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Contents

Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of E-UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description"

[3] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation"

[4] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding"

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements"

[6] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception"

[7] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception"

[8] 3GPP TS36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"

[9] 3GPP TS36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)"

[10] 3GPP TS36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management"

[11] 3GPP TS36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification"

3 Definitions, symbols, and abbreviations

3.1 Symbols

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

n_f	System frame number as defined in [3]
n_s	Slot number within a radio frame as defined in [3]
$N_{\mathrm{RB}}^{\mathrm{DL}}$	Downlink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{RB}}^{\mathrm{UL}}$	Uplink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{symb}}^{\mathrm{UL}}$	Number of SC-FDMA symbols in an uplink slot as defined in [3]
$N_{\mathrm{sc}}^{\mathrm{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers as defined in [3]
T_s	Basic time unit as defined in [3]

3.2 Abbreviations

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

ACK	Acknowledgement
BCH	Broadcast Channel
CCE	Control Channel Element
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CSI	Channel State Information
DAI	Downlink Assignment Index
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
DTX	Discontinuous Transmission
EPRE	Energy Per Resource Element
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
PBCH	Physical Broadcast Channel
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PHICH	Physical Hybrid ARQ Indicator Channel
PMCH	Physical Multicast Channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Symbol
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
QoS	Quality of Service
RBG	Resource Block Group
RE	Resource Element
RI	Rank Indication
RPF	Repetition Factor
RS	Reference Signal
SIR	Signal-to-Interference Ratio
SINR	Signal to Interference plus Noise Ratio

SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
TA	Time alignment
TTI	Transmission Time Interval
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronisation procedures

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

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

4.2 Timing synchronisation

4.2.1 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

In non-DRX mode operation, the physical layer in the UE shall every radio frame assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

In DRX mode operation, the physical layer in the UE shall at least once every DRX period assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

If higher-layer signalling indicates certain subframes for restricted radio link monitoring, the radio link quality shall not be monitored in any subframe other than those indicated.

The physical layer in the UE shall in radio frames where the radio link quality is assessed indicate out-of-sync to higher layers when the radio link quality is worse than the threshold Q_{out}. When the radio link quality is better than the threshold Q_{in}, the physical layer in the UE shall in radio frames where the radio link quality is assessed indicate in-sync to higher layers.

4.2.2 Inter-cell synchronisation

No functionality is specified in this section in this release.

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command, the UE shall adjust its uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell. 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]. The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell.

In case of random access response, 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, 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 received on subframe *n*, the corresponding adjustment of the timing shall apply from the beginning of subframe *n+6*. When the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE shall transmit complete subframe *n* and not transmit the overlapped part of subframe *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.

4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation or deactivation command [8] for a secondary cell in subframe *n*, the corresponding actions in [8] shall apply no later than subframe *n+8*.

5 Power control

Downlink power control determines the energy per resource element (EPRE). The term resource element energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme applied. Uplink power control determines the average power over a SC-FDMA symbol in which the physical channel is transmitted.

5.1 Uplink power control

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

For PUSCH, the transmit power $\hat{P}_{\mathrm{PUSCH},c}(i)$ defined in section 5.1.1, is first scaled by the ratio of the number of antennas ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

For PUCCH or SRS, the transmit power $\hat{P}_{\mathrm{PUCCH}}(i)$, defined in Section 5.1.2, or $\hat{P}_{\mathrm{SRS,c}}(i)$ is split equally across the configured antenna ports for PUCCH or SRS. $\hat{P}_{\mathrm{SRS,c}}(i)$ is the linear value of $P_{\mathrm{SRS,c}}(i)$ defined in Section 5.1.3.

A cell wide overload indicator (OI) and a High Interference Indicator (HII) to control UL interference are defined in [9].

5.1.1 Physical uplink shared channel

5.1.1.1 UE behaviour

The setting of the UE Transmit power for a physical uplink shared channel (PUSCH) transmission is defined as follows.

If the UE transmits PUSCH without a simultaneous PUCCH for the serving cell c, then the UE transmit power $P_{\mathrm{PUSCH},c}(i)$ for PUSCH transmission in subframe *i* for the serving cell c is given by

$$P_{\mathrm{PUSCH,c}}(i) = \min\left\{\begin{matrix} P_{\mathrm{CMAX},c}(i), \\ 10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i) \end{matrix}\right\} \quad \text{[dBm]}$$

If the UE transmits PUSCH simultaneous with PUCCH for the serving cell c, then the UE transmit power $P_{\mathrm{PUSCH},c}(i)$ for the PUSCH transmission in subframe *i* for the serving cell c is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} 10\log_{10}\left(\hat{P}_{\text{CMAX},c}(i) - \hat{P}_{\text{PUCCH}}(i)\right), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell c and $\hat{P}_{\text{CMAX,c}}(i)$ is the linear value of $P_{\text{CMAX,c}}(i)$.
- $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ defined in section 5.1.2.1
- $M_{\text{PUSCH,c}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe *i* and serving cell c.
- $P_{\text{O\_PUSCH,c}}(j)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_PUSCH,c}}(j)$ provided from higher layers for *j=0* and *1* and a component $P_{\text{O\_UE\_PUSCH,c}}(j)$ provided by higher layers for *j=0* and *1* for serving cell c. For PUSCH (re)transmissions corresponding to a semi-persistent grant then *j=0* , for PUSCH (re)transmissions corresponding to a dynamic scheduled grant then *j=1* and for PUSCH (re)transmissions corresponding to the random access response grant then *j=2*. $P_{\text{O\_UE\_PUSCH,c}}(2) = 0$ and $P_{\text{O\_NOMINAL\_PUSCH,c}}(2) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O\_PRE}}$) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers.
- For *j* =0 or *1*, $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit parameter provided by higher layers for serving cell c. For j=2, $\alpha_c(j) = 1$.
- PL_c is the downlink pathloss estimate calculated in the UE for serving cell c in dB and PL_c = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [5] for the reference serving cell and the higher layer filter configuration is defined in [11] for the reference serving cell. The serving cell chosen as the reference serving cell and used for determining *referenceSignalPower* and higher layer filtered RSRP is configured by the higher layer parameter *pathlossReferenceLinking*.
  - $\Delta_{TF,c}(i) = 10\log_{10}\left(\left(2^{BPRE\cdot K_s} - 1\right)\cdot \beta_{offset}^{PUSCH}\right)$ for $K_S = 1.25$ and 0 for $K_S = 0$ where K_S is given by the parameter *deltaMCS-Enabled* provided by higher layers for each serving cell c. $BPRE$ and β_{offset}^{PUSCH}, for each serving cell c, are computed as below. $K_S = 0$ for transmission mode 2.

    $BPRE = O_{\text{CQI}} / N_{\text{RE}}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1} K_r / N_{\text{RE}}$ for other cases.
    - where C is the number of code blocks, K_r is the size for code block r, O_{CQI} is the number of CQI/PMI bits including CRC bits and N_{RE} is the number of resource elements determined as $N_{\text{RE}} = M_{sc}^{PUSCH-initial} \cdot N_{\text{symb}}^{\text{PUSCH-initial}}$, where C, K_r, $M_{sc}^{PUSCH-initial}$ and $N_{\text{symb}}^{\text{PUSCH-initial}}$ are defined in [4].
  - $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$ for control data sent via PUSCH without UL-SCH data and 1 for other cases.
- $\delta_{\text{PUSCH,c}}$ is a correction value, also referred to as a TPC command and is included in PDCCH with DCI format 0/4 for serving cell c or jointly coded with other TPC commands in PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUSCH-RNTI. The current PUSCH power control adjustment state for serving cell c is given by $f_c(i)$ which is defined by:
  - $f_c(i) = f_c(i-1) + \delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{\text{PUSCH,c}}$ is included in a

PDCCH with DCI format 0 for serving cell c where the CRC is scrambled by the Temporary C-RNTI

- where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH with DCI format 0/4 or 3/3A on subframe $i - K_{PUSCH}$, and where $f_c(0)$ is the first value after reset of accumulation.
- The value of K_{PUSCH} is
  - For FDD, K_{PUSCH} = 4
  - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
  - For TDD UL/DL configuration 0
    - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, K_{PUSCH} = 7
    - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.
- The UE attempts to decode a PDCCH of DCI format 0/4 with the UE's C-RNTI or DCI format 0 for SPS C-RNTI and a PDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every subframe except when in DRX
- If DCI format 0/4 for serving cell c and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{\text{PUSCH,c}}$ provided in DCI format 0/4.
- $\delta_{\text{PUSCH,c}} = 0$ dB for a subframe where no TPC command is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD.
- The $\delta_{\text{PUSCH,c}}$ dB accumulated values signalled on PDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH with DCI format 0 is validated as a SPS activation or release PDCCH, then $\delta_{\text{PUSCH,c}}$ is 0dB.
- The δ_{PUSCH} dB accumulated values signalled on PDCCH with DCI format 3/3A are one of SET1 given in Table 5.1.1.1-2 or SET2 given in Table 5.1.1.1-3 as determined by the parameter *TPC-Index* provided by higher layers.
- If UE has reached $P_{\text{CMAX,c}}$ for serving cell c, positive TPC commands for serving cell c shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
  - For serving cell c, when $P_{\text{O\_UE\_PUSCH,c}}$ value is changed by higher layers
  - For the primary cell, when the UE receives random access response message

- $f_c(i) = \delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ if accumulation is not enabled for serving cell c based on the parameter *Accumulation-enabled* provided by higher layers
  - where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH with DCI format 0/4 for serving cell c on subframe $i - K_{PUSCH}$
  - The value of K_{PUSCH} is
    - For FDD, K_{PUSCH} = 4
    - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
    - For TDD UL/DL configuration 0

- If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, K_{PUSCH} = 7
- For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.

- The $\delta_{\text{PUSCH,c}}$ dB absolute values signalled on PDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH with DCI format 0 is validated as a SPS activation or release PDCCH, then $\delta_{\text{PUSCH,c}}$ is 0dB.
- $f_c(i) = f_c(i-1)$ for a subframe where no PDCCH with DCI format 0/4 is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD.

- For both types of $f_c(*)$ (accumulation or current absolute) the first value is set as follows:
  - If $P_{\text{O\_UE\_PUSCH,c}}$ value is changed by higher layers and serving cell c is the primary cell or, if $P_{\text{O\_UE\_PUSCH,c}}$ value is received by higher layers and serving cell c is a Secondary cell $f_c(0) = 0$
  - Else
    - If serving cell c is the primary cell
      - $f_c(0) = \Delta P_{rampup} + \delta_{msg2}$
        - where δ_{msg2} is the TPC command indicated in the random access response, see Section 6.2, and
        - ΔP_{rampup} is provided by higher layers and corresponds to the total power ramp-up from the first to the last preamble

Table 5.1.1.1-1 K_{PUSCH} for TDD configuration 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	7	4	-	-	6	7	4
1	-	-	6	4	-	-	-	6	4	-
2	-	-	4	-	-	-	-	4	-	-
3	-	-	4	4	4	-	-	-	-	-
4	-	-	4	4	-	-	-	-	-	-
5	-	-	4	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 5.1.1.1-2: Mapping of TPC Command Field in DCI format 0/3/4 to absolute and accumulated $\delta_{\text{PUSCH,c}}$ values.

TPC Command Field in DCI format 0/3/4	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]	Absolute $\delta_{\text{PUSCH,c}}$ [dB] only DCI format 0/4
0	-1	-4
1	0	-1
2	1	1
3	3	4

Table 5.1.1.1-3: Mapping of TPC Command Field in DCI format 3A to accumulated $\delta_{\text{PUSCH,c}}$ values.

TPC Command Field in DCI format 3A	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]
0	-1
1	1

If the total transmit power of the UE would exceed $\hat{P}_{\text{PowerClass}}$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell c in subframe i such that the condition

$$\sum_{c} w(i)\cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{PowerClass}} - \hat{P}_{\text{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{\text{PowerClass}}$ is the linear value of $P_{\text{PowerClass}}$ defined in [6] and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe i $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE has PUSCH transmission with UCI on serving cell j and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{\text{PowerClass}}$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe i such that the condition

$$\sum_{c\neq j} w(i)\cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{PowerClass}} - \hat{P}_{\text{PUSCH},j}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c\neq j} w(i)\cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{\text{PowerClass}}$. Note that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{\text{PowerClass}}$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{PowerClass}} - \hat{P}_{\text{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \leq \left(\hat{P}_{\mathrm{PowerClass}} - \hat{P}_{\mathrm{PUCCH}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$$

5.1.1.2 Power headroom

There are two types of UE power headroom reports defined. A UE power headroom PH is valid for subframe *i* for serving cell c.

Type 1:

If the UE transmits PUSCH without PUCCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\mathrm{type1,c}}(i) = P_{\mathrm{CMAX},c}(i) - \left\{10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i)\right\} \quad \text{[dB]}$$

where, $P_{\mathrm{CMAX},c}$, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$., PL_c, $\Delta_{TF,c}(i)$ and $f_c(i)$ are defined in section 5.1.1.1.

If the UE transmits PUSCH with PUCCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\mathrm{type1,c}}(i) = \tilde{P}_{\mathrm{CMAX},c}(i) - \left\{10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i)\right\} \quad \text{[dB]}$$

where, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$., PL_c, $\Delta_{TF,c}(i)$ and $f_c(i)$ are defined in section 5.1.1.1.
$\tilde{P}_{\mathrm{CMAX},c}(i)$ is a computed based on the requirements in [6] assuming a PUSCH only transmission in subframe i. For this case, UE includes $\tilde{P}_{\mathrm{CMAX},c}(i)$ in its Type 1 PHR report instead of $P_{\mathrm{CMAX},c}(i)$

If the UE does not transmit PUSCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\mathrm{type1,c}}(i) = \tilde{P}_{\mathrm{CMAX},c}(i) - \left\{P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j) \cdot PL_c + f_c(i)\right\} \quad \text{[dB]}$$

where, $\tilde{P}_{\mathrm{CMAX,c}}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB, ΔT_C =0dB, MPR , A-MPR, P-MPR, ΔT_C which are defined in [6]. $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$., PL_c, and $f_c(i)$ are defined in section 5.1.1.1. For this case, UE includes $\tilde{P}_{\mathrm{CMAX},c}(i)$ in its Type 1 PHR report instead of $P_{\mathrm{CMAX},c}(i)$.

Type 2:

If the UE transmits PUSCH simultaneous with PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\mathrm{type2}}(i) = P_{\mathrm{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\mathrm{0\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ}, n_{SR}\right) + \Delta_{\mathrm{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{array}\right) \quad \text{[dB]}$$

where, $P_{\text{CMAX,c}}$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$ $\Delta_{TF,c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are defined in section 5.1.2.1

If the UE transmits PUSCH without PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{aligned} &10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ &+ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10} \end{aligned} \right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$ $\Delta_{TF,c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1, $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in section 5.1.2.1.

If the UE transmits PUCCH without PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{aligned} &10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ &+ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ}, n_{SR}\right) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{aligned} \right) \text{ [dB]}$$

where, $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$, K_{PUSCH} and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1, $P_{\text{CMAX,c}}(i)$, $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are also defined in section 5.1.2.1.

If the UE does not transmit PUCCH or PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = \tilde{P}_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{aligned} &10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ &+ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10} \end{aligned} \right) \text{ [dB]}$$

where, $\tilde{P}_{CMAX,c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB, ΔT_C =0dB, MPR , A-MPR, P-MPR, ΔT_C which are defined in [6], $P_{\text{CMAX,c}}$, $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$, K_{PUSCH} and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1, $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in section 5.1.2.1. For this case, UE includes $\tilde{P}_{\text{CMAX},c}(i)$ in its Type 2 PHR report in place of $P_{\text{CMAX},c}(i)$.

The power headroom shall be rounded to the closest value in the range [40; -23] dB with steps of 1 dB and is delivered by the physical layer to higher layers.

5.1.2 Physical uplink control channel

5.1.2.1 UE behaviour

If serving cell c is the primary cell, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{ \begin{aligned} &P_{\text{CMAX,c}}(i), \\ &P_{\text{0\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ,} n_{SR}\right) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i) \end{aligned} \right\} \text{ [dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c.
- The parameter $\Delta_{\text{F\_PUCCH}}(F)$ is provided by higher layers. Each $\Delta_{\text{F\_PUCCH}}(F)$ value corresponds to a PUCCH format (F) relative to PUCCH format 1a, where each PUCCH format (F) is defined in Table 5.4-1 of [3].
- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, the value of $\Delta_{TxD}(F')$ is provided by higher layers where each PUCCH format *F'* is defined in Table 5.4-1 of [3].
- $h(n_{CQI}, n_{HARQ}, n_{SR})$ is a PUCCH format dependent value, where n_{CQI} corresponds to the number of information bits for the channel quality information defined in section 5.2.3.3 in [4]. n_{SR} = 1 if subframe *i* is configured for SR for the UE, otherwise n_{SR} =0. If the UE is configured with one serving cell n_{HARQ} is the number of HARQ bits sent in subframe *i*. In the case of HARQ-ACK bundling is not applied, if the UE is configured with more than one serving cell, and if the UE receives an SPS release PDCCH in one of the subframes $i-k_m$ where $k_m \in K$ and $0 \le m \le M-1$ then n_{HARQ} = (number of transport blocks received in subframes $i-k_m$)+1, if the UE does not receive an SPS release PDCCH in one of the subframes $i-k_m$ then n_{HARQ} = (number of transport blocks received in subframes $i-k_m$). For FDD, $M=1$ and $k_0=4$. For TDD, values of M, K and k_m are given in Table 10.1.3.1-1.
    - For PUCCH format 1,1a and 1b $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
    - For PUCCH format 1b with channel selection, if the UE is configured with more than one serving cell, $h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{(n_{HARQ}-1)}{2}$, otherwise, $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
    - For PUCCH format 2, 2a, 2b and normal cyclic prefix
      $$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI}}{4}\right) & \text{if } n_{CQI} \ge 4 \\ 0 & \text{otherwise} \end{cases}$$
    - For PUCCH format 2 and extended cyclic prefix
      $$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI}+n_{HARQ}}{4}\right) & \text{if } n_{CQI}+n_{HARQ} \ge 4 \\ 0 & \text{otherwise} \end{cases}$$
    - For PUCCH format 3
        - If the UE is configured by higher layers to transmit PUCCH on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK
          $$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ}+n_{SR}-1}{3}$$
        - Otherwise
          $$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ}+n_{SR}-1}{2}$$
- $P_{\text{O\_PUCCH}}$ is a parameter composed of the sum of a parameter $P_{\text{O\_NOMINAL\_PUCCH}}$ provided by higher layers and a parameter $P_{\text{O\_UE\_PUCCH}}$ provided by higher layers.
- δ_{PUCCH} is a UE specific correction value, also referred to as a TPC command, included in a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C for the primary cell or sent jointly coded with other UE specific PUCCH correction values on a PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUCCH-RNTI.
    - The UE attempts to decode a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C with the UE's C-RNTI or SPS C-RNTI on every subframe except when in DRX.

- If the UE decodes a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C for the primary cell and the corresponding detected RNTI equals the C-RNTI or SPS C-RNTI of the UE, the UE shall use the δ_{PUCCH} provided in that PDCCH.

  else

  - if the UE decodes a PDCCH with DCI format 3/3A, the UE shall use the δ_{PUCCH} provided in that PDCCH

    else the UE shall set δ_{PUCCH} = 0 dB.

- $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i-k_m)$ where $g(i)$ is the current PUCCH power control adjustment state and where $g(0)$ is the first value after reset.

  - For FDD, $M = 1$ and $k_0 = 4$.
  - For TDD, values of M and k_m are given in Table 10.1.3.1-1.
  - The δ_{PUCCH} dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C are given in Table 5.1.2.1-1. If the PDCCH with DCI format 1/1A/2/2A/2B/2C is validated as an SPS activation PDCCH, or the PDCCH with DCI format 1A is validated as an SPS release PDCCH, then δ_{PUCCH} is 0dB.
  - The δ_{PUCCH} dB values signalled on PDCCH with DCI format 3/3A are given in Table 5.1.2.1-1 or in Table 5.1.2.1-2 as semi-statically configured by higher layers.
  - If $P_{\mathrm{O\_UE\_PUCCH}}$ value is changed by higher layers,
    - $g(0) = 0$
  - Else
    - $g(0) = \Delta P_{rampup} + \delta_{msg2}$
      - where δ_{msg2} is the TPC command indicated in the random access response, see Section 6.2 and
      - ΔP_{rampup} is the total power ramp-up from the first to the last preamble provided by higher layers
  - If UE has reached $P_{\mathrm{CMAX,c}}$ for the primary cell, positive TPC commands for the primary cell shall not be accumulated
  - If UE has reached minimum power, negative TPC commands shall not be accumulated
  - UE shall reset accumulation
    - when $P_{\mathrm{O\_UE\_PUCCH}}$ value is changed by higher layers
    - when the UE receives a random access response message
  - $g(i) = g(i-1)$ if i is not an uplink subframe in TDD.

Table 5.1.2.1-1: Mapping of TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2/3 to δ_{PUCCH} values.

TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2/3	δ_{PUCCH} [dB]
0	-1
1	0
2	1
3	3

Table 5.1.2.1-2: Mapping of TPC Command Field in DCI format 3A to δ_{PUCCH} values.

TPC Command Field in DCI format 3A	δ_{PUCCH} [dB]
0	-1
1	1

5.1.3 Sounding Reference Symbol

5.1.3.1 UE behaviour

The setting of the UE Transmit power P_{SRS} for the Sounding Reference Symbol transmitted on subframe *i* for serving cell c is defined by

$$P_{\text{SRS,c}}(i) = \min\left\{ P_{\text{CMAX,c}}(i),\ P_{\text{SRS\_OFFSET,c}}(m) + 10\log_{10}(M_{\text{SRS,c}}) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\} \quad \text{[dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell c.
- $P_{\text{SRS\_OFFSET,c}}(m)$ is a 4-bit parameter semi-statically configured by higher layers for *m=0* and *m=1* for serving cell c. For SRS transmission given trigger type 0 then *m=0* and for SRS transmission given trigger type 1 then *m=1*. For $K_S = 1.25$, $P_{\text{SRS\_OFFSET,c}}(m)$ has 1dB step size in the range [-3, 12] dB. For $K_S = 0$, $P_{\text{SRS\_OFFSET,c}}(m)$ has 1.5 dB step size in the range [-10.5, 12] dB.
- $M_{\text{SRS,c}}$ is the bandwidth of the SRS transmission in subframe *i* for serving cell c expressed in number of resource blocks.
- $f_c(i)$ is the current PUSCH power control adjustment state for serving cell c, see Section 5.1.1.1.
- $P_{\text{O\_PUSCH,c}}(j)$ and $\alpha_c(j)$ are parameters as defined in Section 5.1.1.1, where $j = 1$.

5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

A UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes until different cell-specific RS power information is received. The downlink cell-specific reference-signal EPRE can be derived from the downlink reference-signal transmit power given by the parameter *referenceSignalPower* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific reference signals within the operating system bandwidth.

The ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs (not applicable to PDSCH REs with zero EPRE) for each OFDM symbol is denoted by either ρ_A or ρ_B according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, ρ_A and ρ_B are UE-specific.

For a UE in transmission mode 8 or 9 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1 – 7, the UE may assume that for 16 QAM, 64 QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- ρ_A is equal to $\delta_{\text{power-offset}} + P_A + 10\log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to Section 6.3.4.3 of [3];
- ρ_A is equal to $\delta_{\text{power-offset}} + P_A$ [dB] otherwise

where $\delta_{\text{power-offset}}$ is 0 dB for all PDSCH transmission schemes except multi-user MIMO and where P_A is a UE specific parameter provided by higher layers.

For transmission mode 7, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs shall be a constant, and that constant shall be maintained over all the OFDM symbols containing the UE-specific RSs in the corresponding PRBs. In addition, the UE may assume that for 16QAM or 64QAM, this ratio is 0 dB.

For transmission mode 8, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs is 0 dB.

For transmission mode 9, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RS is 0 dB for number of transmission layers less than or equal to two and -3 dB otherwise.

A UE may assume that downlink positioning reference signal EPRE is constant across the positioning reference signal bandwidth and across all OFDM symbols that contain positioning reference signals in a given positioning reference signal occasion [10].

If CSI-RS is configured in a serving cell then a UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes.

The cell-specific ratio ρ_B / ρ_A is given by Table 5.2-1 according to cell-specific parameter P_B signalled by higher layers and the number of configured eNodeB cell specific antenna ports.

Table 5.2-1: The cell-specific ratio ρ_B / ρ_A for 1, 2, or 4 cell specific antenna ports

P_B	ρ_B / ρ_A	
	One Antenna Port	**Two and Four Antenna Ports**
0	1	5/4
1	4/5	1
2	3/5	3/4
3	2/5	1/2

For PMCH with 16QAM or 64QAM, the UE may assume that the ratio of PMCH EPRE to MBSFN RS EPRE is equal to 0 dB.

Table 5.2-2: OFDM symbol indices within a slot of a non-MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A		OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B	
	Normal cyclic prefix	**Extended cyclic prefix**	**Normal cyclic prefix**	**Extended cyclic prefix**

One or two	1, 2, 3, 5, 6	1, 2, 4, 5	0, 4	0, 3
Four	2, 3, 5, 6	2, 4, 5	0, 1, 4	0, 1, 3

Table 5.2-3: OFDM symbol indices within a slot of an MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A				OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B			
	Normal cyclic prefix		Extended cyclic prefix		Normal cyclic prefix		Extended cyclic prefix	
	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1
One or two	1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5	0	-	0	-
Four	2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	2, 4, 3, 5	0, 1, 2, 3, 4, 5	0, 1	-	0, 1	-

5.2.1 eNodeB Relative Narrowband TX Power restrictions

The determination of reported Relative Narrowband TX Power indication $RNTP(n_{PRB})$ is defined as follows:

$$RNTP(n_{PRB}) = \begin{cases} 0 & \text{if} \quad \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \le RNTP_{threshold} \\ 1 & \text{if} \quad \text{no promise about the upper limit of } \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \text{ is made} \end{cases}$$

where $E_A(n_{PRB})$ is the maximum intended EPRE of UE-specific PDSCH REs in OFDM symbols not containing RS in this physical resource block on antenna port p in the considered future time interval; n_{PRB} is the physical resource block number $n_{PRB} = 0,...,N_{RB}^{DL} - 1$; $RNTP_{threshold}$ takes on one of the following values $RNTP_{threshold} \in \{-\infty,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,+1,+2,+3\}$[dB] and

$$E_{\max\_nom}^{(p)} = \frac{P_{\max}^{(p)} \cdot \frac{1}{\Delta f}}{N_{RB}^{DL} \cdot N_{SC}^{RB}}$$

where $P_{\max}^{(p)}$ is the base station maximum output power described in [7], and Δf , N_{RB}^{DL} and N_{SC}^{RB} are defined in [3].

6 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:

1. Random access channel parameters (PRACH configuration and frequency position)
2. Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the primary cell (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted or restricted set))

6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and 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 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

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

1. Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.

2. A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request.

3. A preamble transmission power P_{PRACH} is determined as
$P_{PRACH} = \min\{ P_{CMAX,c}(i)$, PREAMBLE_RECEIVED_TARGET_POWER + PL_c }_[dBm], where $P_{CMAX,c}(i)$ is the configured UE transmit power defined in [6] for subframe *i* of the primary cell and PL_c is the downlink pathloss estimate calculated in the UE for the primary cell.

4. A preamble sequence is selected from the preamble sequence set using the preamble index.

5. A single preamble is transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource.

6. Detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers (see [8], clause 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 20-bit uplink grant to the physical layer, which is processed according to section 6.2.

6.1.1 Timing

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

a. If a PDCCH with associated RA-RNTI is detected in subframe *n*, and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n+k_1$, $k_1 \geq 6$, if the UL delay field in section 6.2 is set to zero where $n+k_1$ is the first available UL subframe for PUSCH transmission. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n+k_1$ if the field is set to 1.

b. If a random access response is received in subframe *n*, and the corresponding DL-SCH transport block 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 in subframe $n+5$.

c. If no 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 in subframe $n+4$.

In case a random access procedure is initiated by a PDCCH order in subframe *n*, the UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n+k_2$, $k_2 \geq 6$, where a PRACH resource is available.

6.2 Random Access Response Grant

The higher layers indicate the 20-bit UL Grant to the physical layer, as defined in [8]. This is referred to the Random Access Response Grant in the physical layer. The content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit
- Fixed size resource block assignment – 10 bits
- Truncated modulation and coding scheme – 4 bits
- TPC command for scheduled PUSCH – 3 bits
- UL delay – 1 bit
- CSI request – 1 bit

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below,

The fixed size resource block assignment field is interpreted as follows:

if $N_{\mathrm{RB}}^{\mathrm{UL}} \leq 44$

Truncate the fixed size resource block assignment to its b least significant bits, where $b = \left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}} + 1\right)/2\right)\right\rceil$, and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

else

Insert b most significant bits with value set to '0' after the N_{UL_hop} hopping bits in the fixed size resource block assignment, where the number of hopping bits N_{UL_hop} is zero when the hopping flag bit is not set to 1, and is defined in Table 8.4-1 when the hopping flag bit is set to 1, and $b = \left(\left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}} + 1\right)/2\right)\right\rceil - 10\right)$, and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

end if

The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 in Table 8.6.1-1.

The TPC command δ_{msg2} shall be used for setting the power of the PUSCH, and is interpreted according to Table 6.2-1.

Table 6.2-1: TPC Command δ_{msg2} for Scheduled PUSCH

TPC Command	Value (in dB)
0	-6
1	-4
2	-2
3	0
4	2
5	4
6	6
7	8

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission according to section 7.2.1. In contention based random access procedure, the CSI request field is reserved.

The UL delay applies for both TDD and FDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced as shown in section 6.1.1.

7 Physical downlink shared channel related procedures

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD, the maximum number of downlink HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 7-1.

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for both FDD and TDD.

Table 7-1: Maximum number of DL HARQ processes for TDD

TDD UL/DL configuration	Maximum number of HARQ processes
0	4
1	7
2	10
3	9
4	12
5	15
6	6

7.1 UE procedure for receiving the physical downlink shared channel

A UE shall upon detection of a PDCCH of a serving cell with DCI format 1, 1A, 1B, 1C, 1D, 2, 2A, 2B or 2C intended for the UE in a subframe, decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers.

A UE may assume that positioning reference signals are not present in resource blocks in which it shall decode PDSCH according to a detected PDCCH with CRC scrambled by the SI-RNTI or P-RNTI with DCI format 1A or 1C intended for the UE.

[A UE is not expected to receive in a MBSFN subframe PDSCH and PRS with different CP sizes. A UE configured to decode PRS only in MBSFN subframes is not expected to decode other transmissions in those MBSFN subframes.]

A UE configured with the carrier indicator field for a given serving cell may assume that the carrier indicator field is not present in any PDCCH of the serving cell with CRC scrambled by SI-RNTI, P-RNTI, RA-RNTI, Temporary C-RNTI, TPC-RNTI, SPS C-RNTI or by C-RNTI if located in the common search space that is described in section 9.1. Otherwise, the configured UE shall assume that for the given serving cell the carrier indicator field is present in PDCCH located in the UE specific search space described in section 9.1 when the PDCCH CRC is scrambled by C-RNTI or SPS C-RNTI.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SI-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-1. The scrambling initialization of PDSCH corresponding to these PDCCHs is by SI-RNTI.

Table 7.1-1: PDCCH and PDSCH configured by SI-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity.
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the P-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-2. The scrambling initialization of PDSCH corresponding to these PDCCHs is by P-RNTI.

Table 7.1-2: PDCCH and PDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3. The scrambling initialization of PDSCH corresponding to these PDCCHs is by RA-RNTI.

When RA-RNTI and either C-RNTI or SPS C-RNTI are assigned in the same subframe, UE is not required to decode a PDSCH indicated by a PDCCH with a CRC scrambled by C-RNTI or SPS C-RNTI.

Table 7.1-3: PDCCH and PDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

The UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH according to one of nine transmission modes, denoted mode 1 to mode 9.

For frame structure type 1,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5, 7, or 8 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of either PBCH or primary or secondary synchronisation signals in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

For frame structure type 2,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of PBCH in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 or 8 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of primary or secondary synchronisation signals in the same subframe;
- with normal CP configuration, the UE is not expected to receive PDSCH on antenna port 5 for which distributed VRB resource allocation is assigned in the special subframe with configuration #1 or #6;
- the UE is not expected to receive PDSCH on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5. The scrambling initialization of PDSCH corresponding to these PDCCHs is by C-RNTI.

If the UE is configured with the carrier indicator field for a given serving cell and, if the UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, then the UE shall decode PDSCH of the serving cell indicated by the carrier indicator field value in the decoded PDCCH.

When a UE configured in transmission mode 3, 4 or 8 receives a DCI Format 1A assignment, it shall assume that the PDSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs is by C-RNTI.

The UE does not support transmission mode 8 if extended cyclic prefix is used in the downlink.

Table 7.1-5: PDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4)or Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see subclause 7.1.5)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding PDCCH. The scrambling initialization of PDSCH corresponding to these PDCCHs and PDSCH without a corresponding PDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs is by SPS C-RNTI.

Table 7.1-6: PDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7(see subclause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see subclause 7.1.1)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-7. The scrambling initialization of PDSCH corresponding to these PDCCHs is by Temporary C-RNTI.

Table 7.1-7: PDCCH and PDSCH configured by Temporary C-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1	UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

The transmission schemes of the PDSCH are described in the following sub-clauses.

7.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 0, port 5, port 7 or port 8) of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to Section 6.3.4.1 of [3].

In case an antenna port $p \in \{7,8\}$ is used, the UE cannot assume that the other antenna port in the set $\{7,8\}$ is not associated with transmission of PDSCH to another UE.

7.1.2 Transmit diversity scheme

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

7.1.3 Large delay CDD scheme

For the large delay CDD transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to large delay CDD as defined in Section 6.3.4.2.2 of [3].

7.1.4 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to the applicable number of transmission layers as defined in Section 6.3.4.2.1 of [3].

7.1.5 Multi-user MIMO scheme

For the multi-user MIMO transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to Section 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH with DCI format 1D using the downlink power offset field is given in Table 7.1.5-1.

Table 7.1.5-1: Mapping of downlink power offset field in DCI format 1D to the $\delta_{\text{power-offset}}$ value.

Downlink power offset field	$\delta_{\text{power-offset}}$ [dB]
0	$-10\log_{10}(2)$
1	0

7.1.5A Dual layer scheme

For the dual layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with two transmission layers on antenna ports 7 and 8 as defined in Section 6.3.4.4 of [3].

7.1.5B Up to 8 layer transmission scheme

For the 8 layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 7 - 14 as defined in Section 6.3.4.4 of [3].

7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH DCI format detected. A resource allocation field in each PDCCH includes two parts, a resource allocation header field and information consisting of the actual resource block assignment. PDCCH DCI formats 1, 2, 2A, 2B and 2C with type 0 and PDCCH DCI formats 1, 2, 2A,2B and 2C with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (section 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. PDCCH with DCI format 1A, 1B, 1C and 1D have a type 2 resource allocation while PDCCH with DCI format 1, 2, 2A, 2B and 2C have type 0 or type 1 resource allocation. PDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the resource block groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks

(VRBs) of localized type as defined in section 6.2.3.1 of [3]. Resource block group size (P) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs (N_{RBG}) for downlink system bandwidth of $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by $N_{RBG} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$ of the RBGs are of size P and if $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P > 0$ then one of the RBGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$. The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{\mathrm{RBG}} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

Table 7.1.6.1-1: Type 0 Resource Allocation RBG Size vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	RBG Size (*P*)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	4

7.1.6.2 Resource allocation type 1

In resource allocations of type 1, a resource block assignment information of size N_{RBG} indicates to a scheduled UE the VRBs from the set of VRBs from one of P RBG subsets. The virtual resource blocks used are of localized type as defined in section 6.2.3.1 of [3]. Also P is the RBG size associated with the system bandwidth as shown in Table 7.1.6.1-1. A RBG subset p , where $0 \le p < P$, consists of every P th RBG starting from RBG p . The resource block assignment information consists of three fields [4].

The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among P RBG subsets.

The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise.

The third field includes a bitmap, where each bit of the bitmap addresses a single VRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the VRBs in the increasing frequency order. The VRB is allocated to the UE if the corresponding bit value in the bit field is 1, the VRB is not allocated to the UE otherwise. The portion of the bitmap used to address VRBs in a selected RBG subset has size $N_{\mathrm{RB}}^{\mathrm{TYPE1}}$ and is defined as

$$N_{\mathrm{RB}}^{\mathrm{TYPE1}} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil - \lceil \log_2(P) \rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\mathrm{shift}}(p)$ to the smallest VRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of VRBs and is done within the selected RBG subset. If the value of the bit in the second field for shift of the resource allocation span is set to 0, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = 0$. Otherwise, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p) - N_{\mathrm{RB}}^{\mathrm{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)$ is the number of VRBs in RBG subset p and can be calculated by the following equation,

$$N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)=\begin{cases}\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P+P & ,p<\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P+(N_{\mathrm{RB}}^{\mathrm{DL}}-1)\bmod P+1 & ,p=\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P & ,p>\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\end{cases}$$

Consequently, when RBG subset p is indicated, bit i for $i=0,1,\cdots,N_{\mathrm{RB}}^{\mathrm{TYPE1}}-1$ in the bitmap field indicates VRB number,

$$n_{\mathrm{VRB}}^{\mathrm{RBG\ subset}}(p)=\left\lfloor \frac{i+\Delta_{\mathrm{shift}}(p)}{P}\right\rfloor P^2+p\cdot P+\left(i+\Delta_{\mathrm{shift}}(p)\right)\bmod P\ .$$

7.1.6.3 Resource allocation type 2

In resource allocations of type 2, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated localized virtual resource blocks or distributed virtual resource blocks. In case of resource allocation signalled with PDCCH DCI format 1A, 1B or 1D, one bit flag indicates whether localized virtual resource blocks or distributed virtual resource blocks are assigned (value 0 indicates Localized and value 1 indicates Distributed VRB assignment) while distributed virtual resource blocks are always assigned in case of resource allocation signalled with PDCCH DCI format 1C. Localized VRB allocations for a UE vary from a single VRB up to a maximum number of VRBs spanning the system bandwidth. For DCI format 1A the distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs, where $N_{\mathrm{VRB}}^{\mathrm{DL}}$ is defined in [3], if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI. With PDCCH DCI format 1B, 1D, or 1A with a CRC scrambled with C-RNTI, distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With PDCCH DCI format 1C, distributed VRB allocations for a UE vary from $N_{\mathrm{RB}}^{\mathrm{step}}$ VRB(s) up to $\left\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}}/N_{\mathrm{RB}}^{\mathrm{step}}\right\rfloor\cdot N_{\mathrm{RB}}^{\mathrm{step}}$ VRBs with an increment step of $N_{\mathrm{RB}}^{\mathrm{step}}$, where $N_{\mathrm{RB}}^{\mathrm{step}}$ value is determined depending on the downlink system bandwidth as shown in Table 7.1.6.3-1.

Table 7.1.6.3-1: $N_{\mathrm{RB}}^{\mathrm{step}}$ values vs. Downlink System Bandwidth

System BW ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	$N_{\mathrm{RB}}^{\mathrm{step}}$
	DCI format 1C
6-49	2
50-110	4

For PDCCH DCI format 1A, 1B or 1D, a type 2 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{start}) and a length in terms of virtually contiguously allocated resource blocks L_{CRBs}. The resource indication value is defined by

if $(L_{CRBs}-1)\le\left\lfloor N_{RB}^{DL}/2\right\rfloor$ then

$$RIV=N_{RB}^{DL}(L_{CRBs}-1)+RB_{start}$$

else

$$RIV=N_{RB}^{DL}(N_{RB}^{DL}-L_{CRBs}+1)+(N_{RB}^{DL}-1-RB_{start})$$

where $L_{CRBs}\ge 1$ and shall not exceed $N_{VRB}^{DL}-RB_{start}$.

For PDCCH DCI format 1C, a type 2 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block ($RB_{start} = 0$, $N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots,$ $(\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor - 1) N_{\mathrm{RB}}^{\mathrm{step}}$) and a length in terms of virtually contiguously allocated resource blocks ($L_{CRBs} = N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots,$ $\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$). The resource indication value is defined by

if $(L'_{CRBs} - 1) \le \lfloor N'^{DL}_{VRB} / 2 \rfloor$ then

$$RIV = N'^{DL}_{VRB}(L'_{CRBs} - 1) + RB'_{start}$$

else

$$RIV = N'^{DL}_{VRB}(N'^{DL}_{VRB} - L'_{CRBs} + 1) + (N'^{DL}_{VRB} - 1 - RB'_{start})$$

where $L'_{CRBs} = L_{CRBs} / N_{RB}^{step}$, $RB'_{start} = RB_{start} / N_{RB}^{step}$ and $N'^{DL}_{VRB} = \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor$. Here,

$L'_{CRBs} \ge 1$ and shall not exceed $N'^{DL}_{VRB} - RB'_{start}$.

7.1.6.4 PDSCH starting position

The starting OFDM symbol for the PDSCH of each activated serving cell given by index $l_{\mathrm{DataStart}}$ in the first of the slots in a subframe is given by

- the higher-layer parameter *pdsch-Start* for the serving cell on which PDSCH is received if the UE is configured with carrier indicator field for the given serving cell and if PDSCH and the corresponding PDCCH are received on different serving cells,
- the span of the DCI given by the CFI of the serving cell according to Section 5.3.4 of [4] otherwise.

7.1.6.5 PRB bundling

A UE configured for transmission mode 9 for a given serving cell *c* may assume that precoding granularity is multiple resource blocks in the frequency domain when [if] PMI/RI feedback is configured. Fixed system bandwidth dependent Precoding Resource block Groups (PRGs) of size P' partition the system bandwidth and each PRG consists of consecutive PRBs. If $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P' > 0$ then one of the PRGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P' \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P' \rfloor$. The PRG size is non-increasing starting at the lowest frequency. The UE may assume that the same precoder applies on all scheduled PRBs within a PRG.

The PRG size a UE may assume for a given system bandwidth is given by:

Table 7.1.6.5-1

System Bandwidth ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	PRG Size (P') (PRBs)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	2

7.1.7 Modulation order and transport block size determination

To determine the modulation order and transport block size(s) in the physical downlink shared channel, the UE shall first

- read the 5-bit "modulation and coding scheme" field (I_{MCS}) in the DCI

and second if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
    - o set the Table 7.1.7.2.1-1 column indicator N_{PRB} to $N_{\mathrm{PRB}}^{1\mathrm{A}}$ from Section 5.3.3.1.3 in [4]
- for DCI format 1C:
    - o use Table 7.1.7.2.3-1 for determining its transport block size.

else

- set N'_{PRB} to the total number of allocated PRBs based on the procedure defined in Section 7.1.6.

  if the transport block is transmitted in DwPTS of the special subframe in frame structure type 2, then

  set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.75 \right\rfloor, \quad 1\right\}$,

  else, set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = N'_{PRB}$.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.930, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH. If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded. For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP, shown in Table 4.2-1 of [3], there shall be no PDSCH transmission in DwPTS of the special subframe.

7.1.7.1 Modulation order determination

The UE shall use Q_m = 2 if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI, otherwise, the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order (Q_m) used in the physical downlink shared channel.

Table 7.1.7.1-1: Modulation and TBS index table for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26
29	2	reserved
30	4	
31	6	

7.1.7.2 Transport block size determination

If the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
  - o the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS by the procedure in Section 7.1.7.2.1.
- for DCI format 1C:
  - o the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS from Table 7.1.7.2.3-1.

else

- for $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B and 2C as specified below. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.5.

- for $29 \le I_{MCS} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 28$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH.

- In DCI formats 2, 2A, 2B and 2C a transport block is disabled if $I_{MCS} = 0$ and if rv_{idx} = 1 otherwise the transport block is enabled.

The NDI and HARQ process ID, as signalled on PDCCH, and the TBS, as determined above, shall be delivered to higher layers.

7.1.7.2.1 Transport blocks not mapped to two or more layer spatial multiplexing

For $1 \le N_{PRB} \le 110$, the TBS is given by the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1.

Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)

I_{TBS}	N_{PRB}									
	1	2	3	4	5	6	7	8	9	10
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200
26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480

I_{TBS}	N_{PRB}									
	11	12	13	14	15	16	17	18	19	20
0	288	328	344	376	392	424	456	488	504	536
1	376	424	456	488	520	568	600	632	680	712
2	472	520	568	616	648	696	744	776	840	872
3	616	680	744	808	872	904	968	1032	1096	1160
4	776	840	904	1000	1064	1128	1192	1288	1352	1416
5	968	1032	1128	1224	1320	1384	1480	1544	1672	1736
6	1128	1224	1352	1480	1544	1672	1736	1864	1992	2088
7	1320	1480	1608	1672	1800	1928	2088	2216	2344	2472

8	1544	1672	1800	1928	2088	2216	2344	2536	2664	2792
9	1736	1864	2024	2216	2344	2536	2664	2856	2984	3112
10	1928	2088	2280	2472	2664	2792	2984	3112	3368	3496
11	2216	2408	2600	2792	2984	3240	3496	3624	3880	4008
12	2472	2728	2984	3240	3368	3624	3880	4136	4392	4584
13	2856	3112	3368	3624	3880	4136	4392	4584	4968	5160
14	3112	3496	3752	4008	4264	4584	4968	5160	5544	5736
15	3368	3624	4008	4264	4584	4968	5160	5544	5736	6200
16	3624	3880	4264	4584	4968	5160	5544	5992	6200	6456
17	4008	4392	4776	5160	5352	5736	6200	6456	6712	7224
18	4392	4776	5160	5544	5992	6200	6712	7224	7480	7992
19	4776	5160	5544	5992	6456	6968	7224	7736	8248	8504
20	5160	5544	5992	6456	6968	7480	7992	8248	8760	9144
21	5544	5992	6456	6968	7480	7992	8504	9144	9528	9912
22	5992	6456	6968	7480	7992	8504	9144	9528	10296	10680
23	6200	6968	7480	7992	8504	9144	9912	10296	11064	11448
24	6712	7224	7992	8504	9144	9912	10296	11064	11448	12216
25	6968	7480	8248	8760	9528	10296	10680	11448	12216	12576
26	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688

I_{TBS}	N_{PRB}									
	21	22	23	24	25	26	27	28	29	30
0	568	600	616	648	680	712	744	776	776	808
1	744	776	808	872	904	936	968	1000	1032	1064
2	936	968	1000	1064	1096	1160	1192	1256	1288	1320
3	1224	1256	1320	1384	1416	1480	1544	1608	1672	1736
4	1480	1544	1608	1736	1800	1864	1928	1992	2088	2152
5	1864	1928	2024	2088	2216	2280	2344	2472	2536	2664
6	2216	2280	2408	2472	2600	2728	2792	2984	2984	3112
7	2536	2664	2792	2984	3112	3240	3368	3368	3496	3624
8	2984	3112	3240	3368	3496	3624	3752	3880	4008	4264
9	3368	3496	3624	3752	4008	4136	4264	4392	4584	4776
10	3752	3880	4008	4264	4392	4584	4776	4968	5160	5352
11	4264	4392	4584	4776	4968	5352	5544	5736	5992	5992
12	4776	4968	5352	5544	5736	5992	6200	6456	6712	6712
13	5352	5736	5992	6200	6456	6712	6968	7224	7480	7736
14	5992	6200	6456	6968	7224	7480	7736	7992	8248	8504
15	6456	6712	6968	7224	7736	7992	8248	8504	8760	9144
16	6712	7224	7480	7736	7992	8504	8760	9144	9528	9912
17	7480	7992	8248	8760	9144	9528	9912	10296	10296	10680
18	8248	8760	9144	9528	9912	10296	10680	11064	11448	11832
19	9144	9528	9912	10296	10680	11064	11448	12216	12576	12960
20	9912	10296	10680	11064	11448	12216	12576	12960	13536	14112
21	10680	11064	11448	12216	12576	12960	13536	14112	14688	15264
22	11448	11832	12576	12960	13536	14112	14688	15264	15840	16416
23	12216	12576	12960	13536	14112	14688	15264	15840	16416	16992
24	12960	13536	14112	14688	15264	15840	16416	16992	17568	18336
25	13536	14112	14688	15264	15840	16416	16992	17568	18336	19080
26	15264	16416	16992	17568	18336	19080	19848	20616	21384	22152

I_{TBS}	N_{PRB}									
	31	32	33	34	35	36	37	38	39	40
0	840	872	904	936	968	1000	1032	1032	1064	1096
1	1128	1160	1192	1224	1256	1288	1352	1384	1416	1416
2	1384	1416	1480	1544	1544	1608	1672	1672	1736	1800
3	1800	1864	1928	1992	2024	2088	2152	2216	2280	2344
4	2216	2280	2344	2408	2472	2600	2664	2728	2792	2856
5	2728	2792	2856	2984	3112	3112	3240	3368	3496	3496
6	3240	3368	3496	3496	3624	3752	3880	4008	4136	4136

7	3752	3880	4008	4136	4264	4392	4584	4584	4776	4968
8	4392	4584	4584	4776	4968	4968	5160	5352	5544	5544
9	4968	5160	5160	5352	5544	5736	5736	5992	6200	6200
10	5544	5736	5736	5992	6200	6200	6456	6712	6712	6968
11	6200	6456	6712	6968	6968	7224	7480	7736	7736	7992
12	6968	7224	7480	7736	7992	8248	8504	8760	8760	9144
13	7992	8248	8504	8760	9144	9144	9528	9912	9912	10296
14	8760	9144	9528	9912	9912	10296	10680	11064	11064	11448
15	9528	9912	10296	10296	10680	11064	11448	11832	11832	12216
16	9912	10296	10680	11064	11448	11832	12216	12216	12576	12960
17	11064	11448	11832	12216	12576	12960	13536	13536	14112	14688
18	12216	12576	12960	13536	14112	14112	14688	15264	15264	15840
19	13536	13536	14112	14688	15264	15264	15840	16416	16992	16992
20	14688	14688	15264	15840	16416	16992	16992	17568	18336	18336
21	15840	15840	16416	16992	17568	18336	18336	19080	19848	19848
22	16992	16992	17568	18336	19080	19080	19848	20616	21384	21384
23	17568	18336	19080	19848	19848	20616	21384	22152	22152	22920
24	19080	19848	19848	20616	21384	22152	22920	22920	23688	24496
25	19848	20616	20616	21384	22152	22920	23688	24496	24496	25456
26	22920	23688	24496	25456	25456	26416	27376	28336	29296	29296

I_{TBS}	N_{PRB}									
	41	42	43	44	45	46	47	48	49	50
0	1128	1160	1192	1224	1256	1256	1288	1320	1352	1384
1	1480	1544	1544	1608	1608	1672	1736	1736	1800	1800
2	1800	1864	1928	1992	2024	2088	2088	2152	2216	2216
3	2408	2472	2536	2536	2600	2664	2728	2792	2856	2856
4	2984	2984	3112	3112	3240	3240	3368	3496	3496	3624
5	3624	3752	3752	3880	4008	4008	4136	4264	4392	4392
6	4264	4392	4584	4584	4776	4776	4968	4968	5160	5160
7	4968	5160	5352	5352	5544	5736	5736	5992	5992	6200
8	5736	5992	5992	6200	6200	6456	6456	6712	6968	6968
9	6456	6712	6712	6968	6968	7224	7480	7480	7736	7992
10	7224	7480	7480	7736	7992	7992	8248	8504	8504	8760
11	8248	8504	8760	8760	9144	9144	9528	9528	9912	9912
12	9528	9528	9912	9912	10296	10680	10680	11064	11064	11448
13	10680	10680	11064	11448	11448	11832	12216	12216	12576	12960
14	11832	12216	12216	12576	12960	12960	13536	13536	14112	14112
15	12576	12960	12960	13536	13536	14112	14688	14688	15264	15264
16	13536	13536	14112	14112	14688	14688	15264	15840	15840	16416
17	14688	15264	15264	15840	16416	16416	16992	17568	17568	18336
18	16416	16416	16992	17568	17568	18336	18336	19080	19080	19848
19	17568	18336	18336	19080	19080	19848	20616	20616	21384	21384
20	19080	19848	19848	20616	20616	21384	22152	22152	22920	22920
21	20616	21384	21384	22152	22920	22920	23688	24496	24496	25456
22	22152	22920	22920	23688	24496	24496	25456	25456	26416	27376
23	23688	24496	24496	25456	25456	26416	27376	27376	28336	28336
24	25456	25456	26416	26416	27376	28336	28336	29296	29296	30576
25	26416	26416	27376	28336	28336	29296	29296	30576	31704	31704
26	30576	30576	31704	32856	32856	34008	35160	35160	36696	36696

I_{TBS}	N_{PRB}									
	51	52	53	54	55	56	57	58	59	60
0	1416	1416	1480	1480	1544	1544	1608	1608	1608	1672
1	1864	1864	1928	1992	1992	2024	2088	2088	2152	2152
2	2280	2344	2344	2408	2472	2536	2536	2600	2664	2664
3	2984	2984	3112	3112	3240	3240	3368	3368	3496	3496
4	3624	3752	3752	3880	4008	4008	4136	4136	4264	4264
5	4584	4584	4776	4776	4776	4968	4968	5160	5160	5352

6	5352	5352	5544	5736	5736	5992	5992	5992	6200	6200
7	6200	6456	6456	6712	6712	6712	6968	6968	7224	7224
8	7224	7224	7480	7480	7736	7736	7992	7992	8248	8504
9	7992	8248	8248	8504	8760	8760	9144	9144	9144	9528
10	9144	9144	9144	9528	9528	9912	9912	10296	10296	10680
11	10296	10680	10680	11064	11064	11448	11448	11832	11832	12216
12	11832	11832	12216	12216	12576	12576	12960	12960	13536	13536
13	12960	13536	13536	14112	14112	14688	14688	14688	15264	15264
14	14688	14688	15264	15264	15840	15840	16416	16416	16992	16992
15	15840	15840	16416	16416	16992	16992	17568	17568	18336	18336
16	16416	16992	16992	17568	17568	18336	18336	19080	19080	19848
17	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
18	19848	20616	21384	21384	22152	22152	22920	22920	23688	23688
19	22152	22152	22920	22920	23688	24496	24496	25456	25456	25456
20	23688	24496	24496	25456	25456	26416	26416	27376	27376	28336
21	25456	26416	26416	27376	27376	28336	28336	29296	29296	30576
22	27376	28336	28336	29296	29296	30576	30576	31704	31704	32856
23	29296	29296	30576	30576	31704	31704	32856	32856	34008	34008
24	31704	31704	32856	32856	34008	34008	35160	35160	36696	36696
25	32856	32856	34008	34008	35160	35160	36696	36696	37888	37888
26	37888	37888	39232	40576	40576	40576	42368	42368	43816	43816

I_{TBS}	N_{PRB}									
	61	62	63	64	65	66	67	68	69	70
0	1672	1736	1736	1800	1800	1800	1864	1864	1928	1928
1	2216	2280	2280	2344	2344	2408	2472	2472	2536	2536
2	2728	2792	2856	2856	2856	2984	2984	3112	3112	3112
3	3624	3624	3624	3752	3752	3880	3880	4008	4008	4136
4	4392	4392	4584	4584	4584	4776	4776	4968	4968	4968
5	5352	5544	5544	5736	5736	5736	5992	5992	5992	6200
6	6456	6456	6456	6712	6712	6968	6968	6968	7224	7224
7	7480	7480	7736	7736	7992	7992	8248	8248	8504	8504
8	8504	8760	8760	9144	9144	9144	9528	9528	9528	9912
9	9528	9912	9912	10296	10296	10296	10680	10680	11064	11064
10	10680	11064	11064	11448	11448	11448	11832	11832	12216	12216
11	12216	12576	12576	12960	12960	13536	13536	13536	14112	14112
12	14112	14112	14112	14688	14688	15264	15264	15264	15840	15840
13	15840	15840	16416	16416	16992	16992	16992	17568	17568	18336
14	17568	17568	18336	18336	18336	19080	19080	19848	19848	19848
15	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
16	19848	19848	20616	20616	21384	21384	22152	22152	22152	22920
17	22152	22152	22920	22920	23688	23688	24496	24496	24496	25456
18	24496	24496	24496	25456	25456	26416	26416	27376	27376	27376
19	26416	26416	27376	27376	28336	28336	29296	29296	29296	30576
20	28336	29296	29296	29296	30576	30576	31704	31704	31704	32856
21	30576	31704	31704	31704	32856	32856	34008	34008	35160	35160
22	32856	34008	34008	34008	35160	35160	36696	36696	36696	37888
23	35160	35160	36696	36696	37888	37888	37888	39232	39232	40576
24	36696	37888	37888	39232	39232	40576	40576	42368	42368	42368
25	39232	39232	40576	40576	40576	42368	42368	43816	43816	43816
26	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752

I_{TBS}	N_{PRB}									
	71	72	73	74	75	76	77	78	79	80
0	1992	1992	2024	2088	2088	2088	2152	2152	2216	2216
1	2600	2600	2664	2728	2728	2792	2792	2856	2856	2856
2	3240	3240	3240	3368	3368	3368	3496	3496	3496	3624
3	4136	4264	4264	4392	4392	4392	4584	4584	4584	4776
4	5160	5160	5160	5352	5352	5544	5544	5544	5736	5736

5	6200	6200	6456	6456	6712	6712	6712	6968	6968	6968
6	7480	7480	7736	7736	7736	7992	7992	8248	8248	8248
7	8760	8760	8760	9144	9144	9144	9528	9528	9528	9912
8	9912	9912	10296	10296	10680	10680	10680	11064	11064	11064
9	11064	11448	11448	11832	11832	11832	12216	12216	12576	12576
10	12576	12576	12960	12960	12960	13536	13536	13536	14112	14112
11	14112	14688	14688	14688	15264	15264	15840	15840	15840	16416
12	16416	16416	16416	16992	16992	17568	17568	17568	18336	18336
13	18336	18336	19080	19080	19080	19848	19848	19848	20616	20616
14	20616	20616	20616	21384	21384	22152	22152	22152	22920	22920
15	22152	22152	22152	22920	22920	23688	23688	23688	24496	24496
16	22920	23688	23688	24496	24496	24496	25456	25456	25456	26416
17	25456	26416	26416	26416	27376	27376	27376	28336	28336	29296
18	28336	28336	29296	29296	29296	30576	30576	30576	31704	31704
19	30576	30576	31704	31704	32856	32856	32856	34008	34008	34008
20	32856	34008	34008	34008	35160	35160	35160	36696	36696	36696
21	35160	36696	36696	36696	37888	37888	39232	39232	39232	40576
22	37888	39232	39232	40576	40576	40576	42368	42368	42368	43816
23	40576	40576	42368	42368	43816	43816	43816	45352	45352	45352
24	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
25	45352	45352	46888	46888	46888	48936	48936	48936	51024	51024
26	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256

I_{TBS}	N_{PRB}									
	81	82	83	84	85	86	87	88	89	90
0	2280	2280	2280	2344	2344	2408	2408	2472	2472	2536
1	2984	2984	2984	3112	3112	3112	3240	3240	3240	3240
2	3624	3624	3752	3752	3880	3880	3880	4008	4008	4008
3	4776	4776	4776	4968	4968	4968	5160	5160	5160	5352
4	5736	5992	5992	5992	5992	6200	6200	6200	6456	6456
5	7224	7224	7224	7480	7480	7480	7736	7736	7736	7992
6	8504	8504	8760	8760	8760	9144	9144	9144	9144	9528
7	9912	9912	10296	10296	10296	10680	10680	10680	11064	11064
8	11448	11448	11448	11832	11832	12216	12216	12216	12576	12576
9	12960	12960	12960	13536	13536	13536	13536	14112	14112	14112
10	14112	14688	14688	14688	14688	15264	15264	15264	15840	15840
11	16416	16416	16992	16992	16992	17568	17568	17568	18336	18336
12	18336	19080	19080	19080	19080	19848	19848	19848	20616	20616
13	20616	21384	21384	21384	22152	22152	22152	22920	22920	22920
14	22920	23688	23688	24496	24496	24496	25456	25456	25456	25456
15	24496	25456	25456	25456	26416	26416	26416	27376	27376	27376
16	26416	26416	27376	27376	27376	28336	28336	28336	29296	29296
17	29296	29296	30576	30576	30576	30576	31704	31704	31704	32856
18	31704	32856	32856	32856	34008	34008	34008	35160	35160	35160
19	35160	35160	35160	36696	36696	36696	37888	37888	37888	39232
20	37888	37888	39232	39232	39232	40576	40576	40576	42368	42368
21	40576	40576	42368	42368	42368	43816	43816	43816	45352	45352
22	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
23	46888	46888	46888	48936	48936	48936	51024	51024	51024	51024
24	48936	51024	51024	51024	52752	52752	52752	52752	55056	55056
25	51024	52752	52752	52752	55056	55056	55056	55056	57336	57336
26	59256	59256	61664	61664	61664	63776	63776	63776	66592	66592

I_{TBS}	N_{PRB}									
	91	92	93	94	95	96	97	98	99	100
0	2536	2536	2600	2600	2664	2664	2728	2728	2728	2792
1	3368	3368	3368	3496	3496	3496	3496	3624	3624	3624
2	4136	4136	4136	4264	4264	4264	4392	4392	4392	4584
3	5352	5352	5352	5544	5544	5544	5736	5736	5736	5736

4	6456	6456	6712	6712	6712	6968	6968	6968	6968	7224
5	7992	7992	8248	8248	8248	8504	8504	8760	8760	8760
6	9528	9528	9528	9912	9912	9912	10296	10296	10296	10296
7	11064	11448	11448	11448	11448	11832	11832	11832	12216	12216
8	12576	12960	12960	12960	13536	13536	13536	13536	14112	14112
9	14112	14688	14688	14688	15264	15264	15264	15264	15840	15840
10	15840	16416	16416	16416	16992	16992	16992	16992	17568	17568
11	18336	18336	19080	19080	19080	19080	19848	19848	19848	19848
12	20616	21384	21384	21384	21384	22152	22152	22152	22920	22920
13	23688	23688	23688	24496	24496	24496	25456	25456	25456	25456
14	26416	26416	26416	27376	27376	27376	28336	28336	28336	28336
15	28336	28336	28336	29296	29296	29296	29296	30576	30576	30576
16	29296	30576	30576	30576	30576	31704	31704	31704	31704	32856
17	32856	32856	34008	34008	34008	35160	35160	35160	35160	36696
18	36696	36696	36696	37888	37888	37888	37888	39232	39232	39232
19	39232	39232	40576	40576	40576	40576	42368	42368	42368	43816
20	42368	42368	43816	43816	43816	45352	45352	45352	46888	46888
21	45352	46888	46888	46888	46888	48936	48936	48936	48936	51024
22	48936	48936	51024	51024	51024	51024	52752	52752	52752	55056
23	52752	52752	52752	55056	55056	55056	55056	57336	57336	57336
24	55056	57336	57336	57336	57336	59256	59256	59256	61664	61664
25	57336	59256	59256	59256	61664	61664	61664	61664	63776	63776
26	66592	68808	68808	68808	71112	71112	71112	73712	73712	75376

I_{TBS}	N_{PRB}									
	101	102	103	104	105	106	107	108	109	110
0	2792	2856	2856	2856	2984	2984	2984	2984	2984	3112
1	3752	3752	3752	3752	3880	3880	3880	4008	4008	4008
2	4584	4584	4584	4584	4776	4776	4776	4776	4968	4968
3	5992	5992	5992	5992	6200	6200	6200	6200	6456	6456
4	7224	7224	7480	7480	7480	7480	7736	7736	7736	7992
5	8760	9144	9144	9144	9144	9528	9528	9528	9528	9528
6	10680	10680	10680	10680	11064	11064	11064	11448	11448	11448
7	12216	12576	12576	12576	12960	12960	12960	12960	13536	13536
8	14112	14112	14688	14688	14688	14688	15264	15264	15264	15264
9	15840	16416	16416	16416	16416	16992	16992	16992	16992	17568
10	17568	18336	18336	18336	18336	18336	19080	19080	19080	19080
11	20616	20616	20616	21384	21384	21384	21384	22152	22152	22152
12	22920	23688	23688	23688	23688	24496	24496	24496	24496	25456
13	26416	26416	26416	26416	27376	27376	27376	27376	28336	28336
14	29296	29296	29296	29296	30576	30576	30576	30576	31704	31704
15	30576	31704	31704	31704	31704	32856	32856	32856	34008	34008
16	32856	32856	34008	34008	34008	34008	35160	35160	35160	35160
17	36696	36696	36696	37888	37888	37888	39232	39232	39232	39232
18	40576	40576	40576	40576	42368	42368	42368	42368	43816	43816
19	43816	43816	43816	45352	45352	45352	46888	46888	46888	46888
20	46888	46888	48936	48936	48936	48936	48936	51024	51024	51024
21	51024	51024	51024	52752	52752	52752	52752	55056	55056	55056
22	55056	55056	55056	57336	57336	57336	57336	59256	59256	59256
23	57336	59256	59256	59256	59256	61664	61664	61664	61664	63776
24	61664	61664	63776	63776	63776	63776	66592	66592	66592	66592
25	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
26	75376	75376	75376	75376	75376	75376	75376	75376	75376	75376

7.1.7.2.2 Transport blocks mapped to two-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 55$, the TBS is given by the (I_{TBS} , $2 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $56 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L2 using the mapping rule shown in Table 7.1.7.2.2-1. The TBS is given by TBS_L2.

Table 7.1.7.2.2-1: One-layer to two-layer TBS translation table

TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2
1544	3112	3752	7480	10296	20616	28336	57336
1608	3240	3880	7736	10680	21384	29296	59256
1672	3368	4008	7992	11064	22152	30576	61664
1736	3496	4136	8248	11448	22920	31704	63776
1800	3624	4264	8504	11832	23688	32856	66592
1864	3752	4392	8760	12216	24496	34008	68808
1928	3880	4584	9144	12576	25456	35160	71112
1992	4008	4776	9528	12960	25456	36696	73712
2024	4008	4968	9912	13536	27376	37888	76208
2088	4136	5160	10296	14112	28336	39232	78704
2152	4264	5352	10680	14688	29296	40576	81176
2216	4392	5544	11064	15264	30576	42368	84760
2280	4584	5736	11448	15840	31704	43816	87936
2344	4776	5992	11832	16416	32856	45352	90816
2408	4776	6200	12576	16992	34008	46888	93800
2472	4968	6456	12960	17568	35160	48936	97896
2536	5160	6712	13536	18336	36696	51024	101840
2600	5160	6968	14112	19080	37888	52752	105528
2664	5352	7224	14688	19848	39232	55056	110136
2728	5544	7480	14688	20616	40576	57336	115040
2792	5544	7736	15264	21384	42368	59256	119816
2856	5736	7992	15840	22152	43816	61664	124464
2984	5992	8248	16416	22920	45352	63776	128496
3112	6200	8504	16992	23688	46888	66592	133208
3240	6456	8760	17568	24496	48936	68808	137792
3368	6712	9144	18336	25456	51024	71112	142248
3496	6968	9528	19080	26416	52752	73712	146856
3624	7224	9912	19848	27376	55056	75376	149776

7.1.7.2.3 Transport blocks mapped for DCI Format 1C

The TBS is given by the I_{TBS} entry of Table 7.1.7.2.3-1.

Table 7.1.7.2.3-1: Transport Block Size Table for DCI format 1C

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	40	56	72	120	136	144	176	208	224	256	280	296	328	336	392	488
I_{TBS}	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS	552	600	632	696	776	840	904	1000	1064	1128	1224	1288	1384	1480	1608	1736

7.1.7.2.4 Transport blocks mapped to three-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 36$, the TBS is given by the (I_{TBS} , $3 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $37 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L3 using the mapping rule shown in Table 7.1.7.2.4-1. The TBS is given by TBS_L3.

Table 7.7.2.4-1: One-layer to three-layer TBS translation table

TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3
1032	3112	2664	7992	8248	24496	26416	78704
1064	3240	2728	8248	8504	25456	27376	81176
1096	3240	2792	8248	8760	26416	28336	84760
1128	3368	2856	8504	9144	27376	29296	87936
1160	3496	2984	8760	9528	28336	30576	90816
1192	3624	3112	9144	9912	29296	31704	93800
1224	3624	3240	9528	10296	30576	32856	97896
1256	3752	3368	9912	10680	31704	34008	101840
1288	3880	3496	10296	11064	32856	35160	105528
1320	4008	3624	10680	11448	34008	36696	110136
1352	4008	3752	11064	11832	35160	37888	115040
1384	4136	3880	11448	12216	36696	39232	119816
1416	4264	4008	11832	12576	37888	40576	119816
1480	4392	4136	12576	12960	39232	42368	128496
1544	4584	4264	12960	13536	40576	43816	133208
1608	4776	4392	12960	14112	42368	45352	137792
1672	4968	4584	13536	14688	43816	46888	142248
1736	5160	4776	14112	15264	45352	48936	146856
1800	5352	4968	14688	15840	46888	51024	152976
1864	5544	5160	15264	16416	48936	52752	157432
1928	5736	5352	15840	16992	51024	55056	165216
1992	5992	5544	16416	17568	52752	57336	171888
2024	5992	5736	16992	18336	55056	59256	177816
2088	6200	5992	18336	19080	57336	61664	185728
2152	6456	6200	18336	19848	59256	63776	191720
2216	6712	6456	19080	20616	61664	66592	199824
2280	6712	6712	19848	21384	63776	68808	205880
2344	6968	6968	20616	22152	66592	71112	214176
2408	7224	7224	21384	22920	68808	73712	221680
2472	7480	7480	22152	23688	71112	75376	226416
2536	7480	7736	22920	24496	73712		
2600	7736	7992	23688	25456	76208		

7.1.7.2.5 Transport blocks mapped to four-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 27$, the TBS is given by the (I_{TBS} , $4 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $28 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L4 using the mapping rule shown in Table 7.1.7.2.5-1. The TBS is given by TBS_L4.

Table 7.1.7.2.5-1: One-layer to four-layer TBS translation table

TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4
776	3112	2280	9144	7224	29296	24496	97896
808	3240	2344	9528	7480	29296	25456	101840
840	3368	2408	9528	7736	30576	26416	105528
872	3496	2472	9912	7992	31704	27376	110136
904	3624	2536	10296	8248	32856	28336	115040
936	3752	2600	10296	8504	34008	29296	115040
968	3880	2664	10680	8760	35160	30576	124464
1000	4008	2728	11064	9144	36696	31704	128496
1032	4136	2792	11064	9528	37888	32856	133208
1064	4264	2856	11448	9912	39232	34008	137792
1096	4392	2984	11832	10296	40576	35160	142248
1128	4584	3112	12576	10680	42368	36696	146856
1160	4584	3240	12960	11064	43816	37888	151376
1192	4776	3368	13536	11448	45352	39232	157432
1224	4968	3496	14112	11832	46888	40576	161760
1256	4968	3624	14688	12216	48936	42368	169544
1288	5160	3752	15264	12576	51024	43816	175600
1320	5352	3880	15264	12960	51024	45352	181656
1352	5352	4008	15840	13536	55056	46888	187712
1384	5544	4136	16416	14112	57336	48936	195816
1416	5736	4264	16992	14688	59256	51024	203704
1480	5992	4392	17568	15264	61664	52752	211936
1544	6200	4584	18336	15840	63776	55056	220296
1608	6456	4776	19080	16416	66592	57336	230104
1672	6712	4968	19848	16992	68808	59256	236160
1736	6968	5160	20616	17568	71112	61664	245648
1800	7224	5352	21384	18336	73712	63776	254328
1864	7480	5544	22152	19080	76208	66592	266440
1928	7736	5736	22920	19848	78704	68808	275376
1992	7992	5992	23688	20616	81176	71112	284608
2024	7992	6200	24496	21384	84760	73712	293736
2088	8248	6456	25456	22152	87936	75376	299856
2152	8504	6712	26416	22920	90816		
2216	8760	6968	28336	23688	93800		

7.1.7.3 Redundancy Version determination for Format 1C

If the DCI Format 1C CRC is scrambled by P-RNTI or RA-RNTI, then

- the UE shall set the Redundancy Version to 0

Else if the DCI Format 1C CRC is scrambled by SI-RNTI, then

- the UE shall set the Redundancy Version as defined in [8].

7.2 UE procedure for reporting Channel State Information (CSI)

The time and frequency resources that can be used by the UE to report CSI which consists of channel quality indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

A UE in transmission mode 8 or 9 is configured with PMI/RI reporting if the parameter *pmi-RI-Report* is configured by higher layer signalling; otherwise, it is configured without PMI/RI reporting.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers.

CSI reporting is periodic or aperiodic.

If the UE is configured with more than one serving cell, it transmits periodic CSI for all activated serving cells as configured by higher layers.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUCCH as defined hereafter in subframes with no PUSCH allocation.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUSCH of the serving cell with smallest *ServCellIndex* as defined hereafter in subframes with a PUSCH allocation, where the UE shall use the same PUCCH-based periodic CSI reporting format on PUSCH.

A UE shall transmit aperiodic CSI reporting on PUSCH if the conditions specified hereafter are met. For aperiodic CQI/PMI reporting, RI reporting is transmitted only if the configured CSI feedback type supports RI reporting.

The CSI transmissions on PUCCH and PUSCH for various scheduling modes are summarized in the following table:

Table 7.2-1: Physical Channels for Aperiodic or Periodic CSI reporting

Scheduling Mode	Periodic CSI reporting channels	Aperiodic CSI reporting channel
Frequency non-selective	PUCCH	
Frequency selective	PUCCH	PUSCH

In case both periodic and aperiodic CSI reporting would occur in the same subframe, the UE shall only transmit the aperiodic CSI report in that subframe.

When reporting RI the UE reports a single instance of the number of useful transmission layers. For each RI reporting interval when the UE is configured in transmission modes 4 or when the UE is configured in transmission mode 8 or 9 with PMI/RI reporting, a UE shall determine a RI from the supported set of RI values for the corresponding eNodeB antenna configuration and UE category and report the number in each RI report. For each RI reporting interval when the UE is configured in transmission mode 3, a UE shall determine RI for the corresponding eNodeB antenna configuration and UE category in each reporting interval and report the detected number in each RI report to support selection between transmit diversity and large delay CDD.

When reporting PMI the UE reports either a single or a multiple PMI report. The number of RBs represented by a single UE PMI report can be $N_{\mathrm{RB}}^{\mathrm{DL}}$ or a smaller subset of RBs. The number of RBs represented by a single PMI report is semi-statically configured by higher layer signalling. A UE is restricted to report PMI, RI and PTI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 3, 4, 5, 6 and for transmission modes 8 and 9 if the UE is configured with PMI/RI reporting. The resulting number of bits for each transmission mode is given in Table 7.2-1b. The bitmap forms the bit sequence $a_{A_c-1},...,a_3,a_2,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

1. Transmission mode 3

   a. 2 antenna ports: bit $a_{\upsilon-1}, \upsilon=2$ is associated with the precoder in Table 6.3.4.2.3-1 of [3] corresponding to υ layers and codebook index 0 while bit a_0 is associated with the precoder for 2 antenna ports in Section 6.3.4.3 of [3].

   b. 4 antenna ports: bit $a_{\upsilon-1}$, $\upsilon = 2,3,4$ is associated with the precoders in Table 6.3.4.2.3-2 of [3] corresponding to υ layers and codebook indices 12, 13, 14, and 15 while bit a_0 is associated with the precoder for 4 antenna ports in Section 6.3.4.3 of [3].

2. Transmission mode 4

   a. 2 antenna ports: see Table 7.2-1c

   b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

3. Transmission modes 5 and 6

   a. 2 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon = 1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].

   b. 4 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon = 1$ layer with codebook index i_c in Table 6.3.4.2.3-2 of [3].

4. Transmission mode 8

   a. 2 antenna ports: see Table 7.2-1c

   b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3], $\upsilon = 1,2$.

5. Transmission mode 9

   a. 2 antenna ports: see Table 7.2-1c

   b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with second component codebook index i_c in Table 6.3.4.2.3-2 of [3].

   c. 8 antenna ports: bit $a_{f1(\upsilon-1)+i_{c1}}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4,5,6,7,8\}$) and codebook index i_{c1} where $f1(\cdot) = \{0,16,32,36,40,44,48,52\}$ and bit $a_{53+g1(\upsilon-1)+i_{c2}}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_{c2} where $g1(\cdot) = \{0,16,32,48\}$. Codebook indices i_{c1} and i_{c2} are given in Table 6.3.4.2.3-3, 6.3.4.2.3-4, 6.3.4.2.3-5, 6.3.4.2.3-6, 6.3.4.2.3-7, 6.3.4.2.3-8, 6.3.4.2.3-9, or 6.3.4.2.3-10 of [3] for υ=1,2,3,4,5,6,7, or 8 respectively.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes.

	Number of bits A_c		
	2 antenna ports	**4 antenna ports**	**8 antenna ports**
Transmission mode 3	2	4	
Transmission mode 4	6	64	
Transmission mode 5	4	16	
Transmission mode 6	4	16	
Transmission mode 8	6	32	
Transmission mode 9	6	64	109

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3].

Codebook index i_c	Number of layers υ	
	1	**2**
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

The set of subbands (*S*) a UE shall evaluate for CQI reporting spans the entire downlink system bandwidth. A subband is a set of *k* contiguous PRBs where *k* is a function of system bandwidth. Note the last subband in set *S* may have fewer than *k* contiguous PRBs depending on N_{RB}^{DL} . The number of subbands for system bandwidth given by N_{RB}^{DL} is defined by $N = \lceil N_{RB}^{DL} / k \rceil$. The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- For transmission modes 1, 2, 3 and 5, as well as transmission modes 8 and 9 if the UE is configured without PMI/RI reporting, transmission mode 4 with RI=1, and transmission modes 8 and 9 with PMI/RI reporting and RI=1, a single 4-bit wideband CQI is reported according to Table 7.2.3-1.
- For transmission modes 3 and 4, as well as transmission modes 8 and 9 if the UE is configured with PMI/RI reporting, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.
- For RI > 1 with transmission mode 4, 8, or 9, if the UE is configured with PMI/RI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
  - A 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1
  - A 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1

- For RI > 1 with transmission mode 4, 8, or 9, if the UE is configured with PMI/RI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1 and a wideband spatial differential CQI. The wideband spatial differential CQI value comprises:
  - A 3-bit wideband spatial differential CQI value for codeword 1 offset level
    - Codeword 1 offset level = wideband CQI index for codeword 0 – wideband CQI index for codeword 1.
  - The mapping from the 3-bit wideband spatial differential CQI value to the offset level is shown in Table 7.2-2.

Table 7.2-2 Mapping spatial differential CQI value to offset level

Spatial differential CQI value	Offset level
0	0
1	1
2	2
3	≥3
4	≤-4
5	-3
6	-2
7	-1

7.2.1 Aperiodic CSI Reporting using PUSCH

A UE shall perform aperiodic CSI reporting using the PUSCH in subframe $n+k$ on serving cell c, upon decoding in subframe n either:

- an uplink DCI format, or
- a Random Access Response Grant,

for serving cell c if the respective CSI request field is set to trigger a report and is not reserved. If the CSI request field is 1 bit [4], a report is triggered for serving cell c if the CSI request field is set to '1'. If the CSI request field size is 2 bits [4], a report is triggered according to the value in Table 7.1.1-1A corresponding to aperiodic CSI reporting.

A UE is not expected to receive more than one aperiodic CSI report request for a given subframe.

Table 7.2.1-1A: CSI Request field for PDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of serving cells configured by higher layers

Note: PDCCH with DCI formats used to grant PUSCH transmissions as given by DCI format 0 and DCI format 4 are herein referred to as uplink DCI format when common behaviour is addressed.

When the CSI request field from an uplink DCI format is set to trigger a report, for FDD $k=4$, and for TDD UL/DL configuration 1-6, k is given in Table 8-2. For TDD UL/DL configuration 0, if the MSB of the UL index is set to 1 and LSB of the UL index is set to 0, k is given in Table 8-2; or if MSB of the UL index is set to 0 and LSB of the UL index is set to 1, k is equal to 7; or if both MSB and LSB of the UL index is set to 1, k is given in Table 8-2.

When the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, *k* is equal to k_1 if the UL delay field in section 6.2 is set to zero, where k_1 is given in section 6.1.1. The UE shall postpone aperiodic CSI reporting to the next available UL subframe if the UL delay field is set to 1.

The minimum reporting interval for aperiodic reporting of CQI and PMI and RI is 1 subframe. The subband size for CQI shall be the same for transmitter-receiver configurations with and without precoding.

When aperiodic CSI report with no transport block associated as defined in section 8.6.2 and positive SR is transmitted in the same subframe, the UE shall transmit SR, and, if applicable, ACK/NAK, on PUCCH resources as described in Section 10.1

A UE is semi-statically configured by higher layers to feed back CQI and PMI and corresponding RI on the same PUSCH using one of the following CSI reporting modes given in Table 7.2.1-1 and described below.

Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes

		PMI Feedback Type		
		No PMI	Single PMI	Multiple PMI
PUSCH CQI Feedback Type	Wideband (wideband CQI)			Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	

For each of the transmission modes defined in Section 7.1, the following reporting modes are supported on PUSCH:

Transmission mode 1 : Modes 2-0, 3-0
Transmission mode 2 : Modes 2-0, 3-0
Transmission mode 3 : Modes 2-0, 3-0
Transmission mode 4 : Modes 1-2, 2-2, 3-1
Transmission mode 5 : Mode 3-1
Transmission mode 6 : Modes 1-2, 2-2, 3-1
Transmission mode 7 : Modes 2-0, 3-0
Transmission mode 8 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1

The aperiodic CSI reporting mode is given by the parameter *cqi-ReportModeAperiodic* which is configured by higher-layer signalling.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, PUSCH reporting modes are not supported for that serving cell.
RI is only reported for transmission modes 3, 4, 8 and 9 if the UE is configured with PMI/RI reporting.

A RI report for a serving cell on an aperiodic reporting mode is valid only for CQI/PMI report for that serving cell on that aperiodic reporting mode

- Wideband feedback
  - Mode 1-2 description:
    - For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband

- A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set *S* subbands.
- The UE shall report the selected precoding matrix indicator for each set *S* subband except for transmission mode 9 with 8 CSI-RS ports configured in which case a first precoding matrix indicator i_1 is reported for the set *S* subbands and a second precoding matrix indicator i_2 is reported for each set *S* subband.
- Subband size is given by Table 7.2.1-3.
- For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.

- Higher Layer-configured subband feedback
  - Mode 3-0 description:
    - A UE shall report a wideband CQI value which is calculated assuming transmission on set *S* subbands
    - The UE shall also report one subband CQI value for each set *S* subband. The subband CQI value is calculated assuming transmission only in the subband
    - Both the wideband and subband CQI represent channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 3-1 description:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report one subband CQI value per codeword for each set *S* subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - The UE shall report the single selected precoding matrix indicator except for transmission mode 9 with 8 CSI-RS ports configured in which case a first and second precoding matrix indicator are reported corresponding to the single selected precoding matrix.
    - For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Subband CQI value for each codeword are encoded differentially with respect to their respective wideband CQI using 2-bits as defined by
    - Subband differential CQI offset level = subband CQI index – wideband CQI index. The mapping from the 2-bit subband differential CQI value to the offset level is shown in Table 7.2.1-2.

Table 7.2.1-2: Mapping subband differential CQI value to offset level

Subband differential CQI value	Offset level
0	0
1	1
2	≥2
3	≤-1

- Supported subband size (*k*) is given in Table 7.2.1-3.

Table 7.2.1-3: Subband Size (*k*) vs. System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size (*k*)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

- UE-selected subband feedback
  - Mode 2-0 description:
    - The UE shall select a set of *M* preferred subbands of size *k* (where *k* and *M* are given in Table 7.2.1-5 for each system bandwidth range) within the set of subbands *S*.
    - The UE shall also report one CQI value reflecting transmission only over the *M* selected subbands determined in the previous step. The CQI represents channel quality for the first codeword, even when RI>1.
    - Additionally, the UE shall also report one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 2-2 description:
    - The UE shall perform joint selection of the set of *M* preferred subbands of size *k* within the set of subbands *S* and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the *M* selected subbands.
    - The UE shall report one CQI value per codeword reflecting transmission only over the selected *M* preferred subbands and using the same selected single precoding matrix in each of the *M* subbands.
    - Except for transmission mode 9 with 8 CSI-RS ports configured, the UE shall also report the single selected precoding matrix indicator preferred for the M selected subbands. A UE shall also report the selected single precoding matrix indicator for all set *S* subbands.
    - For transmission mode 9 with 8 CSI-RS ports configured, a UE shall report a first precoding matrix indicator for all set *S* subbands. A UE shall also report a second precoding matrix indicator for all set *S* subbands and another second precoding matrix indicator for the M selected subbands.

- A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
- A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
- For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.

o For all UE-selected subband feedback modes the UE shall report the positions of the *M* selected subbands using a combinatorial index *r* defined as

- $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$
- where the set $\{s_i\}_{i=0}^{M-1}$, $(1 \le s_i \le N, \quad s_i < s_{i+1})$ contains the *M* sorted subband indices and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{ 0, \cdots, \binom{N}{M} - 1 \right\}$.

o The CQI value for the *M* selected subbands for each codeword is encoded differentially using 2-bits relative to its respective wideband CQI as defined by

- Differential CQI offset level = *M* selected subbands CQI index – wideband CQI index
- The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.

Table 7.2.1-4: Mapping differential CQI value to offset level

Differential CQI value	Offset level
0	≤1
1	2
2	3
3	≥4

o Supported subband size *k* and *M* values include those shown in Table 7.2.1-5. In Table 7.2.1-5 the *k* and *M* values are a function of system bandwidth.

o The number of bits to denote the position of the *M* selected subbands is $L = \left\lceil \log_2 \binom{N}{M} \right\rceil$.

Table 7.2.1-5: Subband Size (*k*) and Number of Subbands (*M*) in S vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size *k* (RBs)	*M*
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

7.2.2 Periodic CSI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CSI (CQI, PMI, PTI, and/or RI) on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below.

Table 7.2.2-1: CQI and PMI Feedback Types for PUCCH CSI reporting Modes

		PMI Feedback Type	
		No PMI	**Single PMI**
PUCCH CQI Feedback Type	**Wideband (wideband CQI)**	Mode 1-0	Mode 1-1
	UE Selected (subband CQI)	Mode 2-0	Mode 2-1

For each of the transmission modes defined in Section 7.1, the following periodic CSI reporting modes are supported on PUCCH:

Transmission mode 1 : Modes 1-0, 2-0
Transmission mode 2 : Modes 1-0, 2-0
Transmission mode 3 : Modes 1-0, 2-0
Transmission mode 4 : Modes 1-1, 2-1
Transmission mode 5 : Modes 1-1, 2-1
Transmission mode 6 : Modes 1-1, 2-1
Transmission mode 7 : Modes 1-0, 2-0
Transmission mode 8 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

The periodic CSI reporting mode for each serving cell is configured by higher-layer signalling. Mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode.*

For the UE-selected subband CQI, a CQI report in a certain subframe of a certain serving cell describes the channel quality in a particular part or in particular parts of the bandwidth of that serving cell described subsequently as bandwidth part (BP) or parts. The bandwidth parts shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

For each serving cell

- There are a total of N subbands for a serving cell system bandwidth given by N_{RB}^{DL} where $\lfloor N_{RB}^{DL}/k \rfloor$ subbands are of size k. If $\lceil N_{RB}^{DL}/k \rceil - \lfloor N_{RB}^{DL}/k \rfloor > 0$ then one of the subbands is of size $N_{RB}^{DL} - k \cdot \lfloor N_{RB}^{DL}/k \rfloor$.
- A bandwidth part j is frequency-consecutive and consists of N_j subbands where J bandwidth parts span S or N_{RB}^{DL} as given in Table 7.2.2-2. If $J=1$ then N_j is $\lceil N_{RB}^{DL}/k/J \rceil$. If $J>1$ then N_j is either $\lceil N_{RB}^{DL}/k/J \rceil$ or $\lceil N_{RB}^{DL}/k/J \rceil - 1$, depending on N_{RB}^{DL}, k and J.
- Each bandwidth part j, where $0 \le j \le J$-1, is scanned in sequential order according to increasing frequency.
- For UE selected subband feedback a single subband out of N_j subbands of a bandwidth part is selected along with a corresponding L-bit label indexed in the order of increasing frequency, where $L = \lceil \log_2 \lceil N_{RB}^{DL}/k/J \rceil \rceil$.

The CQI and PMI payload sizes of each PUCCH CSI reporting mode are given in Table 7.2.2-3.

The following CQI/PMI and RI reporting types with distinct periods and offsets are supported for the PUCCH CSI reporting modes given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 1a report supports subband CQI and second PMI feedback
- Type 2, Type 2b, and Type 2c report supports wideband CQI and PMI feedback
- Type 2a report supports wideband PMI feedback
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI
- Type 5 report supports RI and wideband PMI feedback
- Type 6 report supports RI and PTI feedback

For each serving cell, the periodicity N_{pd} (in subframes) and offset $N_{OFFSET,CQI}$ (in subframes) for CQI/PMI reporting are determined based on the parameter *cqi-pmi-ConfigIndex* ($I_{CQI/PMI}$) given in Table 7.2.2-1A for FDD and Table 7.2.2-1C for TDD. The periodicity M_{RI} and relative offset $N_{OFFSET,RI}$ for RI reporting are determined based on the parameter *ri-ConfigIndex* (I_{RI}) given in Table 7.2.2-1B. Both *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0,-1,...,-(N_{pd}-1)\}$. If a UE is configured to report for more than one CSI subframe set then parameter *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 1 and *cqi-pmi-ConfigIndex2* and *ri-ConfigIndex*2 respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 2.

In the case where wideband CQI/PMI reporting is configured:

- The reporting instances for wideband CQI/PMI are subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(N_{pd}\right) = 0$.
- In case RI reporting is configured, the reporting interval of the RI reporting is an integer multiple M_{RI} of period N_{pd} (in subframes).
    - o The reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \bmod \left(N_{pd} \cdot M_{RI}\right) = 0$.

In the case where both wideband CQI/PMI and subband CQI reporting are configured:

- The reporting instances for wideband CQI/PMI and subband CQI are subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI}\right) \bmod N_{pd} = 0$.
    - ▪ When PTI is not transmitted (due to not being configured) or the most recently transmitted PTI was equal to 1:

- The wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) report has period $H \cdot N_{pd}$, and is reported on the subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(H \cdot N_{pd}\right) = 0$. The integer H is defined as $H = J \cdot K + 1$, where J is the number of bandwidth parts.
- Between every two consecutive wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) reports, the remaining $J \cdot K$ reporting instances are used in sequence for subband CQI reports on K full cycles of bandwidth parts except when the gap between two consecutive wideband CQI/PMI reports contains less than $J \cdot K$ reporting instances due to a system frame number transition to 0, in which case the UE shall not transmit the remainder of the subband CQI reports which have not been transmitted before the second of the two wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) reports. Each full cycle of bandwidth parts shall be in increasing order starting from bandwidth part 0 to bandwidth part $J - 1$. The parameter K is configured by higher-layer signalling.

- When the most recently transmitted PTI is 0:
  - The wideband first precoding matrix indicator report has period $H' \cdot N_{pd}$, and is reported on the subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(H' \cdot N_{pd}\right) = 0$, where H' is signalled by higher layers.
  - Between every two consecutive wideband first precoding matrix indicator reports, the remaining reporting instances are used for a wideband second precoding matrix indicator with wideband CQI as described below

- In case RI reporting is configured, the reporting interval of RI is M_{RI} times the wideband CQI/PMI period $H \cdot N_{pd}$, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.
  - The reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \bmod \left(H \cdot N_{pd} \cdot M_{RI}\right) = 0$

In case of collision of a CSI report with PUCCH format 3, 5, or 6 of one serving cell with a CSI report with PUCCH format 1, 1a, 2, 2a, 2b, 2c, or 4 of the same serving cell the latter CSI report with PUCCH format (1, 1a, 2, 2a, 2b, 2c, or 4) has lower priority and is dropped.

If the UE is configured with more than one serving cell, the UE transmits a CSI report of only one serving cell in any given subframe. For a given subframe, in case of collision of a CSI report with PUCCH format 3, 5, 6, or 2a of one serving cell with a CSI report with PUCCH format 1, 1a, 2, 2b, 2c, or 4 of another serving cell the latter CSI with PUCCH format (1, 1a, 2, 2b, 2c, or 4) has lower priority and is dropped. For a given subframe, in case of collision of CSI report with PUCCH format 2, 2b, 2c, or 4 of one serving cell with CSI report with PUCCH format 1 or 1a of another serving cell the latter CSI report with PUCCH format 1, or 1a has lower priority and is dropped.
For a given subframe, in case of collision between CSI reports of different serving cells with PUCCH format of the same priority the CSI of the serving cell with lowest *ServCellIndex* is reported, and CSI of all other serving cells are dropped.

See section 10.1 regarding UE behaviour for collision between CSI and HARQ-ACK and the corresponding PUCCH format assignment.
The CSI report of a given PUCCH format shall be transmitted on the PUCCH resource $n_{\mathrm{PUCCH}}^{(2,p)}$ as defined in [3], where $n_{\mathrm{PUCCH}}^{(2,p)}$ is UE specific and configured by higher layers for each serving cell.

In case of collision between CSI and positive SR in a same subframe, CSI is dropped.

Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for FDD.

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$0 \le I_{CQI/PMI} \le 1$	2	$I_{CQI/PMI}$
$2 \le I_{CQI/PMI} \le 6$	5	$I_{CQI/PMI} - 2$
$7 \le I_{CQI/PMI} \le 16$	10	$I_{CQI/PMI} - 7$
$17 \le I_{CQI/PMI} \le 36$	20	$I_{CQI/PMI} - 17$
$37 \le I_{CQI/PMI} \le 76$	40	$I_{CQI/PMI} - 37$
$77 \le I_{CQI/PMI} \le 156$	80	$I_{CQI/PMI} - 77$
$157 \le I_{CQI/PMI} \le 316$	160	$I_{CQI/PMI} - 157$
$I_{CQI/PMI} = 317$	Reserved	
$318 \le I_{CQI/PMI} \le 349$	32	$I_{CQI/PMI} - 318$
$350 \le I_{CQI/PMI} \le 413$	64	$I_{CQI/PMI} - 350$
$414 \le I_{CQI/PMI} \le 541$	128	$I_{CQI/PMI} - 414$
$542 \le I_{CQI/PMI} \le 1023$	Reserved	

Table 7.2.2-1B: Mapping of I_{RI} to M_{RI} and $N_{OFFSET,RI}$.

I_{RI}	Value of M_{RI}	Value of $N_{OFFSET,RI}$
$0 \le I_{RI} \le 160$	1	$-I_{RI}$
$161 \le I_{RI} \le 321$	2	$-(I_{RI} - 161)$
$322 \le I_{RI} \le 482$	4	$-(I_{RI} - 322)$
$483 \le I_{RI} \le 643$	8	$-(I_{RI} - 483)$
$644 \le I_{RI} \le 804$	16	$-(I_{RI} - 644)$
$805 \le I_{RI} \le 965$	32	$-(I_{RI} - 805)$
$966 \le I_{RI} \le 1023$	Reserved	

Table 7.2.2-1C: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for TDD.

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$I_{CQI/PMI} = 0$	1	$I_{CQI/PMI}$
$1 \le I_{CQI/PMI} \le 5$	5	$I_{CQI/PMI} - 1$
$6 \le I_{CQI/PMI} \le 15$	10	$I_{CQI/PMI} - 6$
$16 \le I_{CQI/PMI} \le 35$	20	$I_{CQI/PMI} - 16$
$36 \le I_{CQI/PMI} \le 75$	40	$I_{CQI/PMI} - 36$
$76 \le I_{CQI/PMI} \le 155$	80	$I_{CQI/PMI} - 76$
$156 \le I_{CQI/PMI} \le 315$	160	$I_{CQI/PMI} - 156$
$316 \le I_{CQI/PMI} \le 1023$	Reserved	

For TDD periodic CQI/PMI reporting, the following periodicity values apply depending on the TDD UL/DL configuration [3]:

- The reporting period of $N_{pd} = 1$ is only applicable to TDD UL/DL configurations 0, 1, 3, 4, and 6, where all UL subframes in a radio frame are used for CQI/PMI reporting.
- The reporting period of $N_{pd} = 5$ is only applicable to TDD UL/DL configurations 0, 1, 2, and 6.
- The reporting periods of $N_{pd} = \{10,20,40,80,160\}$ are applicable to all TDD UL/DL configurations.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \le 7$, Mode 2-0 and Mode 2-1 are not supported for that serving cell.

The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for the second precoding matrix indicator i_2.

Table 7.2.2-1D: PUCCH mode 1-1 submode 2 codebook subsampling.

	i_1		i_2		total
RI	**#bits**	**values**	**#bits**	**values**	**#bits**
1	3	{0, 2, 4, 6, 8, 10, 12, 14},	1	{0, 2}	4
2	3	{0, 2, 4, 6, 8, 10, 12, 14}	1	{0, 1}	4
3	1	{0, 2}	3	{0, 1, 2, 3, 8, 9, 10, 11}	4
4	1	{0, 1}	3	{0, 1, 2, 3, 4, 5, 6, 7}	4
5	2	{0, 1, 2, 3}	0	{0}	2
6	2	{0, 1, 2, 3}	0	{0}	2
7	2	{0, 1, 2, 3}	0	{0}	2
8	0	{0}	0	{0}	0

Table 7.2.2-1E: Joint encoding of RI and i_1 for PUCCH mode 1-1 submode 1.

hypotheses	RI	i_1 values
0-7	1	{0,2,4,6,8,12,14}
8-15	2	{0,2,4,6,8,12,14}
16-17	3	{0,2}
18-19	4	{0,2}
20-21	5	{0,2}
22-23	6	{0,2}
24-25	7	{0,2}
26	8	{0}
27-31	reserved	NA

Table 7.2.2-1F: PUCCH mode 2-1 codebook subsampling.

RI	i_2	
	#bits	values
1	4	No subsampling
2	2	{0, 2, 4, 6}
3	2	{2, 3, 10, 11}
4	2	{0, 2, 4, 6}
5	0	{0}
6	0	{0}
7	0	{0}
8	0	{0}

A RI report for a serving cell in a periodic reporting mode is valid only for CQI/PMI report for that serving cell on that periodic CSI reporting mode.

For the calculation of CQI/PMI conditioned on the last reported RI, in the absence of a last reported RI the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI as given by the bitmap parameter *codebookSubsetRestriction* . If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI linked to the same subframe set as the CQI/PMI report.

- Wideband feedback
  - Mode 1-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where CQI is reported:
      - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1
  - Mode 1-1 description:

- In the subframe where RI is reported (only for transmission mode 4 and transmission mode 8 and transmission mode 9):
  - A UE shall determine a RI assuming transmission on set *S* subbands.
  - The UE shall report a type 3 report consisting of one RI
- In the subframe where RI and a first precoding matrix indicator are reported (only for transmission mode 9 with submode 1 and when 8 CSI-RS ports are configured)
  - A UE shall determine a RI assuming transmission on set *S* subbands
  - The UE shall report a type 5 report consisting of jointly coded RI and a first precoding matrix indicator corresponding to a single precoding matrix selected from the codebook subset assuming transmission on set *S* subbands
- In the subframe where CQI/PMI is reported:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands
  - A UE shall report a type 2/2b/2c report on each respective successive reporting opportunity consisting of
    - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - For transmission mode 4 and 8 only: a type 2 report composed of the selected single second precoding matrix indicator (wideband PMI).
    - For transmission mode 9 configured to submode 1 only: a type 2b report composed of the selected single second precoding matrix indicator (wideband PMI) as defined in Section 7.2.4.
    - For transmission mode 9 configured to submode 2 only: a type 2c report composed of a first and a second precoding matrix indicator corresponding to the single selected precoding matrix as defined in Section 7.2.4.
    - When RI>1, a 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - For transmission mode 4, 8 and 9, the PMI and CQI are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.

- UE Selected subband feedback
  - Mode 2-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where wideband CQI is reported:
      - The UE shall report a type 4 report on each respective successive reporting opportunity consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.

- In the subframe where CQI for the selected subbands is reported:
  - The UE shall select the preferred subband within the set of N_{j} subbands in each of the *J* bandwidth parts where *J* is given in Table 7.2.2-2.
  - The UE shall report a type 1 report consisting of one CQI value reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label. A type 1 report for each bandwidth part will in turn be reported in respective successive reporting opportunities. The CQI represents channel quality for the first codeword, even when RI>1.
  - For transmission mode 3 the preferred subband selection and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.

- Mode 2-1 description:
  - In the subframe where RI is reported (only for transmission mode 4, 8 and 9 if the number of configured CSI-RS ports is 2 or 4):
    - A UE shall determine a RI assuming transmission on set *S* subbands.
    - The UE shall report a type 3 report consisting of one RI.
  - In the subframe where RI is reported for transmission mode 9 with 8 CSI-RS ports configured then:
    - A UE shall determine a RI assuming transmission on set *S* subbands.
    - A UE shall determine a precoder type indication (PTI).
    - The UE shall report a type 6 report consisting of one RI and the PTI.
  - In the subframe where wideband CQI/PMI is reported:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
    - Except for transmission mode 9, a UE shall report a type 2 report on each respective successive reporting opportunity consisting of:
      - A wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
      - The single selected precoding matrix indicator (wideband PMI).
      - When RI>1, and additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    - For transmission mode 9, a UE shall report a type 2a report if PTI=0 or a type 2b report if either PTI=1 or the number of CSI-RS ports configured is 2 or 4, on each respective successive reporting opportunity consisting of:
      - In case of PTI=1, a wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
      - In case of PTI=0, the first precoding matrix indicator is reported corresponding to the single selected precoding matrix
      - In case of PTI=1, the second precoding matrix indicator is reported corresponding to the single selected precoding matrix
      - In case of PTI=1, when RI>1, and additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.

- For transmission mode 4, 8 and 9, the PMI and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.

▪ In the subframe where CQI for the selected subbands is reported:
  - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
  - Except for transmission mode 9 with 8 CSI-RS ports configured, the UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
    - o CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label.
    - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - ▪ Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - ▪ Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on set *S* subbands.
    - o The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
  - For transmission mode 9 with 8 CSI-RS ports configured, if PTI=0 the UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
    - o A wideband CQI value which is calculated assuming the use of a single selected precoding matrix in all subbands and transmission on set *S* subbands.
    - o A second precoding matrix indicator of the preferred precoding matrix selected from the codebook subset assuming transmission on set *S* subbands.
    - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - ▪ Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - ▪ Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on set *S* subbands.
    - o The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
  - For transmission mode 9, if PTI=1, the UE shall report a type 1a report per bandwidth part on each respective successive reporting opportunity consisting of:
    - o CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label.
    - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level

- Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
- Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on set *S* subbands.

  - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
  - A second precoding matrix indicator of the preferred precoding matrix selected from the codebook subset assuming transmission only over the selected subband of a bandwidth part determined in the previous step.

- For transmission mode 4, 8 and 9, the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI and RI. For other transmission modes they are calculated conditioned on the last reported PMI and transmission rank 1.

Table 7.2.2-2: Subband Size (*k*) and Bandwidth Parts *(J)* vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size *k* (RBs)	Bandwidth Parts (*J*)
6 – 7	NA	NA
8 – 10	4	1
11 – 26	4	2
27 – 63	6	3
64 – 110	8	4

If parameter *ttiBundling* provided by higher layers is set to *TRUE* and if an UL-SCH in subframe bundling operation collides with a periodic CSI reporting instance, then the UE shall drop the periodic CSI report of a given PUCCH format in that subframe and shall not multiplex the periodic CSI report payload in the PUSCH transmission in that subframe.

Table 7.2.2-3: PUCCH Format Payload size per PUCCH Reporting Mode and Mode State

PUCCH Format	Reported	Mode State	PUCCH Reporting Modes			
			Mode 1-1 (bits/BP)	Mode 2-1 (bits/BP)	Mode 1-0 (bits/BP)	Mode 2-0 (bits/BP)
1	Sub-band CQI	RI = 1	NA	4+L	NA	4+L
		RI > 1	NA	7+L	NA	4+L
1a	Sub-band CQI / second PMI	8 antenna ports RI = 1	NA	8+L	NA	NA
		8 antenna ports 1 < RI < 5	NA	9+L	NA	NA
		8 antenna ports RI > 4	NA	7+L	NA	NA
2	Wideband CQI/PMI	2 antenna ports RI = 1	6	6	NA	NA
		4 antenna ports RI = 1	8	8	NA	NA
		2 antenna ports RI > 1	8	8	NA	NA
		4 antenna ports RI > 1	11	11	NA	NA
2a	Wideband first PMI	8 antenna ports RI < 3	NA	4	NA	NA
		8 antenna ports 2 < RI < 8	NA	2	NA	NA
		8 antenna ports RI = 8	NA	0	NA	NA
2b	Wideband CQI / second PMI	8 antenna ports RI = 1	8	8	NA	NA
		8 antenna ports 1 < RI < 4	11	11	NA	NA
		8 antenna ports RI = 4	10	10	NA	NA
		8 antenna ports RI > 4	7	7	NA	NA

2c	Wideband CQI / first PMI / second PMI	8 antenna ports RI = 1	8	-	NA	NA
		8 antenna ports 1 < RI ≤ 4	11	-	NA	NA
		8 antenna ports 4 < RI ≤ 7	9	-	NA	NA
		8 antenna ports RI = 8	7	-	NA	NA
3	RI	2-layer spatial multiplexing	1	1	1	1
		4-layer spatial multiplexing	2	2	2	2
		8-layer spatial multiplexing	3	3	NA	NA
4	Wideband CQI	RI = 1 or RI>1	NA	NA	4	4
5	RI/ first PMI	8 antenna ports, 2-layer spatial multiplexing	4	NA	NA	NA
		8 antenna ports, 4 and 8-layer spatial multiplexing	5			
6	RI/PTI	8 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		8 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
		8 antenna ports, 8-layer spatial multiplexing	NA	4	NA	NA

7.2.3 Channel quality indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1.

Based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value reported in uplink subframe *n* the highest CQI index between 1 and 15 in Table 7.2.3-1 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

If CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{\mathrm{CSI},0}$ or $C_{\mathrm{CSI},1}$ but not to both. When CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers a UE is not expected to receive a trigger for which the CSI reference resource is in subframe that does not belong to either subframe set.

For transmission mode 9 configured PMI/RI and feedback reporting modes the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* based on only the Channel-State Information (CSI) reference signals defined in [3]. For transmission mode 9 when PMI/RI reporting is disabled and other transmission modes and their respective reporting modes the UE shall derive the channel measurements for computing CQI based on CRS.

A combination of modulation scheme and transport block size corresponds to a CQI index if:

- the combination could be signalled for transmission on the PDSCH in the CSI reference resource according to the relevant Transport Block Size table, and
- the modulation scheme is indicated by the CQI index, and
- the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant.

The CSI reference resource is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates.
- In the time domain, the CSI reference resource is defined by a single downlink subframe $n\text{-}n_{CQI\_ref}$,
  - o where for periodic CSI reporting n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe;
  - o where for aperiodic CSI reporting n_{CQI_ref} is such that the reference resource is in the same valid downlink subframe as the corresponding CSI request in an uplink DCI format.
  - o where for aperiodic CSI reporting n_{CQI_ref} is equal to 4 and downlink subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

  A downlink subframe shall be considered to be valid if:

  - ▪ it is configured as a downlink subframe for that UE, and
  - ▪ except for transmission mode 9, it is not an MBSFN subframe, and
  - ▪ it does not contain a DwPTS field in case the length of DwPTS is $7680 \cdot T_s$ and less, and
  - ▪ it does not fall within a configured measurement gap for that UE, and
  - ▪ for periodic CSI reporting, it is an element of the CSI subframe set linked to the periodic CSI report when that UE is configured with CSI subframe sets.

  If there is no valid downlink subframe for the CSI reference resource, CSI reporting is omitted in uplink subframe *n*.

- In the layer domain, the CSI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronisation signals or PBCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- If CSI-RS is used for channel measurements, the ratio of PDSCH EPRE to CSI-RS EPRE is as given in Section 7.2.5
- For transmission mode 9 CSI reporting, if UE is configured for PMI/RI reporting, assume DMRS overhead is consistent with most recent reported rank
- Assume no REs allocated for CSI-RS and zero-power CSI-RS
- Assume no REs allocated for PRS
- The PDSCH transmission scheme given by Table 7.2.3-0 depending on the transmission mode currently configured for the UE (which may be the default mode).
- If CRS is used for channel measurements, the ratio of PDSCH EPRE to cell-specific RS EPRE is as given in Section 5.2 with the exception of ρ_A which shall be assumed to be
  - o $\rho_A = P_A + \Delta_{offset} + 10\log_{10}(2)$ [dB] for any modulation scheme, if the UE is configured with transmission mode 2 with 4 cell-specific antenna ports, or transmission mode 3 with 4 cell-specific antenna ports and the associated RI is equal to one;
  - o $\rho_A = P_A + \Delta_{offset}$ [dB] for any modulation scheme and any number of layers, otherwise.

  The shift Δ_{offset} is given by the parameter *nomPDSCH-RS-EPRE-Offset* which is configured by higher-layer signalling.

Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity
8	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing
9	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity Closed-loop spatial multiplexing with up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

7.2.4 Precoding Matrix Indicator (PMI) definition

For transmission modes 4, 5, 6 and 9, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). For transmission mode 8, the UE shall report PMI if configured with PMI/RI reporting. A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2.

For 2 and 4 antenna ports, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [3] as follows:

- For 2 antenna ports $\{0,1\}$ and an associated RI value of 1, a PMI value of $n \in \{0,1,2,3\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 1$.
- For 2 antenna ports $\{0,1\}$ and an associated RI value of 2, a PMI value of $n \in \{0,1\}$ corresponds to the codebook index $n+1$ given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 2$.
- For 4 antenna ports $\{0,1,2,3\}$, a PMI value of $n \in \{0,1,\cdots,15\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-2 of [3] with υ equal to the associated RI value.

For 8 antenna ports, each PMI value corresponds to a pair of codebook indices given in Table 6.3.4.2.3-3, 6.3.4.2.3-4, 6.3.4.2.3-5, 6.3.4.2.3-6, 6.3.4.2.3-7, 6.3.4.2.3-8, 6.3.4.2.3-9, or 6.3.4.2.3-10 of [3] as follows:

- For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a first PMI value of $n_1 \in \{0,1,\cdots,f(\upsilon)-1\}$ and a second PMI value of $n_2 \in \{0,1,\cdots,g(\upsilon)-1\}$ corresponds to the codebook indices n_1 and n_2 given in Table 6.3.4.2.3-*j* of [3] with υ equal to the associated RI value and where $j = 2+\upsilon$, $f(\upsilon) = \{16,16,4,4,4,4,4,1\}$ and $g(\upsilon) = \{16,16,16,8,1,1,1,1\}$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for the second precoding matrix indicator i_2.

For other transmission modes, PMI reporting is not supported.

7.2.5 Channel-State Information – Reference Symbol (CSI-RS) definition

The following parameters for CSI-RS are cell specific and are configured via higher layer signaling:

- Number of CSI-RS ports. The allowable values and port mapping are given in Section 6.10.5 of [3].
- CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- CSI RS subframe configuration $I_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- Subframe configuration period $T_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- Subframe offset $\Delta_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c. P_c is the assumed ratio of PDSCH EPRE to CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size.

A UE should not expect the configuration of CSI-RS and/or zero-power CSI-RS and PMCH in the same subframe of a serving cell.

7.3 UE procedure for reporting HARQ-ACK

For FDD and PUCCH format 1a/1b/3, when both HARQ-ACKand SR are transmitted in the same sub-frame a UE shall transmit the HARQ-ACKon its assigned HARQ-ACKPUCCH resource for a negative SR transmission and transmit the HARQ-ACKon its assigned SR PUCCH resource for a positive SR transmission.

For FDD with channel selection, when both HARQ-ACK and SR are transmitted in the same sub-frame a UE shall transmit spatially-bundled HARQ-ACK on its assigned SR PUCCH resource.

For TDD and all UL-DL configurations except configuration 5, two HARQ-ACKfeedback modes are supported by higher layer configuration.

- HARQ-ACK bundling, and
- HARQ-ACK multiplexing

For TDD UL-DL configuration 5, only HARQ-ACK bundling is supported.

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination when more than one serving cell is configured for a UE. In this case, if the serving cell is the primary cell, there is no PDCCH indicating downlink SPS release in the special subframe.

For TDD UL-DL configurations 1-6, the value of the Downlink Assignment Index (DAI) in DCI format 0/4, V_{DAI}^{UL}, detected by the UE according to Table 7.3-X in subframe $n-k'$, where k' is defined in Table 7.3-Y, represents the total number of subframes with PDSCH transmissions and with PDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$. The value V_{DAI}^{UL} includes all PDSCH transmission with and without corresponding PDCCH within all the subframe(s) $n-k$. In case neither PDSCH transmission, nor PDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0/4, V_{DAI}^{UL}, if transmitted, is set to 4.

For TDD UL-DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C denotes the accumulative number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$, where $k \in K$, and shall be updated from subframe to subframe. Denote V_{DAI}^{DL} as the value of the DAI in PDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C detected by the UE according to Table 7.3-X in subframe $n-k_m$, where k_m is the smallest value in the set K (defined in Table 10.1.3.1-1) such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C.

For all TDD UL-DL configurations, denote U_{DAI} as the total number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$, where $k \in K$. Denote N_{SPS}, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH within the subframe(s) $n-k$, where $k \in K$.

For TDD HARQ-ACK bundling or HARQ-ACK multiplexing and a subframe n with $M=1$, the UE shall generate one or two HARQ-ACK bits by performing a logical AND operation per codeword across M DL subframes associated with a single UL subframe, of all the corresponding $U_{DAI}+N_{SPS}$ individual PDSCH transmission HARQ-ACKs and individual ACK in response to received PDCCH indicating downlink SPS release, where M is the number of elements in the set K defined in Table 10.1.3.1-1. The UE shall detect if at least one downlink assignment has been missed, and for the case that the UE is transmitting on PUSCH the UE shall also determine the parameter N_{bundled}. For TDD UL-DL configuration 0, N_{bundled} shall be 1 if UE detects the PDSCH transmission with or without corresponding PDCCH within the subframe $n-k$, where $k \in K$.

- For the case that the UE is not transmitting on PUSCH in subframe *n* and TDD UL-DL configurations 1-6, if $U_{DAI}>0$ and $V_{DAI}^{DL} \neq (U_{DAI}-1) \bmod 4+1$, the UE detects that at least one downlink assignment has been missed.
- For the case that the UE is transmitting on PUSCH and the PUSCH transmission is adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE and TDD UL-DL configurations 1-6, if $V_{DAI}^{UL} \neq (U_{DAI}+N_{SPS}-1) \bmod 4+1$ the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords where N_{bundled} is determined by the UE as $N_{\text{bundled}}=V_{DAI}^{UL}+2$. If the UE does not detect any downlink assignment missing, N_{bundled} is determined by the UE as $N_{\text{bundled}}=V_{DAI}^{UL}$. UE shall not transmit HARQ-ACK if $U_{DAI}+N_{SPS}=0$ and $V_{DAI}^{UL}=4$.
- For the case that the UE is transmitting on PUSCH, and the PUSCH transmission is not based on a detected PDCCH with DCI format 0/4 intended for the UE and TDD UL-DL configurations 1-6, if $U_{DAI}>0$ and

$V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords. The UE determines $N_{\text{bundled}} = (U_{DAI} + N_{SPS})$ as the number of assigned subframes. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback $o_{c,0}^{ACK}\ o_{c,1}^{ACK}, \ldots, o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC is constructed as follows, where *c*≥0, $O_c^{ACK} = M$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial bundling is applied and $O_c^{ACK} = 2M$ otherwise.

The HARQ-ACK for a PDSCH transmission with a corresponding PDCCH or for a PDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK.

For TDD HARQ-ACK bundling, when the UE is configured by transmission mode 3, 4 or 8 defined in Section 7.1 and HARQ-ACK bits are transmitted on PUSCH, the UE shall always generate 2 HARQ-ACK bits assuming both codeword 0 and 1 are enabled. For the case that the UE detects only the PDSCH transmission associated with codeword 0 within the bundled subframes, the UE shall generate NACK for codeword 1.

Table 7.3-X: Value of Downlink Assignment Index

DAI MSB, LSB	V_{DAI}^{UL} or V_{DAI}^{DL}	Number of subframes with PDSCH transmission and with PDCCH indicating DL SPS release
0,0	1	1 or 5 or 9
0,1	2	2 or 6
1,0	3	3 or 7
1,1	4	0 or 4 or 8

Table 7.3-Y: Uplink association index *k*' for TDD

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
1			6	4				6	4	
2			4					4		
3			4	4	4					
4			4	4						
5			4							
6			7	7	5			7	7	

For TDD HARQ-ACK multiplexing and a subframe n with $M > 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. In case the UE is transmitting on PUSCH, the UE shall determine the number of HARQ-ACK feedback bits O^{ACK} and the HARQ-ACK feedback bits o_n^{ACK} , $n = 0,\ldots,O^{ACK} - 1$ to be transmitted in subframe *n* in case the UE is transmitting on PUSCH.

- If the PUSCH transmission is adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE, then $O^{ACK} = V_{DAI}^{UL}$ unless $V_{DAI}^{UL} = 4$ and $U_{DAI} + N_{SPS} = 0$ in which case the UE shall not transmit HARQ-ACK. The spatially bundled HARQ-ACK for a PDSCH transmission with a corresponding PDCCH or for a PDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{DAI(k)-1}^{ACK}$ where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C detected in subframe $n-k$. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH is mapped to $o_{O^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK.
- If the PUSCH transmission is not adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE, $O^{ACK} = M$, and o_i^{ACK} is associated with the spatially bundled HARQ-ACK for DL subframe $n-k_i$, where $k_i \in K$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the bundled HARQ-ACK or the multiple ACK/NAK responses (according to section 10.1) on its assigned HARQ-ACK PUCCH resources for a negative SR transmission. For a positive SR, the UE shall transmit $b(0), b(1)$ on its assigned SR PUCCH resource using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $U_{DAI} + N_{SPS}$ HARQ-ACK responses including ACK in response to PDCCH indicating downlink SPS release by spatial ACK/NAK bundling across multiple codewords within each PDSCH transmission. For TDD UL-DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed.

Table 7.3-1: Mapping between multiple HARQ-ACK responses and $b(0), b(1)$

Number of ACK among multiple ($U_{DAI} + N_{SPS}$) HARQ-ACK responses	$b(0), b(1)$
0 or None (UE detect at least one DL assignment is missed)	0, 0
1	1, 1
2	1, 0
3	0, 1
4	1, 1
5	1, 0
6	0, 1
7	1, 1
8	1, 0
9	0, 1

For TDD when both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame on the PUCCH, a UE shall transmit the CSI and $b(0), b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to section 5.2.3.4 in [4] with a_0'', a_1'' replaced by $b(0), b(1)$. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $U_{DAI} + N_{SPS}$ HARQ-ACK responses including ACK in response to PDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission.

For TDD UL-DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed.

When only HARQ-ACK or only a positive SR is transmitted a UE shall use PUCCH Format 1a/1b for the HARQ-ACK resource and PUCCH Format 1 for the SR resource as defined in section 5.4.1 in [3].

8 Physical uplink shared channel related procedures

For FDD, there shall be 8 uplink HARQ processes per serving cell for non-subframe bundling operation, i.e. normal HARQ operation, and 4 uplink HARQ processes for subframe bundling operation. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

In case higher layers configure the use of subframe bundling for FDD and TDD, the subframe bundling operation is only applied to UL-SCH, such that four consecutive uplink subframes are used.

8.0 UE procedure for transmitting the physical uplink shared channel

For FDD and normal HARQ operation, the UE shall upon detection on a given serving cell of a PDCCH with DCI format 0/4 and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+4* according to the PDCCH and PHICH information.

For FDD and normal HARQ operation, in case of uplink spatial multiplexing, if the UE detects a PHICH transmission and the UE does not detect a PDCCH with DCI format 4 in subframe *n* intended for the UE, the UE shall adjust the corresponding PUSCH retransmission in subframe *n+4* according to the PHICH information, and using the number of transmission layers and precoding matrix according to the most recent PDCCH, if the number of negatively acknowledged transport blocks is equal to the number of transport blocks indicated in the most recent PDCCH associated with the corresponding PUSCH.

For FDD and normal HARQ operation, in case of uplink spatial multiplexing, if the UE detects a PHICH transmission and the UE does not detect a PDCCH with DCI format 4 in subframe *n* intended for the UE, and if the number of negatively acknowledged transport blocks is not equal to the number of transport blocks indicated in the most recent PDCCH associated with the corresponding PUSCH then the UE shall adjust the corresponding PUSCH retransmission in subframe *n+4* according to the PHICH information, using the precoding matrix with codebook index 0 and the number of transmission layers equal to number of layers corresponding for the negatively acknowledged transport block from the most recent PDCCH.

If a UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected PDCCH with uplink DCI format to determine the serving cell for the corresponding PUSCH transmission.

For FDD and normal HARQ operation, if a PDCCH with CSI request field set to trigger an aperiodic CSI report, as described in section 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+4* UCI is mapped on the corresponding PUSCH transmission.

For TDD and normal HARQ operation, if a PDCCH with CSI request field set to trigger an aperiodic CSI report, as described in section 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+k* UCI is mapped on the corresponding PUSCH transmission where *k* is given by Table 8.2.

For FDD and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission in subframe *n-5* intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+4* according to the PDCCH and PHICH information.

For FDD and TDD, the NDI as signalled on PDCCH, the RV as determined in section 8.6.1, and the TBS as determined in section 8.6.2, shall be delivered to higher layers.

For TDD, the number of HARQ processes shall be determined by the DL/UL configuration (Table 4.2-2 of [3]), as indicated in Table 8-1.

Table 8-1: Number of synchronous UL HARQ processes for TDD

TDD UL/DL configuration	Number of HARQ processes for normal HARQ operation	Number of HARQ processes for subframe bundling operation
0	7	3
1	4	2
2	2	N/A
3	3	N/A
4	2	N/A
5	1	N/A
6	6	3

For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* if the MSB of the UL index in the PDCCH with uplink DCI format is set to 1 or PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in Section 9.1.2, with *k* given in Table 8-2. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe *n* or a PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in Section 9.1.2, or PHICH is received in subframe *n*=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe *n+7*. If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH with uplink DCI format are set in subframe *n*, the UE shall adjust the corresponding PUSCH transmission in both subframes *n+ k* and *n+7*, with *k* given in Table 8-2

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, if the MSB of the UL index in the DCI format 0 is set to 1 or if $I_{PHICH} = 0$, as defined in Section 9.1.2, with *k* given in Table 8-2, according to the PDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the PDCCH with DCI format 0 is set to 1 in subframe *n* or if $I_{PHICH} = 1$, as defined in Section 9.1.2, the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe *n+7*, according to the PDCCH and PHICH information.

Table 8-2 *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4
4									4	4
5									4	
6	7	7				7	7			5

Table 8-2a *l* for TDD configurations 0, 1 and 6

TDD UL/DL Configuration	subframe number *n*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	9	6				9	6			
1		2			3		2			3
6	5	5				6	6			8

A UE is semi-statically configured via higher layer signalling to transmit PUSCH transmissions signalled via PDCCH according to one of two uplink transmission modes, denoted mode 1 - 2 as defined in Table 8-3.If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-3 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI. Transmission mode 1 is the default uplink transmission mode for a UE until the UE is assigned an uplink transmission mode by higher layer signalling.

When a UE configured in transmission mode 2 receives a DCI Format 0 uplink scheduling grant, it shall assume that the PUSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

Table 8-3: PDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 8.0.2)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by PDCCH orders, the UE shall decode the PDCCH according to the combination defined in Table 8-4.

Table 8-4: PDCCH configured as PDCCH order to initiate random access procedure

DCI format	Search Space
DCI format 1A	Common and UE specific by C-RNTI

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-5 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding PDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

Table 8-5: PDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-6 and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these PDCCH is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling of PUSCH corresponding to the Random Access Response Grant in Section 6.2 and the PUSCH retransmission for the same transport block is by Temporary C-RNTI. Else, the scrambling of PUSCH corresponding to the Random Access Response Grant in Section 6.2 and the PUSCH retransmission for the same transport block is by C-RNTI.

Table 8-6: PDCCH configured by Temporary C-RNTI

DCI format	Search Space
DCI format 0	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8-7. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-7: PDCCH configured by TPC-PUCCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8.8. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-8: PDCCH configured by TPC-PUSCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

8.0.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 10) of the PUSCH, the UE transmission on the PUSCH is performed according to Section 5.3.2A.1 of [3].

8.0.2 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PUSCH, the UE transmission on the PUSCH is performed according to the applicable number of transmission layers as defined in Section 5.3.2A.2 of [3].

8.1 Resource Allocation for PDCCH with uplink DCI Format

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH with uplink DCI format where the selected resource allocation type for a decoded PDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the uplink PDCCH DCI format detected.

8.1.1 Uplink Resource allocation type 0

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB}. A resource allocation field in the scheduling grant consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{\mathrm{CRBs}} \geq 1$). The resource indication value is defined by

if $(L_{\mathrm{CRBs}} - 1) \leq \lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \rfloor$ then

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(L_{\mathrm{CRBs}} - 1) + RB_{\mathrm{START}}$$

else

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}} - L_{\mathrm{CRBs}} + 1) + (N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - RB_{\mathrm{START}})$$

8.1.2 Uplink Resource allocation type 1

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size *P* as given in table 7.1.6.1-1 for uplink system bandwidth $N_{\mathrm{RB}}^{\mathrm{UL}}$. A resource allocation field in the scheduling grant consists of a combinatorial index *r* corresponding to a starting and ending RBG index of resource block set 1, s_0 and $s_1 - 1$, and resource block set 2, s_2 and $s_3 - 1$ respectively, where *r* is given by equation $r = \sum_{i=0}^{M-1} \left\langle {N - s_i \atop M - i} \right\rangle$ defined in section 7.2.1 with *M*=4 and $N = \lceil N_{\mathrm{RB}}^{\mathrm{UL}} / P \rceil + 1$. Section 7.2.1 also defines ordering properties and range of values that s_i (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

8.2 UE sounding procedure

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling

- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C for TDD.

In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe, the UE shall only transmit the trigger type 1 SRS transmission.

A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

- Transmission comb k_{TC}, as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Starting physical resource block assignment n_{RRC}, as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- *duration*: single or indefinite (until disabled), as defined in [11] for trigger type 0

- *srs-ConfigIndex* I_{SRS} for SRS periodicity T_{SRS} and SRS subframe offset T_{offset}, as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{SRS,1}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1
- SRS bandwidth B_{SRS}, as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Frequency hopping bandwidth, b_{hop}, as defined in Section 5.5.3.2 of [3] for trigger type 0
- Cyclic shift n_{SRS}^{cs}, as defined in Section 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1
- Number of antenna ports N_p for trigger type 0 and each configuration of trigger type 1

For trigger type 1 and DCI format 4 three sets of SRS parameters are configured by higher layer signalling. The 2-bit SRS request field [4] in DCI format 4 indicates the SRS parameter set given in Table 8.1-1. For trigger type 1, a single set of SRS parameters is configured by higher layer signalling for each of the DCI formats 0/1A[/2B/2C] [*editor's note: more than one SRS parameters for 2B/2C is FFS*]. The SRS request field is 1 bit [4] for DCI formats 0/1A/2B[/2C], with a type 1 SRS triggered if the value of the SRS request field is set to '1'. A 1-bit SRS request field shall be included in DCI formats 0/1A/2B[/2C] if the UE is configured with SRS parameters for DCI formats 0/1A/2B[/2C] by higher-layer.

Table 8.1-1: SRS request value for trigger type 1 in DCI format 4

Value of SRS request field	Description
'00'	No type 1 SRS trigger
'01'	The 1st SRS parameter set configured by higher layers
'10'	The 2nd SRS parameter set configured by higher layers
'11'	The 3rd SRS parameter set configured by higher layers

The serving cell specific SRS transmission bandwidths C_{SRS} are configured by higher layers. The allowable values are given in Section 5.5.3.2 of [3].

The serving cell specific SRS transmission sub-frames are configured by higher layers. The allowable values are given in Section 5.5.3.3 of [3].

When antenna selection is enabled for a given serving cell for a UE that supports transmit antenna selection, the index $a(n_{SRS})$, of the UE antenna that transmits the SRS at time n_{SRS} is given by

$a(n_{SRS}) = n_{SRS} \bmod 2$, for both partial and full sounding bandwidth, and when frequency hopping is disabled (i.e., $b_{hop} \geq B_{SRS}$),

$$a(n_{SRS}) = \begin{cases} \left(n_{SRS} + \lfloor n_{SRS}/2 \rfloor + \beta \cdot \lfloor n_{SRS}/K \rfloor\right) \bmod 2 & \text{when } K \text{ is even} \\ n_{SRS} \bmod 2 & \text{when } K \text{ is odd} \end{cases}, \quad \beta = \begin{cases} 1 & \text{where } K \bmod 4 = 0 \\ 0 & \text{otherwise} \end{cases}$$

when frequency hopping is enabled (i.e., $b_{hop} < B_{SRS}$),

where values B_{SRS}, b_{hop}, N_b, and n_{SRS} are given in Section 5.5.3.2 of [3], and $K = \prod_{b'=b_{hop}}^{B_{SRS}} N_{b'}$ (where $N_{b_{hop}} = 1$ regardless of the N_b value), except when a single SRS transmission is configured for the UE.

A UE may be configured to transmit SRS on N_p antenna ports of a serving cell where N_p may be configured by higher layer signalling. For PUSCH transmission mode 1 $N_p \in \{0,1,2,4\}$ and for PUSCH transmission mode 2 $N_p \in \{0,1,2\}$ with two antenna ports configured for PUSCH and $N_p \in \{0,1,4\}$ with 4 antenna ports configured for PUSCH. A UE configured for SRS transmission on multiple antenna ports of a serving cell shall transmit SRS for all the configured transmit antenna ports within one SC-FDMA symbol of the same subframe of the serving cell. The SRS transmission bandwidth and starting physical resource block assignment are the same for all the configured antenna ports of a given serving cell.

A UE shall not transmit SRS whenever SRS and PUSCH transmissions happen to coincide in the same symbol.

For TDD, when one SC-FDMA symbol exists in UpPTS of a given serving cell, it can be used for SRS transmission. When two SC-FDMA symbols exist in UpPTS of a given serving cell, both can be used for SRS transmission and both can be assigned to the same UE.

A UE shall not transmit SRS whenever SRS and PUCCH format 2/2a/2b transmissions happen to coincide in the same subframe.

A UE shall not transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACKand/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *FALSE*. A UE shall transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACKand/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE*.

In UpPTS, whenever SRS transmission instance overlaps with the PRACH region for preamble format 4 or exceeds the range of uplink system bandwidth configured in the serving cell, the UE shall not transmit SRS.

The parameter *ackNackSRS-SimultaneousTransmission* provided by higher layers determines if a UE is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe. If it is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe, then in the cell specific SRS subframes UE shall transmit HARQ-ACK and SR using the shortened PUCCH format as defined in Section 5.4.1 of [3], where the HARQ-ACK or the SR symbol corresponding to the SRS location is punctured. This shortened PUCCH format shall be used in a cell specific SRS subframe even if the UE does not transmit SRS in that subframe. The cell specific SRS subframes are defined in Section 5.5.3.3 of [3]. Otherwise, the UE shall use the normal PUCCH format 1/1a/1b as defined in Section 5.4.1 of [3] for the transmission of HARQ-ACK and SR.

Trigger type 0 SRS configuration of a UE in a serving cell for SRS periodicity, T_{SRS}, and SRS subframe offset, T_{offset}, is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD, respectively. The periodicity T_{SRS} of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10, 20, 40, 80, 160, 320} ms or subframes. For the SRS periodicity T_{SRS} of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

Type 0 triggered SRS transmission instances in a given serving cell for TDD with $T_{\mathrm{SRS}} > 2$ and for FDD are the subframes satisfying $(10 \cdot n_f + k_{\mathrm{SRS}} - T_{offset}) \bmod T_{\mathrm{SRS}} = 0$, where for FDD $k_{\mathrm{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame, for TDD k_{SRS} is defined in Table 8.2-3. The SRS transmission instances for TDD with $T_{\mathrm{SRS}} = 2$ are the subframes satisfying $(k_{\mathrm{SRS}} - T_{offset}) \bmod 5 = 0$.

Trigger type 1 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\mathrm{SRS},1}$, and SRS subframe offset, $T_{offset,1}$, is defined in Table 8.2-4 and Table 8.2-5, for FDD and TDD, respectively. The periodicity $T_{\mathrm{SRS},1}$ of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10} ms or subframes. For the SRS periodicity $T_{\mathrm{SRS},1}$ of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and not configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH scheduling PUSCH/PDSCH on serving cell *c*.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH scheduling PUSCH/PDSCH with the value of carrier indicator field corresponding to serving cell *c*.

A UE configured for type 1 triggered SRS transmission on serving cell *c* upon detection of a positive SRS request in subframe *n* of serving cell *c* shall commence SRS transmission in the first subframe satisfying $n+k, k \geq 4$ and

$(10 \cdot n_f + k_{\mathrm{SRS}} - T_{offset,1}) \bmod T_{\mathrm{SRS},1} = 0$ for TDD with $T_{\mathrm{SRS},1} > 2$ and for FDD,

$(k_{\mathrm{SRS}} - T_{offset,1}) \bmod 5 = 0$ for TDD with $T_{\mathrm{SRS},1} = 2$

where for FDD $k_{\mathrm{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame n_f, for TDD k_{SRS} is defined in Table 8.2-3.

A UE configured for type 1 triggered SRS transmission is not expected to receive more than one type 1 SRS triggering event for the same subframe.

A UE shall not transmit SRS whenever SRS and a PUSCH transmission corresponding to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure coincide in the same subframe.

Table 8.2-1: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 36	20	I_{SRS} – 17
37 – 76	40	I_{SRS} – 37
77 – 156	80	I_{SRS} – 77
157 – 316	160	I_{SRS} – 157
317 – 636	320	I_{SRS} – 317
637 – 1023	reserved	reserved

Table 8.2-2: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 44	20	I_{SRS} – 25
45 – 84	40	I_{SRS} – 45
85 – 164	80	I_{SRS} – 85
165 – 324	160	I_{SRS} – 165
325 – 644	320	I_{SRS} – 325
645 – 1023	reserved	reserved

Table 8.2-3: k_{SRS} for TDD

	subframe index *n*											
	0	1		2	3	4	5	6		7	8	9
		1st symbol of UpPTS	2nd symbol of UpPTS					1st symbol of UpPTS	2nd symbol of UpPTS			
k_{SRS} in case UpPTS length of 2 symbols		0	1	2	3	4		5	6	7	8	9
k_{SRS} in case UpPTS length of 1 symbol		1		2	3	4		6		7	8	9

Table 8.2-4: UE Specific SRS Periodicity $T_{\text{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\text{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 31	reserved	reserved

Table 8.2-5: UE Specific SRS Periodicity $T_{\text{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\text{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 31	reserved	reserved

8.3 UE HARQ-ACK procedure

For Frame Structure type 1, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For Frame Structure type 2 UL/DL configuration 1-6, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following table 8.3-1.

For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH}=0$, as defined in Section 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following table 8.3-1. If, for Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH}=1$, as defined in

Section 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6.

Table 8.3-1 *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	1	2	3	4	5	6	7	8	9
0	7	4				7	4			
1		4			6		4			6
2				6					6	
3	6								6	6
4									6	6
5									6	
6	6	4				7	4			6

The physical layer in the UE shall deliver indications to the higher layers as follows:

For downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to the transport block in subframe *i*, ACK for that transport block shall be delivered to the higher layers;
- else NACK for that transport block shall be delivered to the higher layers.

For downlink subframe *i*, in case of a retransmission in the associated PUSCH subframe, if a transport block was disabled in the associated PUSCH subframe then ACK for that transport block shall be delivered to the higher layers.

8.4 UE PUSCH Hopping procedure

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding PDCCH with DCI format 0 is set to 1 and the uplink resource block assignment is type 0 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH resource allocation (RA) for the first slot of a subframe (*S1*) including the lowest index PRB ($n_{PRB}^{S1}(n)$) in subframe *n* from the resource allocation field in the latest PDCCH with DCI format 0 for the same transport block. If there is no PDCCH for the same transport block, the UE shall determine its hopping type based on

- the hopping information in the most recent semi-persistent scheduling assignment PDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled or
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The resource allocation field in DCI format 0 excludes either 1 or 2 bits used for hopping information as indicated by Table 8.4-1 below where the number of PUSCH resource blocks is defined as

$$N_{RB}^{PUSCH} = \begin{cases} N_{RB}^{UL} - \tilde{N}_{RB}^{HO} - \left(N_{RB}^{UL} \bmod 2\right) & \text{Type 1 PUSCH hopping} \\ N_{RB}^{UL} & \text{Type 2 } N_{sb} = 1 \text{ PUSCH hopping} \\ N_{RB}^{UL} - \tilde{N}_{RB}^{HO} & \text{Type 2 } N_{sb} > 1 \text{ PUSCH hopping} \end{cases}$$

For type 1 and type 2 PUSCH hopping, $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}} + 1$ if $N_{\mathrm{RB}}^{\mathrm{HO}}$ is an odd number where $N_{\mathrm{RB}}^{\mathrm{HO}}$ defined in [3]. $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y = \left\lceil \log_2 (N_{\mathrm{RB}}^{\mathrm{UL}} (N_{\mathrm{RB}}^{\mathrm{UL}} + 1)/2) \right\rceil - N_{UL\_hop}$, where N_{UL_hop} = 1 or 2 bits. The number of contiguous RBs that can be assigned to a type-1 hopping user is limited to $\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor$. The number of contiguous RBs that can be assigned to a type-2 hopping user is limited to min$\left(\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor, \left\lfloor N_{\mathrm{RB}}^{\mathrm{PUSCH}} / N_{sb} \right\rfloor \right)$, where the number of sub-bands N_{sb} is given by higher layers.

A UE performing PUSCH frequency hopping shall use one of two possible PUSCH frequency hopping types based on the hopping information. PUSCH hopping type 1 is described in section 8.4.1 and type 2 is described in section 8.4.2.

Table 8.4-1: Number of Hopping Bits N_{UL_hop} vs. System Bandwidth

System BW N_{RB}^{UL}	#Hopping bits for 2nd slot RA (N_{UL_hop})
6-49	1
50-110	2

The parameter *Hopping-mode* provided by higher layers determines if PUSCH frequency hopping is “inter-subframe” or “intra and inter-subframe”.

8.4.1 Type 1 PUSCH Hopping

For PUSCH hopping type 1 the hopping bit or bits indicated in Table 8.4-1 determine $\tilde{n}_{PRB}(i)$ as defined in Table 8.4-2. The lowest index PRB ($n_{PRB}^{S1}(i)$) of the 1st slot RA in subframe *i* is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}/2$, where $n_{PRB}^{S1}(i) = RB_{START}$, and RB_{START} is obtained from the uplink scheduling grant as in Section 8.4 and Section 8.1.

The lowest index PRB ($n_{PRB}(i)$) of the 2nd slot RA in subframe *i* is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}/2$.

The set of physical resource blocks to be used for PUSCH transmission are L_{CRBs} contiguously allocated resource blocks from PRB index $n_{PRB}^{S1}(i)$ for the 1st slot, and from PRB index $n_{PRB}(i)$ for the 2nd slot, respectively, where L_{CRBs} is obtained from the uplink scheduling grant as in Section 8.4 and Section 8.1.

If the *Hopping-mode* is "inter-subframe", the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB, where CURRENT_TX_NB is defined in [8].

8.4.2 Type 2 PUSCH Hopping

In PUSCH hopping type 2 the set of physical resource blocks to be used for transmission in slot n_{s} is given by the scheduling grant together with a predefined pattern according to [3] section 5.3.4. If the system frame number is not acquired by the UE yet, the UE shall not transmit PUSCH with type-2 hopping and $N_{sb} > 1$ for TDD, where N_{sb} is defined in [3].

Table 8.4-2: PDCCH DCI Format 0 Hopping Bit Definition

System BW N_{RB}^{UL}	Number of Hopping bits	Information in hopping bits	$\tilde{n}_{PRB}(i)$
6 – 49	1	0	$\left(\left\lfloor N_{RB}^{PUSCH}/2\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$,
		1	Type 2 PUSCH Hopping
50 – 110	2	00	$\left(\left\lfloor N_{RB}^{PUSCH}/4\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		01	$\left(-\left\lfloor N_{RB}^{PUSCH}/4\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		10	$\left(\left\lfloor N_{RB}^{PUSCH}/2\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		11	Type 2 PUSCH Hopping

8.5 UE Reference Symbol procedure

If UL sequence hopping is configured in a serving cell, it applies to all reference symbols (SRS, PUSCH and PUCCH RS).

8.6 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the “modulation and coding scheme and redundancy version” field (I_{MCS}), and
- check the “CSI request” bit field, and
- compute the total number of allocated PRBs (N_{PRB}) based on the procedure defined in Section 8.1, and
- compute the number of coded symbols for control information.

8.6.1 Modulation order and redundancy version determination

For $0 \le I_{\text{MCS}} \le 28$, the modulation order (Q_m) is determined as follows:

- If the UE is capable of supporting 64QAM in PUSCH and has not been configured by higher layers to transmit only QPSK and 16QAM, the modulation order is given by $Q_m^{'}$ in Table 8.6.1-1.
- If the UE is not capable of supporting 64QAM in PUSCH or has been configured by higher layers to transmit only QPSK and 16QAM, $Q_m^{'}$ is first read from Table 8.6.1-1. The modulation order is set to $Q_m = \min(4, Q_m^{'})$.
- If the parameter *ttiBundling* provided by higher layers is set to *TRUE*, then the resource allocation size is restricted to $N_{\text{PRB}} \le 3$ and the modulation order is set to $Q_m = 2$.

For $29 \le I_{\text{MCS}} \le 31$ the modulation order (Q_m) is determined as follows:

- if DCI format 0 is used and $I_{\text{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\text{MCS}} = 29$ for the enabled TB and the signalled number of transmission layers is 1, and if

- o the "CSI request" bit field is 1 bit and the bit is set to trigger an aperiodic report and, $N_{\mathrm{PRB}} \leq 4$ or,
- o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\mathrm{PRB}} \leq 4$ or,
- o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\mathrm{PRB}} \leq 20$,

then the modulation order is set to $Q_m = 2$.

- Otherwise, the modulation order shall be determined from the DCI transported in the latest PDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$. If there is no PDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$, the modulation order shall be determined from
  - o the most recent semi-persistent scheduling assignment PDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - o the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The UE shall use I_{MCS} and Table 8.6.1-1 to determine the redundancy version (rv_{idx}) to use in the physical uplink shared channel.

Table 8.6.1-1: Modulation, TBS index and redundancy version table for PUSCH

MCS Index I_{MCS}	Modulation Order $Q_m^{'}$	TBS Index I_{TBS}	Redundancy Version rv_{idx}
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
7	2	7	0
8	2	8	0
9	2	9	0
10	2	10	0
11	4	10	0
12	4	11	0
13	4	12	0
14	4	13	0
15	4	14	0
16	4	15	0
17	4	16	0
18	4	17	0
19	4	18	0
20	4	19	0
21	6	19	0
22	6	20	0
23	6	21	0
24	6	22	0
25	6	23	0
26	6	24	0
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

8.6.2 Transport block size determination

For $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-1 except if the transport block is disabled in DCI format 4 as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.17.2.2.

For $29 \le I_{MCS} \le 31$,

- if DCI format 0 is used and $I_{MCS} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{MCS} = 29$ for the enabled TB and the number of transmission layers is 1, and if
    - o the "CSI request" bit field is 1 bit and is set to trigger an aperiodic CSI report and $N_{PRB} \le 4$, or
    - o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and , $N_{PRB} \le 4$ or,
    - o the "CSI request" bit field is 2 bits and is triggering aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{PRB} \le 20$,

then there is no transport block for the UL-SCH and only the control information feedback for the current PUSCH reporting mode is transmitted by the UE.

- Otherwise, the transport block size shall be determined from the initial PDCCH for the same transport block using $0 \le I_{\mathrm{MCS}} \le 28$. If there is no initial PDCCH with an uplink DCI format for the same transport block using $0 \le I_{\mathrm{MCS}} \le 28$, the transport block size shall be determined from
    - the most recent semi-persistent scheduling assignment PDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
    - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

In DCI format 4 a transport block is disabled if either the combination of $I_{\mathrm{MCS}} = 0$ and $N_{\mathrm{PRB}} > 1$ or the combination of $I_{\mathrm{MCS}} = 28$ and $N_{\mathrm{PRB}} = 1$ is signalled, otherwise the transport block is enabled.

8.6.3 Control information MCS offset determination

Offset values are defined for single codeword PUSCH transmission and multiple codeword PUSCH transmission. Single codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset}^{HARQ-ACK}$, I_{offset}^{RI}, and I_{offset}^{CQI}, respectively.

Table 8.6.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers

$I_{offset}^{HARQ-ACK}$	$\beta_{offset}^{HARQ-ACK}$
0	2.000
1	2.500
2	3.125
3	4.000
4	5.000
5	6.250
6	8.000
7	10.000
8	12.625
9	15.875
10	20.000
11	31.000
12	50.000
13	80.000
14	126.000
15	1.0

Table 8.6.3-2: Mapping of RI offset values and the index signalled by higher layers

I_{offset}^{RI}	β_{offset}^{RI}
0	1.250
1	1.625
2	2.000
3	2.500
4	3.125
5	4.000
6	5.000
7	6.250
8	8.000
9	10.000
10	12.625
11	15.875
12	20.000
13	reserved
14	reserved
15	reserved

Table 8.6.3-3: Mapping of CQI offset values and the index signalled by higher layers

I_{offset}^{CQI}	β_{offset}^{CQI}
0	reserved
1	reserved
2	1.125
3	1.250
4	1.375
5	1.625
6	1.750
7	2.000
8	2.250
9	2.500
10	2.875
11	3.125
12	3.500

13	4.000
14	5.000
15	6.250

8.7 UE Transmit Antenna Selection

UE transmit antenna selection is configured by higher layers via parameters *ue-TransmitAntennaSelection* and *ue-TransmitAntennaSelection-r10* .

If UE transmit antenna selection is disabled or not supported by the UE, the UE shall transmit from UE port 0.

If closed-loop UE transmit antenna selection is enabled by higher layers the UE shall perform transmit antenna selection in response to the most recent command received via DCI Format 0 in section 5.3.3.2 of [4].

If open-loop UE transmit antenna selection is enabled by higher layers, the transmit antenna to be selected by the UE is not specified.

9 Physical downlink control channel procedures

9.1 UE procedure for determining physical downlink control channel assignment

9.1.1 PDCCH Assignment Procedure

The control region of each serving cell consists of a set of CCEs, numbered from 0 to $N_{\mathrm{CCE},k}-1$ according to Section 6.8.1 in [3], where $N_{\mathrm{CCE},k}$ is the total number of CCEs in the control region of subframe k . The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1,2,4,8\}$ is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate *m* of the search space $S_k^{(L)}$ are given by

$$L \cdot \left\{(Y_k + m') \bmod \lfloor N_{\mathrm{CCE},k} / L \rfloor\right\} + i$$

where Y_k is defined below, $i = 0,\cdots,L-1$. For the common search space $m' = m$. For the UE specific search space, for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then $m' = m + M^{(L)} \cdot n_{CI}$ where n_{CI} is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then $m' = m$, where $m = 0,\cdots,M^{(L)}-1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

The UE shall monitor one common search space at each of the aggregation levels 4 and 8 on the primary cell.

A UE not configured with a carrier indicator field shall monitor one UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell. A UE configured with a carrier indicator field shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signalling.

The common and UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell *c* shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field.

For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the UE specific search space for PDCCH with carrier indicator field.

A UE is not expected to monitor the PDCCH of a secondary cell if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured with carrier indicator field for a given serving cell and configured to monitor PDCCH candidates with CRC scrambled by C-RNTI with a common payload size and with the same first CCE index n_{CCE} (as described in section 10.1) in the

- common search space
- UE specific search space

may assume that only the PDCCH in the common search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the PDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

The aggregation levels defining the search spaces are listed in Table 9.1.1-1. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in Section 7.1.

Table 9.1.1-1: PDCCH candidates monitored by a UE.

Search space $S_k^{(L)}$			**Number of PDCCH candidates $M^{(L)}$**
Type	**Aggregation level L**	**Size [in CCEs]**	
UE-specific	1	6	6
	2	12	6
	4	8	2
	8	16	2
Common	4	16	4
	8	16	2

For the common search spaces, Y_k is set to 0 for the two aggregation levels $L=4$ and $L=8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level L, the variable Y_k is defined by

$$Y_k = (A \cdot Y_{k-1}) \bmod D$$

where $Y_{-1} = n_{\mathrm{RNTI}} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in section 7.1 in downlink and section 8 in uplink.

9.1.2 PHICH Assignment Procedure

For PUSCH transmissions scheduled from serving cell c in subframe *n*, a UE shall determine the corresponding PHICH resource of serving cell c in subframe $n + k_{PHICH}$, where k_{PHICH} is always 4 for FDD and is given in table 9.1.2-1 for TDD. For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

Table 9.1.2-1: k_{PHICH} for TDD

TDD UL/DL Configuration	subframe index *n*									
	0	1	2	3	4	5	6	7	8	9
0			4	7	6			4	7	6
1			4	6				4	6	
2			6					6		
3			6	6	6					
4			6	6						
5			6							
6			4	6	6			4	7	

The PHICH resource is identified by the index pair $(n_{PHICH}^{group}, n_{PHICH}^{seq})$ where n_{PHICH}^{group} is the PHICH group number and n_{PHICH}^{seq} is the orthogonal sequence index within the group as defined by:

$$n_{PHICH}^{group} = (I_{PRB\_RA} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$
$$n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where

- n_{DMRS} is mapped from the cyclic shift for DMRS field (according to Table 9.1.2-2) in the most recent PDCCH with uplink DCI format [4] for the transport block(s) associated with the corresponding PUSCH transmission. n_{DMRS} shall be set to zero, if there is no PDCCH with uplink DCI format for the same transport block, and
  - if the initial PUSCH for the same transport block is semi-persistently scheduled, or
  - if the initial PUSCH for the same transport block is scheduled by the random access response grant .
- N_{SF}^{PHICH} is the spreading factor size used for PHICH modulation as described in section 6.9.1 in [3].

- $$I_{PRB\_RA} = \begin{cases} I_{PRB\_RA}^{lowest\_index} & \text{for the first TB of a PUSCH with associated PDCCH or for the case of no associated PDCCH when the number of negatively acknowledged TBs is not equal to the number of TBs indicated in the most recent PDCCH associated with the corresponding PUSCH} \\ I_{PRB\_RA}^{lowest\_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH} \end{cases}$$

  where $I_{PRB\_RA}^{lowest\_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission

- N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described in section 6.9 of [3],

- $$I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$$

Table 9.1.2-2: Mapping between n_{DMRS} and the cyclic shift for DMRS field in PDCCH with uplink DCI format in [4]

Cyclic Shift for DMRS Field in PDCCH with uplink DCI format in [4]	n_{DMRS}
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

9.1.3 Control Format Indicator assignment procedure

PHICH duration is signalled by higher layers according to Table 6.9.3-1 in [3]. The duration signalled puts a lower limit on the size of the control region determined from the control format indicator (CFI). When $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, if extended PHICH duration is indicated by higher layers then the UE shall assume that CFI is equal to PHICH duration.

9.2 PDCCH validation for semi-persistent scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to ‘0’. In case of DCI formats 2, 2A, 2B and 2C, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

Table 9.2-1: Special fields for Semi-Persistent Scheduling Activation PDCCH Validation

	DCI format 0	DCI format 1/1A	DCI format 2/2A/2B/2C
TPC command for scheduled PUSCH	set to ‘00’	N/A	N/A
Cyclic shift DM RS	set to ‘000’	N/A	N/A
Modulation and coding scheme and redundancy version	MSB is set to ‘0’	N/A	N/A
HARQ process number	N/A	FDD: set to ‘000’ TDD: set to ‘0000’	FDD: set to ‘000’ TDD: set to ‘0000’
Modulation and coding scheme	N/A	MSB is set to ‘0’	For the enabled transport block: MSB is set to ‘0’
Redundancy version	N/A	set to ‘00’	For the enabled transport block: set to ‘00’

Table 9.2-1A: Special fields for Semi-Persistent Scheduling Release PDCCH Validation

	DCI format 0	DCI format 1A
TPC command for scheduled PUSCH	set to ‘00’	N/A
Cyclic shift DM RS	set to ‘000’	N/A
Modulation and coding scheme and redundancy version	set to ‘11111’	N/A
Resource block assignment and hopping resource allocation	Set to all ‘1’s	N/A
HARQ process number	N/A	FDD: set to ‘000’ TDD: set to ‘0000’
Modulation and coding scheme	N/A	set to ‘11111’
Redundancy version	N/A	set to ‘00’
Resource block assignment	N/A	Set to all ‘1’s

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 9.2-2

Table 9.2-2: PUCCH Resource value for Downlink Semi-Persistent Scheduling

Value of 'TPC command for PUCCH'	$n_{\text{PUCCH}}^{(1,p)}$
'00'	The first PUCCH resource value configured by the higher layers
'01'	The second PUCCH resource value configured by the higher layers
'10'	The third PUCCH resource value configured by the higher layers
'11'	The fourth PUCCH resource value configured by the higher layers

9.3 PDCCH control information procedure

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

10 Physical uplink control channel procedures

10.1 UE procedure for determining physical uplink control channel assignment

If the UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe n uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b or 2/2a/2b if the UE is not transmitting on PUSCH in subframe n
- on PUSCH if the UE is transmitting on PUSCH in subframe n unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b if the UCI consists only of HARQ-ACK/SR
- on PUCCH using format 2/2a/2b if the UCI consists only of CSI.
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK and periodic CSI with HARQ-ACK transmitted on PUCCH using format 1/1a/1b and the periodic CSI transmitted on PUSCH

If the UE is configured with more than one serving cell and is not configured for simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH if the UE is not transmitting on any PUSCH in subframe n if the UCI consists only of periodic CSI
- on primary cell PUSCH if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is transmitting on the primary cell PUSCH in subframe n unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted.
- on PUSCH of secondary cell with smallest *ScellIndex* if the UCI consists of only periodic CSI and/or HARQ-ACK and if the UE is not transmitting on primary cell PUSCH but is transmitting on at least one secondary cell PUSCH in subframe n .

- where reporting prioritization and collision handling of periodic CSI reports of a certain PUCCH type is given in Section 7.2.2.

If the UE is configured with more than one serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCIshall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCIconsists only of HARQ-ACK/SR

- on PUCCH using format 2/2a/2b if the UCIconsists only of CSI and is periodic.

- on PUCCH and primary cell PUSCH if the UCI consists of HARQ-ACK and periodic CSI and the UE is transmitting on the primary cell PUSCH in subframe n, in which case the HARQ-ACK is transmitted on PUCCH using format 1/1a/1b/3 and the periodic CSI transmitted on PUSCH unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic CSI is not transmitted.

- On PUCCH and PUSCH of secondary cell with smallest *ScellIndex* if the UCI consists of HARQ-ACK and periodic CSI and if the UE is not transmitting on primary cell PUSCH but is transmitting on at least one secondary cell PUSCH in subframe n, in which case, the HARQ-ACK is transmitted on PUCCH using format 1/1a/1b/3 and the periodic CSI transmitted on PUSCH.

UE transmits PUCCH only on the primary cell.

A UE is configured by higher layers to transmit HARQ-ACK on one antenna port $(p = p_0)$ or two antenna ports $(p \in [p_0, p_1])$.

Throughout the following sections, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted as k, the first subframe of the next radio frame is denoted as $k+1$.

10.1.1 PUCCH format information

Using the PUCCH formats defined in section 5.4.1 and 5.4.2 in [3], the following combinations of UCI on PUCCH are supported:

- Format 1a for 1-bit HARQ-ACK or in case of FDD for 1-bit HARQ-ACK with positive SR

- Format 1b for 2-bit HARQ-ACK or for 2-bit HARQ-ACK with positive SR

- Format 1b for up to 4-bit HARQ-ACK with channel selection when the UE is configured with more than one serving cell in the case of FDD or, in the case of TDD, when the UE is configured with a single serving cell

- Format 1 for positive SR

- Format 2 for a CSI report when not multiplexed with HARQ-ACK

- Format 2a for a CSI report multiplexed with 1-bit HARQ-ACK for normal cyclic prefix

- Format 2b for a CSI report multiplexed with 2-bit HARQ-ACK for normal cyclic prefix

- Format 2 for a CSI report multiplexed with HARQ-ACK for extended cyclic prefix

- Format 3 for up to 10-bit HARQ-ACK for FDD and for up to 20-bit HARQ-ACK for TDD

- Format 3 for up to 11-bit corresponding to 10-bit HARQ-ACK and 1-bit positive/negative SR for FDD and for up to 21-bit corresponding to 20-bit HARQ-ACK and 1-bit positive/negative SR for TDD.

A UE that supports up to 4 HARQ-ACK bits shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell.

A UE that supports more than 4 HARQ-ACK bits is configured by higher layer signalling to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK for TDD or when configured with more than one serving cell in FDD.

[For PUCCH format 3, a UE shall generate a NACK for a DTX HARQ-ACK response for a transport block associated with a configured serving cell. <editors note: this sentence is considered problematic by some companies in terms of reliable generation of proper number of NACKs >]

The scrambling initialization of PUCCH format 2, 2a, 2b and 3 is by C-RNTI.

In case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH and the UE is configured with a single serving cell, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, otherwise the CSI is dropped.

In case of collision between a CSI and an HARQ-ACK in a same subframe without PUSCH and the UE is configured with more than one serving cell, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set TRUE and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH indicating downlink SPS release only on the primary cell, otherwise CSI is dropped.

In case of collision between a periodic CSI and an HARQ-ACK in a same subframe with PUSCH, the periodic CSI is multiplexed with the HARQ-ACK in the PUSCH transmission in that subframe if the UE is not configured by higher layers simultaneous PUCCH and PUSCH transmissions. Otherwise, if the UE is configured by higher layers simultaneous PUCCH and PUSCH transmissions, the HARQ-ACK is transmitted in the PUCCH and the periodic CSI in transmitted in the PUSCH.

10.1.2 FDD HARQ-ACK feedback procedures

For FDD, a UE shall determine the number of HARQ-ACK bits, O, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. A UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in section 10.1.2.1 and procedures for more than one configured serving cell are given in section 10.1.2.2.

10.1.2.1 FDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,p)}$ for transmission of HARQ-ACK in subframe n on antenna port *p* for PUCCH format 1a/1b, where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$, the UE shall use $n_{\text{PUCCH}}^{(1,p=p_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port $p = p_0$, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port $p = p_1$ is given by $n_{\text{PUCCH}}^{(1,p=p_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH}}^{(1,p)}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0.

10.1.2.2 FDD HARQ-ACK procedures for more than one configured serving cell

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in section 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in section 10.1.2.2.2.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3.

10.1.2.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For FDD with two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n^{(1)}_{\text{PUCCH}}$ selected from A PUCCH resources, $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$ and $A \in [2,3,4]$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe n using PUCCH format 1b. HARQ-ACK(*j*) denote the ACK/NACK/DTX response for a transport block or SPS release PDCCH associated with serving cell, c where the transport block and serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.2.2.1-1.

[A UE configured with a transmission mode that supports up to two transport blocks on serving cell, c, shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH indicating downlink SPS release associated with the serving cell, c. <editors note: there is some disagreement on whether this sentence also applies to PUCCH Format 3>]

Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection

A	***HARQ-ACK(j)***			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
2	TB1 Primary cell	TB2 Secondary cell	NA	NA
3	TB1 Serving cell1	TB2 Serving cell1	TB3 Serving cell2	NA
4	TB1 Primary cell	TB2 Primary cell	TB3 Secondary cell	TB4 Secondary cell

The UE shall determine the A PUCCH resources, $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$ ordered according to the serving cell in increasing order of *j* given in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is $n^{(1)}_{\text{PUCCH,i}} = n_{\text{CCE,i}} + N^{(1)}_{\text{PUCCH}}$, and for transmission mode that support up to two transport blocks, the PUCCH resource $n^{(1)}_{\text{PUCCH},i+1}$ is given by $n^{(1)}_{\text{PUCCH},i+1} = n_{\text{CCE,i}} + 1 + N^{(1)}_{\text{PUCCH}}$ where $n_{\text{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding PDCCH and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the value of $n^{(1)}_{\text{PUCCH},i}$ is determined according to higher layer configuration and Table 9.2-2. For transmission mode that support up to two transport blocks, the PUCCH resource $n^{(1)}_{\text{PUCCH},i+1}$ is given by $n^{(1)}_{\text{PUCCH},i+1} = n^{(1)}_{\text{PUCCH},i} + 1$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH},i}$, and the value of $n^{(1)}_{\text{PUCCH},i+1}$ for the transmission mode that support up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that support up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\mathrm{PUCCH},i}, n^{(1)}_{\mathrm{PUCCH},i+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i}$.

Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'HARQ-ACK Resource for PUCCH'	$n^{(1)}_{\mathrm{PUCCH},i}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for $A = 2$

HARQ-ACK(0)	HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH},i}$	$b(0)b(1)$
ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,0
NACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	NACK/DTX	No Transmission	

Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for $A = 3$

HARQ-ACK(0)	**HARQ-ACK(1)**	**HARQ-ACK(2)**	$n^{(1)}_{\text{PUCCH},i}$	$b(0)b(1)$
ACK	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},1}$	1,0
NACK/DTX	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},2}$	1,1
ACK	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0,1
NACK/DTX	NACK/DTX	NACK	$n^{(1)}_{\text{PUCCH},2}$	0,0
NACK	NACK/DTX	DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
NACK/DTX	NACK	DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
DTX	DTX	DTX	No Transmission	

Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for $A = 4$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH},i}$	$b(0)b(1)$
ACK	ACK	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	0,1
NACK/DTX	ACK	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1,1
ACK	ACK	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1,0
ACK	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0,0
NACK/DTX	ACK	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0,0
NACK/DTX	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1,0
ACK	ACK	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1,1
ACK	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1,0
NACK/DTX	ACK	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0,1
NACK/DTX	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0,0
ACK	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,1
NACK/DTX	NACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
NACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	DTX	NACK/DTX	NACK/DTX	No Transmission	

10.1.2.2.2 PUCCH format 3 HARQ-ACK procedure

For FDD with two configured serving cells and PUCCH format 3, the UE shall use PUCCH resource $n^{(3,p)}_{\mathrm{PUCCH}}$ or $n^{(1,p)}_{\mathrm{PUCCH}}$ for transmission of HARQ-ACK in subframe n on antenna port p where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,p)}_{\mathrm{PUCCH}}$ with $n^{(1,p=p_0)}_{\mathrm{PUCCH}} = n_{\mathrm{CCE}} + N^{(1)}_{\mathrm{PUCCH}}$, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for $p = p_1$ is given by $n^{(1,p=p_1)}_{\mathrm{PUCCH}} = n_{\mathrm{CCE}} + 1 + N^{(1)}_{\mathrm{PUCCH}}$

- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(1,p)}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(3,p)}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p=p_0)}$ for antenna port p_0. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe..

Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'HARQ-ACK Resource for PUCCH'	$n_{\mathrm{PUCCH}}^{(3,p)}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

10.1.3 TDD HARQ-ACK feedback procedures

For TDD and one configured serving cell, two HARQ-ACK feedback modes are supported by higher layer configuration.

- HARQ-ACK bundling and
- HARQ-ACK multiplexing

For TDD UL-DL configuration 5 and one configured serving cell, only HARQ-ACK bundling is supported.

TDD HARQ-ACK bundling is performed per codeword across M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1, by a logical AND operation of all the individual PDSCH transmission (with and without corresponding PDCCH) HARQ-ACKs and ACK in response to PDCCH indicating downlink SPS release. For one configured serving cell the bundled 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD HARQ-ACK multiplexing and a subframe *n* with $M > 1$, where M is the number of elements in the set K defined in Table 10.1.3.1-1, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. PUCCH format 1b with channel selection is used in case of one configured serving cell. For TDD HARQ-ACK multiplexing and a subframe *n* with $M = 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is not performed, 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively for one configured serving cell.

In the case of TDD and more than one configured serving cell with PUCCH format 1b with channel selection and more than 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe for all configured cells is performed and the bundled HARQ-ACK bits for each configured serving cell is transmitted using PUCCH format 1b with channel selection. For TDD and more than one configured serving cell with PUCCH format 1b with channel selection and up to 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

In the case of TDD and more than one configured serving cell with PUCCH format 3 and more than 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs and PUCCH format 3 is used. For TDD and more than one configured serving cell with PUCCH format 3 and up to 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 3.

For TDD with PUCCH format 3, a UE shall determine the number of HARQ-ACK bits, O, associated with an UL subframe *n* based on the number of configured serving cells, the downlink transmission modes configured for each serving cell and M which is the number of elements in the set K defined in Table 10.1.3.1-1 according to $O = \sum_{c=1}^{C} O_c^{ACK}$ where C is the number of configured cells, and O_c^{ACK} is the number of HARQ-bits for the for the *c*-th serving cell defined in section 7.3.

TDD HARQ-ACK feedback procedures for one configured serving cell are given in section 10.1.3.1 and procedures for more than one configured serving cell are given in section 10.1.3.2.

10.1.3.1 TDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b with TDD HARQ-ACK bundling feedback mode.

For TDD HARQ-ACK bundling or TDD HARQ-ACK multiplexing for one configured serving cell and a subframe *n* with $M = 1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,p)}$ for transmission of HARQ-ACK in subframe n on antenna port *p* for PUCCH format 1a/1b, where

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH or there is PDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL-DL configuration (defined in Table 4.2-2 in [3]), the UE first selects a c value out of {0, 1, 2, 3} which makes $N_c \le n_{\text{CCE}} < N_{c+1}$ and shall use $n_{\text{PUCCH}}^{(1,p=p_0)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port $p = p_0$, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and the corresponding *m*, where k_m is the smallest value in set K such that UE detects a PDCCH in subframe $n-k_m$. For two antenna port transmission the PUCCH resource for HARQ-ACK bundling for antenna port $p = p_1$ is given by $n_{\text{PUCCH}}^{(1,p=p_1)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$ [where c value out of {0, 1, 2, 3} is chosen which makes $N_c \le n_{\text{CCE}} + 1 < N_{c+1}$].

- If there is only a PDSCH transmission where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,p)}$ with the value of $n_{\text{PUCCH}}^{(1,p)}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0.

Table 10.1.3.1-1: Downlink association set index K : $\{k_0, k_1, \cdots k_{M-1}\}$ for TDD

UL-DL Configuration	Subframe *n*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	-	4	-	-	6	-	4
1	-	-	7, 6	4	-	-	-	7, 6	4	-
2	-	-	8, 7, 4, 6	-	-	-	-	8, 7, 4, 6	-	-
3	-	-	7, 6, 11	6, 5	5, 4	-	-	-	-	-
4	-	-	12, 8, 7, 11	6, 5, 4, 7	-	-	-	-	-	-
5	-	-	13, 12, 9, 8, 7, 5, 4, 11, 6	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

For TDD HARQ-ACK multiplexing and sub-frame n with $M > 1$ and one configured serving cell, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denote $n_{\mathrm{PUCCH},i}^{(1)}$ as the PUCCH resource derived from sub-frame $n-k_i$ and HARQ-ACK(i) as the ACK/NACK/DTX response from sub-frame $n-k_i$, where $k_i \in K$ (defined in Table 10.1.3.1-1) and $0 \le i \le M-1$.

- For a PDSCH transmission or a PDCCH indicating downlink SPS release in sub-frame $n-k_i$ where $k_i \in K$, the PUCCH resource $n_{\mathrm{PUCCH},i}^{(1)} = (M-i-1)\cdot N_c + i \cdot N_{c+1} + n_{\mathrm{CCE},i} + N_{\mathrm{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{\mathrm{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$, and $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers.
- For a PDSCH transmission where there is not a corresponding PDCCH detected in subframe $n-k_i$, the value of $n_{\mathrm{PUCCH},i}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

Based on higher layer signalling a UE configured with a single serving cell will either perform channel selection either according to the set of Tables 10.1.3-2, 10.1.3-3, and 10.1.3-4 or according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7. For the selected table set indicated by higher layer signaling, the UE shall transmit $b(0), b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1)}$ in sub-frame n using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0), b(1)$ and the PUCCH resource $n_{\mathrm{PUCCH}}^{(1)}$ are generated by channel selection according to the selected set of Tables for *M* = 2, 3, and 4 respectively.

Table 10.1.3-2: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n_{\mathrm{PUCCH}}^{(1)}$	$b(0), b(1)$
ACK, ACK	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK	$n_{\mathrm{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 0
NACK, DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 0
DTX, DTX	No transmission	

Table 10.1.3-3: Transmission of HARQ-ACKmultiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\mathrm{PUCCH}}^{(1)}$	$b(0),b(1)$
ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX, ACK	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 1
ACK, NACK/DTX, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	0, 0
DTX, DTX, NACK	$n_{\mathrm{PUCCH},2}^{(1)}$	0, 1
DTX, NACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 0
NACK, NACK/DTX, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 0
DTX, DTX, DTX	No transmission	

Table 10.1.3-4: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0), b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK/DTX,NACK/DTX,NACK,DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK, DTX, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, NACK/DTX, NACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
DTX, DTX, DTX, DTX	No transmission	

Table 10.1.3-5: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3-6: Transmission of HARQ-ACK multiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0

ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3-7: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

10.1.3.2 TDD HARQ-ACK procedure for more than one configured serving cell

The TDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in section 10.1.3.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in section 10.1.3.2.2.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3 and TDD with more than one configured serving cell. TDD UL-DL configuration 5 with channel selection for two configured serving cells is not supported.

10.1.3.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cell and a subframe *n* with $M = 1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ selected from A PUCCH resources, $n^{(1)}_{\mathrm{PUCCH},i}$ where $0 \le i \le A-1$ and $A \in [2,3,4]$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 in subframe n using PUCCH format 1b. HARQ-ACK(*j*) denote the ACK/NACK/DTX response for a transport block or SPS release PDCCH associated with serving cell, c where the transport block and serving cell for HARQ-ACK(*j*) and A PUCCH resources is given by Table 10.1.2.2.1-1. The UE shall determine the A PUCCH resources, $n^{(1)}_{\mathrm{PUCCH},i}$ where $0 \le i \le A-1$ ordered according to the serving cell in increasing order of *j* given in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$ on the primary cell, the PUCCH resource is $n^{(1)}_{\mathrm{PUCCH},i} = (M-i-1)\cdot N_c + i\cdot N_{c+1} + n_{\mathrm{CCE},i} + N^{(1)}_{\mathrm{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, and for transmission mode that support up to two transport blocks, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i+1}$ is given by $n^{(1)}_{\mathrm{PUCCH},i+1} = (M-i-1)\cdot N_c + i\cdot N_{c+1} + n_{\mathrm{CCE},i} + 1 + N^{(1)}_{\mathrm{PUCCH}}$ where $n_{\mathrm{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding DCI assignment and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$, the value of $n^{(1)}_{\mathrm{PUCCH},i}$ is determined according to higher layer configuration and Table 9.2-2.

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\mathrm{PUCCH},i}$, and the value of $n^{(1)}_{\mathrm{PUCCH},i+1}$ for the transmission mode that support up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that support up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\mathrm{PUCCH},i}, n^{(1)}_{\mathrm{PUCCH},i+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i}$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH assignments on the secondary cells in a given subframe.

Table 10.1.3.2-1: Transmission of HARQ-ACK multiplexing for *A* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-2: Transmission of HARQ-ACK multiplexing for *A* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$

ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-3: Transmission of HARQ-ACK multiplexing for *A* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and sub-frame n with $M > 1$ and two configured serving cells, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denote $n^{(1)}_{\text{PUCCH},i}$ $0 \le i \le 3$ as the PUCCH resource derived from the transmissions in M DL sub-frames associated with the UL subframe n . $n^{(1)}_{\text{PUCCH},0}$ and $n^{(1)}_{\text{PUCCH},1}$ are associated with the PDSCH transmission(s) on the primary cell and $n^{(1)}_{\text{PUCCH},2}$ and $n^{(1)}_{\text{PUCCH},3}$ are associated with the PDSCH transmission(s) on the secondary cell.

For Primary cell:

- If for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected within the subframe(s) $n-k$, where $k \in K$,

  - o the value of $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2.

  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH within the subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) within the subframe(s) $n-k$, where $k \in K$ with the the DAI value in the PDCCH equal to '1', the PUCCH resource $n^{(1)}_{\text{PUCCH},i+1} = (M-i-1)\cdot N_c + i\cdot N_{c+1} + n_{\text{CCE},i} + 1 + N^{(1)}_{\text{PUCCH}}$ where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $n_{\text{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$ and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers.

  - o HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH transmission without a corresponding PDCCH. HARQ-ACK(j), $1 \le j \le M-1$, is the ACK/NACK/DTX response for the PDSCH transmission with corresponding PDCCH and DAI value in the PDCCH equal to 'j'.

- Otherwise,

  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH within the subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in section 9.2) within the subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resource $n^{(1)}_{\text{PUCCH},i} = (M-i-1)\cdot N_c + i\cdot N_{c+1} + n_{\text{CCE},i} + N^{(1)}_{\text{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, , where $n_{\text{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding PUCCH in subframe $n-k_i$, $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers, $i=0$ for the corresponding PDCCH with the DAI value equal to '1' and $i=1$ for the corresponding PDCCH with the DAI value equal to '2'.

  - o HARQ-ACK(j), $0 \le j \le M-1$, is the ACK/NACK/DTX response for the PDSCH transmission with corresponding PDCCH and DAI value in the PDCCH equal to '$j+1$'.

For Secondary cell:

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell within the subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources $n^{(1)}_{\text{PUCCH},i} = (M-i-1)\cdot N_c + i\cdot N_{c+1} + n_{\text{CCE},i} + N^{(1)}_{\text{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $n_{\text{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$, $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers, $i=2$ for the corresponding PDCCH with with the DAI value equal to '1' and $i=3$ for the the corresponding PDCCH with the DAI value equal to '2'.

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH within the subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH},2}$ and $n^{(1)}_{\text{PUCCH},3}$ is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding

PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2.

- HARQ-ACK(j), $0 \le j \le M-1$, is the ACK/NACK/DTX response for the PDSCH transmission with corresponding PDCCH and DAI value in the PDCCH equal to '$j+1$'.

A UE shall perform channel selection according to the Tables 10.1.3.2-4, 10.1.3.2-5, and 10.1.3.2-6 and transmit $b(0),b(1)$ on PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ in sub-frame n using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0),b(1)$ and the PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ are generated by channel selection according to if HARQ-ACK bundling is not performed, otherwise Tables 10.1.3.2-4 for M = 2.The value of $b(0),b(1)$ and the PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ are generated by channel selection according to 10.1.3.2-5, and 10.1.3.2-6 for M = 3, and 4 respectively.

[Table 10.1.3.2-4: Transmission of HARQ-ACK multiplexing for *M* = 2

Primary Cell HARQ-ACK(0), HARQ-ACK(1)	Secondary Cell HARQ-ACK(0), HARQ-ACK(1)	Resource $n^{(1)}_{\mathrm{PUCCH}}$	Constellation $b(0),b(1)$
ACK, ACK	ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
NACK, ACK	ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
ACK, NACK/DTX	ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
NACK, NACK/DTX	ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
DTX, any	ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
ACK, ACK	NACK, ACK	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
NACK, ACK	NACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
ACK, NACK/DTX	NACK, ACK	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1
NACK, NACK/DTX	NACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
DTX, any	NACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
ACK, ACK	ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
NACK, ACK	ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX	ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0
NACK, NACK/DTX	ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
DTX, any	ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
ACK, ACK	NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, ACK	DTX, any	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK, ACK	NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK, ACK	DTX, any	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
ACK, NACK/DTX	NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
ACK, NACK/DTX	DTX, any	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK, NACK/DTX	NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
NACK, NACK/DTX	DTX, any	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0

DTX, any	NACK, NACK/DTX	No Transmission
DTX, any	DTX, any	No Transmission

<editors note: this table has not yet been agreed – table will be updated after further agreements>]

Table 10.1.3.2-5: Transmission of HARQ-ACK multiplexing for *M* = 3

Primary Cell	Secondary Cell	Resource	Constellation
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)**	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$
ACK, ACK, ACK	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
ACK, NACK/DTX, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
NACK/DTX, any, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0
NACK/DTX, any, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
ACK, ACK, ACK	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
ACK, NACK/DTX, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK, any, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission	

Table 10.1.3.2-6: Transmission of HARQ-ACK multiplexing for *M* = 4

Primary Cell	Secondary Cell	Resource	Constellation
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)**	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1

ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	0, 1
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, ACK, ACK, NACK/DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	0, 1
ACK, ACK, NACK/DTX, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	0, 1
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1
ACK, DTX, DTX, DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1
ACK, ACK, ACK, ACK	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK, any, any, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0
NACK, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission	
DTX, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	No Transmission	

10.1.3.2.2 PUCCH format 3 HARQ-ACK procedure

For TDD HARQ-ACK multiplexing and sub-frame n with $M \geq 1$ and more than one configured serving cell and PUCCH format 3, where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p)}$ or $n_{\mathrm{PUCCH}}^{(1,p)}$ for transmission of HARQ-ACK in subframe n on antenna port *p* where

- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p)}$ with $n_{\mathrm{PUCCH}}^{(1,p=p_0)} = n_{\mathrm{CCE,i}} + N_{\mathrm{PUCCH}}^{(1)}$, where $n_{\mathrm{CCE,i}}$ is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for $p = p_1$ is given by $n_{\mathrm{PUCCH}}^{(1,p=p_1)} = n_{\mathrm{CCE,i}} + 1 + N_{\mathrm{PUCCH}}^{(1)}$

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(1,p)}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(1,p=p_0)}$ for antenna port p_0.

[for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) within the subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH equal to '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(3,p)}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 [corresponding to HARQ-ACK PUCCH' resource value of '0,0'. <editor's note; Proposal - some default value for PUCCH format 3 resource as TPC in PDCCH with DAI=1 is actual TPC.>]

- [for $M > 1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ with the DAI value in the PDCCH greater than or equal to '2' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) within the subframe(s) $n-k$, where $k \in K$ with the the DAI value in the PDCCH greater than or equal to '2', the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(3,p)}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments corresponding to primary cell with the DAI value greater than or equal to '2' within the subframe(s) $n-k$, where $k \in K$.]

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,p)}$ with the value of $n_{\mathrm{PUCCH}}^{(3,p)}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments corresponding to secondary cells within the subframe(s) $n-k$, where $k \in K$ and if detected, on all PDCCH assignments corresponding to primary cell with the DAI value greater than or equal to '2' within the subframe(s) $n-k$, where $k \in K$.

- For PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,p)}$ and a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,p=p_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,p=p_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,p=p_0)}$ for antenna port p_0.

10.1.4 HARQ-ACK Repetition procedure

HARQ-ACK repetition is enabled or disabled by a UE specific parameter *ackNackRepetition* configured by higher layers. Once enabled, the UE shall repeat any HARQ-ACK transmission with a repetition factor N_{ANRep}, where N_{ANRep} is provided by higher layers and includs the initial HARQ-ACK transmission, until HARQ-ACK repetition is disabled by higher layers. For a PDSCH transmission without a corresponding PDCCH detected, the UE shall transmit the corresponding HARQ-ACK response N_{ANRep} times using PUCCH resource $n_{\text{PUCCH}}^{(1,p)}$ configured by higher layers. For a PDSCH transmission with a corresponding PDCCH detected, or for a PDCCH indicating downlink SPS release, the UE shall first transmit the corresponding HARQ-ACK response once using PUCCH resource derived from the corresponding PDCCH CCE index (as described in Sections 10.1.2 and 10.1.3), and repeat the transmission of the corresponding HARQ-ACK response $N_{\text{ANRep}}-1$ times always using PUCCH resource $n_{\text{PUCCH, ANRep}}^{(1,p)}$, where $n_{\text{PUCCH, ANRep}}^{(1,p)}$ is configured by higher layers.

For TDD, HARQ-ACK repetition is only applicable for HARQ-ACK bundling and is not applicable for HARQ-ACK multiplexing.

A UE configured with one serving cell shall support both two antenna port transmission and HARQ-ACK repetition for PUCCH format 1a/1b but not PUCCH format 3.

[<editor's note: the following sentence is place holder for further agreements on HARQ-ACK repetition> A UE configured with one serving cell shall support HARQ-ACK repetition for PUCCH format 1a/1b/3.]

A UE configured with more than one serving cell shall not support HARQ-ACK repetition for PUCCH format 3 or PUCCH format 1b with channel selection.

10.1.5 Scheduling Request (SR) procedure

A UE is configured by higher layers to transmit the scheduling request (SR) on one antenna port or two antenna ports. The scheduling request shall be transmitted on the PUCCH resource(s) $n_{\text{PUCCH}}^{(1,p)} = n_{\text{PUCCH,SRI}}^{(1,p)}$ for antenna port *p* as defined in [3], where $n_{\text{PUCCH,SRI}}^{(1,p)}$ is configured by higher layers. The SR configuration for SR transmission periodicity $SR_{\text{PERIODICITY}}$ and SR subframe offset $N_{\text{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter *sr-ConfigIndex* I_{SR} given by higher layers.

SR transmission instances are the uplink subframes satisfying $\left(10\times n_f + \lfloor n_s/2 \rfloor - N_{\text{OFFSET,SR}}\right) \bmod SR_{\text{PERIODICITY}} = 0$.

Table 10.1.5-1: UE-specific SR periodicity and subframe offset configuration

SR configuration Index I_{SR}	SR periodicity (ms) $SR_{\text{PERIODICITY}}$	SR subframe offset $N_{\text{OFFSET,SR}}$
0 – 4	5	I_{SR}
5 – 14	10	$I_{SR}-5$
15 – 34	20	$I_{SR}-15$
35 – 74	40	$I_{SR}-35$
75 – 154	80	$I_{SR}-75$
155 – 156	2	$I_{SR}-155$
157	1	$I_{SR}-157$

10.2 Uplink HARQ-ACK timing

For FDD, the UE shall upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe *n*. If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in subframes $n-N_{\text{ANRep}}-3, \ldots, n-5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes n, $n+1$, …, $n+N_{\text{ANRep}}-1$;
- shall not transmit any other signal in subframes n, $n+1$, …, $n+N_{\text{ANRep}}-1$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3, \ldots, n+N_{\text{ANRep}}-5$.

For TDD, the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*. If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in a DL subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$) on PUCCH in UL subframe n and the next $N_{\text{ANRep}}-1$ UL subframes denoted as n_1, …, $n_{N_{\text{ANRep}}-1}$;
- shall not transmit any other signal in UL subframe n, $n_1, \ldots, n_{N_{\text{ANRep}}-1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes n_i-k, where $k \in K_i$, K_i is the set defined in Table 10.1.3.1-1 corresponding to UL subframe n_i, and $1 \le i \le N_{\text{ANRep}}-1$.

For TDD, HARQ-ACK bundling, if the UE detects that at least one downlink assignment has been missed as described in Section 7.3, the UE shall not transmit HARQ-ACK in case the UE is not transmitting on PUSCH.

The uplink timing for the ACK corresponding to a detected PDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

11 Physical multicast channel related procedures

11.1 UE procedure for receiving the physical multicast channel

The UE shall decode the PMCH when configured by higher layers. The UE may assume that an eNB transmission on the PMCH is performed according to Section 6.5 of [3].

The I_{MCS} for the PMCH is configured by higher layers. The UE shall use I_{MCS} for the PMCH and Table 7.1.7.1-1 to determine the modulation order (Q_m) and TBS index (I_{TBS}) used in the PMCH. The UE shall then follow the procedure in Section 7.1.7.2.1 to determine the transport block size, assuming N_{PRB} is equal to $N_{\mathrm{RB}}^{\mathrm{DL}}$. The UE shall set the redundancy version to 0 for the PMCH.

11.2 UE procedure for receiving MCCH change notification

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the M-RNTI, the UE shall decode the PDCCH according to the combination defined in table 11.2-1.

Table 11.2-1: PDCCH configured by M-RNTI

DCI format	Search Space
DCI format 1C	Common

The 8-bit information for MCCH change notification [11], as signalled on the PDCCH, shall be delivered to higher layers.

Annex A (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2006-09					Draft version created		0.0.0
2006-10					Endorsed by RAN1	0.0.0	0.1.0
2007-01					Inclusion of decisions from RAN1#46bis and RAN1#47	0.1.0	0.1.1
2007-01					Endorsed by RAN1	0.1.1	0.2.0
2007-02					Inclusion of decisions from RAN1#47bis	0.2.0	0.2.1
2007-02					Endorsed by RAN1	0.2.1	0.3.0
2007-02					Editor's version including decisions from RAN1#48 & RAN1#47bis	0.3.0	0.3.1
2007-03					Updated Editor's version	0.3.1	0.3.2
2007-03	RAN#35	RP-070171			For information at RAN#35	0.3.2	1.0.0
2007-03					Random access text modified to better reflect RAN1 scope	1.0.0	1.0.1
2007-03					Updated Editor's version	1.0.1	1.0.2
2007-03					Endorsed by RAN1	1.0.2	1.1.0
2007-05					Updated Editor's version	1.1.0	1.1.1
2007-05					Updated Editor's version	1.1.1	1.1.2
2007-05					Endorsed by RAN1	1.1.2	1.2.0
2007-08					Updated Editor's version	1.2.0	1.2.1
2007-08					Updated Editor's version – uplink power control from RAN1#49bis	1.2.1	1.2.2
2007-08					Endorsed by RAN1	1.2.2	1.3.0
2007-09					Updated Editor's version reflecting RAN#50 decisions	1.3.0	1.3.1
2007-09					Updated Editor's version reflecting comments	1.3.1	1.3.2
2007-09					Updated Editor's version reflecting further comments	1.3.2	1.3.3
2007-09					Updated Editor's version reflecting further comments	1.3.3	1.3.4
2007-09					Updated Edtior's version reflecting further comments	1.3.4	1.3.5
2007-09	RAN#37	RP-070731			Endorsed by RAN1	1.3.5	2.0.0
2007-09	RAN#37	RP-070737			For approval at RAN#37	2.0.0	2.1.0
12/09/07	RAN_37	RP-070737	-	-	Approved version	2.1.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	2	Update of 36.213	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0002	-	Update of TS36.213 according to changes listed in cover sheet	8.1.0	8.2.0
28/05/08	RAN_40	RP-080434	0003	1	PUCCH timing and other formatting and typo corrections	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0006	1	PUCCH power control for non-unicast information	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0008	-	UE ACK/NACK Procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0009	-	UL ACK/NACK timing for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0010	-	Specification of UL control channel assignment	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0011	-	Precoding Matrix for 2Tx Open-loop SM	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0012	-	Clarifications on UE selected CQI reports	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0013	1	UL HARQ Operation and Timing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0014	-	SRS power control	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0015	1	Correction of UE PUSCH frequency hopping procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0017	4	Blind PDCCH decoding	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0019	1	Tx Mode vs DCI format is clarified	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0020	-	Resource allocation for distributed VRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0021	2	Power Headroom	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0022	-	Clarification for RI reporting in PUCCH and PUSCH reporting modes	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0025	-	Correction of the description of PUSCH power control for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0026	-	UL ACK/NACK procedure for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0027	-	Indication of radio problem detection	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0028	-	Definition of Relative Narrowband TX Power Indicator	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0029	-	Calculation of $\Delta_{TF}(i)$ for UL-PC	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0030	-	CQI reference and set S definition, CQI mode removal, and Miscellanious	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0031	-	Modulation order and TBS determination for PDSCH and PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0032	-	On Sounding RS	8.2.0	8.3.0
28/05/08	RAN_40	RP-080426	0033	-	Multiplexing of rank and CQI/PMI reports on PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080466	0034	-	Timing advance command responding time	8.2.0	8.3.0
09/09/08	RAN_41	RP-080670	37	2	SRS hopping pattern for closed loop antenna selection	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	39	2	Clarification on uplink power control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	41	-	Clarification on DCI formats using resource allocation type 2	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	43	2	Clarification on tree structure of CCE aggregations	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	46	2	Correction of the description of PUCCH power control for TDD	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	47	1	Removal of CR0009	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	48	1	Correction of mapping of cyclic shift value to PHICH modifier	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	49	-	TBS disabling for DCI formats 2 and 2A	8.3.0	8.4.0

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
09/09/08	RAN_41	RP-080670	50	-	Correction of maximum TBS sizes	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	51	-	Completion of the table specifying the number of bits for the periodic feedback	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	54	-	Clarification of RNTI for PUSCH/PUCCH power control with DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	55	1	Clarification on mapping of Differential CQI fields	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	59	1	PUSCH Power Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	60	-	RB restriction and modulation order for CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	61	-	Modulation order determination for uplink retransmissions	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	62	2	Introducing missing L1 parameters into 36.213	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	63	2	Correcting the range and representation of delta_TF_PUCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	64	1	Adjusting TBS sizes to for VoIP	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	67	-	Correction to the downlink resource allocation	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	68	-	Removal of special handling for PUSCH mapping in PUCCH region	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	69	-	Correction to the formulas for uplink power control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	70	1	Definition of Bit Mapping for DCI Signalling	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	71	-	Clarification on PUSCH TPC commands	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	72	1	Reference for CQI/PMI Reporting Offset	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	74	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	75	-	Correction to the time alignment command	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	77	1	Correction of offset signalling of UL Control information MCS	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	78	2	DCI format1C	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	80	-	Correction to Precoder Cycling for Open-loop Spatial Multiplexing	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	81	1	Clarifying Periodic CQI Reporting using PUCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	84	1	CQI reference measurement period	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	86	-	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	87	-	PUCCH Reporting	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	88	1	Handling of Uplink Grant in Random Access Response	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	89	-	Correction to UL Hopping operation	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	90	-	DRS EPRE	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	92	-	Uplink ACK/NACK mapping for TDD	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	93	-	UL SRI Parameters Configuration	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	94	-	Miscellaneous updates for 36.213	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	95	-	Clarifying Requirement for Max PDSCH Coding Rate	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	96	-	UE Specific SRS Configuration	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	97	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	98	-	Processing of TPC bits in the random access response	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	100	1	Support of multi-bit ACK/NAK transmission in TDD	8.3.0	8.4.0
03/12/08	RAN_42	RP-081075	82	3	Corrections to RI for CQI reporting	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	83	2	Moving description of large delay CDD to 36.211	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	102	3	Reception of DCI formats	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	105	8	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	107	1	General correction of reset of power control and random access response message	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	108	2	Final details on codebook subset restrictions	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	109	-	Correction on the definition of Pmax	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	112	2	CQI/PMI reference measurement periods	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	113	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	114	-	RAN1/2 specification alignment on HARQ operation	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	115	-	Introducing other missing L1 parameters in 36.213	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	116	-	PDCCH blind decoding	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	117	-	PDCCH search space	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	119	-	Delta_TF for PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	120	-	Delta_preamble_msg3 parameter values and TPC command in RA response	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	122	1	Correction of offset signaling of uplink control information MCS	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	124	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	125	-	Clarification of the uplink index in TDD mode	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	126	-	Clarification of the uplink transmission configurations	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	127	2	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	128	-	Clarification of type-2 PDSCH resource allocation for format 1C	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	129	-	Clarification of uplink grant in random access response	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	130	-	UE sounding procedure	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	134	-	Change for determining DCI format 1A TBS table column indicator for broadcast control	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	135	-	Clarifying UL VRB Allocation	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	136	1	Correction for Aperiodic CQI	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	137	1	Correction for Aperiodic CQI Reporting	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	138	1	Correction to PUCCH CQI reporting mode for N^DL_RB <= 7	8.4.0	8.5.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
03/12/08	RAN_42	RP-081075	140	1	On sounding procedure in TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	141	1	Alignment of RAN1/RAN3 specification	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	143	1	TTI bundling	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	144	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	145	1	Timing relationship between PHICH and its associated PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	147	1	Definition of parameter for downlink reference signal transmit power	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	148	1	Radio link monitoring	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	149	1	Correction in 36.213 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	151	-	Nominal PDSCH-to-RS EPRE Offset for CQI Reporting	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	152	1	Support of UL ACK/NAK repetition in Rel-8	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	155	-	Clarification of misconfiguration of aperiodic CQI and SR	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	156	1	Correction of control information multiplexing in subframe bundling mode	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	157	-	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	158	1	UE transmit antenna selection	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	159	-	Clarification of spatial different CQI for CQI reporting Mode 2-1	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	160	1	Corrections for TDD ACK/NACK bundling and multiplexing	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	161	-	Correction to RI for Open-Loop Spatial Multiplexing	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	162	-	Correction of differential CQI	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	163	-	Inconsistency between PMI definition and codebook index	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	164	-	PDCCH validation for semi-persistent scheduling	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	165	1	Correction to the UE behavior of PUCCH CQI piggybacked on PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	166	-	Correction on SRS procedure when shortened PUCCH format is used	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	167	1	Transmission overlapping of physical channels/signals with PDSCH for transmission mode 7	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	169	-	Clarification of SRS and SR transmission	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	171	-	Clarification on UE behavior when skipping decoding	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	172	1	PUSCH Hopping operation corrections	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	173	-	Clarification on message 3 transmission timing	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	174	-	MCS handling for DwPTS	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	175	-	Clarification of UE-specific time domain position for SR transmission	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	176	1	Physical layer parameters for CQI reporting	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	177	-	A-periodic CQI clarification for TDD UL/DL configuration 0	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	179	1	Correction to the definitions of rho_A and rho_B (downlink power allocation)	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	180	-	Clarification of uplink A/N resource indication	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	181	-	PDCCH format 0 for message 3 adaptive retransmission and transmission of control information in message 3 during contention based random access procedure	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	182	-	To Fix the Discrepancy of Uplink Power Control and Channel Coding of Control Information in PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081122	183	1	CQI reporting for antenna port 5	8.4.0	8.5.0
03/12/08	RAN_42	RP-081110	168	1	Clarification on path loss definition	8.4.0	8.5.0
04/03/09	RAN_43	RP-090236	184	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	185	4	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	186	2	Delta_TF configuration for control only PUSCH	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	187	1	Correction to concurrent SRS and ACK/NACK transmission	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	191	1	PDCCH release for semi-persistent scheduling	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	192	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	193	-	Correction to subband differential CQI value to offset level mapping for aperiodic CQI reporting	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	194	-	Correction for DRS Collision handling	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	196	2	Alignment of RAN1/RAN4 specification on UE maximum output power	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	197	-	Transmission scheme for transmission mode 7 with SPS C-RNTI	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	198	-	Clarifying bandwidth parts for periodic CQI reporting and CQI refererence period	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	199	2	Correction to the ACK/NACK bundling in case of transmission mode 3 and 4	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	200	-	ACK/NAK repetition for TDD ACK/NAK multiplexing	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	201	-	Clarifying UL ACK/NAK transmission in TDD	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	202	-	Corrections to UE Transmit Antenna Selection	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	203	-	Correction to UE PUSCH hopping procedure	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	204	-	Correction to PHICH resource association in TTI bundling	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	205	-	Clarification of the length of resource assignment	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	206	-	Correction on ACK/NACK transmission for downlink SPS resource	8.5.0	8.6.0

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Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
					release		
04/03/09	RAN_43	RP-090236	207	-	Introduction of additional values of wideband CQI/PMI periodicities	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	208	2	Correction to CQI/PMI/RI reporting field	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	209	2	Correction to rho_A definition for CQI calculation	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	210	-	Correction to erroneous cases in PUSCH linear block codes	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	211	1	Removing RL monitoring start and stop	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	214	1	Correction to type-1 and type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	215	-	Contradicting statements on determination of CQI subband size	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	216	-	Corrections to SRS	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	219	2	Miscellaneous corrections on TDD ACKNACK	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	221	1	CR for Redundancy Version mapping function for DCI 1C	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	223	-	Scrambling of PUSCH corresponding to Random Access Response Grant	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	225	-	Removal of SRS with message 3	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	226	3	PRACH retransmission timing	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	227	-	Clarifying error handling of PDSCH and PUSCH assignments	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	228	-	Clarify PHICH index mapping	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	229	-	Correction of CQI timing	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	230	-	Alignment of CQI parameter names with RRC	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	231	1	Removal of 'Off' values for periodic reporting in L1	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	232	-	Default value of RI	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	233	1	Clarification of uplink timing adjustments	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	234	-	Clarification on ACK/NAK repetition	8.5.0	8.6.0
27/05/09	RAN_44	RP-090529	235	1	Correction to the condition of resetting accumulated uplink power correction	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	236	-	Correction to the random access channel parameters received from higher layer	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	237	-	Correction on TDD ACKNACK	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	238	1	Correction on CQI reporting	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	239	-	Correction on the HARQ process number	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	241	1	CR correction of the description on TTI-bundling	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	242	1	Clarify latest and initial PDCCH for PDSCH and PUSCH transmisisons, and NDI for SPS activation	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	243	-	Clarify DRS EPRE	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	244	1	Clarification on TPC commands for SPS	8.6.0	8.7.0
15/09/09	RAN_45	RP-090888	245	1	Correction to PUSCH hopping and PHICH mapping procedures	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	246	-	Clarification on subband indexing in periodic CQI reporting	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	247	2	Correction to DVRB operation in TDD transmission mode 7	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	249	-	Clarification of concurrent ACKNACK and periodic PMI/RI transmission on PUCCH for TDD	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	250	-	Clarify Inter-cell synchronization text	8.7.0	8.8.0
01/12/09	RAN_46	RP-091172	248	1	Introduction of LTE positioning	8.8.0	9.0.0
01/12/09	RAN_46	RP-091172	254	-	Clarification of PDSCH and PRS in combination for LTE positioning	8.8.0	9.0.0
01/12/09	RAN_46	RP-091177	255	5	Editorial corrections to 36.213	8.8.0	9.0.0
01/12/09	RAN_46	RP-091257	256	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
01/12/09	RAN_46	RP-091177	257	1	Add shorter SR periodicity	8.8.0	9.0.0
01/12/09	RAN_46	RP-091256	258	-	Introduction of LTE MBMS	8.8.0	9.0.0
17/12/09	RAN_46	RP-091257	256	1	Correction by MCC due to wrong implementation of CR0256r1 – Sentence is added to Single-antenna port scheme section 7.1.1	9.0.0	9.0.1
16/03/10	RAN_47	RP-100211	259	3	UE behavior when collision of antenna port 7/8 with PBCH or SCH happened and when distributed VRB is used with antenna port 7	9.0.1	9.1.0
16/03/10	RAN_47	RP-100210	260	1	MCCH change notification using DCI format 1C	9.0.1	9.1.0
16/03/10	RAN_47	RP-100211	263	-	Correction on PDSCH EPRE and UE-specific RS EPRE for Rel-9 enhanced DL transmissions	9.0.1	9.1.0
01/06/10	RAN_48	RP-100589	265	-	Clarification for TDD when multiplexing ACK/NACK with SR of ACK/NACK with CQI/PMI or RI	9.1.0	9.2.0
01/06/10	RAN_48	RP-100590	268	1	Clarification of PRS EPRE	9.1.0	9.2.0
14/09/10	RAN_49	RP-100900	269	-	Clarification on Extended CP support with Transmission Mode 8	9.2.0	9.3.0
07/12/10	RAN_50	RP-101320	270	-	Introduction of Rel-10 LTE-Advanced features in 36.213	9.3.0	10.0.0
27/12/10	-	-	-	-	Editorial change to correct a copy/past error in section 7.2.2	10.0.0	10.0.1
15/03/11	RAN_51	RP-110255	271	1	A clarification for redundancy version of PMCH	10.0.1	10.1.0
15/03/11	RAN_51	RP-110258	272	-	RLM Procedure with restricted measurements	10.0.1	10.1.0
15/03/11	RAN_51	RP-110256	273	-	Corrections to Rel-10 LTE-Advanced features in 36.213	10.0.1	10.1.0

History

Document history		
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