14 UE procedures related to Sidelink

A UE can be configured by higher layers with one or more PSSCH resource configuration(s). A PSSCH resource configuration can be for reception of PSSCH, or for transmission of PSSCH. The physical sidelink shared channel related procedures are described in Subclause 14.1.

A UE can be configured by higher layers with one or more PSCCH resource configuration(s). A PSCCH resource configuration can be for reception of PSCCH, or for transmission of PSCCH and the PSCCH resource configuration is associated with either sidelink transmission mode 1,2,3 or sidelink transmission mode 4. The physical sidelink control channel related procedures are described in Subclause 14.2.

A UE can be configured by higher layers with one or more PSDCH resource configuration(s). A PSDCH resource configuration can be for reception of PSDCH, or for transmission of PSDCH. The transmissions of PSDCH according to a PSDCH resource configuration are associated with either sidelink discovery type 1 or sidelink discovery type 2B. The physical sidelink discovery channel related procedures are described in Subclause 14.3.

The physical sidelink synchronization related procedures are described in Subclause 14.4.

Except in the case of secondary sidelink synchronization signal transmission, sidelink transmission power shall not change during a sidelink subframe. For a UE transmitting PSBCH, the transmit power of PSBCH (P_{PSBCH}) is same as the transmit power of primary sidelink synchronisation signal P_{PSSS}.

A UE is not expected to be configured with PSCCH resource configuration(s) such that, in a given subframe, the total number of resource blocks across the resource block pools (as described in Subclause 14.2.3) indicated by the PSCCH resource configuration(s) exceeds 50 in sidelink transmission mode 1 or 2.

In sidelink transmission mode 3 or 4, a UE is

- not expected to attempt to decode more than 10 or 20 PSCCHs in a subframe depending on UE capability [12].
- not expected to attempt to decode more than 100 or 136 RBs in a subframe depending on UE capability [12].
- not expected to combine PSCCH transmitted in different subframes.
- not required to perform PSSCH-RSRP measurement in a subframe that occurs before the reception of a successfully decoded associated SCI format 1.

If the UE supports decoding less than 20 PSCCH candidates, it shall implement a mechanism to avoid systematic dropping of PSCCH when the number of PSCCH candidates exceeds the UE's capability. UE applies the PSSCH-RSRP measured in a subframe that occurs at the reception of a successfully decoded associated SCI format 1 to a subframe that is indicated by the SCI format 1 but occurs before the reception of the SCI format 1. UE applies the PSSCH-RSRP measured in a subframe that occurs at the reception of a successfully decoded associated SCI format 1 to a subframe that is indicated by the SCI format 1 if SCI format 1 scheduling the same transport block is successfully decoded in only one subframe. UE is not expected to decode PSSCH that occurs before the reception of a successfully decoded associated SCI format 1.

If a UE uplink transmission that is not a PRACH transmission in subframe n+1 of a serving cell overlaps in time domain with a PSDCH transmission or a SLSS transmission for PSDCH by the UE in subframe n and subframe n+1 is included in *discTxGapConfig* [11], then the UE shall drop the uplink transmission in subframe n+1. Else, if a UE uplink transmission in subframe n+1 of a serving cell overlaps in time domain with sidelink transmission/reception for sidelink transmission mode 1 or 2 by the UE in subframe n of the serving cell, then the UE shall drop the sidelink transmission/reception in subframe n.

If a UE uplink transmission of a serving cell overlaps in time domain with a sidelink transmission for sidelink transmission mode 3 or 4 of the same serving cell and the value in "Priority" field of the corresponding SCI is smaller than the high layer parameter *thresSL-TxPrioritization*, then the UE shall drop the uplink transmission. Else, if a UE uplink transmission of a serving cell overlaps in time domain with sidelink transmission for sidelink transmission mode 3 or 4 of the same serving cell, then the UE shall drop the sidelink transmission.

For a given carrier frequency, a UE is not expected to receive sidelink physical channels/signals with different cyclic prefix lengths in the same sidelink subframe.

For a given carrier frequency, in a sidelink subframe, if a UE has a sidelink transmission, the sidelink transmission shall occur only in contiguous physical resource blocks in sidelink transmission mode 1 or 2.

In sidelink transmission mode 1 or 2, if a UE's sidelink transmission does not occur on a serving cell with its uplink transmission(s), and if the UE's sidelink transmission in a subframe overlaps in time with its uplink transmission(s), the UE shall adjust the sidelink transmission power such that its total transmission power does not exceed P_{CMAX} defined in [6] on any overlapped portion. In this case, calculation of the adjustment to the sidelink transmission power is not specified.

In sidelink transmission mode 3 or 4, if a UE's sidelink transmission has SCI whose "Priority" field is set to a value smaller than the high layer parameter *thresSL-TxPrioritization*, and if the UE's sidelink transmission in a subframe overlaps in time with its uplink transmission(s) occurring on serving cell(s) where the sidelink transmission does not occur, the UE shall adjust the uplink transmission power such that its total transmission power does not exceed P_{CMAX} defined in [6] on any overlapped portion. In this case, calculation of the adjustment to the uplink transmission power is not specified.

In sidelink transmission mode 3 or 4, if a UE's sidelink transmission has SCI whose "Priority" field is set to a value greater than or equal to the high layer parameter *thresSL-TxPrioritization*, and if the UE's sidelink transmission in a subframe overlaps in time with its uplink transmission(s) occurring on serving cell(s) where the sidelink transmission does not occur, the UE shall adjust the sidelink transmission power such that its total transmission power does not exceed P_{CMAX} defined in [6] on any overlapped portion. In this case, calculation of the adjustment to the sidelink transmission power is not specified.

14.1 Physical Sidelink Shared Channel related procedures

14.1.1 UE procedure for transmitting the PSSCH

If the UE transmits SCI format 0 on PSCCH according to a PSCCH resource configuration in subframe *n* belonging to a PSCCH period (described in Subclause 14.2.3), then for the corresponding PSSCH transmissions

- the transmissions occur in a set of subframes in the PSCCH period and in a set of resource blocks within the set of subframes. The first PSSCH transport block is transmitted in the first four subframes in the set, the second transport block is transmitted in the next four subframes in the set, and so on.
  - for sidelink transmission mode 1,
    - the set of subframes is determined using the subframe pool indicated by the PSSCH resource configuration (described in Subclause 14.1.4) and using time resource pattern (I_{TRP}) in the SCI format 0 as described in Subclause 14.1.1.1.
    - the set of resource blocks is determined using Resource block assignment and hopping allocation in the SCI format 0 as described in Subclause 14.1.1.2.
  - for sidelink transmission mode 2,
    - the set of subframes is determined using the subframe pool indicated by the PSSCH resource configuration (described in Subclause 14.1.3) and using time resource pattern (I_{TRP}) in the SCI format 0 as described in Subclause 14.1.1.3.
    - the set of resource blocks is determined using the resource block pool indicated by the PSSCH resource configuration (described in Subclause 14.1.3) and using Resource block assignment and hopping allocation in the SCI format 0 as described in Subclause 14.1.1.4.
- the modulation order is determined using the "modulation and coding scheme " field (I_{MCS}) in SCI format 0. For $0 \le I_{\text{MCS}} \le 28$, the modulation order is set to $Q' = \min(4, Q'_{\text{m}})$, where Q'_{m} is determined from Table 8.6.1-1.
- the TBS index (I_{TBS}) is determined based on I_{MCS} and Table 8.6.1-1, and the transport block size is determined using I_{TBS} and the number of allocated resource blocks (N_{PRB}) using the procedure in Subclause 7.1.7.2.1.

If the UE transmits SCI format 1 on PSCCH according to a PSCCH resource configuration in subframe *n*, then for the corresponding PSSCH transmissions of one TB

- for sidelink transmission mode 3,
  - the set of subframes and the set of resource blocks are determined using the subframe pool indicated by the PSSCH resource configuration (described in Subclause 14.1.5) and using "Retransmission index and Time gap between initial transmission and retransmission" field and "Frequency resource location of the initial transmission and retransmission" field in the SCI format 1 as described in Subclause 14.1.1.4A.
- for sidelink transmission mode 4,
  - the set of subframes and the set of resource blocks are determined using the subframe pool indicated by the PSSCH resource configuration (described in Subclause 14.1.5) and using "Retransmission index and Time gap between initial transmission and retransmission" field and "Frequency resource location of the initial transmission and retransmission" field in the SCI format 1 as described in Subclause 14.1.1.4B.
- the modulation order is determined using the "modulation and coding scheme " field (I_{MCS}) in SCI format 1. For $0 \le I_{\mathrm{MCS}} \le 28$, the modulation order is set to $Q' = \min(4, Q'_{\mathrm{m}})$, where Q'_{m} is determined from Table 8.6.1-1.
- the TBS index (I_{TBS}) is determined based on I_{MCS} and Table 8.6.1-1, and the transport block size is determined using I_{TBS} and the number of allocated resource blocks (N_{PRB}) using the procedure in Subclause 7.1.7.2.1.

For sidelink transmission mode 3 and 4, the parameter P_{step} is given by table 14.1.1-1.

Table 14.1.1-1: Determination of P_{step} for sidelink transmission mode 3 and 4

	P_{step}
TDD with UL/DL configuration 0	60
TDD with UL/DL configuration 1	40
TDD with UL/DL configuration 2	20
TDD with UL/DL configuration 3	30
TDD with UL/DL configuration 4	20
TDD with UL/DL configuration 5	10
TDD with UL/DL configuration 6	50
Otherwise	100

14.1.1.1 UE procedure for determining subframes for transmitting PSSCH for sidelink transmission mode 1

Within the PSCCH period (described in Subclause 14.2.3), the subframes used for PSSCH are determined as follows:

- a subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ and N_{TRP} are determined using the procedure described in Subclause 14.1.1.1.1.
- a bitmap $\left(b_0, b_1, \ldots b_{L_{PSSCH}-1}\right)$ is determined using $b_j = b'_{j \bmod N_{TRP}}$ and a subframe l_j^{PSSCH} in the subframe pool is used for PSSCH if $b_j = 1$, otherwise the subframe l_j^{PSSCH} is not used for PSSCH, where $\left(l_0^{PSSCH}, l_1^{PSSCH}, \ldots, l_{L_{PSSCH}-1}^{PSSCH}\right)$ and L_{PSSCH} are described in Subclause 14.1.4. The subframes used for PSSCH are denoted by $\left(n_0^{PSSCH}, n_1^{PSSCH}, \ldots, n_{N_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and where N_{PSSCH} is the number of subframes that can be used for PSSCH transmission in a PSCCH period and is a multiple of 4.

14.1.1.1.1 Determination of subframe indicator bitmap

For FDD and TDD with UL/DL configuration belonging to {1,2,4,5}, N_{TRP} is 8, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-1.

For TDD with UL/DL configuration 0, N_{TRP} is 7, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-2.

For TDD with UL/DL configuration belonging to {3,6}, N_{TRP} is 6, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-3.

Table 14.1.1.1.1-1: Time Resource pattern Index mapping for $N_{TRP} = 8$

I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$
0	1	(1,0,0,0,0,0,0,0)	37	4	(1,1,1,0,1,0,0,0)	74	4	(0,1,1,1,0,0,0,1)
1	1	(0,1,0,0,0,0,0,0)	38	4	(1,1,0,1,1,0,0,0)	75	4	(1,1,0,0,1,0,0,1)
2	1	(0,0,1,0,0,0,0,0)	39	4	(1,0,1,1,1,0,0,0)	76	4	(1,0,1,0,1,0,0,1)
3	1	(0,0,0,1,0,0,0,0)	40	4	(0,1,1,1,1,0,0,0)	77	4	(0,1,1,0,1,0,0,1)
4	1	(0,0,0,0,1,0,0,0)	41	4	(1,1,1,0,0,1,0,0)	78	4	(1,0,0,1,1,0,0,1)
5	1	(0,0,0,0,0,1,0,0)	42	4	(1,1,0,1,0,1,0,0)	79	4	(0,1,0,1,1,0,0,1)
6	1	(0,0,0,0,0,0,1,0)	43	4	(1,0,1,1,0,1,0,0)	80	4	(0,0,1,1,1,0,0,1)
7	1	(0,0,0,0,0,0,0,1)	44	4	(0,1,1,1,0,1,0,0)	81	4	(1,1,0,0,0,1,0,1)
8	2	(1,1,0,0,0,0,0,0)	45	4	(1,1,0,0,1,1,0,0)	82	4	(1,0,1,0,0,1,0,1)
9	2	(1,0,1,0,0,0,0,0)	46	4	(1,0,1,0,1,1,0,0)	83	4	(0,1,1,0,0,1,0,1)
10	2	(0,1,1,0,0,0,0,0)	47	4	(0,1,1,0,1,1,0,0)	84	4	(1,0,0,1,0,1,0,1)
11	2	(1,0,0,1,0,0,0,0)	48	4	(1,0,0,1,1,1,0,0)	85	4	(0,1,0,1,0,1,0,1)
12	2	(0,1,0,1,0,0,0,0)	49	4	(0,1,0,1,1,1,0,0)	86	4	(0,0,1,1,0,1,0,1)
13	2	(0,0,1,1,0,0,0,0)	50	4	(0,0,1,1,1,1,0,0)	87	4	(1,0,0,0,1,1,0,1)
14	2	(1,0,0,0,1,0,0,0)	51	4	(1,1,1,0,0,0,1,0)	88	4	(0,1,0,0,1,1,0,1)
15	2	(0,1,0,0,1,0,0,0)	52	4	(1,1,0,1,0,0,1,0)	89	4	(0,0,1,0,1,1,0,1)
16	2	(0,0,1,0,1,0,0,0)	53	4	(1,0,1,1,0,0,1,0)	90	4	(0,0,0,1,1,1,0,1)
17	2	(0,0,0,1,1,0,0,0)	54	4	(0,1,1,1,0,0,1,0)	91	4	(1,1,0,0,0,0,1,1)
18	2	(1,0,0,0,0,1,0,0)	55	4	(1,1,0,0,1,0,1,0)	92	4	(1,0,1,0,0,0,1,1)
19	2	(0,1,0,0,0,1,0,0)	56	4	(1,0,1,0,1,0,1,0)	93	4	(0,1,1,0,0,0,1,1)
20	2	(0,0,1,0,0,1,0,0)	57	4	(0,1,1,0,1,0,1,0)	94	4	(1,0,0,1,0,0,1,1)
21	2	(0,0,0,1,0,1,0,0)	58	4	(1,0,0,1,1,0,1,0)	95	4	(0,1,0,1,0,0,1,1)
22	2	(0,0,0,0,1,1,0,0)	59	4	(0,1,0,1,1,0,1,0)	96	4	(0,0,1,1,0,0,1,1)
23	2	(1,0,0,0,0,0,1,0)	60	4	(0,0,1,1,1,0,1,0)	97	4	(1,0,0,0,1,0,1,1)
24	2	(0,1,0,0,0,0,1,0)	61	4	(1,1,0,0,0,1,1,0)	98	4	(0,1,0,0,1,0,1,1)
25	2	(0,0,1,0,0,0,1,0)	62	4	(1,0,1,0,0,1,1,0)	99	4	(0,0,1,0,1,0,1,1)
26	2	(0,0,0,1,0,0,1,0)	63	4	(0,1,1,0,0,1,1,0)	100	4	(0,0,0,1,1,0,1,1)
27	2	(0,0,0,0,1,0,1,0)	64	4	(1,0,0,1,0,1,1,0)	101	4	(1,0,0,0,0,1,1,1)
28	2	(0,0,0,0,0,1,1,0)	65	4	(0,1,0,1,0,1,1,0)	102	4	(0,1,0,0,0,1,1,1)
29	2	(1,0,0,0,0,0,0,1)	66	4	(0,0,1,1,0,1,1,0)	103	4	(0,0,1,0,0,1,1,1)
30	2	(0,1,0,0,0,0,0,1)	67	4	(1,0,0,0,1,1,1,0)	104	4	(0,0,0,1,0,1,1,1)
31	2	(0,0,1,0,0,0,0,1)	68	4	(0,1,0,0,1,1,1,0)	105	4	(0,0,0,0,1,1,1,1)

32	2	(0,0,0,1,0,0,0,1)	69	4	(0,0,1,0,1,1,1,0)	106	8	(1,1,1,1,1,1,1,1)
33	2	(0,0,0,0,1,0,0,1)	70	4	(0,0,0,1,1,1,1,0)	107-127	reserved	reserved
34	2	(0,0,0,0,0,1,0,1)	71	4	(1,1,1,0,0,0,0,1)			
35	2	(0,0,0,0,0,0,1,1)	72	4	(1,1,0,1,0,0,0,1)			
36	4	(1,1,1,1,0,0,0,0)	73	4	(1,0,1,1,0,0,0,1)			

Table 14.1.1.1.1-2: Time Resource pattern Index mapping for $N_{TRP} = 7$

I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$	I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$	I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$
0	reserved	reserved	44	3	(0,0,1,1,0,1,0)	88	3	(0,0,0,1,1,0,1)
1	1	(1,0,0,0,0,0,0)	45	4	(1,0,1,1,0,1,0)	89	4	(1,0,0,1,1,0,1)
2	1	(0,1,0,0,0,0,0)	46	4	(0,1,1,1,0,1,0)	90	4	(0,1,0,1,1,0,1)
3	2	(1,1,0,0,0,0,0)	47	5	(1,1,1,1,0,1,0)	91	5	(1,1,0,1,1,0,1)
4	1	(0,0,1,0,0,0,0)	48	2	(0,0,0,0,1,1,0)	92	4	(0,0,1,1,1,0,1)
5	2	(1,0,1,0,0,0,0)	49	3	(1,0,0,0,1,1,0)	93	5	(1,0,1,1,1,0,1)
6	2	(0,1,1,0,0,0,0)	50	3	(0,1,0,0,1,1,0)	94	5	(0,1,1,1,1,0,1)
7	3	(1,1,1,0,0,0,0)	51	4	(1,1,0,0,1,1,0)	95	6	(1,1,1,1,1,0,1)
8	1	(0,0,0,1,0,0,0)	52	3	(0,0,1,0,1,1,0)	96	2	(0,0,0,0,0,1,1)
9	2	(1,0,0,1,0,0,0)	53	4	(1,0,1,0,1,1,0)	97	3	(1,0,0,0,0,1,1)
10	2	(0,1,0,1,0,0,0)	54	4	(0,1,1,0,1,1,0)	98	3	(0,1,0,0,0,1,1)
11	3	(1,1,0,1,0,0,0)	55	5	(1,1,1,0,1,1,0)	99	4	(1,1,0,0,0,1,1)
12	2	(0,0,1,1,0,0,0)	56	3	(0,0,0,1,1,1,0)	100	3	(0,0,1,0,0,1,1)
13	3	(1,0,1,1,0,0,0)	57	4	(1,0,0,1,1,1,0)	101	4	(1,0,1,0,0,1,1)
14	3	(0,1,1,1,0,0,0)	58	4	(0,1,0,1,1,1,0)	102	4	(0,1,1,0,0,1,1)
15	4	(1,1,1,1,0,0,0)	59	5	(1,1,0,1,1,1,0)	103	5	(1,1,1,0,0,1,1)
16	1	(0,0,0,0,1,0,0)	60	4	(0,0,1,1,1,1,0)	104	3	(0,0,0,1,0,1,1)
17	2	(1,0,0,0,1,0,0)	61	5	(1,0,1,1,1,1,0)	105	4	(1,0,0,1,0,1,1)
18	2	(0,1,0,0,1,0,0)	62	5	(0,1,1,1,1,1,0)	106	4	(0,1,0,1,0,1,1)
19	3	(1,1,0,0,1,0,0)	63	6	(1,1,1,1,1,1,0)	107	5	(1,1,0,1,0,1,1)
20	2	(0,0,1,0,1,0,0)	64	1	(0,0,0,0,0,0,1)	108	4	(0,0,1,1,0,1,1)
21	3	(1,0,1,0,1,0,0)	65	2	(1,0,0,0,0,0,1)	109	5	(1,0,1,1,0,1,1)
22	3	(0,1,1,0,1,0,0)	66	2	(0,1,0,0,0,0,1)	110	5	(0,1,1,1,0,1,1)
23	4	(1,1,1,0,1,0,0)	67	3	(1,1,0,0,0,0,1)	111	6	(1,1,1,1,0,1,1)
24	2	(0,0,0,1,1,0,0)	68	2	(0,0,1,0,0,0,1)	112	3	(0,0,0,0,1,1,1)
25	3	(1,0,0,1,1,0,0)	69	3	(1,0,1,0,0,0,1)	113	4	(1,0,0,0,1,1,1)
26	3	(0,1,0,1,1,0,0)	70	3	(0,1,1,0,0,0,1)	114	4	(0,1,0,0,1,1,1)
27	4	(1,1,0,1,1,0,0)	71	4	(1,1,1,0,0,0,1)	115	5	(1,1,0,0,1,1,1)
28	3	(0,0,1,1,1,0,0)	72	2	(0,0,0,1,0,0,1)	116	4	(0,0,1,0,1,1,1)
29	4	(1,0,1,1,1,0,0)	73	3	(1,0,0,1,0,0,1)	117	5	(1,0,1,0,1,1,1)
30	4	(0,1,1,1,1,0,0)	74	3	(0,1,0,1,0,0,1)	118	5	(0,1,1,0,1,1,1)
31	5	(1,1,1,1,1,0,0)	75	4	(1,1,0,1,0,0,1)	119	6	(1,1,1,0,1,1,1)
32	1	(0,0,0,0,0,1,0)	76	3	(0,0,1,1,0,0,1)	120	4	(0,0,0,1,1,1,1)
33	2	(1,0,0,0,0,1,0)	77	4	(1,0,1,1,0,0,1)	121	5	(1,0,0,1,1,1,1)
34	2	(0,1,0,0,0,1,0)	78	4	(0,1,1,1,0,0,1)	122	5	(0,1,0,1,1,1,1)
35	3	(1,1,0,0,0,1,0)	79	5	(1,1,1,1,0,0,1)	123	6	(1,1,0,1,1,1,1)

36	2	(0,0,1,0,0,1,0)	80	2	(0,0,0,0,1,0,1)	124	5	(0,0,1,1,1,1,1)
37	3	(1,0,1,0,0,1,0)	81	3	(1,0,0,0,1,0,1)	125	6	(1,0,1,1,1,1,1)
38	3	(0,1,1,0,0,1,0)	82	3	(0,1,0,0,1,0,1)	126	6	(0,1,1,1,1,1,1)
39	4	(1,1,1,0,0,1,0)	83	4	(1,1,0,0,1,0,1)	127	7	(1,1,1,1,1,1,1)
40	2	(0,0,0,1,0,1,0)	84	3	(0,0,1,0,1,0,1)			
41	3	(1,0,0,1,0,1,0)	85	4	(1,0,1,0,1,0,1)			
42	3	(0,1,0,1,0,1,0)	86	4	(0,1,1,0,1,0,1)			
43	4	(1,1,0,1,0,1,0)	87	5	(1,1,1,0,1,0,1)			

Table 14.1.1.1.1-3: Time Resource pattern Index mapping for $N_{TRP} = 6$

I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$	I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$	I_{TRP}	k_{TRP}	$(b'_0, b'_1, \ldots b'_{N_{TRP}-1})$
0	reserved	reserved	22	3	(0,1,1,0,1,0)	44	3	(0,0,1,1,0,1)
1	1	(1,0,0,0,0,0)	23	4	(1,1,1,0,1,0)	45	4	(1,0,1,1,0,1)
2	1	(0,1,0,0,0,0)	24	2	(0,0,0,1,1,0)	46	4	(0,1,1,1,0,1)
3	2	(1,1,0,0,0,0)	25	3	(1,0,0,1,1,0)	47	5	(1,1,1,1,0,1)
4	1	(0,0,1,0,0,0)	26	3	(0,1,0,1,1,0)	48	2	(0,0,0,0,1,1)
5	2	(1,0,1,0,0,0)	27	4	(1,1,0,1,1,0)	49	3	(1,0,0,0,1,1)
6	2	(0,1,1,0,0,0)	28	3	(0,0,1,1,1,0)	50	3	(0,1,0,0,1,1)
7	3	(1,1,1,0,0,0)	29	4	(1,0,1,1,1,0)	51	4	(1,1,0,0,1,1)
8	1	(0,0,0,1,0,0)	30	4	(0,1,1,1,1,0)	52	3	(0,0,1,0,1,1)
9	2	(1,0,0,1,0,0)	31	5	(1,1,1,1,1,0)	53	4	(1,0,1,0,1,1)
10	2	(0,1,0,1,0,0)	32	1	(0,0,0,0,0,1)	54	4	(0,1,1,0,1,1)
11	3	(1,1,0,1,0,0)	33	2	(1,0,0,0,0,1)	55	5	(1,1,1,0,1,1)
12	2	(0,0,1,1,0,0)	34	2	(0,1,0,0,0,1)	56	3	(0,0,0,1,1,1)
13	3	(1,0,1,1,0,0)	35	3	(1,1,0,0,0,1)	57	4	(1,0,0,1,1,1)
14	3	(0,1,1,1,0,0)	36	2	(0,0,1,0,0,1)	58	4	(0,1,0,1,1,1)
15	4	(1,1,1,1,0,0)	37	3	(1,0,1,0,0,1)	59	5	(1,1,0,1,1,1)
16	1	(0,0,0,0,1,0)	38	3	(0,1,1,0,0,1)	60	4	(0,0,1,1,1,1)
17	2	(1,0,0,0,1,0)	39	4	(1,1,1,0,0,1)	61	5	(1,0,1,1,1,1)
18	2	(0,1,0,0,1,0)	40	2	(0,0,0,1,0,1)	62	5	(0,1,1,1,1,1)
19	3	(1,1,0,0,1,0)	41	3	(1,0,0,1,0,1)	63	6	(1,1,1,1,1,1)
20	2	(0,0,1,0,1,0)	42	3	(0,1,0,1,0,1)	64-127	reserved	reserved
21	3	(1,0,1,0,1,0)	43	4	(1,1,0,1,0,1)			

14.1.1.2 UE procedure for determining resource blocks for transmitting PSSCH for sidelink transmission mode 1

The set of resource blocks is determined using the procedure described in Subclause 14.1.1.2.1 and 14.1.1.2.2.

14.1.1.2.1 PSSCH resource allocation for sidelink transmission mode 1

The resource allocation and hopping field of the SCI format 0 is used to determine a set of indices denoted by n'_{VRB} (0 ≤ n'_{VRB} < $N_{\text{RB}}^{\text{SL}}$), a starting index RB'_{START} , and a number of allocated PRBs L'_{CRBs} and $N_{\text{RB}}^{\text{PSSCH}}$ using the procedure in Subclause 8.1.1, and 8.4 (for sidelink frequency hopping with type 1 or type 2 hopping) with the following exceptions:

- the term 'PUSCH' in Subclauses 8.1.1 and 8.4 is replaced with 'PSSCH'.
- the quantity n_{VRB} in Subclause 8.1.1 is replaced with n'_{VRB} .
- the quantity $N_{\text{RB}}^{\text{UL}}$ in Subclauses 8.1.1 and 8.4 is replaced with $N_{\text{RB}}^{\text{SL}}$.
- the quantity RB_{START} in Subclauses 8.1.1and 8.4 is replaced with RB'_{START}.
- the quantity L_{CRBs} in Subclauses 8.1.1 and 8.4 is replaced with L'_{CRBs} .
- the quantity $N_{\text{RB}}^{\text{PUSCH}}$ in Subclause 8.4 is replaced with $N_{\text{RB}}^{\text{PSSCH}}$.
- the quantity $N_{\text{RB}}^{\text{HO}}$ is given by higher layer parameter *rb-Offset-r12* associated with the corresponding PSSCH resource configuration.
- the quantity N_{sb} is given by higher layer parameter *numSubbands-r12* associated with the corresponding PSSCH resource configuration.

14.1.1.2.2 PSSCH frequency hopping for sidelink transmission mode 1

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks for PSSCH transmission is determined using Subclause 8.4 with the following exceptions:

- the term 'PUSCH' is replaced with 'PSSCH'.
- only inter-subframe hopping shall be used.
- the quantity RB_{START} is replaced with RB'_{START}.
- the quantity $N_{\text{RB}}^{\text{UL}}$ is replaced with $N_{\text{RB}}^{\text{SL}}$.
- the quantity $N_{\text{RB}}^{\text{PUSCH}}$ is replaced with $N_{\text{RB}}^{\text{PSSCH}}$.
- the quantity $N_{\text{RB}}^{\text{HO}}$ is given by higher layer parameter *rb-Offset-r12* associated with the PSSCH resource configuration.
- the frequency hopping field in the SCI format 0 is used instead of DCI format 0.
- the quantity $n_{\text{PRB}}^{\text{S1}}(i)$ is replaced with $n_{\text{PRB}}^{\text{SL0}}$.
- the quantity $n_{\text{PRB}}(i)$ is replaced with $n_{\text{PRB}}^{\text{SL1}}$.
- for odd $n_{\text{ssf}}^{\text{PSSCH}}$ (described in Subclause 9.2.4 of [3]), the set of physical resource blocks for PSSCH transmission are L'_{CRBs} contiguous resource blocks starting from PRB with index $n_{\text{PRB}}^{\text{SL0}}$.
- for even $n_{\text{ssf}}^{\text{PSSCH}}$ (described in Subclause 9.2.4 of [3]), the set of physical resource blocks for PSSCH transmission are L'_{CRBs} contiguous resource blocks starting from PRB with index $n_{\text{PRB}}^{\text{SL1}}$.

14.1.1.3 UE procedure for determining subframes for transmitting PSSCH for sidelink transmission mode 2

For FDD or for TDD, and the UE not configured with the higher layer parameter *trpt-Subset-r12*

- The allowed values of I_{TRP} correspond to the values of k_{TRP} satisfying $k_{TRP} = k_i$, for a value of i in $0 \le i < X_{TRP}$, where k_i and X_{TRP} are determined from table 14.1.1.3-1.

For FDD or for TDD with UL/DL configuration belonging to {0,1,2,3,4,6}, and the UE configured with the higher layer parameter *trpt-Subset-r12*

- The allowed values of I_{TRP} correspond to the values of k_{TRP} satisfying $k_{TRP} = k_i$, for values of i in $0 \le i < X_{TRP}$ satisfying $a_i = 1$, $0 \le i < X_{TRP}$ and where k_i and X_{TRP} are determined from table 14.1.1.3-1, and $(a_0, a_1, ..., a_{X_{TRP}-1})$ is the bitmap indicated by *trpt-Subset-r12*.

Table 14.1.1.3-1: Determination of X_{TRP} and k_i for sidelink transmission mode 2

	X_{TRP}	k_0	k_1	k_2	k_3	k_4
FDD and TDD with UL/DL configuration 1,2,4,5	3	1	2	4	-	-
TDD with UL/DL configuration 0	5	1	2	3	4	5
TDD with UL/DL configuration 3,6	4	1	2	3	4	-

Within a PSCCH period, the subframes used for PSSCH are determined as follows:

- a subframe indicator bitmap $(b'_0, b'_1, ...b'_{N_{TRP}-1})$ and N_{TRP} are determined using the procedure described in Subclause 14.1.1.1.1 from the allowed values of I_{TRP} described in this Subclause.

- a bitmap $(b_0, b_1, ...b_{L_{PSSCH}-1})$ is determined using $b_j = b'_{j \bmod N_{TRP}}$ and a subframe l_j^{PSSCH} in the subframe pool is used for PSSCH if $b_j = 1$, otherwise the subframe l_j^{PSSCH} is not used for PSSCH, where $(l_0^{PSSCH}, l_1^{PSSCH}, ..., l_{L_{PSSCH}-1}^{PSSCH})$ and L_{PSSCH} are described in Subclause 14.1.3. The subframes used for PSSCH are denoted by $(n_0^{PSSCH}, n_1^{PSSCH}, ..., n_{N_{PSSCH}-1}^{PSSCH})$ arranged in increasing order of subframe index and where N_{PSSCH} is the number of subframes that can be used for PSSCH transmission in a PSCCH period and is a multiple of 4.

14.1.1.4 UE procedure for determining resource blocks for transmitting PSSCH for sidelink transmission mode 2

The set of resource blocks within the resource block pool (defined in 14.1.3) is determined using the Subclause 14.1.1.2.1 .

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks for PSSCH transmission is determined using Subclause 14.1.1.2.2 with the following exceptions

- the quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ is replaced with $M_{RB}^{PSSCH\_RP}$ (defined in 14.1.3).

- for odd $n_{\mathrm{ssf}}^{\mathrm{PSSCH}}$, the set of physical resource blocks for PSSCH transmission are given by L'_{CRBs} contiguous resource blocks $m_x, m_{x+1}, ..m_{x+L'_{CRBs}-1}$ belonging to the resource block pool, where $x = n_{\mathrm{PRB}}^{\mathrm{SL0}}$.

- for even $n_{\mathrm{ssf}}^{\mathrm{PSSCH}}$, the set of physical resource blocks for PSSCH transmission are given by L'_{CRBs} contiguous resource blocks $m_x, m_{x+1}, ..m_{x+L'_{CRBs}-1}$ belonging to the resource block pool, where $x = n_{\mathrm{PRB}}^{\mathrm{SL1}}$.

14.1.1.4A UE procedure for determining subframes and resource blocks for transmitting PSSCH for sidelink transmission mode 3

If the UE has a configured sidelink grant (described in [8]) in subframe t_n^{SL} with the corresponding PSCCH resource m (described in Subclause 14.2.4), the resource blocks and subframes of the corresponding PSSCH transmissions are determined according to 14.1.1.4C.

If the UE has a configured sidelink grant (described in [8]) for an SL SPS configuration activated by Subclause 14.2.1 and if a set of sub-channels in subframe t_m^{SL} is determined as the time and frequency resource for PSSCH transmission corresponding to the configured sidelink grant (described in [8]) of the SL SPS configuration, the same set of sub-channels in subframes $t_{m+j\times P'_{SPS}}^{SL}$ are also determined for PSSCH transmissions corresponding to the same sidelink grant where j=1, 2,..., $P'_{SPS} = P_{step} \times P_{SPS} / 100$, and $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, ...\right)$ is determined by Subclause 14.1.5. Here, P_{SPS} is the sidelink SPS interval of the corresponding SL SPS configuration.

14.1.1.4B UE procedure for determining subframes and resource blocks for transmitting PSSCH and reserving resources for sidelink transmission mode 4

If the UE has a configured sidelink grant (described in [8]) in subframe t_n^{SL} with the corresponding PSCCH resource m (described in Subclause 14.2.4), the resource blocks and subframes of the corresponding PSSCH transmissions are determined according to 14.1.1.4C.

The number of subframes in one set of the time and frequency resources for transmission opportunities of PSSCH is given by C_{resel} where C_{resel} = 10*SL_RESOURCE_RESELECTION_COUNTER [8] if configured else C_{resel} is set to 1.

If a set of sub-channels in subframe t_m^{SL} is determined as the time and frequency resource for PSSCH transmission corresponding to the configured sidelink grant (described in [8]), the same set of sub-channels in subframes $t_{m+j\times P'_{rsvp\_TX}}^{SL}$ are also determined for PSSCH transmissions corresponding to the same sidelink grant where j=1, 2,..., $C_{resel}-1$, $P'_{rsvp\_TX} = P_{step} \times P_{rsvp\_TX} / 100$, and $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, ...\right)$ is determined by Subclause 14.1.5. Here, $P_{\mathrm{rsvp\_TX}}$ is the resource reservation interval indicated by higher layers.

If a UE is configured with high layer parameter *cr-Limit* and transmits PSSCH in subframe n, the UE shall ensure the following limits for any priority value k;

$$\sum_{i\geq k} CR(i) \leq CR_{Limit}(k)$$

where $CR(i)$ is the CR evaluated in subframe n-4 for the PSSCH transmissions with "Priority" field in the SCI set to i, and $CR_{Limit}(k)$ corresponds to the high layer parameter *cr-Limit* that is associated with the priority value k and the CBR range which includes the CBR measured in subframe n-4. It is up to UE implementation how to meet the above limits, including dropping the transmissions in subframe n.

14.1.1.4C UE procedure for determining subframes and resource blocks for PSSCH transmission associated with an SCI format 1

The set of subframes and resource blocks for PSSCH transmission is determined by the resource used for the PSCCH transmission containing the associated SCI format 1, and "Frequency resource location of the initial transmission and retransmission" field, "Retransmission index" field, "Time gap between initial transmission and retransmission" field of the associated SCI format 1 as described below.

"Frequency resource location of the initial transmission and retransmission" field in the SCI format 1 is equal to resource indication value (RIV) corresponding to a starting sub-channel index (n_{subCH}^{start}) and a length in terms of contiguously allocated sub-channels ($L_{subCH} \geq 1$). The resource indication value is defined by

if $(L_{subCH}-1) \leq \lfloor N_{subCH}/2 \rfloor$ then

$$RIV = N_{subCH}(L_{subCH}-1) + n_{subCH}^{start}$$

else

$$RIV = N_{subCH}\left(N_{subCH} - L_{subCH} + 1\right) + \left(N_{subCH} - 1 - n_{subCH}^{start}\right)$$

where N_{subCH} is the total number of sub-channels in the pool determined by higher layer parameter *numSubchannel*.

For the SCI format 1 transmitted on the PSCCH resource *m* (described in subcaluse 14.2.4) in subframe t_n^{SL}, the set of subframes and sub-channels for the corresponding PSSCH are determined as follows:

- if SF_{gap} is zero,
  - the time and frequency resources for the corresponding PSSCH is given by
    - sub-channel(s) $m, m+1, ..., m + L_{subCH} - 1$ in subframe t_n^{SL}.
- else if "Retransmission index" in the SCI format 1 is zero,
  - the time and frequency resources for the corresponding PSSCH is given by
    - sub-channel(s) $m, m+1, ..., m + L_{subCH} - 1$ in subframe t_n^{SL}, and
    - sub-channels n_{subCH}^{start}, $n_{subCH}^{start} + 1, ...,$ $n_{subCH}^{start} + L_{subCH} - 1$ in subframe $t_{n+SF_{gap}}^{SL}$.
- else if "Retransmission index" in the SCI format 1 is one,
  - the time and frequency resources for the corresponding PSSCH is given by
    - sub-channels n_{subCH}^{start}, $n_{subCH}^{start} + 1, ...,$ $n_{subCH}^{start} + L_{subCH} - 1$ in subframe $t_{n-SF_{gap}}^{SL}$, and
    - sub-channels $m, m+1, ..., m + L_{subCH} - 1$ in subframe t_n^{SL}.

where SF_{gap} is the value indicated by "Time gap between initial transmission and retransmission" field the SCI format 1 and $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, ...\right)$ is determined by Subclause 14.1.5.

When sub-channel(s) $m, m+1, ..., m + L_{subCH} - 1$ are determined in a subframe for the transmission of PSSCH, the set of resource blocks determined for the PSSCH transmission is given by N_{PSSCH}^{RB} contiguous resource blocks with the physical resource block number $n_{PRB} = n_{subCHRBstart} + m * n_{subCHsize} + j + \beta$ for $j = 0, ..., N_{PSSCH}^{RB} - 1$. Here, $n_{subCHRBstart}$ and $n_{subCHsize}$ are given by higher layer parameters *startRBSubchannel* and *sizeSubchannel*, respectively. The parameters N_{PSSCH}^{RB} and β are given as follows:

- if a pool is (pre)configured such that a UE always transmits PSCCH and the corresponding PSSCH in adjacent resource blocks in a subframe, $\beta = 2$ and N_{PSSCH}^{RB} is the largest integer that fulfils

$$N_{PSSCH}^{RB} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le L_{subCH} * n_{subCHsize} - 2$$

  where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers

- if a pool is (pre)configured such that a UE may transmit PSCCH and the corresponding PSSCH in non-adjacent resource blocks in a subframe, $\beta = 0$ and N_{PSSCH}^{RB} is the largest integer that fulfils

$$N_{PSSCH}^{RB} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le L_{subCH} * n_{subCHsize}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

14.1.1.5 UE procedure for PSSCH power control

For sidelink transmission mode 1 and PSCCH period *i*, the UE transmit power P_{PSSCH} for PSSCH transmission is given by the following

- if the TPC command field in configured sidelink grant (described in [8]) for PSCCH period *i* is set to 0
  - $P_{\text{PSSCH}} = P_{\text{CMAX},PSSCH}$
- if the TPC command field in configured sidelink grant (described in [8]) for PSCCH period *i* is set to 1
  - $P_{\text{PSSCH}} = \min\left\{P_{\text{CMAX},PSSCH},\quad 10\log_{10}(M_{\text{PSSCH}}) + P_{\text{O\_PSSCH},1} + \alpha_{PSSCH,1}\cdot PL\right\}$ [dBm]

where $P_{\text{CMAX},PSSCH}$ is defined in [6], and M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource block and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\text{O\_PSSCH},1}$ and $\alpha_{PSSCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and that are associated with the corresponding PSSCH resource configuration.

For sidelink transmission mode 2, the UE transmit power P_{PSSCH} for PSSCH transmission is given by

$$P_{\text{PSSCH}} = \min\left\{P_{\text{CMAX},PSSCH},\quad 10\log_{10}(M_{\text{PSSCH}}) + P_{\text{O\_PSSCH},2} + \alpha_{PSSCH,2}\cdot PL\right\} \text{ [dBm]},$$

where $P_{\text{CMAX},PSSCH}$ is defined in [6], and M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource blocks and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\text{O\_PSSCH},2}$ and $\alpha_{PSSCH,2}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and that are associated with the corresponding PSSCH resource configuration.

For sidelink transmission mode 3, the UE transmit power P_{PSSCH} for PSSCH transmission is given by

$$P_{\text{PSSCH}} = 10\log_{10}\left(\frac{M_{\text{PSSCH}}}{M_{\text{PSSCH}} + 10^{\frac{3}{10}}\times M_{\text{PSCCH}}}\right) + \min\left\{P_{\text{CMAX}},\quad 10\log_{10}\left(M_{\text{PSSCH}} + 10^{\frac{3}{10}}\times M_{\text{PSCCH}}\right) + P_{\text{O\_PSSCH},3} + \alpha_{PSSCH,3}\cdot PL\right\} \text{ [dBm]},$$

where P_{CMAX} is defined in [6], and M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource blocks and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\text{O\_PSSCH},3}$ and $\alpha_{PSSCH,3}$ are provided by higher layer parameters *p0SL-V2V* and *alphaSL-V2V*, respectively and that are associated with the corresponding PSSCH resource configuration.

For sidelink transmission mode 4, the UE transmit power P_{PSSCH} for PSSCH transmission in subframe *n* is given by

$$P_{\text{PSSCH}} = 10\log_{10}\left(\frac{M_{\text{PSSCH}}}{M_{\text{PSSCH}} + 10^{\frac{3}{10}}\times M_{\text{PSCCH}}}\right) + A \text{ [dBm]},$$

where P_{CMAX} is defined in [6], M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource blocks, $M_{\text{PSCCH}} = 2$, and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\text{O\_PSSCH},4}$ and

$\alpha_{PSSCH,4}$ are provided by higher layer parameters *p0SL-V2V* and *alphaSL-V2V*, respectively and that are associated with the corresponding PSSCH resource configuration. If higher layer parameter *maxTxpower* is configured then

$$A = \min\left\{P_{\mathrm{CMAX}},\, P_{MAX\_CBR},\, 10\log_{10}\left(M_{\mathrm{PSSCH}} + 10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}\right) + P_{\mathrm{O\_PSSCH,4}} + \alpha_{PSSCH,4}\cdot PL\right\}$$

else

$$A = \min\left\{P_{\mathrm{CMAX}},\, 10\log_{10}\left(M_{\mathrm{PSSCH}} + 10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}\right) + P_{\mathrm{O\_PSSCH,4}} + \alpha_{PSSCH,4}\cdot PL\right\}$$

where P_{MAX_CBR} is set to a *maxTxpower* value based on the priority level of the PSSCH and the CBR range which includes the CBR measured in subframe *n*-4.

14.1.1.6 UE procedure for determining the subset of resources to be reported to higher layers in PSSCH resource selection in sidelink transmission mode 4

When requested by higher layers in subframe *n*, the UE shall determine the set of resources to be reported to higher layers for PSSCH transmission according to the following steps. Parameters L_{subCH} the number of sub-channels to be used for the PSSCH transmission in a subframe, $P_{\mathrm{rsvp\_TX}}$ the resource reservation interval, and $prio_{TX}$ the priority to be transmitted in the associated SCI format 1 by the UE are all provided by higher layers. C_{resel} is determined according to Subclause 14.1.1.4B.

If partial sensing is not configured by higher layers then the following steps are used:

1) A candidate single-subframe resource for PSSCH transmission $R_{\mathrm{x,y}}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel *x+j* in subframe t_y^{SL} where $j = 0,...,L_{\mathrm{subCH}} - 1$. The UE shall assume that any set of L_{subCH} contiguous sub-channels included in the corresponding PSSCH resource pool (described in 14.1.5) within the time interval $[n+T_1, n+T_2]$ corresponds to one candidate single-subframe resource, where selections of T_1 and T_2 are up to UE implementations under $T_1 \le 4$ and $20 \le T_2 \le 100$. UE selection of T_2 shall fulfil the latency requirement. The total number of the candidate single-subframe resources is denoted by M_{total}.

2) The UE shall monitor subframes $t^{\mathrm{SL}}_{n'-10\times P_{step}}$, $t^{\mathrm{SL}}_{n'-10\times P_{step}+1}$, …, $t^{\mathrm{SL}}_{n'-1}$ except for those in which its transmissions occur, where $t^{\mathrm{SL}}_{n'} = n$ if subframe n belongs to the set $\left(t_0^{SL}, t_1^{SL}, ..., t_{T_{\max}}^{SL}\right)$, otherwise subframe $t^{\mathrm{SL}}_{n'}$ is the first subframe after subframe n belonging to the set $\left(t_0^{SL}, t_1^{SL}, ..., t_{T_{\max}}^{SL}\right)$. The UE shall perform the behaviour in the following steps based on PSCCH decoded and S-RSSI measured in these subframes.

3) The parameter $Th_{a,b}$ is set to the value indicated by the i-th *SL-ThresPSSCH-RSRP* field in *SL-ThresPSSCH-RSRP-List* where $i = a*8+b+1$.

4) The set S_A is initialized to the union of all the candidate single-subframe resources. The set S_B is initialized to an empty set.

5) The UE shall exclude any candidate single-subframe resource $R_{\mathrm{x,y}}$ from the set S_A if it meets all the following conditions:

   - the UE has not monitored subframe t_z^{SL} in Step 2.

- there is an integer *j* which meets $y + j \times P'_{rsvp\_TX} = z + P_{step} \times k \times q$ where *j*=0, 1, …, $C_{resel} - 1$, $P'_{rsvp\_TX} = P_{step} \times P_{rsvp\_TX} / 100$, *k* is any value allowed by the higher layer parameter *restrictResourceReservationPeriod* and *q*=1,2,…,*Q*. Here, $Q = \frac{1}{k}$ if $k < 1$ and $n' - z \le P_{step} \times k$, where $t^{SL}_{n'} = n$ if subframe *n* belongs to the set $t^{SL}_0, t^{SL}_1, \ldots, t^{SL}_{T_{max}}$, otherwise subframe $t^{SL}_{n'}$ is the first subframe belonging to the set $t^{SL}_0, t^{SL}_1, \ldots, t^{SL}_{T_{max}}$ after subframe *n*; and $Q = 1$ otherwise.

6) The UE shall exclude any candidate single-subframe resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

   - the UE receives an SCI format 1 in subframe t^{SL}_m, and "Resource reservation" field and "Priority" field in the received SCI format 1 indicate the values P_{rsvp_RX} and $prio_{RX}$, respectively according to Subclause 14.2.1.

   - PSSCH-RSRP measurement according to the received SCI format 1 is higher than $Th_{prio_{TX}, prio_{RX}}$.

   - the SCI format received in subframe t^{SL}_m or the same SCI format 1 which is assumed to be received in subframe(s) $t^{SL}_{m+q \times P_{step} \times P_{rsvp\_RX}}$ determines according to 14.1.1.4C the set of resource blocks and subframes which overlaps with $R_{x, y+j \times P'_{rsvp\_TX}}$ for *q*=1, 2, …, *Q* and *j*=0, 1, …, $C_{resel} - 1$. Here, $Q = \frac{1}{P_{rsvp\_RX}}$ if $P_{rsvp\_RX} < 1$ and $n' - m \le P_{step} \times P_{rsvp\_RX}$, where $t^{SL}_{n'} = n$ if subframe n belongs to the set $\left(t^{SL}_0, t^{SL}_1, \ldots, t^{SL}_{T_{max}}\right)$, otherwise subframe $t^{SL}_{n'}$ is the first subframe after subframe n belonging to the set $\left(t^{SL}_0, t^{SL}_1, \ldots, t^{SL}_{T_{max}}\right)$; otherwise $Q = 1$.

7) If the number of candidate single-subframe resources remaining in the set S_A is smaller than $0.2 \cdot M_{total}$, then Step 4 is repeated with $Th_{a,b}$ increased by 3 dB.

8) For a candidate single-subframe resource $R_{x,y}$ remaining in the set S_A, the metric $E_{x,y}$ is defined as the linear average of S-RSSI measured in sub-channels *x*+*k* for $k = 0, \ldots, L_{subCH} - 1$ in the monitored subframes in Step 2 that can be expressed by $t^{SL}_{y - P_{step} * j}$ for a non-negative integer *j* if $P_{rsvp\_TX} \ge 100$, and $t^{SL}_{y - P'_{rsvp\_TX} * j}$ for a non-negative integer *j* otherwise.

9) The UE moves the candidate single-subframe resource $R_{x,y}$ with the smallest metric $E_{x,y}$ from the set S_A to S_B. This step is repeated until the number of candidate single-subframe resources in the set S_B becomes greater than or equal to $0.2 \cdot M_{total}$,

The UE shall report set S_B to higher layers.

If partial sensing is configured by higher layers then the following steps are used:

1) A candidate single-subframe resource for PSSCH transmission $R_{x,y}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel *x*+*j* in subframe t^{SL}_y where $j = 0, \ldots, L_{subCH} - 1$. The UE shall determine by its implementation a set of subframes which consists of at least Y subframes within the time interval $[n + T_1, n + T_2]$ where selections of T_1 and T_2 are up to UE implementations under $T_1 \le 4$ and $20 \le T_2 \le 100$. UE selection of T_2 shall fulfil the latency requirement and Y shall be greater than or equal

to the high layer parameter *minNumCandidateSF*. The UE shall assume that any set of L_{subCH} contiguous sub-channels included in the corresponding PSSCH resource pool (described in 14.1.5) within the determined set of subframes correspond to one candidate single-subframe resource. The total number of the candidate single-subframe resources is denoted by M_{total}.

2) If a subframe t_y^{SL} is included in the set of subframes in Step 1, the UE shall monitor any subframe $t_{y-k\times P_{step}}^{\text{SL}}$ if k-th bit of the high layer parameter *gapCandidateSensing* is set to 1. The UE shall perform the behaviour in the following steps based on PSCCH decoded and S-RSSI measured in these subframes.

3) The parameter $Th_{a,b}$ is set to the value indicated by the i-th *SL-ThresPSSCH-RSRP* field in *SL-ThresPSSCH-RSRP-List* where $i = a*8+b+1$.

4) The set S_A is initialized to the union of all the candidate single-subframe resources. The set S_B is initialized to an empty set.

5) The UE shall exclude any candidate single-subframe resource $R_{\text{x,y}}$ from the set S_A if it meets all the following conditions:

   - the UE receives an SCI format 1 in subframe t_m^{SL}, and "Resource reservation" field and "Priority" field in the received SCI format 1 indicate the values $P_{\text{rsvp\_RX}}$ and $prio_{RX}$, respectively according to Subclause 14.2.1.

   - PSSCH-RSRP measurement according to the received SCI format 1 is higher than $Th_{prio_{TX},prio_{RX}}$.

   - the SCI format received in subframe t_m^{SL} or the same SCI format 1 which is assumed to be received in subframe(s) $t_{m+q\times P_{step}\times P_{rsvp\_RX}}^{SL}$ determines according to 14.1.1.4C the set of resource blocks and subframes which overlaps with $R_{x,y+j\times P'_{rsvp\_TX}}$ for *q*=1, 2, …, *Q* and *j*=0, 1, …, $C_{resel}-1$. Here, $Q=\frac{1}{P_{rsvp\_RX}}$ if $P_{rsvp\_RX}<1$ and $y'-m \le P_{step} \times P_{rsvp\_RX} + P_{step}$, where $t_{y'}^{SL}$ is the last subframe of the Y subframes , and $Q=1$ otherwise.

6) If the number of candidate single-subframe resources remaining in the set S_A is smaller than $0.2\cdot M_{\text{total}}$, then Step 4 is repeated with $Th_{a,b}$ increased by 3 dB.

7) For a candidate single-subframe resource $R_{\text{x,y}}$ remaining in the set S_A, the metric $E_{\text{x,y}}$ is defined as the linear average of S-RSSI measured in sub-channels *x*+*k* for $k=0,...,L_{\text{subCH}}-1$ in the monitored subframes in Step 2 that can be expressed by $t_{y-P_{step}*j}^{SL}$ for a non-negative integer *j*.

8) The UE moves the candidate single-subframe resource $R_{\text{x,y}}$ with the smallest metric $E_{\text{x,y}}$ from the set S_A to S_B. This step is repeated until the number of candidate single-subframe resources in the set S_B becomes greater than or equal to $0.2\cdot M_{\text{total}}$.

The UE shall report set S_B to higher layers.

14.1.1.7 Conditions for selecting resources when the number of HARQ transmissions is two in sidelink transmission mode 4

When a set of subframes $t^{SL}_{n+j\times P'_{rsvp\_TX}}$ for $j = 0,1,..., J-1$ have been selected for a set of transmission opportunities of PSSCH, a set of subframes $t^{SL}_{n+k+j\times P'_{rsvp\_TX}}$ for $j = 0,1,..., J-1$ for another set of transmission opportunities of PSSCH shall meet the conditions $-15 \le k \le 15$ and $k \ne 0$ where $P'_{rsvp\_TX} = P_{step} \times P_{rsvp\_TX} / 100$ and J is the maximum number of transmission opportunities of PSSCH in a selected subframe set. Here, $P_{\text{rsvp\_TX}}$ is the resource reservation interval provided by higher layers.

14.1.2 UE procedure for receiving the PSSCH

For sidelink transmission mode 1, a UE upon detection of SCI format 0 on PSCCH can decode PSSCH according to the detected SCI format 0.

For sidelink transmission mode 2, a UE upon detection of SCI format 0 on PSCCH can decode PSSCH according to the detected SCI format 0, and associated PSSCH resource configuration configured by higher layers.

For sidelink transmission mode 3, a UE upon detection of SCI format 1 on PSCCH can decode PSSCH according to the detected SCI format 1, and associated PSSCH resource configuration configured by higher layers.

For sidelink transmission mode 4, a UE upon detection of SCI format 1 on PSCCH can decode PSSCH according to the detected SCI format 1, and associated PSSCH resource configuration configured by higher layers.

14.1.3 UE procedure for determining resource block pool and subframe pool for sidelink transmission mode 2

For a PSCCH period associated with the PSCCH resource configuration (determined in Subclause 14.2.3) which is also associated with the PSSCH resource configuration, the UE determines a PSSCH pool consisting of a subframe pool and resource block pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.

- Within the PSCCH period, the uplink subframes with subframe index greater than or equal to $j_{begin} + O_2$ are denoted by $\left(l_0, l_1, ..., l_{N'-1}\right)$ arranged in increasing order of subframe index, where j_{begin} is described in Subclause 14.2.3 and O_2 is the *offsetIndicator-r12* indicated by the PSSCH resource configuration, where N' denotes the number of uplink subframes within the PSCCH period with subframe index greater than or equal to $j_{begin} + O_2$.

- A bitmap $b_0, b_1, b_2, ..., b_{N'-1}$ is determined using $b_j = a_{j \bmod N_B}$, for $0 \le j < N'$, where $a_0, a_1, a_2, ..., a_{N_B-1}$ and N_B are the bitmap and the length of the bitmap indicated by *subframeBitmap-r12*, respectively.

- A subframe l_j $(0 \le j < N')$ belongs to the subframe pool if $b_j = 1$. The subframes in the subframe pool are denoted by $\left(l_0^{PSSCH}, l_1^{PSSCH}, ..., l_{L_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and L_{PSSCH} denotes the number of subframes in the subframe pool.

- A PRB with index q $(0 \le q < N_{RB}^{SL})$ belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1, S2,* and *M* denote the *prb-Start-r12, prb-End-r12* and *prb-Num-r12* indicated by the PSSCH resource configuration respectively.

- The resource blocks in the resource block pool are denoted by $\left(m_0^{PSSCH}, m_1^{PSSCH}, ..., m_{M_{RB}^{PSSCH\_RP}-1}^{PSSCH}\right)$ arranged in increasing order of resource block indices and $M_{RB}^{PSSCH\_RP}$ is the number of resource blocks in the resource block pool.

14.1.4 UE procedure for determining subframe pool for sidelink transmission mode 1

For a PSCCH period associated with the PSCCH resource configuration (described in Subclause 14.2.3) which is also associated with the PSSCH resource configuration, the UE determines a PSSCH pool consisting of a subframe pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12,* otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.
- Each uplink subframe with subframe index greater than or equal to $l_{L_{PSCCH}-1}^{PSCCH}+1$ belongs to the subframe pool for PSSCH, where $l_{L_{PSCCH}-1}^{PSCCH}+1$ and L_{PSCCH} are described in Subclause 14.2.3.
- The subframes in the subframe pool for PSSCH are denoted by $\left(l_0^{PSSCH}, l_1^{PSSCH}, ..., l_{L_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and L_{PSSCH} denotes the number of subframes in the subframe pool.

14.1.5 UE procedure for determining resource block pool and subframe pool for sidelink transmission mode 3 and 4

The set of subframes that may belong to a PSSCH resource pool for sidelink transmission mode 3 or 4 is denoted by $\left(t_0^{SL}, t_1^{SL}, ..., t_{T_{\max}}^{SL}\right)$ where

- $0 \le t_i^{SL} < 10240$,
- the subframe index is relative to subframe#0 of the radio frame corresponding to SFN 0 of the serving cell or DFN 0 (described in [11]),
- the set includes all the subframes except the following subframes,
  - subframes in which SLSS resource is configured,
  - downlink subframes and special subframes if the sidelink transmission occurs in a TDD cell,
  - reserved subframes which are determined by the following steps:
    1) the remaining subframes excluding N_{slss} and N_{dssf} subframes from the set of all the subframes are denoted by $\left(l_0, l_1, ..., l_{(10240-N_{slss}-N_{dssf}-1)}\right)$ arranged in increasing order of subframe index, where N_{slss} is the number of subframes in which SLSS resource is configured within 10240 subframes and N_{dssf} is the number of downlink subframes and special subframes within 10240 subframes if the sidelink transmission occurs in a TDD cell.
    2) a subframe $l_r \left(0 \le r < \left(10240 - N_{slss} - N_{dssf}\right)\right)$ belongs to the reserved subframes if $r = \left\lfloor \frac{m \cdot \left(10240 - N_{slss} - N_{dssf}\right)}{N_{reserved}} \right\rfloor$ where $m = 0, \dots, N_{reserved} - 1$ and $N_{reserved} = \left(10240 - N_{slss} - N_{dssf}\right) mod\ L_{bitmap}$. Here, L_{bitmap} the length of the bitmap is configured by higher layers.

- the subframes are arranged in increasing order of subframe index.

The UE determines the set of subframes assigned to a PSSCH resource pool as follows:

- A bitmap $\left(b_0, b_1, ..., b_{L_{bitmap}}\right)$ associated with the resource pool is used where L_{bitmap} the length of the bitmap is configured by higher layers.

- A subframe $t_k^{SL}\left(0 \le k < \left(10240 - N_{slss} - N_{dssf} - N_{reserved}\right)\right)$ belongs to the subframe pool if $b_{k'} = 1$ where $k' = k \bmod L_{bitmap}$.

The UE determines the set of resource blocks assigned to a PSSCH resource pool as follows:

- The resource block pool consists of N_{subCH} sub-channels where N_{subCH} is given by higher layer parameter *numSubchannel*.

- The sub-channel *m* for $m = 0,1,..., N_{subCH} - 1$ consists of a set of $n_{subCHsize}$ contiguous resource blocks with the physical resource block number $n_{PRB} = n_{subCHRBstart} + m * n_{subCHsize} + j$ for $j = 0,1,..., n_{subCHsize} - 1$ where $n_{subCHRBstart}$ and $n_{subCHsize}$ are given by higher layer parameters *startRBSubchannel* and *sizeSubchannel*, respectively

14.2 Physical Sidelink Control Channel related procedures

For sidelink transmission mode 1, if a UE is configured by higher layers to receive DCI format 5 with the CRC scrambled by the SL-RNTI, the UE shall decode the PDCCH/EPDCCH according to the combination defined in Table 14.2-1.

Table 14.2-1: PDCCH/EPDCCH configured by SL-RNTI

DCI format	Search Space
DCI format 5	For PDCCH: Common and UE specific by C-RNTI For EPDCCH: UE specific by C-RNTI

For sidelink transmission mode 3, if a UE is configured by higher layers to receive DCI format 5A with the CRC scrambled by the SL-V-RNTI or SL-SPS-V-RNTI , the UE shall decode the PDCCH/EPDCCH according to the combination defined in Table 14.2-2. A UE is not expected to receive DCI format 5A with size larger than DCI format 0 in the same search space that DCI format 0 is defined on.

Table 14.2-2: PDCCH/EPDCCH configured by SL-V-RNTI or SL-SPS-V-RNTI

DCI format	Search Space
DCI format 5A	For PDCCH: Common and UE specific by C-RNTI For EPDCCH: UE specific by C-RNTI

The carrier indicator field value in DCI format 5A corresponds to *v2x-InterFreqInfo*.

14.2.1 UE procedure for transmitting the PSCCH

For sidelink transmission mode 1and PSCCH period *i*,

- the UE shall determine the subframes and resource blocks for transmitting SCI format 0 as follows.
  - SCI format 0 is transmitted in two subframes in the subframe pool and one physical resource block per slot in each of the two subframes, wherein the physical resource blocks belong to the resource block pool, where the subframe pool and the resource block pool are indicated by the PSCCH resource configuration (as defined in Subclause 14.2.3)
  - the two subframes and the resource blocks are determined using "Resource for PSCCH" field (n_{PSCCH}) in the configured sidelink grant (described in [8]) as described in Subclause 14.2.1.1.

- the UE shall set the contents of the SCI format 0 as follows:
  - the UE shall set the Modulation and coding scheme field according to the Modulation and coding scheme indicated by the higher layer parameter *mcs-r12* if the parameter is configured by higher layers.
  - the UE shall set the Frequency hopping flag according to the "Frequency hopping flag" field in the configured sidelink grant.
  - the UE shall set the Resource block assignment and hopping resource allocation according to the "Resource block assignment and hopping resource allocation" field in the configured sidelink grant.
  - the UE shall set the Time resource pattern according to the "Time resource pattern" field in the configured sidelink grant .
  - the UE shall set the eleven-bit Timing advance indication to $I_{TAI} = \left\lfloor \frac{N_{TA}}{16} \right\rfloor$ to indicate sidelink reception timing adjustment value using the N_{TA} (defined in [3]) value for the UE in the subframe that is no earlier than subframe $l_{b1}^{PSCCH} - 4$ (l_{b1}^{PSCCH} described in Subclause 14.2.1.1).

For sidelink transmission mode 2,

- SCI format 0 is transmitted in two subframes in the subframe pool and one physical resource block per slot in each of the two subframes, wherein the physical resource blocks belongs to the resource block pool, where the subframe pool and the resource block pool are indicated by the PSCCH resource configuration (as defined in Subclause 14.2.3)
  - the two subframes and the resource blocks are determined using the procedure described in Subclause 14.2.1.2
  - the UE shall set the eleven-bit Timing advance indication I_{TAI} in the SCI format 0 to zero.

For sidelink transmission mode 3,

- The UE shall determine the subframes and resource blocks for transmitting SCI format 1 as follows:
  - SCI format 1 is transmitted in two physical resource blocks per slot in each subframe where the corresponding PSSCH is transmitted.
  - If the UE receives in subframe *n* DCI format 5A with the CRC scrambled by the SL-V-RNTI, one transmission of PSCCH is in the PSCCH resource L_{Init} (described in Subclause 14.2.4) in the first subframe that is included in $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, \ldots\right)$ and that starts not earlier than $T_{\mathrm{DL}} - \frac{N_{\mathrm{TA}}}{2} \times T_{\mathrm{S}} + (4 + m) \times 10^{-3}$. L_{Init} is the value indicated by "Lowest index of the sub-channel allocation to the initial transmission" associated with the configured sidelink grant (described in [8]), $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, \ldots\right)$ is determined by Subclause 14.1.5, the value *m* is indicated by 'SL index' field in the corresponding DCI format 5A according to Table 14.2.1-1 if this field is present and *m*=0 otherwise, T_{DL} is the start of the downlink subframe carrying the DCI, and N_{TA} and T_{S} are described in [3].
    - If "Time gap between initial transmission and retransmission" in the configured sidelink grant (described in [8]) is not equal to zero, another transmission of PSCCH is in the PSCCH resource $L_{\mathrm{Re}TX}$ in subframe $t_{q+SF_{gap}}^{SL}$, where SF_{gap} is the value indicated by "Time gap between initial transmission and retransmission" field in the configured sidelink grant, subframe t_q^{SL} corresponds to the subframe $n + k_{init}$. $L_{\mathrm{Re}TX}$ corresponds to the value n_{subCH}^{start} determined by the procedure in Subclause 14.1.1.4C with the RIV set to the value indicated by "Frequency resource location of the initial transmission and retransmission" field in the configured sidelink grant.
  - If the UE receives in subframe *n* DCI format 5A with the CRC scrambled by the SL-SPS-V-RNTI , the UE shall consider the received DCI information as a valid sidelink semi-persistent activation or release only for the SPS configuration indicated by the SL SPS configuration index field. If the received DCI activates an SL SPS configuration, one transmission of PSCCH is in the PSCCH resource L_{Init} (described in Subclause

14.2.4) in the first subframe that is included in $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, \ldots\right)$ and that starts not earlier than $T_{\mathrm{DL}} - \frac{N_{\mathrm{TA}}}{2} \times T_{\mathrm{S}} + (4+m) \times 10^{-3}$. L_{Init} is the value indicated by "Lowest index of the sub-channel allocation to the initial transmission" associated with the configured sidelink grant (described in [8]), $\left(t_0^{SL}, t_1^{SL}, t_2^{SL}, \ldots\right)$ is determined by Subclause 14.1.5, the value *m* is indicated by 'SL index' field in the corresponding DCI format 5A according to Table 14.2.1-1 if this field is present and *m*=0 otherwise, T_{DL} is the start of the downlink subframe carrying the DCI, and N_{TA} and T_{S} are described in [3]..

- If "Time gap between initial transmission and retransmission" in the configured sidelink grant (described in [8]) is not equal to zero, another transmission of PSCCH is in the PSCCH resource $L_{\mathrm{Re}TX}$ in subframe $t_{q+SF_{gap}}^{SL}$, where SF_{gap} is the value indicated by "Time gap between initial transmission and retransmission" field in the configured sidelink grant, subframe t_q^{SL} corresponds to the subframe $n+k_{init}$. $L_{\mathrm{Re}TX}$ corresponds to the value n_{subCH}^{start} determined by the procedure in Subclause 14.1.1.4C with the RIV set to the value indicated by "Frequency resource location of the initial transmission and retransmission" field in the configured sidelink grant.

- The UE shall set the contents of the SCI format 1 as follows:
  - the UE shall set the Modulation and coding scheme as indicated by higher layers.
  - the UE shall set the "Priority" field according to the highest priority among those priority(s) indicated by higher layers corresponding to the transport block.
  - the UE shall set the Time gap between initial transmission and retransmission field, the Frequency resource location of the initial transmission and retransmission field, and the Retransmission index field such that the set of time and frequency resources determined for PSSCH according to Subclause 14.1.1.4C is in accordance with the PSSCH resource allocation indicated by the configured sidelink grant.
  - the UE shall set the Resource reservation to zero.
  - Each transmission of SCI format 1 is transmitted in one subframe and two physical resource blocks per slot of the subframe.
- The UE shall randomly select the cyclic shift $n_{\mathrm{cs},\lambda}$ among {0, 3, 6, 9} in each PSCCH transmission.

For sidelink transmission mode 4,

- The UE shall determine the subframes and resource blocks for transmitting SCI format 1 as follows:
  - SCI format 1 is transmitted in two physical resource blocks per slot in each subframe where the corresponding PSSCH is transmitted.
  - If the configured sidelink grant from higher layer indicates the PSCCH resource in subframe t_n^{SL}, one transmission of PSCCH is in the indicated PSCCH resource *m* (described in Subclause 14.2.4) in subframe t_n^{SL}.
    - If "Time gap between initial transmission and retransmission" in the configured sidelink grant (described in [8]) is not equal to zero, another transmission of PSCCH is in the PSCCH resource $L_{\mathrm{Re}TX}$ in subframe $t_{n+SF_{gap}}^{SL}$ where SF_{gap} is the value indicated by "Time gap between initial transmission and retransmission" field in the configured sidelink grant, $L_{\mathrm{Re}TX}$ corresponds to the value n_{subCH}^{start} determined by the procedure in Subclause 14.1.1.4C with the RIV set to the value indicated by "Frequency resource location of the initial transmission and retransmission" field in the configured sidelink grant.
- the UE shall set the contents of the SCI format 1 as follows:
  - the UE shall set the Modulation and coding scheme as indicated by higher layers.

- the UE shall set the "Priority" field according to the highest priority among those priority(s) indicated by higher layers corresponding to the transport block.
- the UE shall set the Time gap between initial transmission and retransmission field, the Frequency resource location of the initial transmission and retransmission field, and the Retransmission index field such that the set of time and frequency resources determined for PSSCH according to Subclause 14.1.1.4C is in accordance with the PSSCH resource allocation indicated by the configured sidelink grant.
- the UE shall set the Resource reservation field according to table 14.2.1-2 based on indicated value *X*, where *X* is equal to the Resource reservation interval provided by higher layers divided by 100.
- Each transmission of SCI format 1 is transmitted in one subframe and two physical resource blocks per slot of the subframe.
- The UE shall randomly select the cyclic shift $n_{\mathrm{cs},\lambda}$ among {0, 3, 6, 9} in each PSCCH transmission.

Table 14.2.1-1: Mapping of DCI format 5A offset field to indicated value *m*

SL index field in DCI format 5A	Indicated value *m*
'00'	0
'01'	1
'10'	2
'11'	3

Table 14.2.1-2: Determination of the Resource reservation field in SCI format 1

Resource reservation field in SCI format 1	Indicated value *X*	Condition
'0001', '0010', …, '1010'	Decimal equivalent of the field	The higher layer decides to keep the resource for the transmission of the next transport block and the value *X* meets $1 \le X \le 10$.
'1011'	0.5	The higher layer decides to keep the resource for the transmission of the next transport block and the value *X* is 0.5.
'1100'	0.2	The higher layer decides to keep the resource for the transmission of the next transport block and the value *X* is 0.2.
'0000'	0	The higher layer decides not to keep the resource for the transmission of the next transport block.
'1101', '1110', '1111'	Reserved	

14.2.1.1 UE procedure for determining subframes and resource blocks for transmitting PSCCH for sidelink transmission mode 1

For $0 \le n_{PSCCH} < \lfloor M_{RB}^{PSCCH\_RP} / 2 \rfloor \cdot L_{PSCCH}$,

- one transmission of the PSCCH is in resource block m_{a1}^{PSCCH} of subframe l_{b1}^{PSCCH} of the PSCCH period, where $a1 = \lfloor n_{PSCCH} / L_{PSCCH} \rfloor$ and $b1 = n_{PSCCH} \bmod L_{PSCCH}$.
- the other transmission of the PSCCH is in resource block m_{a2}^{PSCCH} of subframe l_{b2}^{PSCCH} of the PSCCH period, where $a2 = \lfloor n_{PSCCH} / L_{PSCCH} \rfloor + \lfloor M_{RB}^{PSCCH\_RP} / 2 \rfloor$ and $b2 = \left(n_{PSCCH} + 1 + \lfloor n_{PSCCH} / L_{PSCCH} \rfloor \bmod \left(L_{PSCCH} - 1\right)\right) \bmod L_{PSCCH}$.

where $\left(l_0^{PSCCH}, l_1^{PSCCH}, \ldots, l_{L_{PSCCH}-1}^{PSCCH}\right)$, $\left(m_0^{PSCCH}, m_1^{PSCCH}, \ldots, m_{M_{RB}^{PSCCH\_RP}-1}^{PSCCH}\right)$, L_{PSCCH} and $M_{RB}^{PSCCH\_RP}$ are described in Subclause 14.2.3.

14.2.1.2 UE procedure for determining subframes and resource blocks for transmitting PSCCH for sidelink transmission mode 2

The allowed values for PSCCH resource selection are given by 0,1… $\left(\lfloor M_{RB}^{PSCCH\_RP}/2\rfloor\cdot L_{PSCCH}-1\right)$ where L_{PSCCH} and $M_{RB}^{PSCCH\_RP}$ described in Subclause 14.2.3. The two subframes and the resource blocks are determined using selected resource value n_{PSCCH} (described in [8]) and the procedure described in Subclause 14.2.1.1.

14.2.1.3 UE procedure for PSCCH power control

For sidelink transmission mode 1 and PSCCH period *i*, the UE transmit power P_{PSCCH} for PSCCH transmission is given by the following

- if the TPC command field in the configured sidelink grant (described in [8]) for PSCCH period *i* is set to 0
  - $P_{\mathrm{PSCCH}}=P_{\mathrm{CMAX},PSCCH}$
- if the TPC command field in the configured sidelink grant (described in [8]) for PSCCH period *i* is set to 1
  - $P_{\mathrm{PSCCH}}=\min\left\{P_{\mathrm{CMAX},PSCCH},\quad 10\log_{10}(M_{\mathrm{PSCCH}})+P_{\mathrm{O\_PSCCH,1}}+\alpha_{PSCCH,1}\cdot PL\right\}$ [dBm]

where $P_{\mathrm{CMAX},PSCCH}$ is defined in [6], and M_{PSCCH}=1 and $PL=PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\mathrm{O\_PSCCH,1}}$ and $\alpha_{PSCCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSCCH resource configuration.

For sidelink transmission mode 2, the UE transmit power P_{PSCCH} for PSCCH transmission is given by

$$P_{\mathrm{PSCCH}}=\min\left\{P_{\mathrm{CMAX},PSCCH},\quad 10\log_{10}(M_{\mathrm{PSCCH}})+P_{\mathrm{O\_PSCCH,2}}+\alpha_{PSCCH,2}\cdot PL\right\}\ \text{[dBm]},$$

where $P_{\mathrm{CMAX},PSCCH}$ is the $P_{\mathrm{CMAX},c}$ configured by higher layers and M_{PSCCH}=1 and $PL=PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\mathrm{O\_PSCCH,2}}$ and $\alpha_{PSCCH,2}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSCCH resource configuration.

For sidelink transmission mode 3, the UE transmit power P_{PSCCH} for PSCCH transmission is given by

$$P_{\mathrm{PSCCH}}=10\log_{10}\left(\frac{10^{\frac{3}{10}}\times M_{\mathrm{PSCCH}}}{M_{\mathrm{PSSCH}}+10^{\frac{3}{10}}\times M_{\mathrm{PSCCH}}}\right)+\min\left\{P_{\mathrm{CMAX}},\quad 10\log_{10}\left(M_{\mathrm{PSSCH}}+10^{\frac{3}{10}}\times M_{\mathrm{PSCCH}}\right)+P_{\mathrm{O\_PSSCH,3}}+\alpha_{PSSCH,3}\cdot PL\right\}\ \text{[dBm]},$$

where P_{CMAX} is defined in [6], M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource block, $M_{\mathrm{PSCCH}}=2$, and $PL=PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\mathrm{O\_PSSCH,3}}$ and $\alpha_{PSSCH,3}$ are provided by higher layer parameters *p0SL-V2V* and *alphaSL-V2V*, respectively and that are associated with the corresponding PSSCH resource configuration.

For sidelink transmission mode 4, the UE transmit power P_{PSCCH} for PSCCH transmission in subframe *n* is given by

$$P_{\mathrm{PSCCH}} = 10\log_{10}\left(\frac{10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}}{M_{\mathrm{PSSCH}} + 10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}}\right) + B \ \ \text{[dBm]},$$

where P_{CMAX} is defined in [6], M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource block, $M_{\mathrm{PSCCH}} = 2$, and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\mathrm{O\_PSSCH,4}}$ and $\alpha_{PSSCH,4}$ are provided by higher layer parameters *p0SL-V2V* and *alphaSL-V2V*, respectively and that are associated with the corresponding PSSCH resource configuration. If higher layer parameter *maxTxpower* is configured then

$$B = \min\left\{P_{\mathrm{CMAX}},\ P_{MAX\_CBR},\ 10\log_{10}\left(M_{\mathrm{PSSCH}} + 10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}\right) + P_{\mathrm{O\_PSSCH,4}} + \alpha_{PSSCH,4} \cdot PL\right\}$$

else

$$B = \min\left\{P_{\mathrm{CMAX}},\ 10\log_{10}\left(M_{\mathrm{PSSCH}} + 10^{\frac{3}{10}} \times M_{\mathrm{PSCCH}}\right) + P_{\mathrm{O\_PSSCH,4}} + \alpha_{PSSCH,4} \cdot PL\right\}$$

where P_{MAX_CBR} is set to a *maxTxpower* value based on the priority level of the PSSCH and the CBR range which includes the CBR measured in subframe *n*-4.

14.2.2 UE procedure for receiving the PSCCH

For each PSCCH resource configuration associated with sidelink transmission mode 1, a UE configured by higher layers to detect SCI format 0 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration, and using the Group destination IDs indicated by higher layers.

For each PSCCH resource configuration associated with sidelink transmission mode 2, a UE configured by higher layers to detect SCI format 0 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration, and using the Group destination IDs indicated by higher layers.

For each PSCCH resource configuration associated with sidelink transmission mode 3, a UE configured by higher layers to detect SCI format 1 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration. The UE is not required to decode more than one PSCCH at each PSCCH resource candidate. The UE shall not assume any value for the "Reserved bits" before decoding a SCI format 1.

For each PSCCH resource configuration associated with sidelink transmission mode 4, a UE configured by higher layers to detect SCI format 1 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration. The UE is not required to decode more than one PSCCH at each PSCCH resource candidate. The UE shall not assume any value for the "Reserved bits" before decoding a SCI format 1.

14.2.3 UE procedure for determining resource block pool and subframe pool for PSCCH

The following procedure is used for sidelink transmission mode 1 and 2.

A PSCCH resource configuration for transmission/reception is associated with a set of periodically occurring time-domain periods (known as PSCCH periods). The *i*-th PSCCH period begins at subframe with subframe index $j_{begin} = O + i \cdot P$ and ends in subframe with subframe index $j_{end} = O + (i+1) \cdot P - 1$, where

- $0 \le j_{begin}, j_{end} < 10240$,
- the subframe index is relative to subframe#0 of the radio frame corresponding to SFN 0 of the serving cell or DFN 0 (described in [11]),
- O is the *offsetIndicator-r12* indicated by the PSCCH resource configuration,

- P is the *sc-Period-r12* indicated by the PSCCH resource configuration.

For a PSCCH period, the UE determines a PSCCH pool consisting of a subframe pool and a resource block pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.

- The first N' uplink subframes are denoted by $\left(l_0, l_1, ..., l_{N'-1}\right)$ arranged in increasing order of subframe index, where N' is the length of the bitmap *subframeBitmap-r12* indicated by the PSCCH resource configuration.

- A subframe l_j $(0 \le j < N')$ belongs to the subframe pool if $a_j = 1$, where $\left(a_0, a_1, a_2, ..., a_{N'-1}\right)$ is the bitmap *subframeBitmap-r12* indicated by the PSCCH resource configuration. The subframes in the subframe pool are denoted by $\left(l_0^{PSCCH}, l_1^{PSCCH}, ..., l_{L_{PSCCH}-1}^{PSCCH}\right)$ arranged in increasing order of subframe index and L_{PSCCH} is the number of subframes in the subframe pool. A PRB with index q $(0 \le q < N_{RB}^{SL})$ belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1*, *S2,* and *M* denote the *prb-Start-r12, prb-End-r12 and prb-Num-r12* indicated by the PSCCH resource configuration respectively.

- The resource blocks in the resource block pool are denoted by $\left(m_0^{PSCCH}, m_1^{PSCCH}, ..., m_{M_{RB}^{PSCCH\_RP}-1}^{PSCCH}\right)$ arranged in increasing order of resource block indices and $M_{RB}^{PSCCH\_RP}$ is the number of resource blocks in the resource block pool.

14.2.4 UE procedure for determining resource block pool for PSCCH in sidelink transmission mode 3 and 4

The following procedure is used for sidelink transmission mode 3 and 4.

If a pool is (pre)configured such that a UE always transmits PSCCH and the corresponding PSSCH in adjacent resource blocks in a subframe, the PSCCH resource *m* is the set of two contiguous resource blocks with the physical resource block number $n_{PRB} = n_{subCHRBstart} + m * n_{subCHsize} + j$ for *j*=0 and 1 where $n_{subCHRBstart}$ and $n_{subCHsize}$ are given by higher layer parameters *startRBSubchannel* and *sizeSubchannel*, respectively.

If a pool is (pre)configured such that a UE may transmit PSCCH and the corresponding PSSCH in non-adjacent resource blocks in a subframe, the PSCCH resource *m* is the set of two contiguous resource blocks with the physical resource block number $n_{PRB} = n_{PSCCHstart} + 2 * m + j$ for *j*=0 and 1 where $n_{PSCCHstart}$ is given by higher layer parameter *startRBPSCCHPool*.

14.3 Physical Sidelink Discovery Channel related procedures

14.3.1 UE procedure for transmitting the PSDCH

If a UE is configured by higher layers to transmit PSDCH according to a PSDCH resource configuration, in a PSDCH period i,

- the number of transmissions for a transport block on PSDCH is $N_{\mathrm{SLD}}^{\mathrm{TX}} = n + 1$ where n is given by the higher layer parameter *numRetx-r12*, and each transmission corresponds to one subframe belonging to a set of subframes, and in each subframe, the PSDCH is transmitted on two physical resource blocks per slot.

  - for sidelink discovery type 1,

    - the allowed values for PSDCH resource selection are given by 0,1… $(N_t \cdot N_f - 1)$, where $N_t = \left\lfloor L_{PSDCH} / N_{\mathrm{SLD}}^{\mathrm{TX}} \right\rfloor$ and $N_f = \left\lfloor M_{RB}^{PSDCH\_RP} / 2 \right\rfloor$, and

- the *j*-th transmission ($1 \le j \le N_{\text{SLD}}^{\text{TX}}$) for the transport block occurs in contiguous resource blocks $m_{2\cdot a_j^{(i)}}^{PSDCH}$ and $m_{2\cdot a_j^{(i)}+1}^{PSDCH}$ of subframe $l_{N_{\text{SLD}}^{\text{TX}}\cdot b_1^{(i)}+j-1}^{PSDCH}$ of the PSDCH period, where
  - $a_j^{(i)} = \left((j-1)\cdot\left\lfloor N_f / N_{SLD}^{TX}\right\rfloor + \left\lfloor n_{PSDCH} / N_t \right\rfloor\right) \bmod N_f$ and $b_1^{(i)} = n_{PSDCH} \bmod N_t$ and using selected resource value n_{PSDCH} (described in [8]).
  - $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right), \left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right), L_{PSDCH}$ and $M_{RB}^{PSDCH\_RP}$ are described in Subclause 14.3.3.

- for sidelink discovery type 2B,
  - The *j*-th transmission ($1 \le j \le N_{\text{SLD}}^{\text{TX}}$) for the transport block occurs in contiguous resource blocks $m_{2\cdot a_j^{(i)}}^{PSDCH}$ and $m_{2\cdot a_j^{(i)}+1}^{PSDCH}$ of subframe $l_{N_{\text{SLD}}^{\text{TX}}\cdot b_1^{(i)}+j-1}^{PSDCH}$ of the PSDCH period, where
  - $a_1^{(i)} = \left((N_{PSDCH}^{(2)} + n') \bmod 10 + \left\lfloor \left(a_1^{(i-1)} + N_f \cdot b_1^{(i-1)}\right) / N_t \right\rfloor\right) \bmod N_f$
  - $b_1^{(i)} = \left(N_{PSDCH}^{(1)} + N_{PSDCH}^{(3)} \cdot a_1^{(i-1)} + N_f \cdot b_1^{(i-1)}\right) \bmod N_t$
  - $a_j^{(i)} = \left((j-1)\cdot\left\lfloor N_f / N_{SLD}^{TX}\right\rfloor + a_1^{(i)}\right) \bmod N_f$ for $1 < j \le N_{\text{SLD}}^{\text{TX}}$
  - $N_t = \left\lfloor L_{PSDCH} / N_{\text{SLD}}^{\text{TX}} \right\rfloor$ and $N_f = \left\lfloor M_{RB}^{PSDCH\_RP} / 2 \right\rfloor$, and $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right)$, $\left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right), L_{PSDCH}$ and $M_{RB}^{PSDCH\_RP}$ are described in Subclause 14.3.3.
  - $a_1^{(0)}$ and $b_1^{(0)}$ are given by higher layer parameters *discPRB-Index* and *discSF-Index*, respectively and that associated with the PSDCH resource configuration.
  - $N_{PSDCH}^{(1)}$, $N_{PSDCH}^{(2)}$ and $N_{PSDCH}^{(3)}$ are given by higher layer parameters *a-r12*, *b-r12*, and *c-r12*, repectively and that are associated with the PSDCH resource configuration.
  - n' is the number of PSDCH periods since $N_{PSDCH}^{(2)}$ was received.

- the transport block size is 232

For sidelink discovery, the UE transmit power P_{PSDCH} for PSDCH transmission is given by the following

$$P_{\text{PSDCH}} = \min\left\{P_{\text{CMAX},PSDCH},\quad 10\log_{10}(M_{\text{PSDCH}}) + P_{\text{O\_PSDCH},1} + \alpha_{PSDCH,1}\cdot PL\right\} \text{ [dBm]}$$

where $P_{\text{CMAX},PSDCH}$ is defined in [6], and M_{PSDCH} =2 and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1 where c

is the serving cell if the sidelink discovery transmission occurs on the uplink carrier frequency of a serving cell, or

is the cell indicated by higher layers on downlink carrier frequency indicated by *discCarrierRef-r13*[11] if sidelink discovery transmission does not occur on the uplink carrier frequency of a serving cell.

$P_{\text{O\_PSDCH},1}$ and $\alpha_{PSDCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSDCH resource configuration.

A UE shall drop any PSDCH transmissions that are associated with sidelink discovery type 1 in a sidelink subframe if the UE has a PSDCH transmission associated with sidelink discovery type 2B in that subframe.

14.3.2 UE procedure for receiving the PSDCH

For sidelink discovery type 1, for each PSDCH resource configuration associated with reception of PSDCH, a UE configured by higher layers to detect a transport block on PSDCH can decode the PSDCH according to the PSDCH resource configuration.

For sidelink discovery type 2B, for each PSDCH resource configuration associated with reception of PSDCH, a UE configured by higher layers to detect a transport block on PSDCH can decode the PSDCH according to the PSDCH resource configuration.

14.3.3 UE procedure for determining resource block pool and subframe pool for sidelink discovery

A PSDCH resource configuration for transmission/reception is associated with a set of periodically occurring time-domain periods (known as PSDCH periods). The *i*-th PSDCH period begins at subframe with subframe index $j_{begin} = O_3 + i \cdot P$ and ends in subframe with subframe index $j_{end} = O_3 + (i+1) \cdot P - 1$, where

- $0 \le j_{begin} < 10240$,
- the subframe index is relative to subframe#0 of a radio frame corresponding to SFN 0 of the serving cell or DFN 0 (described in [11]),
- O_3 is the *offsetIndicator-r12* indicated by the PSDCH resource configuration
- P is the *discPeriod-r12* indicated by the PSDCH resource configuration.

For a PSDCH period, the UE determines a discovery pool consisting of a subframe pool and a resource block pool for PSDCH as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSDCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.
- A bitmap $b_0, b_1, b_2, ..., b_{N'-1}$ is obtained using $b_j = a_{j \bmod N_B}$, for $0 \le j < N'$, where $a_0, a_1, a_2, ..., a_{N_B-1}$ and N_B are the bitmap and the length of the bitmap indicated by *subframeBitmap-r12*, respectively, and $N' = N_B \cdot N_R$, where N_R is the *numRepetition-r12* indicated by the PSDCH resource configuration.
- The first N' uplink subframes are denoted by $(l_0, l_1, ..., l_{N'-1})$ arranged in increasing order of subframe index.
- A subframe l_j ($0 \le j < N'$) belongs to the subframe pool if $b_j = 1$. The subframes in the subframe pool are denoted by $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right)$ arranged in increasing order of subframe index and L_{PSDCH} denotes the number of subframes in the subframe pool.
- A PRB with index q ($0 \le q < N_{RB}^{SL}$) belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1*, *S2*, and *M* denote the *prb-Start-r12*, *prb-End-r12* and *prb-Num-r12* indicated by the PSDCH resource configuration respectively.
- The resource blocks in the resource block pool are denoted by $\left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right)$ arranged in increasing order of resource block indices and $M_{RB}^{PSDCH\_RP}$ is the number of resource blocks in the resource block pool.

14.4 Physical Sidelink Synchronization related procedures

The synchronization resource configuration(s) for the UE are given by the higher layer parameter *SL-SyncConfig-r12 or v2x-SyncConfig*.

A UE shall transmit sidelink synchronisation signals according to Subclause 5.10.7 in [11].

A UE may assume that sidelink synchronization signals are signals transmitted by an eNB as described in Subclause 6.11 of [3] or are signals transmitted by a UE as described in [11].

A UE is not expected to blindly detect the cyclic prefix length of sidelink synchronization signals transmitted by another UE.

For a sidelink synchronization resource configuration associated with PSDCH reception, if cell *c* is indicated by the parameter *physCellId-r12* and if the parameter *discSyncWindow-r12* is configured with value *w1* for cell *c*, the UE may assume that sidelink synchronization signals are transmitted in cell *c* and that they are received within a reference synchronization window of size +/-*w1* ms with respect to the sidelink synchronization resource of cell *c* indicated by higher layers. The sidelink synchronization identity associated with the sidelink synchronization resource is indicated by higher layers.

For PSDCH reception, if cell *c* is indicated by the parameter *physCellId-r12* and if the parameter *discSyncWindow-r12* is configured with value *w2* for cell *c*, the UE may assume that PSDCH of UE in cell *c* is received within a reference synchronization window of size +/-*w2* ms with respect to the discovery resource of cell *c* indicated by higher layers.

The UE transmit power of primary sidelink synchronization signal P_{PSSS} and the UE transmit power of secondary synchronization signal P_{SSSS} are given by

- If the UE is configured with sidelink transmission mode 1, and if the UE transmits sidelink synchronization signals in PSCCH period *i*, and if the TPC command field in the configured sidelink grant (described in [8]) for the PSCCH period *i* is set to 0
  - $P_{\mathrm{PSSS}} = P_{\mathrm{CMAX},PSBCH}$
  - $P_{\mathrm{SSSS}} = P_{\mathrm{CMAX},SSSS}$
- otherwise
  - $P_{\mathrm{PSSS}} = \min\left\{P_{\mathrm{CMAX},PSBCH},\quad 10\log_{10}(M_{\mathrm{PSSS}}) + P_{\mathrm{O\_PSSS}} + \alpha_{PSSS}\cdot PL\right\}$ [dBm] ,
  - $P_{\mathrm{SSSS}} = \min\left\{P_{\mathrm{CMAX},SSSS},\quad 10\log_{10}(M_{\mathrm{PSSS}}) + P_{\mathrm{O\_PSSS}} + \alpha_{PSSS}\cdot PL\right\}$ [dBm] ,

where $P_{\mathrm{CMAX},PSBCH}$ and $P_{\mathrm{CMAX},SSSS}$ are defined in [6]. $M_{\mathrm{PSSS}} = 6$ and $PL = PL_c$ where PL_c is defined in Subclause 5.1.1.1. $P_{\mathrm{O\_PSSS}}$ and α_{PSSS} are provided by higher layer parameters associated with the corresponding sidelink synchronization signal resource configuration.

If sidelink synchronization signals are transmitted for PSDCH, and if the PSDCH transmission does not occur on any serving cell configured for the UE, c is the cell indicated by higher layers on downlink carrier frequency indicated by *discCarrierRef* [11]. Otherwise, c is the serving cell on which the sidelink synchronization signals are transmitted. If sidelink synchronization signals are transmitted for PSDCH, then PSDCH and sidelink synchronization signal transmission occur on the same carrier frequency.

15 Channel access procedures for LAA

15.1 Downlink channel access procedures

An eNB operating LAA Scell(s) shall perform the channel access procedures described in this sub clause for accessing the channel(s) on which the LAA Scell(s) transmission(s) are performed.

15.1.1 Channel access procedure for transmission(s) including PDSCH/PDCCH/EPDCCH

The eNB may transmit a transmission including PDSCH/PDCCH/EPDCCH on a carrier on which LAA Scell(s) transmission(s) are performed , after first sensing the channel to be idle during the slot durations of a defer duration T_d ; and after the counter N is zero in step 4. The counter N is adjusted by sensing the channel for additional slot duration(s) according to the steps below:

1) set $N = N_{init}$, where N_{init} is a random number uniformly distributed between 0 and CW_p , and go to step 4;
2) if $N > 0$ and the eNB chooses to decrement the counter, set $N = N - 1$;
3) sense the channel for an additional slot duration, and if the additional slot duration is idle, go to step 4; else, go to step 5;
4) if $N = 0$, stop; else, go to step 2.
5) sense the channel until either a busy slot is detected within an additional defer duration T_d or all the slots of the additional defer duration T_d are detected to be idle;
6) if the channel is sensed to be idle during all the slot durations of the additional defer duration T_d , go to step 4; else, go to step 5;

If an eNB has not transmitted a transmission including PDSCH/PDCCH/EPDCCH on a carrier on which LAA Scell(s) transmission(s) are performed after step 4 in the procedure above, the eNB may transmit a transmission including PDSCH/PDCCH/EPDCCH on the carrier, if the channel is sensed to be idle at least in a slot duration T_{sl} when the eNB is ready to transmit PDSCH/PDCCH/EPDCCH and if the channel has been sensed to be idle during all the slot durations of a defer duration T_d immediately before this transmission. If the channel has not been sensed to be idle in a slot duration T_{sl} when the eNB first senses the channel after it is ready to transmit or if the channel has been sensed to be not idle during any of the slot durations of a defer duration T_d immediately before this intended transmission, the eNB proceeds to step 1 after sensing the channel to be idle during the slot durations of a defer duration T_d .

The defer duration T_d consists of duration $T_f = 16us$ immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9us$, and T_f includes an idle slot duration T_{sl} at start of T_f ;

A slot duration T_{sl} is considered to be idle if the eNB senses the channel during the slot duration, and the power detected by the eNB for at least $4us$ within the slot duration is less than energy detection threshold X_{Thresh} . Otherwise, the slot duration T_{sl} is considered to be busy.

$CW_{\min,p} \le CW_p \le CW_{\max,p}$ is the contention window. CW_p adjustment is described in sub clause 15.1.3.

$CW_{\min,p}$ and $CW_{\max,p}$ are chosen before step 1 of the procedure above.

m_p , $CW_{\min,p}$, and $CW_{\max,p}$ are based on channel access priority class associated with the eNB transmission, as shown in Table 15.1.1-1.

X_{Thresh} adjustment is described in sub clause 15.1.4

If the eNB transmits discovery signal transmission(s) not including PDSCH/PDCCH/EPDCCH when $N > 0$ in the procedure above, the eNB shall not decrement N during the slot duration(s) overlapping with discovery signal transmission.

The eNB shall not continuously transmit on a carrier on which the LAA Scell(s) transmission(s) are performed, for a period exceeding $T_{m\cot,p}$ as given in Table 15.1.1-1.

For $p=3$ and $p=4$, if the absence of any other technology sharing the carrier can be guaranteed on a long term basis (e.g. by level of regulation), $T_{m\cot,p}=10ms$, otherwise, $T_{m\cot,p}=8ms$.

Table 15.1.1-1: Channel Access Priority Class

Channel Access Priority Class (p)	m_p	$CW_{\min,p}$	$CW_{\max,p}$	$T_{m\cot,p}$	allowed CW_p sizes
1	1	3	7	2 ms	{3,7}
2	1	7	15	3 ms	{7,15}
3	3	15	63	8 or 10 ms	{15,31,63}
4	7	15	1023	8 or 10 ms	{15,31,63,127,255,511,1023}

For LAA operation in Japan, if the eNB has transmitted a transmission after $N=0$ in step 4 of the procedure above, the eNB may transmit the next continuous transmission, for duration of maximum T_j =4 msec, immediately after sensing the channel to be idle for at least a sensing interval of T_{js} =34usec and if the total sensing and transmission time is not more than $1000 \cdot T_{mcot} + \lceil T_{mcot} / T_j - 1 \rceil \cdot T_{js}$ μsec. T_{js} consists of duration $T_f = 16us$ immediately followed by two slot durations $T_{sl} = 9us$ each and T_f includes an idle slot duration T_{sl} at start of T_f . The channel is considered to be idle for T_{js} if it is sensed to be idle during the during the slot durations of T_{js} .

15.1.2 Channel access procedure for transmissions including discovery signal transmission(s) and not including PDSCH

An eNB may transmit a transmission including discovery signal but not including PDSCH on a carrier on which LAA Scell(s) transmission(s) are performed immediately after sensing the channel to be idle for at least a sensing interval $T_{\mathrm{drs}} = 25us$ and if the duration of the transmission is less than 1 ms. T_{drs} consists of a duration $T_f = 16us$ immediately followed by one slot duration $T_{sl} = 9us$ and T_f includes an idle slot duration T_{sl} at start of T_f . The channel is considered to be idle for T_{drs} if it is sensed to be idle during the slot durations of T_{drs} .

15.1.3 Contention window adjustment procedure

If the eNB transmits transmissions including PDSCH that are associated with channel access priority class p on a carrier, the eNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in sub clause 15.1.1 for those transmissions using the following steps:

1) for every priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{\min,p}$

2) if at least $Z = 80\%$ of HARQ-ACK values corresponding to PDSCH transmission(s) in reference subframe k are determined as NACK, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value and remain in step 2; otherwise, go to step 1.

Reference subframe k is the starting subframe of the most recent transmission on the carrier made by the eNB, for which at least some HARQ-ACK feedback is expected to be available.

The eNB shall adjust the value of CW_p for every priority class $p \in \{1,2,3,4\}$ based on a given reference subframe k only once.

If $CW_p = CW_{\max,p}$, the next higher allowed value for adjusting CW_p is $CW_{\max,p}$.

For determining Z,

- if the eNB transmission(s) for which HARQ-ACK feedback is available start in the second slot of subframe k, HARQ-ACK values corresponding to PDSCH transmission(s) in subframe $k+1$ are also used in addition to the HARQ-ACK values corresponding to PDSCH transmission(s) in subframe k.
- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on the same LAA SCell,
  - if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB, or if the eNB detects 'DTX', 'NACK/DTX' or 'any' state, it is counted as NACK.
- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on another serving cell,
  - if the HARQ-ACK feedback for a PDSCH transmission is detected by the eNB, 'NACK/DTX' or 'any' state is counted as NACK, and 'DTX' state is ignored.
  - if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB
    - if PUCCH format 1b with channel selection is expected to be used by the UE, 'NACK/DTX' state corresponding to 'no transmission' as described in Subclauses 10.1.2.2.1, 10.1.3.1 and 10.1.3.2.1 is counted as NACK, and 'DTX' state corresponding to 'no transmission' is ignored.- Otherwise, the HARQ-ACK for the PDSCH transmission is ignored.
- if a PDSCH transmission has two codewords, the HARQ-ACK value of each codeword is considered separately
- bundled HARQ-ACK across M subframes is considered as M HARQ-ACK responses.

If the eNB transmits transmissions including PDCCH/EPDCCH with DCI format 0A/0B/4A/4B and not including PDSCH that are associated with channel access priority class p on a channel starting from time t_0, the eNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in sub clause 15.1.1 for those transmissions using the following steps:

1) for every priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{\min,p}$
2) if less than 10% of the UL transport blocks scheduled by the eNB using Type 2 channel access procedure (described in sub clause 15.2.1.2) in the time interval between t_0 and $t_0 + T_{CO}$ have been received successfully, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value and remain in step 2; otherwise, go to step 1.

where T_{CO} is computed as described in Subclause 15.2.1.

If the $CW_p = CW_{\max,p}$ is consecutively used K times for generation of N_{init}, CW_p is reset to $CW_{\min,p}$ only for that priority class p for which $CW_p = CW_{\max,p}$ is consecutively used K times for generation of N_{init}. K is selected by eNB from the set of values {1, 2, …,8} for each priority class $p \in \{1,2,3,4\}$.

15.1.4 Energy detection threshold adaptation procedure

An eNB accessing a carrier on which LAA Scell(s) transmission(s) are performed, shall set the energy detection threshold (X_{Thresh}) to be less than or equal to the maximum energy detection threshold $X_{\text{Thresh\_max}}$.

$X_{\text{Thresh\_max}}$ is determined as follows:

- If the absence of any other technology sharing the carrier can be guaranteed on a long term basis (e.g. by level of regulation) then:

  - $X_{\text{Thresh\_max}} = \min\left\{\begin{matrix} T_{\max} + 10\,dB, \\ X_r \end{matrix}\right\}$

    - X_r is Maximum energy detection threshold defined by regulatory requirements in dBm when such requirements are defined, otherwise $X_r = T_{\max} + 10\,dB$

- Otherwise,

  - $X_{\text{Thres\_max}} = \max\left\{\begin{matrix} -72 + 10 \cdot \log 10(BWMHz\ /20MHz)\ dBm, \\ \min\left\{\begin{matrix} T_{\max}, \\ T_{\max} - T_A + \left(P_H + 10 \cdot \log 10(BWMHz\ /20MHz) - P_{TX}\right) \end{matrix}\right\} \end{matrix}\right\}$

- Where:

  - T_A = 10dB for transmission(s) including PDSCH;

  - T_A = 5dB for transmissions including discovery signal transmission(s) and not including PDSCH;

  - P_H = 23 dBm;

  - P_{TX} is the set maximum eNB output power in dBm for the carrier;

    - eNB uses the set maximum transmission power over a single carrier irrespective of whether single carrier or multi-carrier transmission is employed

  - $T_{\max}(\text{dBm}) = 10 \cdot \log 10\left(3.16228 \cdot 10^{-8}\,(mW\ /\ MHz) \cdot BWMHz\ (MHz)\right)$;

  - BWMHz is the single carrier bandwidth in MHz.

15.1.5 Channel access procedure for transmission(s) on multiple carriers

An eNB can access multiple carriers on which LAA Scell(s) transmission(s) are performed, according to one of the Type A or Type B procedures described in this Subclause.

15.1.5.1 Type A multi-carrier access procedures

The eNB shall perform channel access on each carrier $c_i \in C$, according to the procedures described in Subclause 15.1.1, where C is a set of carriers on which the eNB intends to transmit, and $i = 0,1,\ldots q-1$, and q is the number of carriers on which the eNB intends to transmit.

The counter N described in Subclause 15.1.1 is determined for each carrier c_i and is denoted as N_{c_i}. N_{c_i} is maintained according to Subclause 15.1.5.1.1or 15.1.5.1.2.

15.1.5.1.1 Type A1

Counter N as described in Subclause 15.1.1 is independently determined for each carrier c_i and is denoted as N_{c_i}.

If the absence of any other technology sharing the carrier cannot be guaranteed on a long term basis (e.g. by level of regulation), when the eNB ceases transmission on any one carrier $c_j \in C$, for each carrier $c_i \neq c_j$, the eNB can resume decrementing N_{c_i} when idle slots are detected either after waiting for a duration of $4 \cdot T_{sl}$, or after reinitialising N_{c_i}.

15.1.5.1.2 Type A2

Counter N is determined as described in Subclause 15.1.1 for carrier $c_j \in C$, and is denoted as N_{c_j}, where c_j is the carrier that has the largest CW_p value. For each carrier c_i, $N_{c_i} = N_{c_j}$.

When the eNB ceases transmission on any one carrier for which N_{c_i} is determined, the eNB shall reinitialise N_{c_i} for all carriers.

15.1.5.2 Type B multi-carrier access procedure

A carrier $c_j \in C$ is selected by the eNB as follows

- the eNB selects c_j by uniformly randomly choosing c_j from C before each transmission on multiple carriers $c_i \in C$, or

- the eNB selects c_j no more frequently than once every 1 second,

where C is a set of carriers on which the eNB intends to transmit, $i = 0,1,\ldots q-1$, and q is the number of carriers on which the eNB intends to transmit.

To transmit on carrier c_j

- the eNB shall perform channel access on carrier c_j according to the procedures described in Subclause 15.1.1 with the modifications described in 15.1.5.2.1 or 15.1.5.2.2.

To transmit on carrier $c_i \neq c_j$, $c_i \in C$

- for each carrier c_i, the eNB shall sense the carrier c_i for at least a sensing interval $T_{mc} = 25us$ immediately before the transmitting on carrier c_j, and the eNB may transmit on carrier c_i immediately after sensing the carrier c_i to be idle for at least the sensing interval T_{mc}. The carrier c_i is considered to be idle for T_{mc} if the channel is sensed to be idle during all the time durations in which such idle sensing is performed on the carrier c_j in given interval T_{mc}.

The eNB shall not continuously transmit on a carrier $c_i \neq c_j$, $c_i \in C$, for a period exceeding $T_{m\cot,p}$ as given in Table 15.1.1-1, where the value of $T_{m\cot,p}$ is determined using the channel access parameters used for carrier c_j.

15.1.5.2.1 Type B1

A single CW_p value is maintained for the set of carriers C.

For determining CW_p for channel access on carrier c_j, step 2 of the procedure described in sub clause 15.1.3 is modified as follows

- if at least $Z = 80\%$ of HARQ-ACK values corresponding to PDSCH transmission(s) in reference subframe k of all carriers $c_i \in C$ are determined as NACK, increase CW_p for each priority class $p \in \{1,2,3,4\}$ to the next higher allowed value; otherwise, go to step 1.

15.1.5.2.2 Type B2

A CW_p value is maintained independently for each carrier $c_i \in C$ using the procedure described in Subclause 15.1.3.

For determining N_{init} for carrier c_j, CW_p value of carrier $c_{j1} \in C$ is used, where c_{j1} is the carrier with largest CW_p among all carriers in set C.

15.2 Uplink channel access procedures

A UE and a eNB scheduling UL transmission(s) for the UE shall perform the procedures described in this sub clause for the UE to access the channel(s) on which the LAA Scell(s) transmission(s) are performed.

15.2.1 Channel access procedure for Uplink transmission(s)

The UE can access a carrier on which LAA Scell(s) UL transmission(s) are performed according to one of Type 1 or Type 2 UL channel access procedures. Type 1 channel access procedure is described in sub clause 15.2.1.1. Type 2 channel access procedure is described in sub clause 15.2.1.2.

If an UL grant scheduling a PUSCH transmission indicates Type 1 channel access procedure, the UE shall use Type 1 channel access procedure for transmitting transmissions including the PUSCH transmission unless stated otherwise in this sub clause.

If an UL grant scheduling a PUSCH transmission indicates Type 2 channel access procedure, the UE shall use Type 2 channel access procedure for transmitting transmissions including the PUSCH transmission unless stated otherwise in this sub clause.

The UE shall use Type 1 channel access procedure for transmitting SRS transmissions not including a PUSCH transmission. UL channel access priority class $p=1$ is used for SRS transmissions not including a PUSCH.

If the UE is scheduled to transmit PUSCH and SRS in subframe n, and if the UE cannot access the channel for PUSCH transmission in subframe n, the UE shall attempt to make SRS transmission in subframe n according to uplink channel access procedures specified for SRS transmission.

Table 15.2.1-1: Channel Access Priority Class for UL

Channel Access Priority Class (p)	m_p	$CW_{\min,p}$	$CW_{\max,p}$	$T_{ulm\cot,p}$	allowed CW_p sizes
1	2	3	7	2 ms	{3,7}
2	2	7	15	4 ms	{7,15}
3	3	15	1023	6ms or 10 ms	{15,31,63,127,255,511,1023}
4	7	15	1023	6ms or 10 ms	{15,31,63,127,255,511,1023}
NOTE1: For $p=3,4$, $T_{ulm\cot,p}$ =10ms if the higher layer parameter '*absenceOfAnyOtherTechnology-r14*' indicates TRUE, otherwise, $T_{ulm\cot,p}$ =6ms. NOTE 2: When $T_{ulm\cot,p}$ =6ms it may be increased to 8 ms by inserting one or more gaps. The minimum duration of a gap shall be 100 µs. The maximum duration before including any such gap shall be 6 ms..					

If the 'UL duration and offset' field configures an 'UL offset' l and an 'UL duration' d for subframe n, then

the UE may use channel access Type 2 for transmissions in subframes $n+l+i$ where $i=0,1,\ldots d-1$, irrespective of the channel access Type signalled in the UL grant for those subframes, if the end of UE transmission occurs in or before subframe $n+l+d-1$.

If the UE scheduled to transmit transmissions including PUSCH in a set subframes $n_0, n_1, \cdots, n_{w-1}$ using PDCCH DCI Format 0B/4B, and if the UE cannot access the channel for a transmission in subframe n_k, the UE shall attempt to make a transmission in subframe n_{k+1} according to the channel access type indicated in the DCI, where $k \in \{0,1, \cdots w-2\}$, and w is the number of scheduled subframes indicated in the DCI.

If the UE is scheduled to transmit transmissions without gaps including PUSCH in a set of subframes $n_0, n_1, \cdots, n_{w-1}$ using one or more PDCCH DCI Format 0A/0B/4A/4B and the UE performs a transmission in subframe n_k after accessing the carrier according to one of Type 1 or Type 2 UL channel access procedures, the UE may continue transmission in subframes after n_k where $k \in \{0,1, \cdots w-1\}$.

If the beginning of UE transmission in subframe $n+1$ immediately follows the end of UE transmission in subframe n, the UE is not expected to be indicated with different channel access types for the transmissions in those subframes .

If the UE is scheduled to transmit without gaps in subframes $n_0, n_1, \cdots, n_{w-1}$ using one or more PDCCH DCI Format 0A/0B/4A/4B, and if the UE has stopped transmitting during or before subframe n_{k1}, $k1 \in \{0,1, \cdots w-2\}$, and if the channel is sensed by the UE to be continuously idle after the UE has stopped transmitting, the UE may transmit in a later subframe n_{k2}, $k2 \in \{1, \cdots w-1\}$ using Type 2 channel access procedure. If the channel sensed by the UE is not continuously idle after the UE has stopped transmitting, the UE may transmit in a later subframe n_{k2}, $k2 \in \{1, \cdots w-1\}$ using Type 1 channel access procedure with the UL channel access priority class indicated in the DCI corresponding to subframe n_{k2}.

If the UE receives an UL grant and the DCI indicates a PUSCH transmission starting in subframe n using Type 1 channel access procedure, and if the UE has an ongoing Type 1 channel access procedure before subframe n.

- if the UL channel access priority class value p_1 used for the ongoing Type 1 channel access procedure is same or larger than the UL channel access priority class value p_2 indicated in the DCI, the UE may transmit the PUSCH transmission in response to the UL grant by accessing the carrier by using the ongoing Type 1 channel access procedure.
- if the UL channel access priority class value p_1 used for the ongoing Type 1 channel access procedure is smaller than the UL channel access priority class value p_2 indicated in the DCI, the UE shall terminate the ongoing channel access procedure.

If the UE is scheduled to transmit on a set of carriers C in subframe n, and if the UL grants scheduling PUSCH transmissions on the set of carriers C indicate Type 1 channel access procedure, and if the same '*PUSCH starting position*' is indicated for all carriers in the set of carriers C, , and if the carrier frequencies of set of carriers C is a subset of one of the sets of carrier frequencies defined in Subclause 5.7.4 in [7]

- the UE may transmit on carrier $c_i \in C$ using Type 2 channel access procedure,
  - if Type 2 channel access procedure is performed on carrier c_i immediately before the UE transmission on carrier $c_j \in C$, $i \neq j$, and
  - if the UE has accessed carrier c_j using Type 1 channel access procedure,
    - where carrier c_j is selected by the UE uniformly randomly from the set of carriers C before performing Type 1 channel access procedure on any carrier in the set of carriers C.

A eNB may indicate Type 2 channel access procedure in the DCI of an UL grant scheduling transmission(s) including PUSCH on a carrier in subframe n when the eNB has transmitted on the carrier according to the channel access procedure described in sub clause 15.1.1, or an eNB may indicate using the 'UL duration and offset' field that the UE may perform a Type 2 channel access procedure for transmissions(s) including PUSCH on a carrier in subframe n when the eNB has transmitted on the carrier according to the channel access procedure described in sub clause 15.1.1, or an eNB may schedule transmissions including PUSCH on a carrier in subframe n, that follows a transmission by the eNB on that carrier with a duration of $T_{\text{short\_ul}} = 25us$, if subframe n occurs within the time interval starting at t_0 and ending at $t_0 + T_{CO}$, where $T_{CO} = T_{m\text{cot},p} + T_g$, where

- t_0 is the time instant when the eNB has started transmission,
- $T_{m\text{cot},p}$ value is determined by the eNB as described in sub clause 15.1 ,
- T_g is the total duration of all gaps of duration greater than 25us that occur between the DL transmission of the eNB and UL transmissions scheduled by the eNB, and between any two UL transmissions scheduled by the eNB starting from t_0 .

The eNB shall schedule UL transmissions between t_0 and $t_0 + T_{CO}$ in contiguous subframes if they can be scheduled contiguously.

For an UL transmission on a carrier that follows a transmission by the eNB on that carrier within a duration of $T_{\text{short\_ul}} = 25us$, the UE may use Type 2 channel access procedure for the UL transmission.

If the eNB indicates Type 2 channel access procedure for the UE in the DCI, the eNB indicates the channel access priority class used to obtain access to the channel in the DCI.

15.2.1.1 Type 1 UL channel access procedure

The UE may transmit the transmission using Type 1 channel access procedure after first sensing the channel to be idle during the slot durations of a defer duration T_d ; and after the counter N is zero in step 4. The counter N is adjusted by sensing the channel for additional slot duration(s) according to the steps described below.

1) set $N = N_{init}$, where N_{init} is a random number uniformly distributed between 0 and CW_p , and go to step 4;
2) if $N > 0$ and the UE chooses to decrement the counter, set $N = N - 1$;
3) sense the channel for an additional slot duration, and if the additional slot duration is idle, go to step 4; else, go to step 5;
4) if $N = 0$, stop; else, go to step 2.
5) sense the channel until either a busy slot is detected within an additional defer duration T_d or all the slots of the additional defer duration T_d are detected to be idle;
6) if the channel is sensed to be idle during all the slot durations of the additional defer duration T_d , go to step 4; else, go to step 5;

If the UE has not transmitted a transmission including PUSCH or SRS on a carrier on which LAA Scell(s) transmission(s) are performed after step 4 in the procedure above, the UE may transmit a transmission including PUSCH or SRS on the carrier, if the channel is sensed to be idle at least in a slot duration T_{sl} when the UE is ready to transmit the transmission including PUSCH or SRS, and if the channel has been sensed to be idle during all the slot durations of a defer duration T_d immediately before the transmission including PUSCH or SRS. If the channel has not been sensed to be idle in a slot duration T_{sl} when the UE first senses the channel after it is ready to transmit, or if the channel has not been sensed to be idle during any of the slot durations of a defer duration T_d immediately before the intended transmission including PUSCH or SRS, the UE proceeds to step 1 after sensing the channel to be idle during the slot durations of a defer duration T_d .

The defer duration T_d consists of duration $T_f = 16us$ immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9us$, and T_f includes an idle slot duration T_{sl} at start of T_f ;

A slot duration T_{sl} is considered to be idle if the UE senses the channel during the slot duration, and the power detected by the UE for at least $4us$ within the slot duration is less than energy detection threshold X_{Thresh} . Otherwise, the slot duration T_{sl} is considered to be busy.

$CW_{\min,p} \le CW_p \le CW_{\max,p}$ is the contention window. CW_p adjustment is described in sub clause 15.2.2.

$CW_{\min,p}$ and $CW_{\max,p}$ are chosen before step 1 of the procedure above.

m_p , $CW_{\min,p}$, and $CW_{\max,p}$ are based on channel access priority class signalled to the UE , as shown in Table 15.2.1-1.

X_{Thresh} adjustment is described in sub clause 15.2.3.

15.2.1.2 Type 2 UL channel access procedure

If the UL UE uses Type 2 channel access procedure for a transmission including PUSCH, the UE may transmit the transmission including PUSCH immediately after sensing the channel to be idle for at least a sensing interval $T_{\text{short\_ul}} = 25us$. $T_{\text{short\_ul}}$ consists of a duration $T_f = 16us$ immediately followed by one slot duration $T_{sl} = 9us$ and T_f includes an idle slot duration T_{sl} at start of T_f . The channel is considered to be idle for $T_{\text{short\_ul}}$ if it is sensed to be idle during the slot durations of $T_{\text{short\_ul}}$.

15.2.2 Contention window adjustment procedure

If the UE transmits transmissions using Type 1 channel access procedure that are associated with channel access priority class p on a carrier, the UE maintains the contention window value CW_p and adjusts CW_p for those transmissions before step 1 of the procedure described in sub clause 15.2.1.1, using the following procedure

- if the NDI value for at least one HARQ process associated with HARQ_ID_ref is toggled,
  - for every priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{\min,p}$
- otherwise, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value;

HARQ_ID_ref is the HARQ process ID of UL-SCH in reference subframe n_{ref} . The reference subframe n_{ref} is determined as follows

- If the UE receives an UL grant in subframe n_g , subframe n_w is the most recent subframe before subframe $n_g - 3$ in which the UE has transmitted UL-SCH using Type 1 channel access procedure.
  - If the UE transmits transmissions including UL-SCH without gaps starting with subframe n_0 and in subframes $n_0, n_1, \cdots, n_w$, reference subframe n_{ref} is subframe n_0 ,
  - otherwise, reference subframe n_{ref} is subframe n_w ,

The UE may keep the value of CW_p unchanged for every priority class $p \in \{1,2,3,4\}$, if the UE scheduled to transmit transmissions without gaps including PUSCH in a set subframes $n_0, n_1, \cdots, n_{w-1}$ using Type 1 channel access procedure, and if the UE is not able to transmit any transmission including PUSCH in the set of subframes.

The UE may keep the value of CW_p for every priority class $p \in \{1,2,3,4\}$ the same as that for the last scheduled transmission including PUSCH using Type 1 channel access procedure, if the reference subframe for the last scheduled transmission is also n_{ref}.

If $CW_p = CW_{\max,\,p}$, the next higher allowed value for adjusting CW_p is $CW_{\max,\,p}$.

If the $CW_p = CW_{\max,\,p}$ is consecutively used K times for generation of N_{init}, CW_p is reset to $CW_{\min,p}$ only for that priority class p for which $CW_p = CW_{\max,\,p}$ is consecutively used K times for generation of N_{init}. K is selected by UE from the set of values {1, 2, …,8} for each priority class $p \in \{1,2,3,4\}$.

15.2.3 Energy detection threshold adaptation procedure

A UE accessing a carrier on which LAA Scell(s) transmission(s) are performed, shall set the energy detection threshold (X_{Thresh}) to be less than or equal to the maximum energy detection threshold $X_{\text{Thresh\_max}}$.

$X_{\text{Thresh\_max}}$ is determined as follows:

- If the UE is configured with higher layer parameter '*maxEnergyDetectionThreshold-r14*',
  - $X_{\text{Thresh\_max}}$ is set equal to the value signalled by the higher layer parameter.
- otherwise
  - the UE shall determine $X'_{\text{Thresh\_max}}$ according to the procedure described in sub clause 15.2.3.1
  - if the UE is configured with higher layer parameter '*energyDetectionThresholdOffset-r14*'
    - $X_{\text{Thresh\_max}}$ is set by adjusting $X'_{\text{Thresh\_max}}$ according to the offset value signalled by the higher layer parameter
  - otherwise
    - The UE shall set $X_{\text{Thresh\_max}} = X'_{\text{Thresh\_max}}$

15.2.3.1 Default maximum energy detection threshold computation procedure

If the higher layer parameter '*absenceOfAnyOtherTechnology-r14*' indicates TRUE:

- $X'_{\text{Thresh\_max}} = \min \begin{Bmatrix} T_{\max} + 10dB, \\ X_r \end{Bmatrix}$ where
  - X_r is Maximum energy detection threshold defined by regulatory requirements in dBm when such requirements are defined, otherwise $X_r = T_{\max} + 10\,dB$

otherwise

- $$X'_{\text{Thres\_max}} = \max\left\{\begin{array}{l} -72 + 10\cdot\log 10(BWMHz\ /20MHz)\ dBm, \\ \min\left\{\begin{array}{l} T_{\max}, \\ T_{\max} - T_A + \left(P_H + 10\cdot\log 10(BWMHz\ /20MHz) - P_{TX}\right)\end{array}\right\}\end{array}\right\}$$

Where

- T_A = 10dB
- P_H = 23 dBm;
- P_{TX} is the set to the value of $P_{CMAX\_H,c}$ as defined in [6].
- $T_{\max}(\text{dBm}) = 10\cdot\log 10\left(3.16228\cdot 10^{-8}\,(mW\ /\ MHz)\cdot BWMHz\ (MHz)\right)$;
  - BWMHz is the single carrier bandwidth in MHz.

16 UE Procedures related to narrowband IoT

16.1 Synchronization procedures

16.1.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the narrowband physical layer Cell ID.

If the higher layer parameter *operationModeInfo* indicates '*inband-SamePCI*' or *samePCI-Indicator* indicates '*samePCI*' for a cell, the UE may assume that the physical layer cell ID is same as the narrowband physical layer cell ID for the cell.

The following signals are transmitted in the downlink to facilitate cell search for Narrowband IoT: the narrowband primary and narrowband secondary synchronization signals.

A UE may assume the antenna ports 2000 – 2001 and the antenna port for the narrowband primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

16.1.2 Timing synchronization

Upon reception of a timing advance command, the UE shall adjust uplink transmission timing for NPUSCH based on the received timing advance command.

The timing advance command indicates the change of the uplink timing relative to the current uplink timing as multiples of $16\,T_s$. The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], T_A, indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 1282, where an amount of the time alignment is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, a 6-bit timing advance command [8], T_A, indicates adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of T_A = 0, 1, 2,..., 63, where $N_{TA,new} = N_{TA,old} + (T_A - 31)\times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing by a given amount respectively.

For a timing advance command reception ending in DL subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the first available NB-IoT uplink slot following the end of *n+12* DL subframe and the first available NB-IoT uplink slot is the first slot of a NPUSCH transmission. When the UE's uplink NPUSCH transmissions in NB-IoT uplink slot n and NB-IoT uplink slot n+1 are overlapped due to the timing adjustment, the UE shall complete transmission of NB-IoT uplink slot n and not transmit the overlapped part of NB-IoT uplink slot n+1.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes N_{TA} accordingly.

16.2 Power control

16.2.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

16.2.1.1 Narrowband physical uplink shared channel

16.2.1.1.1 UE behaviour

The setting of the UE Transmit power for a Narrowband Physical Uplink Shared Channel (NPUSCH) transmission is defined as follows. If the UE is capable of enhanced random access power control [12], and it is configured by higher layers, then enhanced random access power control shall be applied for a UE which started the random access procedure in the first or second configured NPRACH repetition level.

The UE transmit power $P_{\mathrm{NPUSCH},c}(i)$ for NPUSCH transmission in NB-IoT UL slot i for the serving cell c is given by:

For NPUSCH (re)transmissions corresponding to the random access response grant if enhanced random access power control is not applied, and for all other NPUSCH transmissions, when the number of repetitions of the allocated NPUSCH RUs is greater than 2:

$$P_{\mathrm{NPUSCH,c}}(i) = P_{\mathrm{CMAX},c}(i) \text{ [dBm]}$$

otherwise

$$P_{\mathrm{NPUSCH,c}}(i) = \min\begin{Bmatrix} P_{\mathrm{CMAX},c}(i), \\ 10\log_{10}(M_{\mathrm{NPUSCH,c}}(i)) + P_{\mathrm{O\_NPUSCH,c}}(j) + \alpha_c(j)\cdot PL_c \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in NB-IoT UL slot i for serving cell c.
- $M_{\mathrm{NPUSCH},c}(i)$ is {1/4} for 3.75 kHz subcarrier spacing and {1, 3, 6, 12}for 15kHz subcarrier spacing
- $P_{\mathrm{O\_NPUSCH},c}(j)$ is a parameter composed of the sum of a component $P_{\mathrm{O\_NOMINAL\_NPUSCH,c}}(j)$ provided from higher layers and a component $P_{\mathrm{O\_UE\_NPUSCH,c}}(j)$ provided by higher layers for $j=1$ and for serving cell c where $j \in \{1,2\}$. For NPUSCH (re)transmissions corresponding to a dynamic scheduled grant then $j=1$ and for NPUSCH (re)transmissions corresponding to the random access response grant then $j=2$. $P_{\mathrm{O\_UE\_NPUSCH,c}}(2) = 0$. If enhanced random access power control is not applied, $P_{\mathrm{O\_NORMINAL\_NPUSCH},c}(2) = P_{\mathrm{O\_PRE}} + \Delta_{\mathrm{PREAMBLE\_Msg3}}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\mathrm{O\_PRE}}$) and $\Delta_{\mathrm{PREAMBLE\_Msg3}}$ are signalled from higher layers for serving cell c. If enhanced random access power control is applied,
$$P_{\mathrm{O\_NORMINAL\_NPUSCH,c}}(2) = \mathrm{MSG3\_RECEIVED\_TARGET\_POWER} + \Delta_{\mathrm{PREAMBLE\_Msg3}}$$
- For $j=1$, for NPUSCH format 2, $\alpha_c(j)$ =1; for NPUSCH format 1, $\alpha_c(j)$ is provided by higher layers for serving cell c. For j=2, $\alpha_c(j) = 1$.

- PL_c is the downlink path loss estimate calculated in the UE for serving cell c in dB and PL_c = *nrs-Power* + *nrs-PowerOffsetNonAnchor* – NRSRP, where *nrs-Power* is provided by higher layers and Subclause 16.2.2, and *nrs-powerOffsetNonAnchor* is set to zero if it is not provided by higher layers and NRSRP is defined in [5] for serving cell c.

16.2.1.1.2 Power headroom

If the UE transmits NPUSCH in NB-IoT UL slot i for serving cell c, power headroom is computed using

$$PH_{\mathrm{c}}(i) = P_{\mathrm{CMAX},c}(i) - \left\{ P_{\mathrm{O\_NPUSCH,c}}(1) + \alpha_c(1) \cdot PL_c \right\} \quad \text{[dB]}$$

where, $P_{\mathrm{CMAX},c}(i)$, $P_{\mathrm{O\_NPUSCH,c}}(1)$, $\alpha_c(1)$, and PL_c, are defined in Subclause 16.2.1.1.1.

The power headroom shall be rounded down to the closest value in the set [PH1, PH2, PH3, PH4] dB as defined in [10] and is delivered by the physical layer to higher layers.

16.2.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

For an NB-IoT cell, the UE may assume NRS EPRE is constant across the downlink NB-IoT system bandwidth and constant across all subframes that contain NRS, until different NRS power information is received.

The downlink NRS EPRE can be derived from the downlink narrowband reference-signal transmit power given by *nrs-Power* + *nrs-PowerOffsetNonAnchor*, where the parameter *nrs-Power* is provided by higher layers and *nrs-powerOffsetNonAnchor* is zero if it is not provided by higher layers. The downlink narrowband reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry narrowband reference signals within the operating NB-IoT system bandwidth.

A UE may assume the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs (not applicable to NPDSCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

A UE may assume the ratio of NPBCH EPRE to NRS EPRE among NPBCH REs (not applicable to NPBCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

A UE may assume the ratio of NPDCCH EPRE to NRS EPRE among NPDCCH REs (not applicable to NPDCCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

If higher layer parameter *operationModeInfo* indicates '00' or *samePCI-Indicator* indicates '*samePCI*' for a cell, the ratio of NRS EPRE to CRS EPRE is given by the parameter *nrs-CRS-PowerOffset* if the parameter *nrs-CRS-PowerOffset* is provided by higher layers, and the ratio of NRS EPRE to CRS EPRE may be assumed to be 0 dB if the parameter *nrs-CRS-PowerOffset* is not provided by higher layers. If *nrs-CRS-PowerOffset* is provided by higher layers and is a non-integer value, the value of *nrs-Power* is 0.23 dBm higher than indicated.

16.3 Random access procedure

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

- Narrowband Random access channel parameters (NPRACH configuration)

16.3.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of narrowband random access preamble and narrowband random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies one subcarrier per set of consecutive symbols reserved for narrowband random access preamble transmissions.

The following steps are required for the L1 random access procedure:

- Layer 1 procedure is triggered upon request of a narrowband preamble transmission by higher layers.
- A target narrowband preamble received power (NARROWBAND_PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a NPRACH resource are indicated by higher layers as part of the request.
- If enhanced random access power control is not applied, for the lowest configured repetition level; and if enhanced random access power control is applied then for all configured repetition levels, a narrowband preamble transmission power P_{NPRACH} is determined as P_{NPRACH} = min{ $P_{\mathrm{CMAX,c}}(i)$, NARROWBAND_PREAMBLE_RECEIVED_TARGET_POWER + PL_c }_[dBm], where $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power for narrowband IoT transmission defined in [6] for subframe *i* of serving cell c and PL_c is the downlink path loss estimate calculated in the UE for serving cell c . If enhanced random access power control is not applied, for a repetition level other than the lowest configured repetition level, P_{NPRACH} is set to $P_{\mathrm{CMAX,c}}(i)$.
- The narrowband preamble is transmitted with transmission power P_{NPRACH} commencing on the indicated NPRACH resource. The narrowband preamble is transmitted for the number of NPRACH repetitions for the associated NPRACH repetition level as indicated by higher layers.
- Detection of a NPDCCH with DCI scrambled by RA-RNTI is attempted during a window controlled by higher layers (see [8], Subclause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the Nr-bit uplink grant to the physical layer, which is processed according to Subclause 16.3.3

16.3.2 Timing

For the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission is as follows.

a) If a NPDCCH with associated RA-RNTI is detected and the corresponding DL-SCH transport block ending in subframe *n* contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block according to Subclause 16.3.3.

b) If a random access response is received and the corresponding DL-SCH transport block ending in subframe *n* does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than the NB-IoT UL slot starting 12 milliseconds after the end of subframe *n*.

c) If no NPDCCH scheduling random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than the NB-IoT UL slot starting 12 milliseconds after the end of subframe *n*.

d) If an NPDCCH scheduling random access response with associated RA-RNTI is detected and the corresponding DL-SCH transport block reception ending in subframe *n* cannot be successfully decoded, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than the NB-IoT UL slot starting 12 milliseconds after the end of subframe *n*.

In case a random access procedure is initiated by a "PDCCH order" ending in subframe *n*, the UE shall, if requested by higher layers, start transmission of random access preamble at the end of the first subframe $n+k_2$, $k_2 \geq 8$, where a NPRACH resource is available. The "PDCCH order" in DCI format N1 indicates to the UE,

- allocated subcarrier for NPRACH, $n_{\mathrm{sc}} = I_{sc}$ where I_{sc} is the subcarrier indication field in the corresponding DCI, $I_{sc} = 48,49,...,63$ is reserved.
- a repetition number (N_{Rep}) for NPRACH determined by the repetition number field (I_{Rep}) in the corresponding DCI according to Table 16.3.2-1 where R_1, R_2 (if any) and R_3 (if any) are given by the higher layer parameter *numRepetitionsPerPreambleAttempt* for each NPRACH resource, respectively. $R_1 < R_2 < R_3$.

Table 16.3.2-1: Number of repetitions (N_{Rep}) for NPRACH following a "PDCCH order"

I_{Rep}	N_{Rep}
0	R_1
1	R_2
2	R_3
3	Reserved

The UE shall transmit random access preamble on the NB-IoT carrier indicated by "Carrier indication of NPRACH" field, if the field is present in the "PDCCH order". If the value of "Carrier indication of NPRACH" is non-zero, it indicates a NPRACH carrier derived from *SystemInformationBlockType22-NB* [11] for which the index in the list is equal to the carrier indication. If the value of "Carrier indication of NPRACH" is zero, the uplink carrier used for NPRACH is derived from *SystemInformationBlockType2-NB* [11].

16.3.3 Narrowband random access response grant

The higher layers indicate the Nr-bit UL Grant to the physical layer, as defined in 3GPP TS 36.321 [8].
This is referred to as the Narrowband Random Access Response Grant in the physical layer.

Nr-bit =15, and the content of these 15 bits starting with the MSB and ending with the LSB are as follows:

- Uplink subcarrier spacing Δf is '0'=3.75 kHz or '1'=15 kHz – 1 bit
- Subcarrier indication field I_{sc} as determined in Subclause 16.5.1.1 – 6 bits
- Scheduling delay field (I_{Delay}) as determined in Subclause 16.5.1 with $k_0 = 12$ for $I_{\text{Delay}} = 0$, where NB-IoT DL subframe *n* is the last subframe in which the NPDSCH associated with the Narrowband Random Access Response Grant is transmitted – 2 bits
- Msg3 repetition number N_{Rep} as determine in Subclause 16.5.1.1 – 3 bits
- MCS index indicating TBS, modulation, and number of RUs for Msg3 according to Table 16.3.3-1 – 3 bits

The redundancy version for the first transmission of Msg3 is 0.

Table 16.3.3-1: MCS index for Msg3 NPUSCH

MCS Index I_{MCS}	Modulation $\Delta f = 3.75\,\text{kHz}$ or $\Delta f = 15\,\text{kHz}$ and $I_{sc} = 0,1,...,11$	Modulation $\Delta f = 15\,\text{kHz}$ and $I_{sc} > 11$	Number of RUs N_{RU}	TBS
'000'	pi/2 BPSK	QPSK	4	88 bits
'001'	pi/4 QPSK	QPSK	3	88 bits
'010'	pi/4 QPSK	QPSK	1	88 bits
'011'	reserved	reserved	reserved	reserved
'100'	reserved	reserved	reserved	reserved
'101'	reserved	reserved	reserved	reserved
'110'	reserved	reserved	reserved	reserved
'111'	reserved	reserved	reserved	reserved

16.4 Narrowband physical downlink shared channel related procedures

A NB-IoT UE shall assume a subframe as a NB-IoT DL subframe if

- the UE determines that the subframe does not contain NPSS/NSSS/NPBCH/ *SystemInformationBlockType1-NB* transmission, and

- for a NB-IoT carrier that a UE receives higher layer parameter *operationModeInfo*, the subframe is configured as NB-IoT DL subframe after the UE has obtained *SystemInformationBlockType1-NB*.
- for a NB-IoT carrier that *DL-CarrierConfigCommon-NB* is present, the subframe is configured as NB-IoT DL subframe by the higher layer parameter *downlinkBitmapNonAnchor*.

For a NB-IoT UE that supports *twoHARQ-Processes-r14*, there shall be a maximum of 2 downlink HARQ processes.

16.4.1 UE procedure for receiving the narrowband physical downlink shared channel

A UE shall upon detection on a given serving cell of a NPDCCH with DCI format N1, N2 ending in subframe n intended for the UE, decode, starting in $n+5$ DL subframe, the corresponding NPDSCH transmission in N consecutive NB-IoT DL subframe(s) n_i with $i = 0, 1, \ldots, N-1$ according to the NPDCCH information, where

- subframe n is the last subframe in which the NPDCCH is transmitted and is determined from the starting subframe of NPDCCH transmission and the DCI subframe repetition number field in the corresponding DCI;
- subframe(s) n_i with $i=0,1,\ldots,N-1$ are N consecutive NB-IoT DL subframe(s) excluding subframes used for SI messages where, $n_0<n_1<\ldots,n_{N-1}$,,
- $N = N_{\mathrm{Rep}} N_{\mathrm{SF}}$, where the value of N_{Rep} is determined by the repetition number field in the corresponding DCI (see Subclause 16.4.1.3), and the value of N_{SF} is determined by the resource assignment field in the corresponding DCI (see Subclause 16.4.1.3), and
- k_0 is the number of NB-IoT DL subframe(s) starting in DL subframe n+5 until DL subframe n_0, where k_0 is determined by the scheduling delay field (I_{Delay}) for DCI format N1, and k_0 = 0 for DCI format N2. For DCI CRC scrambled by G-RNTI, k_0 is determined by the scheduling delay field (I_{Delay}) according to Table 16.4.1-1a, otherwise k_0 is determined by the scheduling delay field (I_{Delay}) according to Table 16.4.1-1. The value of $R_{\max}$ is according to Subclause 16.6 for the corresponding DCI format N1.

Table 16.4.1-1: k_0 for DCI format N1.

I_{Delay}	k_0	
	$R_{\max} < 128$	$R_{\max} \geq 128$
0	0	0
1	4	16
2	8	32
3	12	64
4	16	128
5	32	256
6	64	512
7	128	1024

Table 16.4.1-1a: k_0 for DCI format N1 with DCI CRC scrambled by G-RNTI.

I_{Delay}	k_0
0	0
1	4
2	8
3	12
4	16
5	32
6	64
7	128

If a UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*

- the UE is not expected to receive transmissions in the Type B half duplex guard periods as specified in [3]

otherwise

- the UE is not expected to receive transmissions in 3 DL subframes following the end of a NPUSCH transmission by the UE.

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the P-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-2. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by P-RNTI.

Table 16.4.1-2: NPDCCH and NPDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N2	Type-1 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-3. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by RA-RNTI.

Table 16.4.1-3: NPDCCH and NPDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	Type-2 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI except during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-4. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by C-RNTI.

Table 16.4.1-4: NPDCCH and NPDSCH configured by C-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	UE specific by C-RNTI	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to the combination defined in Table 16.4.1-5. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by Temporary C-RNTI.

If a UE is also configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to the combination defined in Table 16.4.1-5. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by C-RNTI.

Table 16.4.1-5: NPDCCH and NPDSCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	Type-2 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

For NPDSCH carrying *SystemInformationBlockType1-NB* and SI-messages, the UE shall decode NPDSCH according to the transmission scheme defined in Table 16.4.1-6. The scrambling initialization of NPDSCH is by SI-RNTI.

Table 16.4.1-6: NPDSCH configured by SI-RNTI

Transmission scheme of NPDSCH
If the number of NPBCH antenna ports is one, Single-antenna port, port 0 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the SC-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-7. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by SC-RNTI.

Table 16.4.1-7: NPDCCH and NPDSCH configured by SC-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N2	Type-1A Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the G-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-8. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by G-RNTI.

Table 16.4.1-8: NPDCCH and NPDSCH configured by G-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	Type-2A Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see Subclause 16.4.1.1), otherwise Transmit diversity (see Subclause 16.4.1.2).

A UE is not required to receive NPDSCH assigned by NPDCCH with DCI CRC scrambled by G-RNTI in subframes in which the UE monitors a Type1A-NPDCCH common search space or in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by SC-RNTI

A UE is not required to receive NPDSCH assigned by NPDCCH with DCI CRC scrambled by SC-RNTI or G-RNTI in subframes in which the UE monitors a Type1-NPDCCH common search space or in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by P-RNTI

A UE is not required to receive NPDSCH assigned by NPDCCH with DCI CRC scrambled by SC-RNTI or G-RNTI in subframes in which the UE monitors a Type2-NPDCCH common search space or in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by C-RNTI or Temporary C-RNTI.

The transmission schemes for NPDSCH are defined in the following Subclauses.

16.4.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 2000) of the NPDSCH, the UE may assume that an eNB transmission on the NPDSCH would be performed according to Subclause 6.3.4.1 of [3].

16.4.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the NPDSCH, the UE may assume that an eNB transmission on the NPDSCH would be performed according to Subclause 6.3.4.3 of [3]

16.4.1.3 Resource allocation

The resource allocation information in DCI format N1, N2 (paging) for NPDSCH indicates to a scheduled UE

- a number of subframes (N_{SF}) determined by the resource assignment field (I_{SF}) in the corresponding DCI according to Table 16.4.1.3-1.
- a repetition number (N_{Rep}) determined by the repetition number field (I_{Rep}) in the corresponding DCI according to Table 16.4.1.3-2.

Table 16.4.1.3-1: Number of subframes (N_{SF}) for NPDSCH.

I_{SF}	N_{SF}
0	1
1	2
2	3
3	4
4	5
5	6
6	8
7	10

Table 16.4.1.3-2: Number of repetitions (N_{Rep}) for NPDSCH.

I_{Rep}	N_{Rep}
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
8	192
9	256
10	384
11	512
12	768
13	1024
14	1536
15	2048

The number of repetitions for the NPDSCH carrying *SystemInformationBlockType1-NB* is determined based on the parameter *schedulingInfoSIB1* configured by higher-layers and according to Table 16.4.1.3-3.

Table 16.4.1.3-3: Number of repetitions for NPDSCH carrying *SystemInformationBlockType1-NB*.

Value of *schedulingInfoSIB1*	Number of NPDSCH repetitions
0	4
1	8
2	16
3	4
4	8
5	16
6	4
7	8
8	16
9	4
10	8
11	16
12-15	Reserved

The starting radio frame for the first transmission of the NPDSCH carrying *SystemInformationBlockType1-NB* is determined according to Table 16.4.1.3-4.

Table 16.4.1.3-4: Starting radio frame for the first transmission of the NPDSCH carrying *SystemInformationBlockType1-NB*.

Number of NPDSCH repetitions	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$	Starting radio frame number for *SystemInformationBlockType1-NB* repetitions (*n_f mod 256*)
4	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 4 = 0	0
	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 4 = 1	16
	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 4 = 2	32
	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 4 = 3	48
8	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 2 = 0	0
	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 2 = 1	16
16	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 2 = 0	0
	$N_{\mathrm{ID}}^{\mathrm{Ncell}}$ mod 2 = 1	1

16.4.1.4 NPDSCH starting position

The starting OFDM symbol for NPDSCH is given by index $l_{\mathrm{DataStart}}$ in the first slot in a subframe k and is determined as follows

- if subframe k is a subframe used for receiving SIB1-NB
  - $l_{\mathrm{DataStart}} = 3$ if the value of the higher layer parameter *operationModeInfo* is set to '00' or '01'
  - $l_{\mathrm{DataStart}} = 0$ otherwise
- else
  - $l_{\mathrm{DataStart}}$ is given by the higher layer parameter *eutraControlRegionSize* if the value of the higher layer parameter *eutraControlRegionSize* is present
  - $l_{\mathrm{DataStart}} = 0$ otherwise

16.4.1.5 Modulation order and transport block size determination

The UE shall use modulation order, $Q_m = 2$.

To determine the transport block size in the NPDSCH, the UE shall first,

- if NPDSCH carriers SystemInformationBlockType1-NB
  - set I_{TBS} to the value of the parameter schedulingInfoSIB1 configured by higher-layers
- otherwise
  - read the 4-bit "modulation and coding scheme" field (I_{MCS}) in the DCI and set $I_{\text{TBS}} = I_{\text{MCS}}$.

and second,

- if NPDSCH carriers SystemInformationBlockType1-NB
  - use Subclause 16.4.1.5.2 for determining its transport block size.
- otherwise,
  - read the 3-bit "resource assignment" field (I_{SF}) in the DCI and determine its TBS by the procedure in Subclause 16.4.1.5.1.

For a NPDCCH UE-specific search space, if the UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*

- the NDI and HARQ process ID as signalled on NPDCCH, and the TBS, as determined above, shall be delivered to higher layers,

otherwise

- the NDI as signalled on NPDCCH, and the TBS, as determined above, shall be delivered to higher layers. HARQ process ID of 0 shall be assumed.

16.4.1.5.1 Transport blocks not mapped for *SystemInformationBlockType1-NB*

The TBS is given by the (I_{TBS} , I_{SF}) entry of Table 16.4.1.5.1-1. For the value of the higher layer parameter *operationModeInfo* set to '00' or '01', $0 \le I_{\text{TBS}} \le 10$.

Table 16.4.1.5.1-1: Transport block size (TBS) table.

I_{TBS}	I_{SF}							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	872
6	88	176	256	392	504	600	808	1032
7	104	224	328	472	584	680	968	1224
8	120	256	392	536	680	808	1096	1352
9	136	296	456	616	776	936	1256	1544
10	144	328	504	680	872	1032	1384	1736
11	176	376	584	776	1000	1192	1608	2024
12	208	440	680	904	1128	1352	1800	2280
13	224	488	744	1032	1256	1544	2024	2536

16.4.1.5.2 Transport blocks mapped for *SystemInformationBlockType1-NB*

The TBS is given by the I_{TBS} entry of Table 16.4.1.5.2-1.

Table 16.4.1.5.2-1: Transport block size (TBS) table for NPDSCH carrying *SystemInformationBlockType1-NB*

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	208	208	208	328	328	328	440	440	440	680	680	680	Reserved			

16.4.2 UE procedure for reporting ACK/NACK

The UE shall upon detection of a NPDSCH transmission ending in NB-IoT subframe *n* intended for the UE and for which an ACK/NACK shall be provided, start, after the end of $n+k_0-1$ DL subframe transmission of the NPUSCH carrying ACK/NACK response using NPUSCH format 2 in *N* consecutive NB-IoT UL slots, where

- $N = N_{\mathrm{Rep}}^{AN} N_{\mathrm{slots}}^{UL}$, where the value of N_{Rep}^{AN} is given by the higher layer parameter *ack-NACK-NumRepetitions-Msg4* configured for the associated NPRACH resource for Msg4 NPDSCH transmission, and higher layer parameter *ack-NACK-NumRepetitions* otherwise, and the value of N_{slots}^{UL} is the number of slots of the resource unit (defined in clause 10.1.2.3 of [3]),
- allocated subcarrier for ACK/NACK and value of k_0 is determined by the ACK/NACK resource field in the DCI format of the corresponding NPDCCH according to Table 16.4.2-1, and Table 16.4.2-2.

Table 16.4.2-1: ACK/NACK subcarrier and k_0 for NPUSCH with subcarrier spacing $\Delta f = 3.75\ \mathrm{kHz}$.

ACK/NACK resource field	ACK/NACK subcarrier	k_0
0	38	13
1	39	13
2	40	13
3	41	13
4	42	13
5	43	13
6	44	13
7	45	13
8	38	21
9	39	21
10	40	21
11	41	21
12	42	21
13	43	21
14	44	21
15	45	21

Table 16.4.2-2: ACK/NACK subcarrier and k_0 for NPUSCH with subcarrier spacing $\Delta f = 15\,\text{kHz}$.

ACK/NACK resource field	ACK/NACK subcarrier	k_0
0	0	13
1	1	13
2	2	13
3	3	13
4	0	15
5	1	15
6	2	15
7	3	15
8	0	17
9	1	17
10	2	17
11	3	17
12	0	18
13	1	18
14	2	18
15	3	18

16.5 Narrowband physical uplink shared channel related procedures

For a NB-IoT UE that supports *twoHARQ-Processes-r14*, there shall be a maximum of 2 uplink HARQ processes.

16.5.1 UE procedure for transmitting format 1 narrowband physical uplink shared channel

A UE shall upon detection on a given serving cell of a NPDCCH with DCI format N0 ending in NB-IoT DL subframe n intended for the UE, perform, at the end of $n+k_0$ DL subframe, a corresponding NPUSCH transmission using NPUSCH format 1 in N consecutive NB-IoT UL slots n_i with $i = 0, 1, \ldots, N-1$ according to the NPDCCH information where

- subframe n is the last subframe in which the NPDCCH is transmitted and is determined from the starting subframe of NPDCCH transmission and the DCI subframe repetition number field in the corresponding DCI; and
- $N = N_{\text{Rep}} N_{\text{RU}} N_{\text{slots}}^{UL}$, where the value of N_{Rep} is determined by the repetition number field in the corresponding DCI (see Subclause 16.5.1.1), the value of N_{RU} is determined by the resource assignment field in the corresponding DCI (see Subclause 16.5.1.1), and the value of N_{slots}^{UL} is the number of NB-IoT UL slots of the resource unit (defined in clause 10.1.2.3 of [3]) corresponding to the allocated number of subcarriers (as determined in Subclause 16.5.1.1) in the corresponding DCI,
- n_0 is the first NB-IoT UL slot starting after the end of subframe $n+k_0$
- value of k_0 is determined by the scheduling delay field (I_{Delay}) in the corresponding DCI according to Table 16.5.1-1.

Table 16.5.1-1: k_0 for DCI format N0.

I_{Delay}	k_0
0	8
1	16
2	32
3	64

If a UE is configured by higher layers to decode NPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-2 and transmit a corresponding NPUSCH. The scrambling initialization of this NPUSCH corresponding to these NPDCCHs and the NPUSCH retransmission for the same transport block is by C-RNTI.

Table 16.5.1-2: NPDCCH and NPUSCH configured by C-RNTI

DCI format	Search Space
DCI format N0	UE specific by C-RNTI

If a UE is configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-3.

Table 16.5.1-3: NPDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format N1	UE specific by C-RNTI

If a UE is configured by higher layers to decode NPDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode NPDCCH with the CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-4 and transmit the corresponding NPUSCH. The scrambling initialization of NPUSCH corresponding to these NPDCCHs is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling initialization of NPUSCH corresponding to the Narrowband Random Access Response Grant in Subclause 16.3.3 and any NPUSCH retransmission(s) for the same transport block is by Temporary C-RNTI. Otherwise, the scrambling initialization of NPUSCH corresponding to the Narrowband Random Access Response Grant in Subclause 16.3.3 and any NPUSCH retransmission(s) for the same transport block is by C-RNTI.

If a UE is also configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-4 and transmit the corresponding NPUSCH. The scrambling initialization of NPUSCH corresponding to these NPDCCH is by C-RNTI.

Table 16.5.1-4: NPDCCH and NPUSCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space
DCI format N0	Type-2 Common

16.5.1.1 Resource allocation

The resource allocation information in uplink DCI format N0 for NPUSCH transmission indicates to a scheduled UE

- a set of contiguously allocated subcarriers (n_{sc}) of a resource unit determined by the Subcarrier indication field in the corresponding DCI,
- a number of resource units (N_{RU}) determined by the resource assignment field in the corresponding DCI according to Table 16.5.1.1-2,
- a repetition number (N_{Rep}) determined by the repetition number field in the corresponding DCI according to Table 16.5.1.1-3.

The subcarrier spacing Δf of NPUSCH transmission is determined by the uplink subcarrier spacing field in the Narrowband Random Access Response Grant according to Subclause 16.3.3.

For NPUSCH transmission with subcarrier spacing $\Delta f = 3.75\,\text{kHz}$, $n_{\text{sc}} = I_{sc}$ where I_{sc} is the subcarrier indication field in the DCI. $I_{sc} = 48,49,...,63$ is reserved.

For NPUSCH transmission with subcarrier spacing $\Delta f = 15\,\text{kHz}$, the subcarrier indication field (I_{sc}) in the DCI determines the set of contiguously allocated subcarriers (n_{sc}) according to Table 16.5.1.1-1.

Table 16.5.1.1-1: Allocated subcarriers for NPUSCH with $\Delta f = 15\,\text{kHz}$.

Subcarrier indication field (I_{sc})	Set of Allocated subcarriers (n_{sc})
0 – 11	I_{sc}
12-15	$3(I_{sc} - 12) + \{0,1,2\}$
16-17	$6(I_{sc} - 16) + \{0,1,2,3,4,5\}$
18	$\{0,1,2,3,4,5,6,7,8,9,10,11\}$
19-63	Reserved

Table 16.5.1.1-2: Number of resource units (N_{RU}) for NPUSCH.

I_{RU}	N_{RU}
0	1
1	2
2	3
3	4
4	5
5	6
6	8
7	10

Table 16.5.1.1-3: Number of repetitions (N_{Rep}) for NPUSCH.

I_{Rep}	N_{Rep}
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128

16.5.1.2 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the NPUSCH, the UE shall first

- read the "modulation and coding scheme" field (I_{MCS}) in the DCI, and
- read the "redundancy version" field (rv_{DCI}) in the DCI, and
- read the "resource assignment" field (I_{RU}) in the DCI, and
- compute the total number of allocated subcarriers ($N_{\text{sc}}^{\text{RU}}$), number of resource units (N_{RU}), and repetition number (N_{Rep}) according to Subclause 16.5.1.1.

The UE shall use modulation order, Q_m = 2 if $N_{\mathrm{sc}}^{\mathrm{RU}} > 1$. The UE shall use I_{MCS} and Table 16.5.1.2-1 to determine the modulation order to use for NPUSCH if $N_{\mathrm{sc}}^{\mathrm{RU}} = 1$.

Table 16.5.1.2-1: Modulation and TBS index table for NPUSCH with $N_{\mathrm{sc}}^{\mathrm{RU}} = 1$.

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	1	0
1	1	2
2	2	1
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	2	10

NPUSCH is transmitted in N consecutive NB-IoT UL slots, n_i , $i=0,1,\ldots,N-1$. The redundancy version $rv_{\mathrm{idx}}(j)$ of the NPUSCH transmission in j^{th} block of B consecutive NB-IoT UL slots n_i ,

$i = jB + b,\ b = 0,1,\ldots,B-1,\ j = 0,1,\ldots,\frac{N_{\mathrm{Rep}}}{L}-1,\quad B = LN_{\mathrm{RU}}N_{\mathrm{slots}}^{UL}$ is determined by, $rv_{\mathrm{idx}}(j) = 2\cdot\mathrm{mod}\left(rv_{\mathrm{DCI}} + j,\, 2\right)$, where $L=1$ if $N_{\mathrm{sc}}^{\mathrm{RU}} = 1$, $L = \min\left(4, \left\lceil N_{\mathrm{Rep}}/2 \right\rceil\right)$ otherwise. Portion of NPUSCH codeword with $rv_{\mathrm{idx}}(j)$ as defined in clause 6.3.2 in [4] mapped to slot $\left\lfloor \frac{b}{L} \right\rfloor$ of allocated N_{RU} resource unit(s) is transmitted in NB-IoT UL slots n_i $i = jB + L\left\lfloor \frac{b}{L} \right\rfloor + l,\ l = 0,1,\ldots,L-1$ for $\Delta f = 3.75kHz$ and $i = jB + 2L\left\lfloor \frac{b}{2L} \right\rfloor + 2l + \mathrm{mod}(\left\lfloor \frac{b}{L} \right\rfloor,\ \ 2), l = 0,1,\ldots L-1$ for $\Delta f = 15kHz$

The UE shall use (I_{TBS} , I_{RU}) and Table 16.5.1.2-2 to determine the TBS to use for the NPUSCH. I_{TBS} is given in Table 16.5.1.2-1 if $N_{\mathrm{sc}}^{\mathrm{RU}} = 1$, $I_{\mathrm{TBS}} = I_{\mathrm{MCS}}$ otherwise.

Table 16.5.1.2-2: Transport block size (TBS) table for NPUSCH.

I_{TBS}	I_{RU}							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	872
6	88	176	256	392	504	600	808	1000
7	104	224	328	472	584	712	1000	1224
8	120	256	392	536	680	808	1096	1384
9	136	296	456	616	776	936	1256	1544
10	144	328	504	680	872	1000	1384	1736
11	176	376	584	776	1000	1192	1608	2024
12	208	440	680	1000	1128	1352	1800	2280
13	224	488	744	1032	1256	1544	2024	2536

For a NPDCCH UE-specific search space, if the UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*

- the NDI and HARQ process ID as signalled on NPDCCH, and the RV and TBS, as determined above, shall be delivered to higher layers,

otherwise

- the NDI as signalled on NPDCCH, and the RV and TBS, as determined above, shall be delivered to higher layers.

16.5.2 UE procedure for NPUSCH retransmission

For a NPUSCH retransmission, the UE shall follow the HARQ information in DCI as specified in [8].

16.6 Narrowband physical downlink control channel related procedures

A UE shall monitor a set of NPDCCH candidates (described in Subclause 10.2.5.1 of [3]) as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the NPDCCHs in the set according to all the monitored DCI formats.

The set of NPDCCH candidates to monitor are defined in terms of NPDCCH search spaces.

The UE shall monitor one or more of the following search spaces

- a Type1-NPDCCH common search space,
- a Type1A-NPDCCH common search space,
- a Type2-NPDCCH common search space,
- a Type2A-NPDCCH common search space, and
- a NPDCCH UE-specific search space.

A UE is not required to simultaneously monitor a NPDCCH UE-specific search space and a Type-1-NPDCCH common search space.

A UE is not required to simultaneously monitor a NPDCCH UE-specific search space and a Type2-NPDCCH common search space.

A UE is not required to simultaneously monitor a Type-1-NPDCCH common search space and a Type2-NPDCCH common search space.

A UE is not required to monitor Type1A-NPDCCH common search space or Type2A-NPDCCH common search space in subframes in which the UE monitors a Type1-NPDCCH common search space or in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by P-RNTI

A UE is not required to monitor Type1A-NPDCCH common search space or Type2A-NPDCCH common search space in subframes in which the UE monitors a Type2-NPDCCH common search space or in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by C-RNTI or Temporary C-RNTI.

A UE is not required to monitor Type2A-NPDCCH common search space in the same subframe in which it monitors Type1A-NPDCCH common search space.

UE is not required to monitor Type1A-NPDCCH common search space in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by SC-RNTI.

UE is not required to monitor Type2A-NPDCCH common search space in subframes in which the UE receives NPDSCH assigned by NPDCCH with DCI CRC scrambled by G-RNTI or SC-RNTI.

Until UE receives higher layer configuration of NPDCCH UE-specific search space, the UE monitors NPDCCH according to the same configuration of NPDCCH search space as that for NPDCCH scheduling Msg4.

An NPDCCH search space $NS_k^{(L',R)}$ at aggregation level $L' \in \{1,2\}$ and repetition level $R \in \{1,2,4,8,16,32,64,128,256,512,1024,2048\}$ is defined by a set of NPDCCH candidates where each candidate is repeated in a set of R consecutive NB-IoT downlink subframes excluding subframes used for transmission of SI messages starting with subframe k.

For NPDCCH UE-specific search space, the aggregation and repetition levels defining the search spaces and the corresponding NPDCCH candidates are listed in Table 16.6-1 by substituting the value of $R_{\max}$ with the higher layer configured parameter *npdcch-NumRepetitions*.

For Type1-NPDCCH common search space and Type1A-NPDCCH common search space, the aggregation and repetition levels defining the search spaces are listed in Table 16.6-2 by substituting the value of $R_{\max}$

- with the higher layer configured parameter *npdcch-NumRepetitionPaging* for Type1-NPDCCH common search space;
- with the higher layer configured parameter *npdcch-NumRepetitions-SC-MCCH* for Type1A-NPDCCH common search space.

For Type2-NPDCCH common search space and Type2A-NPDCCH common search space, the aggregation and repetition levels defining the search spaces and the corresponding monitored NPDCCH candidates are listed in Table 16.6-3 by substituting the value of $R_{\max}$

- with the higher layer configured parameter *npdcch-NumRepetitions-RA* for Type2-NPDCCH common search space;
- with the higher layer configured parameter *npdcch-NumRepetitions-SC-MTCH* for Type2A-NPDCCH common search space.

The locations of starting subframe k are given by $k = k_b$ where k_b is the b^{th} consecutive NB-IoT DL subframe from subframe $k0$, excluding subframes used for transmission of SI messages, and $b = u \cdot R$, and $u = 0,1,\ldots \frac{R_{\max}}{R} - 1$, and where

- subframe $k0$ is a subframe satisfying the condition $\left(10n_{\mathrm{f}} + \lfloor n_{\mathrm{s}}/2 \rfloor\right) \bmod T = \lfloor \alpha_{offset} \cdot T \rfloor$, where $T = R_{\max} \cdot G$, $T \geq 4$.
  - for NPDCCH UE-specific search space,
    - G is given by the higher layer parameter *npdcch-StartSF-USS*,
    - α_{offset} is given by the higher layer parameter *npdcch-Offset-USS*,
  - for NPDCCH Type2-NPDCCH common search space,
    - G is given by the higher layer parameter *npdcch-StartSF-CSS-RA*,
    - α_{offset} is given by the higher layer parameter *npdcch-Offset-RA*,
  - for NPDCCH Type2A-NPDCCH common search space,
    - G is given by the higher layer parameter *npdcch-startSF-SC-MTCH*,
    - α_{offset} is given by the higher layer parameter *npdcch-Offset-SC-MTCH*,

For Type1-NPDCCH common search space, $k = k0$ and is determined from locations of NB-IoT paging opportunity subframes.

For Type1A-NPDCCH common search space, $k = k0$ and subframe $k0$ is a subframe satisfying the condition $\left(10n_{\mathrm{f}} + \lfloor n_{\mathrm{s}}/2 \rfloor\right) \bmod T = \lfloor \alpha_{offset} \cdot T \rfloor$, where $T = R_{\max} \cdot G$, $T \geq 4$ and

- G is given by the higher layer parameter *npdcch-StartSF-SC-MCCH*,
- α_{offset} is given by the higher layer parameter *npdcch-Offset-SC-MCCH*.

If the UE is configured by high layers with a NB-IoT carrier for monitoring of NPDCCH UE-specific search space,

- the UE shall monitor the NPDCCH UE-specific search space on the higher layer configured NB-IoT carrier,
- the UE is not expected to receive NPSS, NSSS, NPBCH on the higher layer configured NB-IoT carrier.

otherwise,

- the UE shall monitor the NPDCCH UE-specific search space on the same NB-IoT carrier on which NPSS/NSSS/NPBCH are detected.

Table 16.6-1: NPDCCH UE- specific search space candidates

$R_{\max}$	R	DCI subframe repetition number	NCCE indices of monitored NPDCCH candidates	
			L'=1	L'=2
1	1	00	{0},{1}	{0,1}
2	1	00	{0},{1}	{0,1}
	2	01	-	{0,1}
4	1	00	-	{0,1}
	2	01	-	{0,1}
	4	10	-	{0,1}
>=8	$R_{\max}/8$	00	-	{0,1}
	$R_{\max}/4$	01	-	{0,1}
	$R_{\max}/2$	10	-	{0,1}
	$R_{\max}$	11	-	{0,1}
Note 1: {x}, {y} denotes NPDCCH Format 0 candidate with NCCE index 'x', and NPDCCH Format 0 candidate with NCCE index 'y' are monitored Note 2: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.				

Table 16.6-2: Type 1/Type 1A - NPDCCH common search space candidates

$R_{\max}$	R								NCCE indices of monitored NPDCCH candidates	
									L'=1	L'=2
1	1	-	-	-	-	-	-	-	-	{0,1}
2	1	2	-	-	-	-	-	-	-	{0,1}
4	1	2	4	-	-	-	-	-	-	{0,1}
8	1	2	4	8	-	-	-	-	-	{0,1}

16	1	2	4	8	16	-	-	-	--	{0,1}
32	1	2	4	8	16	32	-	-	-	{0,1}
64	1	2	4	8	16	32	64	-	-	{0,1}
128	1	2	4	8	16	32	64	128	-	{0,1}
256	1	4	8	16	32	64	128	256	-	{0,1}
512	1	4	16	32	64	128	256	512	-	{0,1}
1024	1	8	32	64	128	256	512	1024	-	{0,1}
2048	1	8	64	128	256	512	1024	2048	-	{0,1}
DCI subframe repetition number	000	001	010	011	100	101	110	111		
Note 1: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.										

Table 16.6-3: Type 2/Type 2A - NPDCCH common search space candidates

R_{max}	R	DCI subframe repetition number	NCCE indices of monitored NPDCCH candidates	
			L'=1	L'=2
1	1	00	-	{0,1}
2	1	00	-	{0,1}
	2	01	-	{0,1}
4	1	00	-	{0,1}
	2	01	-	{0,1}
	4	10	-	{0,1}
>=8	$R_{max}/8$	00	-	{0,1}
	$R_{max}/4$	01	-	{0,1}
	$R_{max}/2$	10	-	{0,1}
	R_{max}	11	-	{0,1}
Note 1: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.				

For a NPDCCH UE-specific search space, if a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig* and if the NB-IoT UE detects NPDCCH with DCI Format N0 ending in subframe *n*, and if the corresponding NPUSCH format 1 transmission starts from *n+k,*

- the UE is not required to monitor an NPDCCH candidate in any subframe starting from subframe *n+k-2* to subframe *n+k-1*; and

- the UE does not expect to receive a DCI Format N0 before subframe *n*+*k*-2 for which the corresponding NPUSCH format 1 transmission ends later than subframe *n*+*k*+255;

otherwise

- if the NB-IoT UE detects NPDCCH with DCI Format N0 ending in subframe *n* or receives a NPDSCH carrying a random access response grant ending in subframe *n*, and if the corresponding NPUSCH format 1 transmission starts from $n+k$, the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+1$ to subframe $n+k-1$.

For a NPDCCH UE-specific search space, if a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*,

- and if the NB-IoT UE detects NPDCCH with DCI Format N1 or N2 ending in subframe n, and if a NPDSCH transmission starts from $n+k$, the UE is not required to monitor an NPDCCH candidate in any subframe starting from subframe $n+k-2$ to subframe $n+k-1$;

otherwise

- if the NB-IoT UE detects NPDCCH with DCI Format N1 or N2 ending in subframe n, and if the corresponding NPDSCH transmission starts from $n+k$, the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+1$ to subframe $n+k-1$.

If a NB-IoT UE detects NPDCCH with DCI Format N1 ending in subframe n, and if the corresponding NPDSCH transmission starts from $n+k$, and if the corresponding NPUSCH format 2 transmission starts from subframe $n+m$ the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+ k$ to subframe $n+m-1$.

If a NB-IoT UE detects NPDCCH with DCI Format N1 for "PDCCH order" ending in subframe n, and if the corresponding NPRACH transmission starts from subframe $n+k$, the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+1$ to subframe $n+k-1$.

If a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*

- and if the UE has a NPUSCH transmission ending in subframe n,
  - the UE is not required to receive transmissions in the Type B half-duplex guard periods as specified in [3]*; and*
  - the UE is not expected to receive an NPDCCH with DCI format N0/N1 for the same HARQ process ID as the NPUSCH transmission in any subframe starting from subframe n+1 to subframe n+3*;*

otherwise

- if the NB-IoT UE has a NPUSCH transmission ending in subframe n , the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+1$ to subframe $n+3$.

If a NB-IoT UE receives a NPDSCH transmission ending in subframe n, and if the UE is not required to transmit a corresponding NPUSCH format 2, the UE is not required to monitor NPDCCH in any subframe starting from subframe $n+1$ to subframe $n+12$.

If a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*

- the UE is not required to monitor an NPDCCH candidate of an NPDCCH search space if the candidate ends in subframe n, and if the UE is configured to monitor NPDCCH candidates of another NPDCCH search space having starting subframe k0 before subframe n+5

otherwise

- the UE is not required to monitor NPDCCH candidates of an NPDCCH search space if an NPDCCH candidate of the NPDCCH search space ends in subframe n, and if the UE is configured to monitor NPDCCH candidates of another NPDCCH search space having starting subframe k0 before subframe $n+5$.

An NB-IoT UE is not required to monitor NPDCCH candidates of an NPDCCH search space during an NPUSCH UL gap.

16.6.1 NPDCCH starting position

The starting OFDM symbol for NPDCCH given by index $l_{\mathrm{NPDCCHStart}}$ in the first slot in a subframe k and is determined as follows

- if higher layer parameter *eutraControlRegionSize* is present

  - $l_{\text{NPDCCHStart}}$ is given by the higher layer parameter *eutraControlRegionSize*

- otherwise

  - $l_{\text{NPDCCHStart}} = 0$

16.6.2 NPDCCH control information procedure

A UE shall discard the NPDCCH if consistent control information is not detected.

16.7 Assumptions independent of physical channel related to narrowband IoT

A UE may assume the antenna ports 2000 – 2001 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

16.8 UE procedure for acquiring cell-specific reference signal sequence and raster offset

If the higher layer parameter *operationModeInfo* indicates *inband-SamePCI* for a cell, the UE may derive cell-specific reference signal sequence and raster offset from the higher layer parameter *eutra-CRS-SequenceInfo* according to Table 16.8-1, where E-UTRA PRB index n'_{PRB} is defined as $n'_{\text{PRB}} = n_{\text{PRB}} - \lfloor N_{\text{RB}}^{\text{DL}} / 2 \rfloor$.

Table 16.8-1: Definition of *eutra-CRS-SequenceInfo*

eutra-CRS-SequenceInfo	E-UTRA PRB index n'_{PRB} for odd number of $N_{\text{RB}}^{\text{DL}}$	Raster offset	*eutra-CRS-SequenceInfo*	E-UTRA PRB index n'_{PRB} for even number of $N_{\text{RB}}^{\text{DL}}$	Raster offset
0	-35	-7.5 kHz	14	-46	+2.5 kHz
1	-30		15	-41	
2	-25		16	-36	
3	-20		17	-31	
4	-15		18	-26	
5	-10		19	-21	
6	-5		20	-16	
7	5	+7.5 kHz	21	-11	
8	10		22	-6	
9	15		23	5	-2.5 kHz
10	20		24	10	
11	25		25	15	
12	30		26	20	
13	35		27	25	
			28	30	
			29	35	
			30	40	
			31	45	