parts)	HARQ-ACK, CSI	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, SR, CSI (CSI not of two parts)	HARQ-ACK, SR, CSI	$E_{\text{UCI}} = E_{\text{tot}}$
CSI (CSI of two parts)	CSI part 1	$E_{\text{UCI}} = \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$
HARQ-ACK, CSI (CSI of two parts)	HARQ-ACK, CSI part 1	$E_{\text{UCI}} = \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{ACK}} + O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{ACK}} + O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$
HARQ-ACK, SR, CSI (CSI of two parts)	HARQ-ACK, SR, CSI part 1	$E_{\text{UCI}} = \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min\left(E_{\text{tot}}, \left\lceil \left(O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}} + L\right) / R_{\text{UCI}}^{\max} / Q_m \right\rceil \cdot Q_m \right)$

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL} = 1$ and the rate matching output sequence length to $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$, where C_{UCI} is the number of code blocks for UCI determined according to Subclause 6.3.1.2.1 and the value of E_{UCI} is given by Table 6.3.1.4.1-1:

- O^{ACK} is the number of bits for HARQ-ACK for transmission on the current PUCCH;
- O^{SR} is the number of bits for SR for transmission on the current PUCCH;
- $O^{\text{CSI-part1}}$ is the number of bits for CSI part 1 for transmission on the current PUCCH;

- $O^{\text{CSI-part2}}$ is the number of bits for CSI part 2 for transmission on the current PUCCH;
- L is the number of CRC bits;
- $R_{\text{UCI}}^{\max}$ is the configured maximum PUCCH coding rate;
- E_{tot} is given by Table 6.3.1.4-1.

The output bit sequence after rate matching is denoted as $f_{r0}, f_{r1}, f_{r2},..., f_{r(E_r-1)}$ where E_r is the length of rate matching output sequence in code block number r.

6.3.1.4.2 UCI encoded by channel coding of small block lengths

The input bit sequence to rate matching is $d_0, d_1, d_2,..., d_{N-1}$.

The value of E_{UCI} is determined according to Table 6.3.1.4.1-1 by setting $L = 0$.

Rate matching is performed according to Subclause 5.4.3 by setting the rate matching output sequence length $E = E_{\text{UCI}}$.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2,..., f_{E-1}$.

6.3.1.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences $f_{r0}, f_{r1}, f_{r2},..., f_{r(E_r-1)}$, for $r = 0,..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to Subclause 5.5.

The bits after code block concatenation are denoted by $g_0, g_1, g_2, g_3,..., g_{G'-1}$, where $G' = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor \cdot C_{\text{UCI}}$ with the values of E_{UCI} and C_{UCI} given in Subclause 6.3.1.4.1. Let G be the total number of coded bits for transmission and $G = G' + \text{mod}(E_{\text{UCI}}, C_{\text{UCI}})$. Set $g_i = 0$ for $i = G', G'+1,..., G-1$.

6.3.1.6 Multiplexing of coded UCI bits to PUCCH

If CSI of two parts are transmitted on a PUCCH, the coded bits corresponding to UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)},..., a_{A^{(1)}-1}^{(1)}$ is denoted by $g_0^{(1)}, g_1^{(1)}, g_2^{(1)}, g_3^{(1)},..., g_{G^{(1)}-1}^{(1)}$ and the coded bits corresponding to UCI bit sequence $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)},..., a_{A^{(2)}-1}^{(2)}$ is denoted by $g_0^{(2)}, g_1^{(2)}, g_2^{(2)}, g_3^{(2)},..., g_{G^{(2)}-1}^{(2)}$. The coded bit sequence $g_0, g_1, g_2, g_3,..., g_{G-1}$, where $G = G^{(1)} + G^{(2)}$, is generated according to the following.

Table 6.3.1.6-1: PUCCH DMRS and UCI symbols

PUCCH duration (symbols)	PUCCH DMRS symbol indices	Number of UCI symbol indices sets $N_{\mathrm{UCI}}^{\mathrm{set}}$	1st UCI symbol indices set $S_{\mathrm{UCI}}^{(1)}$	2nd UCI symbol indices set $S_{\mathrm{UCI}}^{(2)}$	3rd UCI symbol indices set $S_{\mathrm{UCI}}^{(3)}$
4	{1}	2	{0,2}	{3}	-
4	{0,2}	1	{1,3}	-	-
5	{0, 3}	1	{1, 2, 4}	-	-
6	{1, 4}	1	{0, 2, 3, 5}	-	-
7	{1, 4}	2	{0, 2, 3, 5}	{6}	-
8	{1, 5}	2	{0, 2, 4, 6}	{3, 7}	-
9	{1, 6}	2	{0, 2, 5, 7}	{3, 4, 8}	-
10	{2, 7}	2	{1, 3, 6, 8}	{0, 4, 5, 9}	-
10	{1, 3, 6, 8}	1	{0,2,4,5,7,9}	-	-
11	{2, 7}	3	{1,3,6,8}	{0,4,5,9}	{10}
11	{1,3,6,9}	1	{0,2,4,5,7,8,10}	-	-
12	{2, 8}	3	{1,3,7,9}	{0,4,6,10}	{5, 11}
12	{1,4,7,10}	1	{0,2,3,5,6,8,9,11}	-	-
13	{2, 9}	3	{1,3,8,10}	{0,4,7,11}	{5,6,12}
13	{1,4,7,11}	2	{0,2,3,5,6,8,10,12}	{9}	-
14	{3, 10}	3	{2,4,9,11}	{1,5,8,12}	{0,6,7,13}
14	{1,5,8,12}	2	{0,2,4,6,7,9,11,13}	{3, 10}	-

Denote s_l as UCI OFDM symbol index. Denote $N_{\mathrm{UCI}}^{(\mathrm{i})}$ as the number of elements in UCI symbol indices set $S_{\mathrm{UCI}}^{(i)}$ for $i = 1,..., N_{\mathrm{UCI}}^{\mathrm{set}}$, where $S_{\mathrm{UCI}}^{(i)}$ and $N_{\mathrm{UCI}}^{\mathrm{set}}$ are given by Table 6.3.1.6-1 according to the PUCCH duration and the PUCCH DMRS configuration. Denote $N_{\mathrm{symb,UCI}}^{\mathrm{PUCCH,}} = \sum_{i=1}^{N_{\mathrm{UCI}}^{\mathrm{set}}} N_{\mathrm{UCI}}^{(i)}$ as the number of OFDM symbols carrying UCI in the PUCCH. Denote Q_m as the modulation order of the PUCCH.

For PUCCH format 3, set $N_{\mathrm{UCI}}^{\mathrm{symbol}} = 12 \cdot N_{\mathrm{PRB}}^{\mathrm{PUCCH,3}}$, where $N_{\mathrm{PRB}}^{\mathrm{PUCCH,3}}$ is the number of PRBs that is determined by the UE for PUCCH format 3 transmission according to Subclause x.x of [5, TS 38.213].

For PUCCH format 4, set $N_{\mathrm{UCI}}^{\mathrm{symbol}} = 12 / N_{\mathrm{SF}}^{\mathrm{PUCCH,\,4}}$, where $N_{\mathrm{SF}}^{\mathrm{PUCCH,\,4}}$ is the spreading factor for PUCCH format 4.

Find the smallest $j > 0$ such that $\left(\sum_{i=1}^{j} N_{\mathrm{UCI}}^{(\mathrm{i})}\right) \cdot N_{\mathrm{UCI}}^{\mathrm{symbol}} \cdot Q_m \geq G^{(1)}$.

Set $n_1 = 0$;

Set $n_2 = 0$;

Set $\overline{N}_{\mathrm{UCI}}^{\mathrm{symbol}} = \left\lfloor \left(G^{(1)} - \left(\sum_{i=1}^{j-1} N_{\mathrm{UCI}}^{(\mathrm{i})} \right) \cdot N_{\mathrm{UCI}}^{\mathrm{symbol}} \cdot Q_m \right) \Big/ \left(N_{\mathrm{UCI}}^{(j)} \cdot Q_m \right) \right\rfloor$;

Set $M = \mathrm{mod}\left(\left(G^{(1)} - \left(\sum_{i=1}^{j-1} N_{\mathrm{UCI}}^{(\mathrm{i})} \right) \cdot N_{\mathrm{UCI}}^{\mathrm{symbol}} \cdot Q_m \right) \Big/ Q_m , N_{\mathrm{UCI}}^{(j)} \right)$;

for $l = 0$ to $N_{\mathrm{symb,UCI}}^{\mathrm{PUCCH,}} - 1$

  if $s_l \in \bigcup_{i=1}^{j-1} S_{\mathrm{UCI}}^{(i)}$

    for $k = 0$ to $N_{\mathrm{UCI}}^{\mathrm{symbol}} - 1$

      for $v = 0$ to $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_1}^{(1)}$;

$n_1 = n_1 + 1$;

end for

end for

elseif $s_l \in S_{\mathrm{UCI}}^{(j)}$

if $M > 0$

$\gamma = 1$;

else

$\gamma = 0$;

end if

$M = M - 1$;

for $k = 0$ to $\bar{N}_{\mathrm{UCI}}^{\mathrm{symbol}} + \gamma - 1$

for $v = 0$ to $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_1}^{(1)}$;

$n_1 = n_1 + 1$;

end for

end for

for $k = \bar{N}_{\mathrm{UCI}}^{\mathrm{symbol}} + \gamma$ to $N_{\mathrm{UCI}}^{\mathrm{symbol}} - 1$

for $v = 0$ to $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_2}^{(2)}$;

$n_2 = n_2 + 1$;

end for

end for

else

for $k = 0$ to $N_{\mathrm{UCI}}^{\mathrm{symbol}} - 1$

for $v = 0$ to $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_2}^{(2)}$;

$n_2 = n_2 + 1$;

end for

end for

end if

end for

Set $n=0$

for $l=0$ to $N_{\text{symb,UCI}}^{\text{PUCCH,}}-1$

for $k=0$ to $N_{\text{UCI}}^{\text{symbol}}-1$

for $v=0$ to Q_m-1

$g_n=\bar{g}_{l,k,v}$;

$n=n+1$;

end for

end for

end for

6.3.2 Uplink control information on PUSCH

6.3.2.1 UCI bit sequence generation

6.3.2.1.1 HARQ-ACK

If HARQ-ACK bits are transmitted on a PUSCH, the UCI bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is determined as follows:

- If UCI is transmitted on PUSCH without UL-SCH and the UCI includes CSI part 1 without CSI part 2,
  - if there is no HARQ-ACK bit given by Subclause 9.1 of [5, TS 38.213], set $a_0=0$, $a_1=0$, and $A=2$;
  - if there is only one HARQ-ACK bit $\tilde{o}_0^{ACK}$ given by Subclause 9.1 of [5, TS 38.213], set $a_0=\tilde{o}_0^{ACK}$, $a_1=0$, and $A=2$;
- otherwise, ser $a_i=\tilde{o}_i^{ACK}$ for $i=0,1,...,O^{\text{ACK}}-1$ and $A=O^{\text{ACK}}$, where the HARQ-ACK bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is given by Subclause 9.1 of [5, TS 38.213].

6.3.2.1.2 CSI

The bitwidth for PMI of *CodebookType=TypeII* is provided in Tables 6.3.2.1.2-1, where the values of (N_1,N_2), (O_1,O_2), L, N_{PSK}, M_1, M_2, and $K^{(2)}$ are given by Subclause 5.2.2.2.3 in [6, TS 38.214].

Table 6.3.2.1.2-1: PMI of *CodebookType= TypeII*

	Information fields for wideband PMI						Information fields per subband PMI			
	$i_{1,1}$	$i_{1,2}$	$i_{1,3,1}$	$i_{1,4,1}$	$i_{1,3,2}$	$i_{1,4,2}$	$i_{2,1,1}$	$i_{2,1,2}$	$i_{2,2,1}$	$i_{2,2,2}$
Rank=1 SBAmp off	$\lceil \log_2(O_1O_2) \rceil$	$\left\lceil \log_2 \binom{N_1N_2}{L} \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$(M_1-1)\cdot \log_2 N_{\text{PSK}}$	N/A	N/A	N/A
Rank=2 SBAmp off	$\lceil \log_2(O_1O_2) \rceil$	$\left\lceil \log_2 \binom{N_1N_2}{L} \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$(M_1-1)\cdot \log_2 N_{\text{PSK}}$	$(M_2-1)\cdot \log_2 N_{\text{PSK}}$	N/A	N/A

Rank=1 SBAmp on	$\lceil \log_2(O_1O_2) \rceil$	$\left\lceil \log_2 \binom{N_1N_2}{L} \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$\min(M_1,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_1-\min(M_1,K^{(2)}))$	N/A	$\min(M_1,K^{(2)})-1$	N/A
Rank=2 SBAmp on	$\lceil \log_2(O_1O_2) \rceil$	$\left\lceil \log_2 \binom{N_1N_2}{L} \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\min(M_1,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_1-\min(M_1,K^{(2)}))$	$\min(M_2,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_2-\min(M_2,K^{(2)}))$	$\min(M_1,K^{(2)})-1$	$\min(M_2,K^{(2)})-1$

The bitwidth for PMI of *CodebookType= TypeII-PortSelection* is provided in Tables 6.3.2.1.2-2, where the values of P_{CSI-RS}, d, L, N_{PSK}, M_1, M_2, and $K^{(2)}$ are given by Subclause 5.2.2.2.4 in [6, TS 38.214].

Table 6.3.2.1.2-2: PMI of *CodebookType= TypeII-PortSelection*

	Information fields for wideband PMI					Information fields per subband PMI			
	$i_{1,1}$	$i_{1,3,1}$	$i_{1,4,1}$	$i_{1,3,2}$	$i_{1,4,2}$	$i_{2,1,1}$	$i_{2,1,2}$	$i_{2,2,1}$	$i_{2,2,2}$
Rank=1 SBAmp off	$\left\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$(M_1-1)\cdot\log_2 N_{\mathrm{PSK}}$	N/A	N/A	N/A
Rank=2 SBAmp off	$\left\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$(M_1-1)\cdot\log_2 N_{\mathrm{PSK}}$	$(M_2-1)\cdot\log_2 N_{\mathrm{PSK}}$	N/A	N/A
Rank=1 SBAmp on	$\left\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$\min(M_1,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_1-\min(M_1,K^{(2)}))$	N/A	$\min(M_1,K^{(2)})-1$	N/A
Rank=2 SBAmp on	$\left\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \right\rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\min(M_1,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_1-\min(M_1,K^{(2)}))$	$\min(M_2,K^{(2)})\cdot\log_2 N_{\mathrm{PSK}} - \log_2 N_{\mathrm{PSK}} + 2\cdot(M_2-\min(M_2,K^{(2)}))$	$\min(M_1,K^{(2)})-1$	$\min(M_2,K^{(2)})-1$

For CSI on PUSCH, two UCI bit sequences are generated, $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$ and $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$. The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.2.1.2-6, are mapped to the UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$ starting with $a_0^{(1)}$. The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.2.1.2-7, are mapped to the UCI bit sequence $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$ starting with $a_0^{(2)}$.

Table 6.3.2.1.2-3: Mapping order of CSI fields of one CSI report, CSI part 1

CSI report number	CSI fields
CSI report #n CSI part 1	CRI or SSB index as in Tables 6.3.1.1.2-6, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	Wideband CQI as in Tables 6.3.1.1.2-3/4/5, if reported
	Subband differential CQI for the first TB as in Tables 6.3.1.1.2-3/4/5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients M_l for layer l as in Table 6.3.1.1.2-5, if reported
	RSRP as in Table 6.3.1.1.2-6, if reported
	Differential RSRP as in Table 6.3.1.1.2-6, if reported

Table 6.3.2.1.2-4: Mapping order of CSI fields of one CSI report, CSI part 2 wideband

CSI report number	CSI fields
CSI report #n CSI part 2 wideband	Wideband CQI for the second TB as in Tables 6.3.1.1.2-3/4/5, if present and reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	PMI wideband information fields X_1, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, if reported
	PMI wideband information fields X_2, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, if *PMI-FormatIndicator= widebandPMI* and if reported

Table 6.3.2.1.2-5: Mapping order of CSI fields of one CSI report, CSI part 2 subband

CSI report #n Part 2 subband	Subband differential CQI for the second TB of all even subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if *CQI-FormatIndicator=subbandCQI* and if reported
	PMI subband information fields X_2 of all even subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, if *PMI-FormatIndicator= subbandPMI* and if reported
	Subband differential CQI for the second TB of all odd subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if *CQI-FormatIndicator=subbandCQI* and if reported
	PMI subband information fields X_2 of all odd subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, if *PMI-FormatIndicator= subbandPMI* and if reported

Table 6.3.2.1.2-6: Mapping order of CSI reports to UCI bit sequence $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, ..., a_{A^{(1)}-1}^{(1)}$, with two-part CSI report(s)

UCI bit sequence	CSI report number
$a_0^{(1)}$ $a_1^{(1)}$ $a_2^{(1)}$ $a_3^{(1)}$ $\vdots$ $a_{A^{(1)}-1}^{(1)}$	CSI part 1 of CSI report #1 as in Table 6.3.2.1.2-3
	CSI part 1 of CSI report #2 as in Table 6.3.2.1.2-3
	…
	CSI part 1 of CSI report #n as in Table 6.3.2.1.2-3

Table 6.3.2.1.2-7: Mapping order of CSI reports to UCI bit sequence $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, ..., a_{A^{(2)}-1}^{(2)}$, with two-part CSI report(s)

UCI bit sequence	CSI report number
$a_0^{(2)}$ $a_1^{(2)}$ $a_2^{(2)}$ $a_3^{(2)}$ $\vdots$ $a_{A^{(2)}-1}^{(2)}$	CSI report #1, CSI part 2 wideband, as in Table 6.3.2.1.2-4 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 wideband, as in Table 6.3.2.1.2-4 if CSI part 2 exists for CSI report #2
	…
	CSI report #n, CSI part 2 wideband, as in Table 6.3.2.1.2-4 if CSI part 2 exists for CSI report #n
	CSI report #1, CSI part 2 subband, as in Table 6.3.2.1.2-5 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 subband, as in Table 6.3.2.1.2-5 if CSI part 2 exists for CSI report #2
	…
	CSI report #n, CSI part 2 subband, as in Table 6.3.2.1.2-5 if CSI part 2 exists for CSI report #n

6.3.2.2 Code block segmentation and CRC attachment

Denote the bits of the payload by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, where A is the payload size. The procedure in 6.3.2.2.1 applies for $A \geq 12$ and the procedure in Subclause 6.3.2.2.2 applies for $A \leq 11$.

6.3.2.2.1 UCI encoded by Polar code

Code block segmentation and CRC attachment is performed according to Subclause 6.3.1.2.1.

6.3.2.2.2 UCI encoded by channel coding of small block lengths

The procedure in Subclause 6.3.1.2.2 applies.

6.3.2.3 Channel coding of UCI

6.3.2.3.1 UCI encoded by Polar code

Channel coding is performed according to Subclause 6.3.1.3.1.

6.3.2.3.2 UCI encoded by channel coding of small block lengths

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits.

The information bits are encoded according to Subclause 5.3.3.

After encoding the bits are denoted by $d_0, d_1, d_2, d_3, ..., d_{N-1}$, where N is the number of coded bits.

6.3.2.4 Rate matching

6.3.2.4.1 UCI encoded by Polar code

6.3.2.4.1.1 HARQ-ACK

For HARQ-ACK transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as Q'_{ACK}, is determined as follows:

$$Q'_{\mathrm{ACK}} = \min\left\{ \left\lceil \frac{(O_{\mathrm{ACK}} + L_{\mathrm{ACK}}) \cdot \beta_{\mathrm{offset}}^{\mathrm{PUSCH}} \cdot \sum_{l=0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1} M_{\mathrm{sc}}^{\mathrm{UCI}}(l)}{\sum_{r=0}^{C_{\mathrm{UL-SCH}}-1} K_r} \right\rceil, \left\lceil \alpha \cdot \sum_{l=l_0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1} M_{\mathrm{sc}}^{\mathrm{UCI}}(l) \right\rceil \right\}$$

where

- O_{ACK} is the number of HARQ-ACK bits;
- L_{ACK} is the number of CRC bits for HARQ-ACK;
- $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}} = \beta_{\mathrm{offset}}^{\mathrm{HARQ-ACK}}$;
- $C_{\mathrm{UL-SCH}}$ is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the r-th code block, K_r=0; otherwise, K_r is the r-th code block size for UL-SCH of the PUSCH transmission;
- $M_{\mathrm{sc}}^{\mathrm{PUSCH}}$ is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\mathrm{sc}}^{\mathrm{PT-RS}}(l)$ is the number of subcarriers in OFDM symbol l that carries PTRS, in the PUSCH transmission;
- $M_{\mathrm{sc}}^{\mathrm{UCI}}(l)$ is the number of resource elements that can be used for transmission of UCI in OFDM symbol l, for $l = 0,1,2,...,N_{\mathrm{symb,all}}^{\mathrm{PUSCH}} - 1$, in the PUSCH transmission and $N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}$ is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH, $M_{\mathrm{sc}}^{\mathrm{UCI}}(l) = 0$;
  - for any OFDM symbol that does not carry DMRS of the PUSCH, $M_{\mathrm{sc}}^{\mathrm{UCI}}(l) = M_{\mathrm{sc}}^{\mathrm{PUSCH}} - M_{\mathrm{sc}}^{\mathrm{PT-RS}}(l)$;
- $\alpha \in \{0.5,\ 0.65,\ 0.8,\ 1\}$ is configured by higher layer parameter *uci-on-pusch-scaling*;
- l_0 is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission.

For HARQ-ACK transmission on PUSCH without UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as Q'_{ACK}, is determined as follows:

$$Q'_{\mathrm{ACK}} = \min\left\{ \left\lceil \frac{(O_{\mathrm{ACK}} + L_{\mathrm{ACK}}) \cdot \beta_{\mathrm{offset}}^{\mathrm{PUSCH}} \cdot \sum_{l=0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1} M_{\mathrm{sc}}^{\mathrm{UCI}}(l)}{O_{\mathrm{CSI}}} \right\rceil, \sum_{l=l_0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1} M_{\mathrm{sc}}^{\mathrm{UCI}}(l) \right\}$$

where

- O_{ACK} is the number of HARQ-ACK bits;
- L_{ACK} is the number of CRC bits for HARQ-ACK bits;
- O_{CSI} is the number of bits for CSI part 1;
  - $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}} = \beta_{\mathrm{offset}}^{\mathrm{HARQ-ACK}} / \beta_{\mathrm{offset}}^{\mathrm{CSI-part1}}$;
- $M_{\mathrm{sc}}^{\mathrm{PUSCH}}$ is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\mathrm{sc}}^{\text{PT-RS}}(l)$ is the number of subcarriers in OFDM symbol l that carries PTRS, in the PUSCH transmission;
- $M_{\mathrm{sc}}^{\mathrm{UCI}}(l)$ is the number of resource elements that can be used for transmission of UCI in OFDM symbol l, for $l = 0, 1, 2, ..., N_{\mathrm{symb,all}}^{\mathrm{PUSCH}} - 1$, in the PUSCH transmission and $N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}$ is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH, $M_{\mathrm{sc}}^{\mathrm{UCI}}(l) = 0$;
  - for any OFDM symbol that does not carry DMRS of the PUSCH, $M_{\mathrm{sc}}^{\mathrm{UCI}}(l) = M_{\mathrm{sc}}^{\mathrm{PUSCH}} - M_{\mathrm{sc}}^{\text{PT-RS}}(l)$;
- l_0 is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission.

The input bit sequence to rate matching is $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$ where r is the code block number, and N_r is the number of coded bits in code block number r.

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL} = 1$ and the rate matching output sequence length to $E_r = \lfloor E_{\mathrm{UCI}} / C_{\mathrm{UCI}} \rfloor$, where

- C_{UCI} is the number of code blocks for UCI determined according to Subclause 5.2.1;
- N_L is the number of transmission layers of the PUSCH;
- Q_m is the modulation order of the PUSCH;
- $E_{\mathrm{UCI}} = N_L \cdot Q'_{\mathrm{ACK}} \cdot Q_m$.

The output bit sequence after rate matching is denoted as $f_{r0}, f_{r1}, f_{r2}, ..., f_{r(E_r-1)}$ where E_r is the length of rate matching output sequence in code block number r.

6.3.2.4.1.2 CSI part 1

For CSI part 1 transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as $Q'_{\text{CSI-part1}}$, is determined as follows:

$$Q'_{\text{CSI-1}} = \min\left\{ \left\lceil \frac{\left(O_{\text{CSI-1}} + L_{\text{CSI-1}}\right) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r} \right\rceil, \left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil - Q'_{\text{ACK}} \right\}$$

where

- $O_{\text{CSI-1}}$ is the number of bits for CSI part 1;
- $L_{\text{CSI-1}}$ is the number of CRC bits for CSI part 1;
- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{CSI-part1}}$;
- $C_{\text{UL-SCH}}$ is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the r-th code block, K_r=0; otherwise, K_r is the r-th code block size for UL-SCH of the PUSCH transmission;
- $M_{\text{sc}}^{\text{PUSCH}}$ is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$ is the number of subcarriers in OFDM symbol l that carries PTRS, in the PUSCH transmission;
- Q'_{ACK} is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH if number of HARQ-ACK information bits is more than 2, and $Q'_{\text{ACK}} = \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} \bar{M}_{\text{sc, rvd}}^{\text{ACK}}(l)$ if the number of HARQ-ACK information bits is no more than 2 bits, where $\bar{M}_{\text{sc, rvd}}^{\text{ACK}}(l)$ is the number of reserved resource elements for potential HARQ-ACK transmission in OFDM symbol l, for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$, in the PUSCH transmission, defined in Subclause 6.2.7;
- $M_{\text{sc}}^{\text{UCI}}(l)$ is the number of resource elements that can be used for transmission of UCI in OFDM symbol l, for $l = 0,1,2,...,N_{\text{symb,all}}^{\text{PUSCH}} - 1$, in the PUSCH transmission and $N_{\text{symb,all}}^{\text{PUSCH}}$ is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH, $M_{\text{sc}}^{\text{UCI}}(l) = 0$;
  - for any OFDM symbol that does not carry DMRS of the PUSCH, $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$;
- $\alpha \in \{0.5,\ 0.65,\ 0.8,\ 1\}$ is configured by higher layer parameter *uci-on-pusch-scaling*.

The input bit sequence to rate matching is $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$ where r is the code block number, and N_r is the number of coded bits in code block number r.

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL}=1$ and the rate matching output sequence length to $E_r=\lfloor E_{\mathrm{UCI}}/C_{\mathrm{UCI}}\rfloor$, where

- C_{UCI} is the number of code blocks for UCI determined according to Subclause 5.2.1;
- N_L is the number of transmission layers of the PUSCH;
- Q_m is the modulation order of the PUSCH;
- $E_{\mathrm{UCI}}=N_L\cdot Q'_{\mathrm{CSI,1}}\cdot Q_m$.

The output bit sequence after rate matching is denoted as $f_{r0},f_{r1},f_{r2},...,f_{r(E_r-1)}$ where E_r is the length of rate matching output sequence in code block number r.

6.3.2.4.1.3 CSI part 2

For CSI part 2 transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as $Q'_{\mathrm{CSI\text{-}part2}}$, is determined as follows:

$$Q'_{\mathrm{CSI\text{-}2}}=\min\left\{\left\lceil\frac{(O_{\mathrm{CSI\text{-}2}}+L_{\mathrm{CSI\text{-}2}})\cdot\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}\cdot\sum_{l=0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1}M_{\mathrm{sc}}^{\mathrm{UCI}}(l)}{\sum_{r=0}^{C_{\mathrm{UL\text{-}SCH}}-1}K_r}\right\rceil,\left\lceil\alpha\cdot\sum_{l=0}^{N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1}M_{\mathrm{sc}}^{\mathrm{UCI}}(l)\right\rceil-Q'_{\mathrm{ACK}}-Q'_{\mathrm{CSI\text{-}1}}\right\}$$

where

- $O_{\mathrm{CSI\text{-}2}}$ is the number of bits for CSI part 2;
- $L_{\mathrm{CSI\text{-}2}}$ is the number of CRC bits for CSI part 2;
- $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}=\beta_{\mathrm{offset}}^{\mathrm{CSI\text{-}part2}}$;
- $C_{\mathrm{UL-SCH}}$ is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the r-th code block, K_r=0; otherwise, K_r is the r-th code block size for UL-SCH of the PUSCH transmission;
- $M_{\mathrm{sc}}^{\mathrm{PUSCH}}$ is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\mathrm{sc}}^{\mathrm{PT\text{-}RS}}(l)$ is the number of subcarriers in OFDM symbol l that carries PTRS, in the PUSCH transmission;
- Q'_{ACK} is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH if number of HARQ-ACK information bits is more than 2, and $Q'_{\mathrm{ACK}}=0$ if the number of HARQ-ACK information bits is 1 or 2 bits;
- $Q'_{\mathrm{CSI\text{-}1}}$ is the number of coded modulation symbols per layer for CSI part 1 transmitted on the PUSCH;
- $M_{\mathrm{sc}}^{\mathrm{UCI}}(l)$ is the number of resource elements that can be used for transmission of UCI in OFDM symbol l, for $l=0,1,2,...,N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}-1$, in the PUSCH transmission and $N_{\mathrm{symb,all}}^{\mathrm{PUSCH}}$ is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;

  - for any OFDM symbol that carries DMRS of the PUSCH, $M_{\text{sc}}^{\text{UCI}}(l)=0$;
  - for any OFDM symbol that does not carry DMRS of the PUSCH, $M_{\text{sc}}^{\text{UCI}}(l)=M_{\text{sc}}^{\text{PUSCH}}-M_{\text{sc}}^{\text{PT-RS}}(l)$.
- $\alpha \in \{0.5,\ 0.65,\ 0.8,\ 1\}$ is configured by higher layer parameter *uci-on-pusch-scaling*.

The input bit sequence to rate matching is $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$ where r is the code block number, and N_r is the number of coded bits in code block number r.

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL}=1$ and the rate matching output sequence length to $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$, where

- C_{UCI} is the number of code blocks for UCI determined according to Subclause 5.2.1;
- N_L is the number of transmission layers of the PUSCH;
- Q_m is the modulation order of the PUSCH;
- $E_{\text{UCI}} = N_L \cdot Q'_{\text{CSI,2}} \cdot Q_m$.

The output bit sequence after rate matching is denoted as $f_{r0}, f_{r1}, f_{r2}, ..., f_{r(E_r-1)}$ where E_r is the length of rate matching output sequence in code block number r.

6.3.2.4.2 UCI encoded by channel coding of small block lengths

6.3.2.4.2.1 HARQ-ACK

For HARQ-ACK transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as Q'_{ACK}, is determined according to Subclause 6.3.2.4.1.1, by setting the number of CRC bits $L=0$.

The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$.

Rate matching is performed according to Subclause 5.4.3, by setting the rate matching output sequence length $E = N_L \cdot Q'_{\text{ACK}} \cdot Q_m$, where

- N_L is the number of transmission layers of the PUSCH;
- Q_m is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

6.3.2.4.2.2 CSI part 1

For CSI part 1 transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as $Q'_{\text{CSI,1}}$, is determined according to Subclause 6.3.2.4.1.2, by setting the number of CRC bits $L=0$.

Rate matching is performed according to Subclause 5.4.3, by setting the rate matching output sequence length $E = N_L \cdot Q'_{\text{CSI,1}} \cdot Q_m$, where

- N_L is the number of transmission layers of the PUSCH;

- Q_m is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

6.3.2.4.2.3 CSI part 2

For CSI part 2 transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as $Q'_{\mathrm{CSI},2}$, is determined according to Subclause 6.3.2.4.1.3, by setting the number of CRC bits $L = 0$.

Rate matching is performed according to Subclause 5.4.3, by setting the rate matching output sequence length $E = N_L \cdot Q'_{\mathrm{CSI},2} \cdot Q_m$, where

- N_L is the number of transmission layers of the PUSCH;

- Q_m is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

6.3.2.5 Code block concatenation

Code block concatenation is performed according to Subclause 6.3.1.5, except that the values of E_{UCI} and C_{UCI} given in Subclause 6.3.2.4.1.

6.3.2.6 Multiplexing of coded UCI bits to PUSCH

The coded UCI bits are multiplexed onto PUSCH according to the procedures in Subclause 6.2.7.

7 Downlink transport channels and control information

7.1 Broadcast channel

Data arrives to the coding unit in the form of a maximum of one transport block every 80ms. The following coding steps can be identified:

- Payload generation
- Scrambling
- Transport block CRC attachment
- Channel coding
- Rate matching

7.1.1 PBCH payload generation

Denote the bits in a transport block delivered to layer 1 by $\bar{a}_0, \bar{a}_1, \bar{a}_2, \bar{a}_3, ..., \bar{a}_{\bar{A}-1}$, where $\bar{A}$ is the payload size generated by higher layers. The lowest order information bit $\bar{a}_0$ is mapped to the most significant bit of the transport block as defined in Subclause [6.1.4] of [8, TS 38.321].

Generate the following additional timing related PBCH payload bits $\bar{a}_{\bar{A}}, \bar{a}_{\bar{A}+1}, \bar{a}_{\bar{A}+2}, \bar{a}_{\bar{A}+3}, ..., \bar{a}_{\bar{A}+7}$, where:

- $\bar{a}_{\bar{A}}, \bar{a}_{\bar{A}+1}, \bar{a}_{\bar{A}+2}, \bar{a}_{\bar{A}+3}$ are the 4th, 3rd, 2nd, and 1st LSB of SFN, respectively;

- $\bar{a}_{\bar{A}+4}$ is the half radio frame bit $\bar{a}_{\mathrm{HRF}}$;

- if $L_{\text{SSB}} = 64$

  $\bar{a}_{\bar{A}+5}, \bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ are the 6th, 5th, and 4th bits of SS/PBCH block index, respectively.

  else

  $\bar{a}_{\bar{A}+5}$ is the MSB of k_0 as defined in Subclause 7.4.3.1 of [4, TS 38.211].

  $\bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ are reserved.

  end if

Let $A = \bar{A} + 8$; $j_{\text{SFN}} = 0$; $j_{\text{HRF}} = 10$; $j_{\text{SSB}} = 11$; $j_{\text{other}} = 14$;

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

if $\bar{a}_i$ is an SFN bit

$a_{G(j_{\text{SFN}})} = \bar{a}_i$;

$j_{\text{SFN}} = j_{\text{SFN}} + 1$;

elseif $\bar{a}_i$ is the half radio frame bit

$a_{G(j_{\text{HRF}})} = \bar{a}_i$

elseif $\bar{A} + 5 \le i \le \bar{A} + 7$

$a_{G(j_{\text{SSB}})} = \bar{a}_i$;

$j_{\text{SSB}} = j_{\text{SSB}} + 1$;

else

$a_{G(j_{\text{Other}})} = \bar{a}_i$;

$j_{\text{Other}} = j_{\text{Other}} + 1$;

end if

end for

where L_{SSB} is the number of candidate SS/PBCH blocks in a half frame according to Subclause 4.1 of [5, TS38.213], and the value of $G(j)$ is given by Table 7.1.1-1.

Table 7.1.1-1: Value of PBCH payload interleaver pattern $G(j)$

j	$G(j)$	j	$G(j)$	j	$G(j)$	j	$G(j)$	j	$G(j)$	j	$G(j)$	j	$G(j)$	j	$G(j)$
0	16	4	8	8	24	12	3	16	9	20	14	24	21	28	27
1	23	5	30	9	7	13	2	17	11	21	15	25	22	29	28
2	18	6	10	10	0	14	1	18	12	22	19	26	25	30	29
3	17	7	6	11	5	15	4	19	13	23	20	27	26	31	31

7.1.2 Scrambling

For PBCH transmission in a frame, the bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is scrambled into a bit sequence $a'_0, a'_1, a'_2, a'_3, ..., a'_{A-1}$, where $a'_i = (a_i + s_i) \mod 2$ for $i = 0,1,..., A-1$ and $s_0, s_1, s_2, s_3, ..., s_{A-1}$ is generated according to the following:

$i = 0$;

$j = 0$;

while $i < A$

if a_i corresponds to any one of the bits belonging to the SS/PBCH block index, the half radio frame index, and 2nd and 3rd least significant bits of the system frame number

$s_i = 0$;

else

$s_i = c(j + vM)$;

$j = j + 1$;

end if

$i = i + 1$;

end while

The scrambling sequence $c(i)$ is given by Subclause 5.2.1of [4, TS38.211] and initialized with $c_{\text{init}} = N_{ID}^{cell}$ at the start of each SFN satisfying $\mathrm{mod}(SFN, 8) = 0$; $M = A - 3$ for $L = 4$ or $L = 8$, and $M = A - 6$ for $L = 64$, where L is the number of candidate SS/PBCH blocks in a half frame according to Subclause 4.1 of [5, TS38.213]; and v is determined according to Table 7.1.2-1 using the 3rd and 2nd LSB of the SFN in which the PBCH is transmitted.

Table 7.1.2-1: Value of v for PBCH scrambling

(3rd LSB of SFN, 2nd LSB of SFN)	*Value of v*
(0, 0)	0
(0, 1)	1
(1, 0)	2
(1, 1)	3

7.1.3 Transport block CRC attachment

Error detection is provided on BCH transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. The input bit sequence is denoted 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 payload size and L is the number of parity bits.

The parity bits are computed and attached to the BCH transport block according to Subclause 5.1 by setting L to 24 bits and using the generator polynomial $g_{\text{CRC24C}}(D)$, resulting in the sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$.

The bit sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$ is the input bit sequence $c_0, c_1, c_2, c_3, ..., c_{K-1}$ to the channel encoder, where $c_i = b_i$ for $i = 0, 1, ..., B-1$ and $K = B$.

7.1.4 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are encoded via Polar coding according to Subclause 5.3.1, by setting $n_{\max} = 9$, $I_{IL} = 1$, $n_{PC} = 0$, and $n_{PC}^{wm} = 0$.

After encoding the bits are denoted by $d_0, d_1, d_2, d_3, ..., d_{N-1}$, where N is the number of coded bits.

7.1.5 Rate matching

The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$.

The rate matching output sequence length $E = 864$.

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL} = 0$.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

7.2 Downlink shared channel and paging channel

7.2.1 Transport block CRC attachment

Error detection is provided on each transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 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 payload size and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in Subclause x.x of [TS38.321].

The parity bits are computed and attached to the DL-SCH transport block according to Subclause 5.1, by setting L to 24 bits and using the generator polynomial $g_{\mathrm{CRC24A}}(D)$ if $A > 3824$; and by setting L to 16 bits and using the generator polynomial $g_{\mathrm{CRC16}}(D)$ otherwise.

The bits after CRC attachment are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$.

7.2.2 LDPC base graph selection

For initial transmission of a transport block with coding rate R indicated by the MCS index according to Subclause 5.1.3.1 in [6, TS 38.214] and subsequent re-transmission of the same transport block, each code block of the transport block is encoded with either LDPC base graph 1 or 2 according to the following:

- if $A \le 292$, or if $A \le 3824$ and $R \le 0.67$, or if $R \le 0.25$, LDPC base graph 2 is used;
- otherwise, LDPC base graph 1 is used,

where A is the payload size in Subclause 7.2.1.

7.2.3 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to Subclause 5.2.2.

The bits after code block segmentation 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 code block number r according to Subclause 5.2.2.

7.2.4 Channel coding

Code blocks are delivered to the channel coding block. The bits in a code block 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 in code block number r. The total number of code blocks is denoted by C and each code block is individually LDPC encoded according to Subclause 5.3.2.

After encoding the bits are denoted by $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$, where the values of N_r is given in Subclause 5.3.2.

7.2.5 Rate matching

Coded bits for each code block, denoted as $d_{r0}, d_{r1}, d_{r2}, d_{r3}, ..., d_{r(N_r-1)}$, are delivered to the rate match block, where r is the code block number, and N_r is the number of encoded bits in code block number r. The total number of code blocks is denoted by C and each code block is individually rate matched according to Subclause 5.4.2 by setting $I_{LBRM} = 1$.

After rate matching, the bits are denoted by $f_{r0}, f_{r1}, f_{r2}, f_{r3}, ..., f_{r(E_r-1)}$, where E_r is the number of rate matched bits for code block number r.

7.2.6 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences $f_{r0}, f_{r1}, f_{r2}, f_{r3}, ..., f_{r(E_r-1)}$, for $r = 0, ..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to Subclause 5.5.

The bits after code block concatenation are denoted by $g_0, g_1, g_2, g_3, ..., g_{G-1}$, where G is the total number of coded bits for transmission.

7.3 Downlink control information

A DCI transports downlink and uplink scheduling information, requests for aperiodic CQI reports, or uplink power control commands for one cell and one RNTI.

The following coding steps can be identified:

- Information element multiplexing
- CRC attachment
- Channel coding
- Rate matching

7.3.1 DCI formats

The DCI formats defined in table 7.3.1-1 are supported.

Table 7.3.1-1: DCI formats

DCI format	Usage
0_0	Scheduling of PUSCH in one cell
0_1	Scheduling of PUSCH in one cell
1_0	Scheduling of PDSCH in one cell
1_1	Scheduling of PDSCH in one cell
2_0	Notifying a group of UEs of the slot format
2_1	Notifying a group of UEs of the PRB(s) and OFDM symbol(s) where UE may assume no transmission is intended for the UE
2_2	Transmission of TPC commands for PUCCH and PUSCH
2_3	Transmission of a group of TPC commands for SRS transmissions by one or more UEs

The fields defined in the DCI formats below are mapped to the information bits a_0 to a_{A-1} as follows.

Each field is mapped in the order in which it appears in the description, including the zero-padding bit(s), if any, with the first field mapped to the lowest order information bit a_0 and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to a_0.

If the number of information bits in a DCI format is less than 12 bits, zeros shall be appended to the DCI format until the payload size equals 12.

7.3.1.1 DCI formats for scheduling of PUSCH

7.3.1.1.1 Format 0_0

DCI format 0_0 is used for the scheduling of PUSCH in one cell.

The following information is transmitted by means of the DCI format 0_0 with CRC scrambled by C-RNTI:

- Identifier for DCI formats – 1 bit
- The value of this bit field is always set to 0, indicating an UL DCI format
- Frequency domain resource assignment – $\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP}+1)/2) \rceil$ bits where
  - $N_{RB}^{UL,BWP}$ is the size of the initial bandwidth part in case DCI format 0_0 is monitored in the common search space
  - $N_{RB}^{UL,BWP}$ is the size of the active bandwidth part in case DCI format 0_0 is monitored in the UE specific search space and satisfying
    - the total number of different DCI sizes monitored per slot is no more than 4, and
    - the total number of different DCI sizes with C-RNTI monitored per slot is no more than 3
  - For PUSCH hopping with resource allocation type 1:
    - N_{UL_hop} MSB bits are used to indicate the frequency offset according to Subclause 6.3 of [6, TS 38.214], where $N_{UL\_hop}=1$ if the higher layer parameter *Frequency-hopping-offsets-set* contains two offset values and $N_{UL\_hop}=2$ if the higher layer parameter *Frequency-hopping-offsets-set* contains four offset values
    - $\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP}+1)/2) \rceil - N_{UL\_hop}$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]
  - For non-PUSCH hopping with resource allocation type 1:

      - $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \right\rceil$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]

- Time domain resource assignment – X bits as defined in Subclause 6.1.2.1 of [6, TS 38.214]
- Frequency hopping flag – 1 bit.
- Modulation and coding scheme – 5 bits as defined in Subclause 6.1.3 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits
- TPC command for scheduled PUSCH – [2] bits as defined in Subclause x.x of [5, TS 38.213]
- UL/SUL indicator – 1 bit for UEs configured with SUL in the cell as defined in Table 7.3.1.1.1-1 and the number of bits for DCI format 1_0 before padding is larger than the number of bits for DCI format 0_0 before padding; 0 bit otherwise.
  - If the UL/SUL indicator is present in DCI format 0_0 and the higher layer parameter *dynamicPUSCHSUL* is set to *Disabled*, the UE ignores the UL/SUL indicator field in DCI format 0_0, and the corresponding PUSCH scheduled by the DCI format 0_0 is for the carrier indicated by the higher layer parameter *pucchCarrierSUL*;
  - If the UL/SUL indicator is not present in DCI format 0_0, the corresponding PUSCH scheduled by the DCI format 0_0 is for the carrier indicated by the higher layer parameter *pucchCarrierSUL*.

The following information is transmitted by means of the DCI format 0_0 with CRC scrambled by TC-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 0, indicating an UL DCI format
- Frequency domain resource assignment – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \right\rceil$ bits where
  - $N_{\mathrm{RB}}^{\mathrm{UL,BWP}}$ is the size of the initial bandwidth part in case DCI format 0_0 is monitored in the common search space in CORESET 0
  - $N_{\mathrm{RB}}^{\mathrm{UL,BWP}}$ is the size of the active bandwidth part in case DCI format 0_0 is monitored in the UE specific search space and satisfying
    - the total number of different DCI sizes monitored per slot is no more than 4, and
    - the total number of different DCI sizes with C-RNTI monitored per slot is no more than 3
  - For PUSCH hopping with resource allocation type 1:
    - $N_{\mathrm{UL\_hop}}$ MSB bits are used to indicate the frequency offset according to Subclause 6.3 of [6, TS 38.214], where $N_{\mathrm{UL\_hop}}=1$ if $N_{\mathrm{RB}}^{\mathrm{UL,BWP}}<50$ and $N_{\mathrm{UL\_hop}}=2$ otherwise
    - $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \right\rceil - N_{\mathrm{UL\_hop}}$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]
  - For non-PUSCH hopping with resource allocation type 1:
    - $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \right\rceil$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]
- Time domain resource assignment – X bits as defined in Subclause 6.1.2.1 of [6, TS 38.214]
- Frequency hopping flag – 1 bit.

- Modulation and coding scheme – 5 bits as defined in Subclause 6.1.3 of [6, TS 38.214], using Table 5.1.3.1-1
- New data indicator – 1 bit, reserved
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits, reserved
- TPC command for scheduled PUSCH – [2] bits as defined in Subclause x.x of [5, TS 38.213]
- UL/SUL indicator – 1 bit if the cell has two ULs and the number of bits for DCI format 1_0 before padding is larger than the number of bits for DCI format 0_0 before padding; 0 bit otherwise.
    - If 1 bit, reserved, and the corresponding PUSCH is always on the same UL carrier as the previous transmission of the same TB

The following information is transmitted by means of the DCI format 0_0 with CRC scrambled by CS-RNTI:

- XXX – x bit

If DCI format 0_0 is monitored in common search space and if the number of information bits in the DCI format 0_0 prior to padding is less than the payload size of the DCI format 1_0 monitored in common search space for scheduling the same serving cell, zeros shall be appended to the DCI format 0_0 until the payload size equals that of the DCI format 1_0.

If DCI format 0_0 is monitored in common search space and if the number of information bits in the DCI format 0_0 prior to padding is larger than the payload size of the DCI format 1_0 monitored in common search space for scheduling the same serving cell, the bitwidth of the frequency domain resource allocation field in the DCI format 0_0 is reduced such that the size of DCI format 0_0 equals to the size of the DCI format 1_0..

Table 7.3.1.1.1-1: UL/SUL indicator

Value of UL/SUL indicator	Uplink
0	The non-supplementary uplink
1	The supplementary uplink

Table 7.3.1.1.1-2: Redundancy version

Value of the Redundancy version field	Value of rv_{id} to be applied
00	0
01	1
10	2
11	3

7.3.1.1.2 Format 0_1

DCI format 0_1 is used for the scheduling of PUSCH in one cell.

The following information is transmitted by means of the DCI format 0_1 with CRC scrambled by C-RNTI:

- Carrier indicator – 0 or 3 bits, as defined in Subclause x.x of [5, TS38.213].
- UL/SUL indicator – 0 bit for UEs not configured with SUL in the cell or UEs configured with SUL in the cell but only PUCCH carrier in the cell is configured for PUSCH transmission; 1 bit for UEs configured with SUL in the cell as defined in Table 7.3.1.1.1-1.
- Identifier for DCI formats – 1 bit
    - The value of this bit field is always set to 0, indicating an UL DCI format

- Bandwidth part indicator – 0, 1 or 2 bits as defined in Table 7.3.1.1.2-1. The bitwidth for this field is determined as $\lceil \log_2(n_{\mathrm{BWP}}) \rceil$ bits, where
  - $n_{\mathrm{BWP}} = n_{\mathrm{BWP,RRC}} + 1$ if the higher layer parameter *BandwidthPart-Config* configures up to 3 bandwidth parts and the initial bandwidth part is not included in higher layer parameter *BandwidthPart-Config*;
  - otherwise $n_{\mathrm{BWP}} = n_{\mathrm{BWP,RRC}}$;
  - $n_{\mathrm{BWP,RRC}}$ is the number of configured bandwidth parts according to higher layer parameter *BandwidthPart-Config*.
- Frequency domain resource assignment – number of bits determined by the following, where $N_{\mathrm{RB}}^{\mathrm{UL,BWP}}$ is the size of the active bandwidth part:
  - N_{RBG} bits if only resource allocation type 0 is configured, where N_{RBG} is defined in Subclause 6.1.2.2.1 of [6, TS 38.214],
  - $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \rceil$ bits if only resource allocation type 1 is configured, or $\max\left(\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \rceil, N_{\mathrm{RBG}}\right)+1$ bits if both resource allocation type 0 and 1 are configured.
- If both resource allocation type 0 and 1 are configured, the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.
- For resource allocation type 0, the N_{RBG} LSBs provide the resource allocation as defined in Subclause 6.1.2.2.1 of [6, TS 38.214].
- For resource allocation type 1, the $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \rceil$ LSBs provide the resource allocation as follows:
  - For PUSCH hopping with resource allocation type 1:
    - $N_{\mathrm{UL\_hop}}$ MSB bits are used to indicate the frequency offset according to Subclause 6.3 of [6, TS 38.214], where $N_{\mathrm{UL\_hop}} = 1$ if the higher layer parameter *Frequency-hopping-offsets-set* contains two offset values and $N_{\mathrm{UL\_hop}} = 2$ if the higher layer parameter *Frequency-hopping-offsets-set* contains four offset values
    - $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \rceil - N_{\mathrm{UL\_hop}}$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]
  - For non-PUSCH hopping with resource allocation type 1:
    - $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}(N_{\mathrm{RB}}^{\mathrm{UL,BWP}}+1)/2) \rceil$ bits provides the frequency domain resource allocation according to Subclause 6.1.2.2.2 of [6, TS 38.214]
- Time domain resource assignment – 0, 1, 2, 3, or 4 bits as defined in Subclause 6.1.2.1 of [6, TS38.214]. The bitwidth for this field is determined as $\lceil \log_2(I) \rceil$ bits, where *I* the number of entries in the higher layer parameter *pusch-AllocationList.*
- VRB-to-PRB mapping – 0 or 1 bit:
  - 0 bit if only resource allocation type 0 is configured or if *PUSCH-tp=Enabled*;
  - 1 bit according to Table 7.3.1.1.2-33 otherwise, only applicable to resource allocation type 1, as defined in Subclause 6.3.1.7 of [4, TS 38.211].
- Frequency hopping flag – 0 or 1 bit:
  - 0 bit if only resource allocation type 0 is configured;

  - 1 bit otherwise, only applicable to resource allocation type 1, as defined in Subclause 6.3 of [6, TS 38.214].
- Modulation and coding scheme – 5 bits as defined in Subclause x.x of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits
- 1st downlink assignment index – 1 or 2 bits:
  - 1 bit for semi-static HARQ-ACK codebook;
  - 2 bits for dynamic HARQ-ACK codebook with single HARQ-ACK codebook.
- 2nd downlink assignment index – 0 or 2 bits:
  - 2 bits for dynamic HARQ-ACK codebook with two HARQ-ACK sub-codebooks;
  - 0 bit otherwise.
- TPC command for scheduled PUSCH – 2 bits as defined in Subclause 7.1.1 of [5, TS38.213]
- SRS resource indicator – $\left\lceil \log_2\left(\sum_{k=1}^{\min\{L_{\max},N_{\text{SRS}}\}}\binom{N_{\text{SRS}}}{k}\right)\right\rceil$ or $\lceil \log_2(N_{\text{SRS}})\rceil$ bits, where N_{SRS} is the number of configured SRS resources in the SRS resource set associated with the higher layer parameter *SRS-SetUse* of value '*CodeBook*' or '*NonCodeBook*', and $L_{\max}$ is the maximum number of supported layers for the PUSCH.
  - $\left\lceil \log_2\left(\sum_{k=1}^{\min\{L_{\max},N_{\text{SRS}}\}}\binom{N_{\text{SRS}}}{k}\right)\right\rceil$ bits for non-codebook based PUSCH transmission according to Tables 7.3.1.1.2-28/29/30/31, where N_{SRS} is the number of configured SRS resources in the SRS resource set associated with the higher layer parameter *SRS-SetUse* of value '*NonCodeBook*';
  - $\lceil \log_2(N_{\text{SRS}})\rceil$ bits for codebook based PUSCH transmission according to Tables 7.3.1.1.2-32, where N_{SRS} is the number of configured SRS resources in the SRS resource set associated with the higher layer parameter *SRS-SetUse* of value '*CodeBook*'.
- Precoding information and number of layers – number of bits determined by the following:
  - 0 bits if the higher layer parameter *ulTxConfig = NonCodeBook*;
  - 0 bits for 1 antenna port and if the higher layer parameter *ulTxConfig = Codebook*;
  - 4, 5, or 6 bits according to Table 7.3.1.1.2-2 for 4 antenna ports, if *ulTxConfig = Codebook,* and according to the values of higher layer parameters *PUSCH-tp*, *ULmaxRank*, and *ULCodebookSubset*;
  - 2, 4, or 5 bits according to Table 7.3.1.1.2-3 for 4 antenna ports, if *ulTxConfig = Codebook,* and according to the values of higher layer parameters *PUSCH-tp*, *ULmaxRank*, and *ULCodebookSubset*;
  - 2 or 4 bits according to Table7.3.1.1.2-4 for 2 antenna ports, if *ulTxConfig = Codebook,* and according to the values of higher layer parameters *ULmaxRank* and *ULCodebookSubset*;
  - 1 or 3 bits according to Table7.3.1.1.2-5 for 2 antenna ports, if *ulTxConfig = Codebook,* and according to the values of higher layer parameters *ULmaxRank* and *ULCodebookSubset*.
- Antenna ports – number of bits determined by the following
  - 2 bits as defined by Tables 7.3.1.1.2-6, if *PUSCH-tp=Enabled*, *UL-DMRS-config-type*=1, and *UL-DMRS-max-len*=1;
  - 4 bits as defined by Tables 7.3.1.1.2-7, if *PUSCH-tp=Enabled*, *UL-DMRS-config-type*=1, and *UL-DMRS-max-len*=2;

- 3 bits as defined by Tables 7.3.1.1.2-8/9/10/11, if *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, and *UL-DMRS-max-len*=1, and the value of rank is determined according to the SRS resource indicator field if *SRS-SetUse = NonCodeBook* and according to the Precoding information and number of layers field if *SRS-SetUse = CodeBook*;
- 4 bits as defined by Tables 7.3.1.1.2-12/13/14/15, if *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, and *UL-DMRS-max-len*=2, and the value of rank is determined according to the SRS resource indicator field if *SRS-SetUse = NonCodeBook* and according to the Precoding information and number of layers field if *SRS-SetUse = CodeBook*;
- 4 bits as defined by Tables 7.3.1.1.2-16/17/18/19, if *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, and *UL-DMRS-max-len*=1, and the value of rank is determined according to the SRS resource indicator field if *SRS-SetUse = NonCodeBook* and according to the Precoding information and number of layers field if *SRS-SetUse = CodeBook*;
- 5 bits as defined by Tables 7.3.1.1.2-20/21/22/23, if *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, and *UL-DMRS-max-len*=2, and the value of rank is determined according to the SRS resource indicator field if *SRS-SetUse = NonCodeBook* and according to the Precoding information and number of layers field if *SRS-SetUse = CodeBook*.

where the number of CDM groups without data of values 1, 2, and 3 in Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively.

- SRS request – 2 bits as defined by Table 7.3.1.1.2-24 for UEs not configured with SUL in the cell; 3 bits for UEs configured SUL in the cell where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24. This bit field may also indicate the associated CSI-RS according to Subclause 6.1.1.2 of [6, TS 38.214].
- CSI request – 0, 1, 2, 3, 4, 5, or 6 bits determined by higher layer parameter *ReportTriggerSize*.
- CBG transmission information (CBGTI) – 0, 2, 4, 6, or 8 bits determined by higher layer parameter *maxCodeBlockGroupsPerTransportBlock* for PUSCH.
- PTRS-DMRS association – number of bits determined as follows
  - 0 bit if UL-PTRS-present=OFF and PUSCH-tp=Disabled, or if PUSCH-tp=Enabled;
  - 2 bits otherwise, where Table 7.3.1.1.2-25 and 7.3.1.1.2-26 are used to indicate the association between PTRS port(s) and DMRS port(s) for UL-PTRS-ports = 1 and UL-PTRS-ports = 2 respectively, and the DMRS ports are indicated by the Antenna ports field.
- beta_offset indicator – 0 if the higher layer parameter *dynamic* in *uci-on-PUSCH* is not configured; otherwise 2 bits as defined by Table 9.3-3 in [5, TS 38.213].
- DMRS sequence initialization – 0 if the higher layer parameter *PUSCH-tp=Enabled* or 1 bit if the higher layer parameter *PUSCH-tp=Disabled* for n_{SCID} selection defined in Subclause 7.4.1.1.1 of [4, TS 38.211].

The following information is transmitted by means of the DCI format 0_1 with CRC scrambled by CS-RNTI:

- XXX – x bit

The following information is transmitted by means of the DCI format 0_1 with CRC scrambled by SP-CSI-RNTI:

- XXX – x bit

For a UE configured with SUL in a cell, if PUSCH is configured to be transmitted on both the SUL and the non-SUL of the cell and if the number of information bits in format 0_1 for the SUL is not equal to the number of information bits in format 0_1 for the non-SUL, zeros shall be appended to smaller format 0_1 until the payload size equals that of the larger format 0_1.

Table 7.3.1.1.2-1: Bandwidth part indicator

Value of BWP indicator field		Bandwidth part
1 bit	2 bits	
0	00	First bandwidth part configured by higher layers
1	01	Second bandwidth part configured by higher layers
	10	Third bandwidth part configured by higher layers
	11	Fourth bandwidth part configured by higher layers

Table 7.3.1.1.2-2: Precoding information and number of layers, for 4 antenna ports, if *PUSCH-tp=Disabled* and *ULmaxRank* = 2 or 3 or 4

Bit field mapped to index	*ULCodebookSubset = fullAndPartialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = partialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = nonCoherent*
0	1 layer: TPMI=0	0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1	1	1 layer: TPMI=1
…	…	…	…	…	…
3	1 layer: TPMI=3	3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	2 layers: TPMI=0	4	2 layers: TPMI=0	4	2 layers: TPMI=0
…	…	…	…	…	…
9	2 layers: TPMI=5	9	2 layers: TPMI=5	9	2 layers: TPMI=5
10	3 layers: TPMI=0	10	3 layers: TPMI=0	10	3 layers: TPMI=0
11	4 layers: TPMI=0	11	4 layers: TPMI=0	11	4 layers: TPMI=0
12	1 layer: TPMI=4	12	1 layer: TPMI=4	12-15	reserved
…	…	…	…		
19	1 layer: TPMI=11	19	1 layer: TPMI=11		
20	2 layers: TPMI=6	20	2 layers: TPMI=6		
…	…	…	…		
27	2 layers: TPMI=13	27	2 layers: TPMI=13		
28	3 layers: TPMI=1	28	3 layers: TPMI=1		
29	3 layers: TPMI=2	29	3 layers: TPMI=2		
30	4 layers: TPMI=1	30	4 layers: TPMI=1		
31	4 layers: TPMI=2	31	4 layers: TPMI=2		
32	1 layers: TPMI=12				
…	…				
47	1 layers: TPMI=27				
48	2 layers: TPMI=14				
…	…				
55	2 layers: TPMI=21				
56	3 layers: TPMI=3				
…	…				
59	3 layers: TPMI=6				
60	4 layers: TPMI=3				
61	4 layers: TPMI=4				
62-63	reserved				

Table 7.3.1.1.2-3: Precoding information and number of layers for 4 antenna ports, if *PUSCH-tp= Enabled*, or if *PUSCH-tp=Disabled* and *ULmaxRank* = 1

Bit field mapped to index	*ULCodebookSubset = fullAndPartialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = partialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = nonCoherent*
0	1 layer: TPMI=0	0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1	1	1 layer: TPMI=1
…	…	…	…	…	…
3	1 layer: TPMI=3	3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	1 layer: TPMI=4	4	1 layer: TPMI=4		
…	…	…	…		
11	1 layer: TPMI=11	11	1 layer: TPMI=11		
12	1 layers: TPMI=12	12-15	reserved		
…	…				
27	1 layers: TPMI=27				
28-31	reserved				

Table 7.3.1.1.2-4: Precoding information and number of layers, for 2 antenna ports, if *PUSCH-tp=Disabled* and *ULmaxRank* = 2

Bit field mapped to index	*ULCodebookSubset = fullAndPartialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = nonCoherent*
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
2	2 layers: TPMI=0	2	2 layers: TPMI=0
3	1 layer: TPMI=2	3	reserved
4	1 layer: TPMI=3		
5	1 layer: TPMI=4		
6	1 layer: TPMI=5		
7	2 layers: TPMI=1		
8	2 layers: TPMI=2		
9-15	reserved		

Table 7.3.1.1.2-5: Precoding information and number of layers, for 2 antenna ports, if *PUSCH-tp= Enabled*, or if *PUSCH-tp= Disabled* and *ULmaxRank* = 1

Bit field mapped to index	*ULCodebookSubset = fullAndPartialAndNonCoherent*	Bit field mapped to index	*ULCodebookSubset = nonCoherent*
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
2	1 layer: TPMI=2		
3	1 layer: TPMI=3		
4	1 layer: TPMI=4		
5	1 layer: TPMI=5		
6-7	reserved		

Table 7.3.1.1.2-6: Antenna port(s), *PUSCH-tp=Enabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0
1	2	1
2	2	2
3	2	3

Table 7.3.1.1.2-7: Antenna port(s), *PUSCH-tp=Enabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0	1
1	2	1	1
2	2	2	1
3	2	3	1
4	2	0	2
5	2	1	2
6	2	2	2
7	2	3	2
8	2	4	2
9	2	5	2
10	2	6	2
11	2	7	2
12-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-8: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=1, rank = 1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	2	0
3	2	1
4	2	2
5	2	3
6-7	Reserved	Reserved

Table 7.3.1.1.2-9: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=1, rank = 2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0,1
1	2	0,1
2	2	2,3
3	2	0,2
4-7	Reserved	Reserved

Table 7.3.1.1.2-10: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=1, rank = 3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-2
2-7	Reserved	Reserved

Table 7.3.1.1.2-11: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=1, rank = 4

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-3
2-7	Reserved	Reserved

Table 7.3.1.1.2-12: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=2, rank = 1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1
1	1	1	1
2	2	0	1
3	2	1	1
4	2	2	1
5	2	3	1
6	2	0	2
7	2	1	2
8	2	2	2
9	2	3	2
10	2	4	2
11	2	5	2
12	2	6	2
13	2	7	2
14-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-13: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=2, rank = 2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0,1	1
1	2	0,1	1
2	2	2,3	1
3	2	0,2	1
4	2	0,1	2
5	2	2,3	2
6	2	4,5	2
7	2	6,7	2
8	2	0,4	2
9	2	2,6	2
10-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-14: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=2, rank = 3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-2	1
1	2	0,1,4	2
2	2	2,3,6	2
3-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-15: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=1, *UL-DMRS-max-len*=2, rank = 4

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-3	1
1	2	0,1,4,5	2
2	2	2,3,6,7	2
3	2	0,2,4,6	2
4-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-16: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=1, rank=1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	2	0
3	2	1
4	2	2
5	2	3
6	3	0
7	3	1
8	3	2
9	3	3
10	3	4
11	3	5
12-15	Reserved	Reserved

Table 7.3.1.1.2-17: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *DL-DMRS-max-len*=1, rank=2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0,1
1	2	0,1
2	2	2,3
3	3	0,1
4	3	2,3
5	3	4,5
6	2	0,2
7-15	Reserved	Reserved

Table 7.3.1.1.2-18: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *DL-DMRS-max-len*=1, rank =3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-2
1	3	0-2
2	3	3-5
3-15	Reserved	Reserved

Table 7.3.1.1.2-19: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=1, rank =4

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-3
1	3	0-3
2-15	Reserved	Reserved

Table 7.3.1.1.2-20: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=2, rank=1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1
1	1	1	1
2	2	0	1
3	2	1	1
4	2	2	1
5	2	3	1
6	3	0	1
7	3	1	1
8	3	2	1
9	3	3	1
10	3	4	1
11	3	5	1
12	3	0	2
13	3	1	2
14	3	2	2
15	3	3	2
16	3	4	2
17	3	5	2
18	3	6	2
19	3	7	2
20	3	8	2
21	3	9	2
22	3	10	2
23	3	11	2
24	1	0	2
25	1	1	2
26	1	6	2
27	1	7	2
28-31	Reserved	Reserved	Reserved

Table 7.3.1.1.2-21: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=2, rank=2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0,1	1
1	2	0,1	1
2	2	2,3	1
3	3	0,1	1
4	3	2,3	1
5	3	4,5	1
6	2	0,2	1
7	3	0,1	2
8	3	2,3	2
9	3	4,5	2
10	3	6,7	2
11	3	8,9	2
12	3	10,11	2
13	1	0,1	2
14	1	6,7	2
15	2	0,1	2
16	2	2,3	2
17	2	6,7	2
18	2	8,9	2
19-31	Reserved	Reserved	Reserved

Table 7.3.1.1.2-22: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=2, rank=3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-2	1
1	3	0-2	1
2	3	3-5	1
3	3	0,1,6	2
4	3	2,3,8	2
5	3	4,5,10	2
6-31	Reserved	Reserved	Reserved

Table 7.3.1.1.2-23: Antenna port(s), *PUSCH-tp=Disabled*, *UL-DMRS-config-type*=2, *UL-DMRS-max-len*=2, rank=4

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-3	1
1	3	0-3	1
2	3	0,1,6,7	2
3	3	2,3,8,9	2
4	3	4,5,10,11	2
5-31	Reserved	Reserved	Reserved

Table 7.3.1.1.2-24: SRS request

Value of SRS request field	SRS resource set
00	
01	
10	
11	

Table 7.3.1.1.2-25: PTRS-DMRS association for UL PTRS port 0, *UL-PTRS-ports* = 1

Value	DMRS port
0	0
1	1
2	2
3	3

Table 7.3.1.1.2-26: PTRS-DMRS association for UL PTRS ports 0 and 1, *UL-PTRS-ports* = 2

Value of MSB	DMRS port		Value of LSB	DMRS port
0	1st DMRS port transmitting layers corresponding to SRS port 0 and 2		0	1st DMRS port transmitting layers corresponding to SRS port 1 and 3
1	2nd DMRS port transmitting layers corresponding to SRS port 0 and 2		1	2nd DMRS port transmitting layers corresponding to SRS port 1 and 3

Table 7.3.1.1.2-27: void

Table 7.3.1.1.2-28: SRI indication for non-codebook based PUSCH transmission, $L_{\max}=1$

Bit field mapped to index	SRI(s), $N_{\text{SRS}}=2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=4$
0	0	0	0	0	0
1	1	1	1	1	1
		2	2	2	2
		3	reserved	3	3

Table 7.3.1.1.2-29: SRI indication for non-codebook based PUSCH transmission, $L_{\max}=2$

Bit field mapped to index	SRI(s), $N_{\text{SRS}}=2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6-7	reserved	6	0,3
				7	1,2
				8	1,3
				9	2,3
				10-15	reserved

Table 7.3.1.1.2-30: SRI indication for non-codebook based PUSCH transmission, $L_{\max}=3$

Bit field mapped to index	SRI(s), $N_{\text{SRS}}=2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}}=4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6	0,1,2	6	0,3
		7	reserved	7	1,2
				8	1,3
				9	2,3
				10	0,1,2
				11	0,1,3
				12	0,2,3
				13	1,2,3
				14-15	reserved

Table 7.3.1.1.2-31: SRI indication for non-codebook based PUSCH transmission, $L_{\max} = 4$

Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6	0,1,2	6	0,3
		7	reserved	7	1,2
				8	1,3
				9	2,3
				10	0,1,2
				11	0,1,3
				12	0,2,3
				13	1,2,3
				14	0,1,2,3
				15	reserved

Table 7.3.1.1.2-32: SRI indication for codebook based PUSCH transmission

Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 2$
0	0
1	1

Table 7.3.1.1.2-33: VRB-to-PRB mapping

Bit field mapped to index	VRB-to-PRB mapping
0	Non-interleaved
1	Interleaved

7.3.1.2 DCI formats for scheduling of PDSCH

7.3.1.2.1 Format 1_0

DCI format 1_0 is used for the scheduling of PDSCH in one DL cell.

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by C-RNTI:

- Identifier for DCI formats – 1 bits
  - The value of this bit field is always set to 1, indicating a DL DCI format
- Frequency domain resource assignment – $\left\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}}+1)/2) \right\rceil$ bits
  - $N_{\text{RB}}^{\text{DL,BWP}}$ is the size of the initial bandwidth part in case DCI format 1_0 is monitored in the common search space
  - $N_{\text{RB}}^{\text{DL,BWP}}$ is the size of the active bandwidth part in case DCI format 1_0 is monitored in the UE specific search space and satisfying
    - the total number of different DCI sizes monitored per slot is no more than 4, and
    - the total number of different DCI sizes with C-RNTI monitored per slot is no more than 3
- Time domain resource assignment – X bits as defined in Subclause 5.1.2.1 of [6, TS 38.214]

- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.1.2-33
- Modulation and coding scheme – 5 bits as defined in Subclause 5.1.3 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits
- Downlink assignment index – 2 bits as defined in Subclause 9.1.3 of [5, TS 38.213], as counter DAI
- TPC command for scheduled PUCCH – [2] bits as defined in Subclause 7.2.1 of [5, TS 38.213]
- PUCCH resource indicator – 3 bits as defined in Subclause 9.2.3 of [5, TS 38.213]
- PDSCH-to-HARQ_feedback timing indicator – [3] bits as defined in Subclause x.x of [5, TS38.213]

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by P-RNTI:

- Short Messages Indicator – 1 bit. This bit is used to indicate whether the short message only or scheduling information only is carried in the Paging DCI.

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by SI-RNTI:

- XXX – x bit

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by RA-RNTI:

- Identifier for DCI formats – 1 bit, reserved
- Frequency domain resource assignment – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL,BWP}}(N_{\mathrm{RB}}^{\mathrm{DL,BWP}}+1)/2) \right\rceil$ bits
  - $N_{\mathrm{RB}}^{\mathrm{DL,BWP}}$ is the size of the initial bandwidth part in case DCI format 1_0 is monitored in the common search space in CORESET 0
  - $N_{\mathrm{RB}}^{\mathrm{DL,BWP}}$ is the size of the active bandwidth part in case DCI format 1_0 is monitored in the UE specific search space and satisfying
    - the total number of different DCI sizes monitored per slot is no more than 4, and
    - the total number of different DCI sizes with C-RNTI monitored per slot is no more than 3
- Time domain resource assignment – X bits as defined in Subclause 5.1.2.1 of [6, TS38.214]
- VRB-to-PRB mapping – 1 bit
- Modulation and coding scheme – 5 bits as defined in Subclause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1
- New data indicator – 1 bit, reserved
- Redundancy version – 2 bits, reserved
- HARQ process number – 4 bits, reserved
- Downlink assignment index – 2 bits, reserved
- TPC command for scheduled PUCCH – 2 bits, reserved
- PUCCH resource indicator – 3 bits, reserved
- PDSCH-to-HARQ_feedback timing indicator – 3 bits, reserved

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by TC-RNTI:

- Identifier for DCI formats – 1 bit

- The value of this bit field is always set to 1, indicating a DL DCI format

- Frequency domain resource assignment – $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL,BWP}}(N_{\mathrm{RB}}^{\mathrm{DL,BWP}}+1)/2) \rceil$ bits

  - $N_{\mathrm{RB}}^{\mathrm{DL,BWP}}$ is the size of the initial bandwidth part in case DCI format 1_0 is monitored in the common search space in CORESET 0

  - $N_{\mathrm{RB}}^{\mathrm{DL,BWP}}$ is the size of the active bandwidth part in case DCI format 0_0 is monitored in the UE specific search space and satisfying

    - the total number of different DCI sizes monitored per slot is no more than 4, and

    - the total number of different DCI sizes with C-RNTI monitored per slot is no more than 3

- Time domain resource assignment – X bits as defined in Subclause 5.1.2.1 of [6, TS38.214]

- VRB-to-PRB mapping – 1 bit

- Modulation and coding scheme – 5 bits as defined in Subclause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1

- New data indicator – 1 bit

- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2

- HARQ process number – 4 bits

- Downlink assignment index – 2 bits, reserved

- TPC command for scheduled PUCCH – 2 bits as defined in Subclause 7.2.1 of [5, TS38.213]

- PUCCH resource indicator – 3 bits as defined in Subclause 9.2.3 of [5, TS38.213]

- PDSCH-to-HARQ_feedback timing indicator – 3 bits as defined in Subclause x.x of [5, TS38.213]

The following information is transmitted by means of the DCI format 1_0 with CRC scrambled by CS-RNTI:

- XXX – x bit

7.3.1.2.2 Format 1_1

DCI format 1_1 is used for the scheduling of PDSCH in one cell.

The following information is transmitted by means of the DCI format 1_1 with CRC scrambled by C-RNTI:

- Carrier indicator – 0 or 3 bits as defined in Subclause x.x of [5, TS 38.213].

- Identifier for DCI formats – 1 bits

  - The value of this bit field is always set to 1, indicating a DL DCI format

- Bandwidth part indicator – 0, 1 or 2 bits as defined in Table 7.3.1.1.2-1. The bitwidth for this field is determined as $\lceil \log_2(n_{\mathrm{BWP}}) \rceil$ bits, where

  - $n_{\mathrm{BWP}} = n_{\mathrm{BWP,RRC}} + 1$ if the higher layer parameter *BandwidthPart-Config* configures up to 3 bandwidth parts and the initial bandwidth part is not included in higher layer parameter *BandwidthPart-Config*;

  - otherwise $n_{\mathrm{BWP}} = n_{\mathrm{BWP,RRC}}$;

  - $n_{\mathrm{BWP,RRC}}$ is the number of configured bandwidth parts according to higher layer parameter *BandwidthPart-Config*.

- Frequency domain resource assignment – number of bits determined by the following, where $N_{\mathrm{RB}}^{\mathrm{DL,BWP}}$ is the size of the active bandwidth part:

  - N_{RBG} bits if only resource allocation type 0 is configured, where N_{RBG} is defined in Subclause 5.1.2.2.1 of [6, TS38.214],
  - $\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}}+1)/2) \rceil$ bits if only resource allocation type 1 is configured, or
  - $\max\left(\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}}+1)/2) \rceil, N_{\text{RBG}}\right)+1$ bits if both resource allocation type 0 and 1 are configured.
  - If both resource allocation type 0 and 1 are configured, the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.
  - For resource allocation type 0, the N_{RBG} LSBs provide the resource allocation as defined in Subclause 5.1.2.2.1 of [6, TS 38.214].
  - For resource allocation type 1, the $\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}}+1)/2) \rceil$ LSBs provide the resource allocation as defined in Subclause 5.1.2.2.2 of [6, TS 38.214]
- Time domain resource assignment – 0, 1, 2, 3, or 4 bits as defined in Subclause 5.1.2.1 of [6, TS 38.214]. The bitwidth for this field is determined as $\lceil \log_2(I) \rceil$ bits, where I is the number of entries in the higher layer parameter *pdsch-AllocationList*.
- VRB-to-PRB mapping – 0 or 1 bit:
  - 0 bit if only resource allocation type 0 is configured;
  - 1 bit according to Table 7.3.1.1.2-33 otherwise, only applicable to resource allocation type 1, as defined in Subclause xxx of [4, TS 38.211].
- PRB bundling size indicator – 0 bit if the higher layer parameter *PRB_bundling* is not configured or is set to 'static', or 1 bit if the higher layer parameter *PRB_bundling* is set to 'dynamic' according to Subclause 5.1.2.3 of [6, TS 38.214].
- Rate matching indicator – 0, 1, or 2 bits according to higher layer parameter *rate-match-PDSCH-resource-set*.
- ZP CSI-RS trigger – 0, 1, or 2 bits as defined in Subclause x.x of [6, TS 38.214]. The bitwidth for this field is determined as $\lceil \log_2(n_{ZP}+1) \rceil$ bits, where n_{ZP} is the number of ZP CSI-RS resource sets in the higher layer parameter [*ZP-CSI-RS-ResourceConfigList*].

For transport block 1:

  - Modulation and coding scheme – 5 bits as defined in Subclause x.x of [6, TS 38.214]
  - New data indicator – 1 bit
  - Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2

For transport block 2 (only present if *Number-MCS-HARQ-DL-DCI* equals 2):

  - Modulation and coding scheme – 5 bits as defined in Subclause x.x of [6, TS 38.214]
  - New data indicator – 1 bit
  - Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2

- HARQ process number – 4 bits
- Downlink assignment index – number of bits as defined in the following
  - 4 bits if more than one serving cell are configured in the DL and the higher layer parameter *HARQ-ACK-codebook=dynamic*, where the 2 MSB bits are the counter DAI and the 2 LSB bits are the total DAI;
  - 2 bits if only one serving cell is configured in the DL and the higher layer parameter *HARQ-ACK-codebook=dynamic*, where the 2 bits are the counter DAI;

- 0 bits otherwise.

- TPC command for scheduled PUCCH – 2 bits as defined in Subclause x.x of [5, TS 38.213]

- PUCCH resource indicator – 3 bits as defined in Subclause 9.2.3 of [5, TS 38.213]

- PDSCH-to-HARQ_feedback timing indicator – 3 bits as defined in Subclause 9.2.3 of [5, TS 38.213]

- Antenna port(s) – 4, 5, or 6 bits as defined by Tables 7.3.1.2.2-1/2/3/4, where the number of CDM groups without data of values 1, 2, and 3 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively.

- Transmission configuration indication – 0 bit if higher layer parameter *tci-PresentInDCI* is not enabled; otherwise 3 bits as defined in Subclause x.x of [6, TS38.214].

- SRS request – 2 bits as defined by Table 7.3.1.1.2-24 for UEs not configured with SUL in the cell; 3 bits for UEs configured SUL in the cell where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24.

- CBG transmission information (CBGTI) – 0, 2, 4, 6, or 8 bits as defined in Subclause x.x of [6, TS38.214], determined by higher layer parameter *maxCodeBlockGroupsPerTransportBlock* for the PDSCH.

- CBG flushing out information (CBGFI) – 0 or 1 bit as defined in Subclause x.x of [6, TS38.214], determined by higher layer parameter *codeBlockGroupFlushIndicator*.

- DMRS sequence initialization – 1 bit for n_{SCID} selection defined in Subclause 7.4.1.1.1 of [4, TS 38.211].

The following information is transmitted by means of the DCI format 1_1 with CRC scrambled by CS-RNTI:

- XXX – x bit

Table 7.3.1.2.2-1: Antenna port(s) (1000 + DMRS port), *DL-DMRS-config-type*=1, *DL-DMRS-max-len*=1

One Codeword: Codeword 0 enabled, Codeword 1 disabled		
Value	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**
0	1	0
1	1	1
2	1	0,1
3	2	0
4	2	1
5	2	2
6	2	3
7	2	0,1
8	2	2,3
9	2	0-2
10	2	0-3
11	2	0,2
12-15	Reserved	Reserved

Table 7.3.1.2.2-2: Antenna port(s) (1000 + DMRS port), *DL-DMRS-config-type*=1, *DL-DMRS-max-len*=2

One Codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**	**Number of front-load symbols**	**Value**	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**	**Number of front-load symbols**
0	1	0	1	0	2	0-4	2
1	1	1	1	1	2	0,1,2,3,4,6	2
2	1	0,1	1	2	2	0,1,2,3,4,5,6	2
3	2	0	1	3	2	0,1,2,3,4,5,6,7	2
4	2	1	1	4-31	reserved	reserved	reserved
5	2	2	1				
6	2	3	1				
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	2	0,2	1				
12	2	0	2				
13	2	1	2				
14	2	2	2				
15	2	3	2				
16	2	4	2				
17	2	5	2				
18	2	6	2				
19	2	7	2				
20	2	0,1	2				
21	2	2,3	2				
22	2	4,5	2				
23	2	6,7	2				
24	2	0,4	2				
25	2	2,6	2				
26	2	0,1,4	2				
27	2	2,3,6	2				
28	2	0,1,4,5	2				
29	2	2,3,6,7	2				
30	2	0,2,4,6	2				
31	Reserved	Reserved	Reserved				

Table 7.3.1.2.2-3: Antenna port(s) (1000 + DMRS port), *DL-DMRS-config-type*=2, *DL-DMRS-max-len*=1

One codeword: Codeword 0 enabled, Codeword 1 disabled			Two codewords: Codeword 0 enabled, Codeword 1 enabled		
Value	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**	**Value**	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**
0	1	0	0	3	0-4
1	1	1	1	3	0-5
2	1	0,1	2-31	reserved	reserved
3	2	0			
4	2	1			
5	2	2			
6	2	3			
7	2	0,1			
8	2	2,3			
9	2	0-2			
10	2	0-3			
11	3	0			
12	3	1			
13	3	2			
14	3	3			
15	3	4			
16	3	5			
17	3	0,1			
18	3	2,3			
19	3	4,5			
20	3	0-2			
21	3	3-5			
22	3	0-3			
23	2	0,2			
24-31	Reserved	Reserved			

Table 7.3.1.2.2-4: Antenna port(s) (1000 + DMRS port), *DL-DMRS-config-type*=2, *DL-DMRS-max-len*=2

One codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	3	0-4	1
1	1	1	1	1	3	0-5	1
2	1	0,1	1	2	2	0,1,2,3,6	2
3	2	0	1	3	2	0,1,2,3,6,8	2
4	2	1	1	4	2	0,1,2,3,6,7,8	2
5	2	2	1	5	2	0,1,2,3,6,7,8,9	2
6	2	3	1	6-63	Reserved	Reserved	Reserved
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	3	0	1				
12	3	1	1				
13	3	2	1				
14	3	3	1				
15	3	4	1				
16	3	5	1				
17	3	0,1	1				
18	3	2,3	1				
19	3	4,5	1				
20	3	0-2	1				
21	3	3-5	1				
22	3	0-3	1				
23	2	0,2	1				
24	3	0	2				
25	3	1	2				
26	3	2	2				
27	3	3	2				
28	3	4	2				
29	3	5	2				
30	3	6	2				
31	3	7	2				
32	3	8	2				
33	3	9	2				
34	3	10	2				
35	3	11	2				
36	3	0,1	2				
37	3	2,3	2				
38	3	4,5	2				
39	3	6,7	2				
40	3	8,9	2				
41	3	10,11	2				
42	3	0,1,6	2				
43	3	2,3,8	2				
44	3	4,5,10	2				
45	3	0,1,6,7	2				
46	3	2,3,8,9	2				
47	3	4,5,10,11	2				
48	1	0	2				
49	1	1	2				
50	1	6	2				
51	1	7	2				
52	1	0,1	2				
53	1	6,7	2				
54	2	0,1	2				
55	2	2,3	2				
56	2	6,7	2				

57	2	8,9	2				
58-63	Reserved	Reserved	Reserved				

7.3.1.3 DCI formats for other purposes

7.3.1.3.1 Format 2_0

DCI format 2_0 is used for notifying the slot format.

The following information is transmitted by means of the DCI format 2_0 with CRC scrambled by SFI-RNTI:

- Identifier for DCI formats – [1] bits
- Slot format indicator 1, Slot format indicator 2, …, Slot format indicator *N*.

The size of DCI format 2_0 is configurable by higher layers up to 128 bits, according to Subclause 11.1.1 of [5, TS 38.213].

7.3.1.3.2 Format 2_1

DCI format 2_1 is used for notifying the PRB(s) and OFDM symbol(s) where UE may assume no transmission is intended for the UE.

The following information is transmitted by means of the DCI format 2_1 with CRC scrambled by INT-RNTI:

- Identifier for DCI formats – [1] bits
- Pre-emption indication 1, Pre-emption indication 2, …, Pre-emption indication *N*.

The size of DCI format 2_1 is configurable by higher layers up to 126 bits, according to Subclause 11.2 of [5, TS 38.213]. Each pre-emption indication is 14 bits.

7.3.1.3.3 Format 2_2

DCI format 2_2 is used for the transmission of TPC commands for PUCCH and PUSCH.

The following information is transmitted by means of the DCI format 2_2 with CRC scrambled by TPC-PUSCH-RNTI or TPC-PUCCH-RNTI:

- Identifier for DCI formats – [1] bits
- TPC command number 1, TPC command number 2,…, TPC command number *N*

The parameter *xxx* provided by higher layers determines the index to the TPC command number for an UL of a cell. Each TPC command number is 2 bits.

If the number of information bits in format 2_2 is less than the payload size of format 0_0 as defined in the initial bandwidth part in the same serving cell, zeros shall be appended to format 2_2 until the payload size equals that of format 0_0 as defined in the initial bandwidth part in the same serving cell.

7.3.1.3.4 Format 2_3

DCI format 2_3 is used for the transmission of a group of TPC commands for SRS transmissions by one or more UEs. Along with a TPC command, a SRS request may also be transmitted.

The following information is transmitted by means of the DCI format 2_3 with CRC scrambled by TPC-SRS-RNTI:

- Identifier for DCI formats – [1] bits
- block number 1, block number 2, …, block number B

  where the starting position of a block is determined by the parameter *startingBitOfFormat2_3* provided by higher layers for the UE configured with the block.

For an UL without PUCCH and PUSCH or an UL on which the SRS power control is not tied with PUSCH power control, one block is configured for the UE by higher layers, with the following fields defined for the block:

- SRS request – 0 or 2 bits. The presence of this field is according to the definition in Subclause x.x of [5, TS38.213]. If present, this field is interpreted as defined by Table 7.3.1.1.2-5.

- TPC command number –2 bits

If the number of information bits in format 2_3 is less than the payload size of format 0_0 as defined in the initial bandwidth part in the same serving cell, zeros shall be appended to format 2_3 until the payload size equals that of format 0_0 as defined in the initial bandwidth part in the same serving cell.

7.3.2 CRC attachment

Error detection is provided on DCI transmissions through a Cyclic Redundancy Check (CRC).

The entire payload is used to calculate the CRC parity bits. Denote the bits of the payload 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 payload size and L is the number of parity bits. Let $a'_0, a'_1, a'_2, a'_3, ..., a'_{A+L-1}$ be a bit sequence such that $a'_i = 1$ for $i = 0,1,..., L-1$ and $a'_i = a_{i-L}$ for $i = L, L+1,..., A+L-1$. The parity bits are computed with input bit sequence $a'_0, a'_1, a'_2, a'_3, ..., a'_{A+L-1}$ and attached according to Subclause 5.1 by setting L to 24 bits and using the generator polynomial $g_{\mathrm{CRC24C}}(D)$. The output bit $b_0, b_1, b_2, b_3, ..., b_{B-1}$ is

$b_k = a_k$ for $k = 0,1,2,..., A-1$

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

where $K = A + L$.

After attachment, the CRC parity bits are scrambled with the corresponding RNTI $x_{rnti,0}, x_{rnti,1}, ..., x_{rnti,15}$, where $x_{rnti,0}$ corresponds to the MSB of the RNTI, to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{K-1}$. The relation between c_k and b_k is:

$c_k = b_k$ for k = 0, 1, 2, …, $A+7$

$c_k = (b_k + x_{rnti,k-A-8}) \bmod 2$ for k = $A+8$, $A+9$, $A+10$,..., $A+23$.

7.3.3 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are encoded via Polar coding according to Subclause 5.3.1, by setting $n_{\max} = 9$, $I_{IL} = 1$, $n_{PC} = 0$, and $n_{PC}^{wm} = 0$.

After encoding the bits are denoted by $d_0, d_1, d_2, d_3, ..., d_{N-1}$, where N is the number of coded bits.

7.3.4 Rate matching

The input bit sequence to rate matching is $d_0, d_1, d_2, ..., d_{N-1}$.

Rate matching is performed according to Subclause 5.4.1 by setting $I_{BIL} = 0$.

The output bit sequence after rate matching is denoted as $f_0, f_1, f_2, ..., f_{E-1}$.

Annex <A> (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-05	RAN1#89	R1-1707082				Draft skeleton	0.0.0
2017-07	AH_NR2	R1-1712014				Inclusion of LDPC related agreements	0.0.1
2017-08	RAN1#90	R1-1714564				Inclusion of Polar coding related agreements	0.0.2
2017-08	RAN1#90	R1-1714659				Endorsed version by RAN1#90 as basis for further updates	0.1.0
2017-09	RAN1#90	R1-1715322				Capturing additional agreements on LDPC and Polar code from RAN1 #90	0.1.1
2017-09	RAN#77	RP-171991				For information to plenary	1.0.0
2017-09	RAN1#90b	R1-1716928				Capturing additional agreements on LDPC and Polar code from RAN1 NR AH#3	1.0.1
2017-10	RAN1#90b	R1-1719106				Endorsed as v1.1.0	1.1.0
2017-11	RAN1#91	R1-1719225				Capturing additional agreements on channel coding, etc.	1.1.1
2017-11	RAN1#91	R1-1719245				Capturing additional agreements on DCI format, channel coding, etc.	1.1.2
2017-11	RAN1#91	R1-1721049				Endorsed as v1.2.0	1.2.0
2017-12	RAN1#91	R1-1721342				Capturing additional agreements on UCI, DCI, channel coding, etc.	1.2.1
2017-12	RAN#78	RP-172668				Endorsed version for approval by plenary.	2.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-03	RAN#79	RP-180200	0001	-	F	CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements	15.1.0
2018-04	RAN#79					MCC: correction of typo in DCI format 0_1 (time domain resource assignment) – higher layer parameter should be *pusch-AllocationList*	15.1.1