ETSI TS 137 213 V17.6.0 (2023-07)

LTE;
5G;
Physical layer procedures for shared spectrum channel access
(3GPP TS 37.213 version 17.6.0 Release 17)

Reference
RTS/TSGR-0137213vh60

Keywords
5G,LTE

ETSI

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Contents

Foreword

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

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1 Scope

The present document specifies and establishes the characteristics of the physical layer procedures for shared spectrum channel.

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 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

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

[4] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[5] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[6] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception".

[7] 3GPP TS 38.213: "NR; Physical layer procedures for control".

[8] 3GPP TS 38.214: "NR; Physical layer procedures for data".

[9] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description; Stage 2".

[10] 3GPP TS 38.212: "NR; Multiplexing and channel coding".

[11] 3GPP TS 38.211: "NR; Physical channels and Modulations".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

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

CW_p Contention window for a given priority class

$CW_{\max,p}$ Maximum contention window for a given priority class
$CW_{\min,p}$ Minimum contention window for a given priority class
$T_{m\cot,p}$ Maximum channel occupancy time for a given priority class
$T_{ulm\cot,p}$ Maximum Uplink channel occupancy time for a given priority class
X_{Thresh} Energy detection threshold
$X_{\text{Thresh\_max}}$ Maximum energy detection threshold

3.3 Abbreviations

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

AUL-DFI Autonomous UL Downlink feedback indication
CAPC Channel access priority class
COT Channel Occupancy Time
LAA Licensed Assisted Access
MCOT Maximum Channel Occupancy Time

4 Channel access procedure

4.0 General

Unless otherwise noted, the definitions below are applicable for the following terminologies used in this specification:

- A channel refers to a carrier or a part of a carrier consisting of a contiguous set of resource blocks (RBs) on which a channel access procedure is performed in shared spectrum.
- A channel access procedure is a procedure based on sensing that evaluates the availability of a channel for performing transmissions. The basic unit for sensing is a sensing slot with a duration $T_{sl} = 9\mu s$. The sensing slot duration T_{sl} is considered to be idle if an eNB/gNB or a UE senses the channel during the sensing slot duration, and determines that the detected power for at least $4\mu s$ within the sensing slot duration is less than energy detection threshold X_{Thresh}. Otherwise, the sensing slot duration T_{sl} is considered to be busy.
- A *channel occupancy* refers to transmission(s) on channel(s) by eNB/gNB/UE(s) after performing the corresponding channel access procedures in this clause.
- A *Channel Occupancy Time* refers to the total time for which eNB/gNB/UE and any eNB/gNB/UE(s) sharing the channel occupancy perform transmission(s) on a channel after an eNB/gNB/UE performs the corresponding channel access procedures described in this clause. For determining a *Channel Occupancy Time*, if a transmission gap is less than or equal to $25\mu s$, the gap duration is counted in the channel occupancy time. A channel occupancy time can be shared for transmission between an eNB/gNB and the corresponding UE(s).
- A *DL transmission burst* is defined as a set of transmissions from an eNB/gNB without any gaps greater than $16\mu s$. Transmissions from an eNB/gNB separated by a gap of more than $16\mu s$ are considered as separate DL transmission bursts. An eNB/gNB can transmit transmission(s) after a gap within a *DL transmission burst* without sensing the corresponding channel(s) for availability.
- A *UL transmission burst* is defined as a set of transmissions from a UE without any gaps greater than $16\mu s$. Transmissions from a UE separated by a gap of more than 16μs are considered as separate UL transmission bursts. A UE can transmit transmission(s) after a gap within a *UL transmission burs*t without sensing the corresponding channel(s) for availability.
- A *discovery burst* refers to a DL transmission burst including a set of signal(s) and/or channel(s) confined within a window and associated with a duty cycle. The *discovery burst* can be any of the following:

- Transmission(s) initiated by an eNB that includes a primary synchronization signal (PSS), secondary synchronization signal (SSS) and cell-specific reference signal(s)(CRS) and may include non-zero power CSI reference signals (CSI-RS).

- Transmission(s) initiated by a gNB that includes at least an SS/PBCH block consisting of a primary synchronization signal (PSS), secondary synchronization signal (SSS), physical broadcast channel (PBCH) with associated demodulation reference signal (DM-RS) and may also include CORESET for PDCCH scheduling PDSCH with SIB1, and PDSCH carrying SIB1 and/or non-zero power CSI reference signals (CSI-RS).

4.1 Downlink channel access procedures

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

In this clause, X_{Thresh} for sensing is adjusted as described in clause 4.1.5 when applicable.

A gNB performs channel access procedures in this clause unless the higher layer parameter *channelAccessMode-r16* is provided and *channelAccessMode-r16 ='semiStatic'*.

4.1.1 Type 1 DL channel access procedures

This clause describes channel access procedures to be performed by an eNB/gNB where the time duration spanned by the sensing slots that are sensed to be idle before a downlink transmission(s) is random. The clause is applicable to the following transmissions:

- Transmission(s) initiated by an eNB including PDSCH/PDCCH/EPDCCH, or

- Any transmission(s) initiated by a gNB.

The eNB/gNB may transmit a transmission after first sensing the channel to be idle during the sensing slot durations of a defer duration T_d and after the counter N is zero in step 4. The counter N is adjusted by sensing the channel for additional sensing slot duration(s) according to the steps below:

1) set $N = N_{init}$, where N_{init} is a random number uniformly distributed between 0 and CW_p, and go to step 4;

2) if $N > 0$ and the eNB/gNB chooses to decrement the counter, set $N = N - 1$;

3) sense the channel for an additional sensing slot duration, and if the additional sensing slot duration is idle, go to step 4; else, go to step 5;

4) if $N = 0$, stop; else, go to step 2.

5) sense the channel until either a busy sensing slot is detected within an additional defer duration T_d or all the sensing slots of the additional defer duration T_d are detected to be idle;

6) if the channel is sensed to be idle during all the sensing slot durations of the additional defer duration T_d, go to step 4; else, go to step 5;

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

The defer duration T_d consists of duration $T_f = 16\mu s$ immediately followed by m_p consecutive sensing slot durations T_{sl}, and T_f includes an idle sensing slot duration T_{sl} at start of T_f.

$CW_{min,p} \leq CW_p \leq CW_{max,p}$ is the contention window. CW_p adjustment is described in clause 4.1.4.

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

m_p, $CW_{min,p}$, and $CW_{max,p}$ are based on a channel access priority class p associated with the eNB/gNB transmission, as shown in Table 4.1.1-1.

An eNB/gNB shall not transmit on a channel for a *Channel Occupancy Time* that exceeds $T_{m\,cot,p}$ where the channel access procedures are performed based on a channel access priority class p associated with the eNB/gNB transmissions, as given in Table 4.1.1-1.

If an eNB/gNB transmits discovery burst(s) as described in clause 4.1.2 when $N > 0$ in the procedure above, the eNB/gNB shall not decrement N during the sensing slot duration(s) overlapping with discovery burst(s).

A gNB may use any channel access priority class for performing the procedures above to transmit transmission(s) including discovery burst(s) satisfying the conditions described in this clause.

A gNB shall use a channel access priority class applicable to the unicast user plane data multiplexed in PDSCH for performing the procedures above to transmit transmission(s) including unicast PDSCH with user plane data.

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

Table 4.1.1-1: Channel Access Priority Class (CAPC)

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

4.1.1.1 Regional limitations on channel occupancy time

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

4.1.2 Type 2 DL channel access procedures

This clause describes channel access procedures to be performed by an eNB/gNB where the time duration spanned by sensing slots that are sensed to be idle before a downlink transmission(s) is deterministic.

If an eNB performs Type 2 DL channel access procedures, it follows the procedures described in clause 4.1.2.1.

Type 2A channel access procedures as described in clause 4.1.2.1 are only applicable to the following transmission(s) performed by an eNB/gNB:

- Transmission(s) initiated by an eNB including discovery burst and not including PDSCH where the transmission(s) duration is at most $1ms$, or
- Transmission(s) initiated by a gNB with only discovery burst or with discovery burst multiplexed with non-unicast information, where the transmission(s) duration is at most $1ms$, and the discovery burst duty cycle is at most $1/20$, or

- Transmission(s) by an eNB/ gNB following transmission(s) by a UE after a gap of $25\mu s$ in a shared channel occupancy as described in clause 4.1.3.

Type 2B or Type 2C DL channel access procedures as described in clause 4.1.2.2 and 4.1.2.3, respectively, are applicable to the transmission(s) performed by a gNB following transmission(s) by a UE after a gap of $16\mu s$ or up to $16\mu s$, respectively, in a shared channel occupancy as described in clause 4.1.3.

4.1.2.1 Type 2A DL channel access procedures

An eNB/gNB may transmit a DL transmission immediately after sensing the channel to be idle for at least a sensing interval $T_{short\_dl} = 25\mu s$. T_{short_dl} consists of a duration $T_f = 16\mu s$ immediately followed by one sensing slot and T_f includes a sensing slot at start of T_f. The channel is considered to be idle for T_{short_dl} if both sensing slots of T_{short_dl} are sensed to be idle.

4.1.2.2 Type 2B DL channel access procedures

A gNB may transmit a DL transmission immediately after sensing the channel to be idle within a duration of $T_f = 16\mu s$. T_f includes a sensing slot that occurs within the last $9\mu s$ of T_f. The channel is considered to be idle within the duration T_f if the channel is sensed to be idle for a total of at least $5\mu s$ with at least $4\mu s$ of sensing occurring in the sensing slot.

4.1.2.3 Type 2C DL channel access procedures

When a gNB follows the procedures in this clause for transmission of a DL transmission, the gNB does not sense the channel before transmission of the DL transmission. The duration of the corresponding DL transmission is at most $584\mu s$.

4.1.3 DL channel access procedures in a shared channel occupancy

For the case where an eNB shares a channel occupancy initiated by a UE, the eNB may transmit a transmission that follows an autonomous PUSCH transmission by the UE as follows:

- If 'COT sharing indication' in AUL-UCI in subframe n indicates '1', an eNB may transmit a transmission in subframe $n + X$, where X is subframeOffsetCOT-Sharing, including PDCCH but not including PDSCH on the same channel immediately after performing Type 2A DL channel access procedures in clause 4.1.2.1, if the duration of the PDCCH is less than or equal to duration of two OFDM symbols and it shall contain at least AUL-DFI or UL grant to the UE from which the PUSCH transmission indicating COT sharing was received.

If a gNB shares a channel occupancy initiated by a UE using the channel access procedures described in clause 4.2.1.1 on a channel, the gNB may transmit a transmission that follows a UL transmission on scheduled resources or a PUSCH transmission on configured resources by the UE after a gap as follows:

- The transmission shall contain transmission to the UE that initiated the channel occupancy and can include non-unicast and/or unicast transmissions where any unicast transmission that includes user plane data is only transmitted to the UE that initiated the channel occupancy.
  - If the higher layer parameters *ul-toDL-COT-SharingED-Threshold-r16* is not provided, the transmission shall not include any unicast transmissions with user plane data and the transmission duration is not more than the duration of 2, 4 and 8 symbols for subcarrier spacing of 15, 30 and 60 kHz of the corresponding channel, respectively.
- If the gap is up to $16\mu s$, the gNB can transmit the transmission on the channel after performing Type 2C DL channel access as described in clause 4.1.2.3.
- If the gap is $25\mu s$ or $16\mu s$, the gNB can transmit the transmission on the channel after performing Type 2A or Type 2B DL channel access procedures as described in clause 4.1.2.1 and 4.1.2.2, respectively.

For the case where a gNB shares a channel occupancy initiated by a UE with configured grant PUSCH transmission, the gNB may transmit a transmission that follows the configured grant PUSCH transmission by the UE as follows:

- If the higher layer parameter *ul-toDL-COT-SharingED-Threshold-r16* is provided, the UE is configured by *cg-COT-SharingList-r16* where *cg-COT-SharingList-r16* provides a table configured by higher layer. Each row of the table provides a channel occupancy sharing information given by higher layer parameter *CG-COT-Sharing-r16*. One row of the table is configured for indicating that the channel occupancy sharing is not available.

  - If the 'COT sharing information' in CG-UCI detected in slot *n* indicates a row index that corresponds to a *CG-COT-Sharing-r16* that provides channel occupancy sharing information, the gNB can share the UE channel occupancy assuming a channel access priority class *p= channelAccessPriority-r16*, starting from slot *n+O*, where *O=offset-r16* slots, for a duration of *D=duration-r16* slots where *duration-r16*, *offset-r16*, and *channelAccessPriority-r16* are higher layer parameters provided by *CG-COT-Sharing-r16*.

- If the higher layer parameter *ul-toDL-COT-SharingED-Threshold-r16* is not provided, and if 'COT sharing information' in CG-UCI indicates '1', the gNB can share the UE channel occupancy and start the DL transmission X= *cg-COT-SharingOffset-r16**14 symbols from the end of the slot where CG-UCI is detected, where *cg-COT-SharingOffset-r16* is provided by higher layer. The transmission shall not include any unicast transmissions with user plane data and the transmission duration is not more than the duration of 2, 4 and 8 symbols for subcarrier spacing of 15, 30 and 60 kHz of the corresponding channel, respectively.

For the case where a gNB uses channel access procedures as described in clause 4.1.1 to initiate a transmission and shares the corresponding channel occupancy with a UE that transmits a transmission as described in clause 4.2.1.2, the gNB may transmit a transmission within its channel occupancy that follows the UE's transmission if any gap between any two transmissions in the gNB channel occupancy is at most $25\mu s$. In this case the following applies:

- If the gap is $25\mu s$ or $16\mu s$, the gNB can transmit the transmission on the channel after performing Type 2A or 2B DL channel access procedures as described in clause 4.1.2.1 and 4.1.2.2, respectively.

- If the gap is up to $16\mu s$, the gNB can transmit the transmission on the channel after performing Type 2C DL channel access as described in clause 4.1.2.3.

4.1.4 Contention window adjustment procedures

If an eNB/gNB transmits transmissions including PDSCH that are associated with channel access priority class p on a channel, the eNB/gNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in clause 4.1.1 for those transmissions as described in this clause.

4.1.4.1 Contention window adjustment procedures for transmissions by eNB

If an eNB transmits transmissions including PDSCH that are associated with channel access priority class p on a channel, the eNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in clause 4.1.1 for those transmissions using the following steps:

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

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

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

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

For determining Z,

- if the eNB transmission(s) for which HARQ-ACK feedback is available start in the second slot of subframe k, HARQ-ACK values corresponding to PDSCH transmission(s) in subframe $k+1$ are also used in addition to the HARQ-ACK values corresponding to PDSCH transmission(s) in subframe k.

- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on the same LAA SCell,

- if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB, or if the eNB detects 'DTX', 'NACK/DTX' or 'any' state, it is counted as NACK.

- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on another serving cell,
  - if the HARQ-ACK feedback for a PDSCH transmission is detected by the eNB, 'NACK/DTX' or 'any' state is counted as NACK, and 'DTX' state is ignored.
  - if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB
    - if PUCCH format 1b with channel selection is expected to be used by the UE, 'NACK/DTX' state corresponding to 'no transmission' as described in Clauses 10.1.2.2.1, 10.1.3.1 and 10.1.3.2.1 is counted as NACK, and 'DTX' state corresponding to 'no transmission' is ignored in [4].
    - Otherwise, the HARQ-ACK for the PDSCH transmission is ignored.
- if a PDSCH transmission has two codewords, the HARQ-ACK value of each codeword is considered separately
- bundled HARQ-ACK across M subframes is considered as M HARQ-ACK responses.

If the eNB transmits transmissions including PDCCH/EPDCCH with DCI format 0A/0B/4A/4B and not including PDSCH that are associated with channel access priority class p on a channel starting from time t_0, the eNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in clause 4.1.1 for those transmissions using the following steps:

1) for every priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{min,p}$
2) if less than 10% of the UL transport blocks scheduled by the eNB using Type 2 channel access procedure (described in clause 4.2.1.2) in the time interval between t_0 and $t_0 + T_{CO}$ have been received successfully, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value and remain in step 2; otherwise, go to step 1.

T_{CO} is computed as described in clause 4.2.1.0.3.

4.1.4.2 Contention window adjustment procedures for DL transmissions by gNB

If a gNB transmits transmissions including PDSCH that are associated with channel access priority class p on a channel, the gNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in clause 4.1.1 for those transmissions using the following steps:

1) For every priority class $p \in \{1,2,3,4\}$, set $CW_p = CW_{min,p}$.
2) If HARQ-ACK feedback is available after the last update of CW_p , go to step 3. Otherwise, if the gNB transmission after procedure described in clause 4.1.1 does not include a retransmission or would be transmitted within a duration T_w from the end of the *reference duration* corresponding to the earliest DL channel occupancy after the last update of CW_p, go to step 5; otherwise go to step 4.
3) The HARQ-ACK feedback(s) corresponding to PDSCH(s) in the reference duration for the latest DL channel occupancy for which HARQ-ACK feedback is available is used as follows:
   a. If at least one HARQ-ACK feedback is 'ACK' for PDSCH(s) with transport block based feedback or at least 10% of HARQ-ACK feedbacks is 'ACK' for PDSCH CBGs transmitted at least partially on the channel with code block group based feedback, go to step 1; otherwise go to step 4.
4) Increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value.
5) For every priority class p $\in \{1,2,3,4\}$, maintain $\mathrm{CW_p}$ as it is; go to step 2.

The *reference duration* and duration T_w in the procedure above are defined as follows:

- The *reference duration* corresponding to a channel occupancy initiated by the gNB including transmission of PDSCH(s) is defined in this clause as a duration starting from the beginning of the channel occupancy until the end of the first slot where at least one unicast PDSCH is transmitted over all the resources allocated for the