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TECHNICAL SPECIFICATION

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Physical layer procedures for control
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1 Scope

The present document specifies and establishes the characteristics of the physical layer procedures for control operations in 5G-NR.

2 References

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

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

[2] 3GPP TS 38.201: "NR; Physical Layer – General Description"

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

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

[5] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

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

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

[8-1] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[8-2] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[8-3] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios"

[8-4] 3GPP TS 38.101-4: "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[10] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[13] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"

[14] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"

[15] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access"

[16] 3GPP TS 38.473: "F1 application protocol (F1AP)"

[17] 3GPP TS 38.304: "NR; User Equipment (UE) procedures in Idle mode and RRC Inactive state"

[18] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities"

[19] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description"

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3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1, TR 21.905] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1, TR 21.905]. A parameter referenced in *italics* is provided by higher layers.

3.2 Symbols

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

3.3 Abbreviations

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

BPRE	Bits per resource element
BWP	Bandwidth part
CB	Code block
CBG	Code block group
CBR	Channel busy ratio
CCE	Control channel element
CORESET	Control resource set
CP	Cyclic prefix
CRC	Cyclic redundancy check
C-RNTI	Cell RNTI
CS-RNTI	Configured scheduling RNTI
CSI	Channel state information
CSS	Common search space
DAI	Downlink assignment index
DAPS	Dual active protocol stack
DC	Dual connectivity
DCI	Downlink control information
DL	Downlink
DL-SCH	Downlink shared channel
EPRE	Energy per resource element
EN-DC	E-UTRA NR dual connectivity with MCG using E-UTRA and SCG using NR
FR1	Frequency range 1
FR2	Frequency range 2
G-CS-RNTI	Group configured scheduling RNTI
G-RNTI	Group RNTI
GSCN	Global synchronization channel number
HARQ-ACK	Hybrid automatic repeat request acknowledgement
MBS	Multicast broadcast services
MCG	Master cell group
MCS	Modulation and coding scheme
NDI	New Data Indicator
NE-DC	E-UTRA NR dual connectivity with MCG using NR and SCG using E-UTRA
NR-DC	NR NR dual connectivity
PBCH	Physical broadcast channel
PCell	Primary cell
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PO	Paging occasion
PRACH	Physical random access channel
PRB	Physical resource block

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PRG	Physical resource block group
PSCell	Primary secondary cell
PSBCH	Physical sidelink broadcast channel
PSCCH	Physical sidelink control channel
PSFCH	Physical sidelink feedback channel
PSS	Primary synchronization signal
PSSCH	Physical sidelink shared channel
PUCCH	Physical uplink control channel
PUCCH-SCell	PUCCH SCell
PUCCH-sSCell	PUCCH switching SCell
PUSCH	Physical uplink shared channel
QCL	Quasi co-location
RB	Resource block
RE	Resource element
RLM	Radio link monitoring
RRM	Radio resource management
RS	Reference signal
RSRP	Reference signal received power
SCG	Secondary cell group
SCI	Sidelink control information
SCS	Subcarrier spacing
SFCI	Sidelink feedback control information
SFN	System frame number
SL	Sidelink
SLIV	Start and length indicator value
SPS	Semi-persistent scheduling
SR	Scheduling request
SRI	SRS resource indicator
SRS	Sounding reference signal
SSS	Secondary synchronization signal
SSSG	Search space set group
TA	Timing advance
TAG	Timing advance group
TB	Transport block
TBG	Transport block group
TCI	Transmission Configuration Indicator
UCI	Uplink control information
UE	User equipment
UL	Uplink
UL-SCH	Uplink shared channel
USS	UE-specific search space

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4 Synchronization procedures

4.1 Cell search

Cell search is the procedure for a UE to acquire time and frequency synchronization with a cell and to detect the physical layer Cell ID of the cell.

A UE receives the following synchronization signals (SS) in order to perform cell search: the primary synchronization signal (PSS) and secondary synchronization signal (SSS) as defined in [4, TS 38.211].

A UE assumes that reception occasions of a physical broadcast channel (PBCH), PSS, and SSS are in consecutive symbols, as defined in [4, TS 38.211], and form a SS/PBCH block. The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE. The UE may assume that the ratio of PSS EPRE to SSS EPRE in a SS/PBCH block is either 0 dB or 3 dB. If the UE has not been provided dedicated higher layer parameters, the UE may assume that the ratio of PDCCH DMRS EPRE to SSS EPRE is within -8 dB and 8 dB when the UE monitors PDCCHs for a DCI format 1_0 with CRC scrambled by SI-RNTI, P-RNTI, or RA-RNTI, or for a DCI format 2_7.

For a half frame with SS/PBCH blocks, the first symbol indexes for candidate SS/PBCH blocks are determined according to the SCS of SS/PBCH blocks as follows, where index 0 corresponds to the first symbol of the first slot in a half-frame.

- Case A - 15 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes of $\{2,8\} + 14 \cdot n$.
  - For operation without shared spectrum channel access:
    - For carrier frequencies smaller than or equal to 3 GHz, $n = 0,1$.
    - For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1,2,3$.
  - For operation with shared spectrum channel access, as described in [15, TS 37.213], $n = 0, 1, 2, 3, 4$.
- Case B - 30 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{4,8,16,20\} + 28 \cdot n$. For carrier frequencies smaller than or equal to 3 GHz, $n = 0$. For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1$.
- Case C - 30 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2,8\} + 14 \cdot n$.
  - For operation without shared spectrum channel access
    - For paired spectrum operation
      - For carrier frequencies smaller than or equal to 3 GHz, $n = 0,1$. For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1,2,3$.
    - For unpaired spectrum operation
      - For carrier frequencies smaller than 1.88 GHz, $n = 0,1$. For carrier frequencies within FR1 equal to or larger than 1.88 GHz, $n = 0,1,2,3$.
  - For operation with shared spectrum channel access, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9$.
- Case D - 120 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{4,8,16,20\} + 28 \cdot n$. For carrier frequencies within FR2, $n = 0, 1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18$.
- Case E - 240 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{8,12,16,20,32,36,40,44\} + 56 \cdot n$. For carrier frequencies within FR2-1, $n = 0, 1, 2, 3, 5, 6, 7, 8$.
- Case F – 480 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2, 9\} + 14 \cdot n$. For carrier frequencies within FR2-2, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31$.

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- Case G – 960 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2, 9\} + 14 \cdot n$. For carrier frequencies within FR2-2, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31$.

From the above cases, if the SCS of SS/PBCH blocks is not provided by *ssbSubcarrierSpacing*, the applicable cases for a cell depend on a respective frequency band, as provided in [8-1, TS 38.101-1] and [8-2, TS 38.101-2]. A same case applies for all SS/PBCH blocks on the cell. If a 30 kHz SS/PBCH block SCS is indicated by *ssbSubcarrierSpacing*, Case B applies for frequency bands with only 15 kHz SS/PBCH block SCS as specified in [8-1, TS 38.101-1], and the case specified for 30 kHz SS/PBCH block SCS in [8-1, TS 38.101-1] applies for frequency bands with 30 kHz SS/PBCH block SCS or both 15 kHz and 30 kHz SS/PBCH block SCS as specified in [8-1, TS 38.101-1]. For a UE configured to operate with carrier aggregation over a set of cells in a frequency band of FR2 or with frequency-contiguous carrier aggregation over a set of cells in a frequency band of FR1, if the UE is provided SCS values by *ssbSubcarrierSpacing* for receptions of SS/PBCH blocks on any cells from the set of cells, the UE expects the SCS values to be same.

The candidate SS/PBCH blocks in a half frame are indexed in an ascending order in time from 0 to $\overline{L}_{max} - 1$, where $\overline{L}_{max}$ is determined according to SS/PBCH block patterns for Cases A through G. L_{max} is a maximum number of SS/PBCH block indexes in a cell, and the maximum number of transmitted SS/PBCH blocks within a half frame is L_{max}.

- For operation without shared spectrum channel access in FR1 and FR2, and for operation with shared spectrum channel access in FR2-2, $L_{max} = \overline{L}_{max}$

- For operation with shared spectrum channel access in FR1, $L_{max} = 8$ for $\overline{L}_{max} = 10$ and 15 kHz SCS of SS/PBCH blocks and for $\overline{L}_{max} = 20$ and 30 kHz SCS of SS/PBCH blocks

For $\overline{L}_{max} = 4$, a UE determines the 2 LSB bits of a candidate SS/PBCH block index per half frame from a one-to-one mapping with an index of the DM-RS sequence transmitted in the PBCH as described in [4, TS 38.211].

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For $\overline{L}_{max} > 4$, a UE determines the 3 LSB bits of a candidate SS/PBCH block index per half frame from a one-to-one mapping with an index of the DM-RS sequence transmitted in the PBCH as described in [4, TS 38.211]

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- for $\overline{L}_{max} = 10$, the UE determines the 1 MSB bit of the candidate SS/PBCH block index from PBCH payload bit $\bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]

- for $\overline{L}_{max} = 20$, the UE determines the 2 MSB bits of the candidate SS/PBCH block index from PBCH payload bits $\bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]

- for $\overline{L}_{max} = 64$, the UE determines the 3 MSB bits of the candidate SS/PBCH block index from PBCH payload bits $\bar{a}_{\bar{A}+5}, \bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]

A UE can be provided per serving cell by *ssb-periodicityServingCell* a periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell. If the UE is not configured a periodicity of the half frames for receptions of the SS/PBCH blocks, the UE assumes a periodicity of a half frame. A UE assumes that the periodicity is same for all SS/PBCH blocks in the serving cell.

For initial cell selection, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames.

For operation without shared spectrum channel access, an SS/PBCH block index is same as a candidate SS/PBCH block index.

For operation with shared spectrum channel access, a UE assumes that transmission of SS/PBCH blocks in a half frame is within a discovery burst transmission window that starts from the first symbol of the first slot in a half-frame. The UE can be provided per serving cell by *discoveryBurstWindowLength* a duration of the discovery burst transmission window. If *discoveryBurstWindowLength* is not provided, the UE assumes that the duration of the discovery burst transmission window is a half frame. For a serving cell, the UE assumes that a periodicity of the discovery burst transmission window is same as a periodicity of half frames for receptions of SS/PBCH blocks in the serving cell. The UE assumes that one or more SS/PBCH blocks indicated by *ssb-PositionsInBurst* may be transmitted within the discovery burst transmission window and have candidate SS/PBCH blocks indexes corresponding to SS/PBCH block indexes provided by *ssb-PositionsInBurst*. If MSB k, $k \geq 1$, of *ssb-PositionsInBurst* is set to 1, the UE assumes that SS/PBCH block(s) within the discovery burst transmission window with candidate SS/PBCH block index(es) corresponding to SS/PBCH block index equal to $k-1$ may be transmitted; if MSB k is set to 0, the UE assumes that the SS/PBCH block(s) are not transmitted. If MSB k, $k \geq 1$, of *inOneGroup* is set to 1, and MSB m, $m \geq 1$, of *groupPresence* is set to 1, the UE assumes that SS/PBCH block(s) within the discovery burst transmission window with candidate SS/PBCH block index(es) corresponding to SS/PBCH block index determined by k and m may be transmitted; otherwise, the UE assumes that the SS/PBCH block(s) are not transmitted.

For operation with shared spectrum channel access in FR1, a UE assumes that SS/PBCH blocks in a serving cell that are within a same discovery burst transmission window or across discovery burst transmission windows are quasi co-located with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable [6, TS 38.214], if a value of $\left(N_{DM-RS}^{PBCH} \bmod N_{SSB}^{QCL}\right)$ is same among the SS/PBCH blocks. N_{DM-RS}^{PBCH} is an index of a DM-RS sequence transmitted in a PBCH of a corresponding SS/PBCH block, and N_{SSB}^{QCL} is either provided by *ssb-PositionQCL* or, if *ssb-PositionQCL* is not provided, obtained from a *MIB* provided by a SS/PBCH block according to Table 4.1-1 with $k_{SSB} < 24$ [4, TS 38.211]. The UE can determine an SS/PBCH block index according to $\left(N_{DM-RS}^{PBCH} \bmod N_{SSB}^{QCL}\right)$, or according to $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$ where $\bar{\imath}$ is the candidate SS/PBCH block index. The UE assumes that within a discovery burst transmission window, a number of transmitted SS/PBCH blocks on a serving cell is not larger than N_{SSB}^{QCL} and a number of transmitted SS/PBCH blocks with a same SS/PBCH block index is not larger than one.

Table 4.1-1: Mapping between the combination of *subCarrierSpacingCommon* and LSB of *ssb-SubcarrierOffset* to N_{SSB}^{QCL} for operation with shared spectrum channel access in FR1

subCarrierSpacingCommon	LSB of *ssb-SubcarrierOffset*	N_{SSB}^{QCL}
scs15or60	0	1
scs15or60	1	2
scs30or120	0	4
scs30or120	1	8

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For operation with shared spectrum channel access in FR2-2, a UE assumes that SS/PBCH blocks in a serving cell that are within a same discovery burst transmission window or across discovery burst transmission windows are quasi co-located with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable, if a value of $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$ is same among the SS/PBCH blocks, where $\bar{\imath}$ is the candidate SS/PBCH block index. N_{SSB}^{QCL} is either provided by *ssb-PositionQCL* or, if *ssb-PositionQCL* is not provided, obtained from a *MIB* provided by a SS/PBCH block according to Table 4.1-2. The UE can determine an SS/PBCH block index according to $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$. The UE assumes that within a discovery burst transmission window, a number of transmitted SS/PBCH blocks on a serving cell is not larger than N_{SSB}^{QCL} and a number of transmitted SS/PBCH blocks with a same SS/PBCH block index is not larger than one.

Table 4.1-2: Mapping between *subCarrierSpacingCommon* to N_{SSB}^{QCL} for operation with shared spectrum channel access in FR2-2

subCarrierSpacingCommon	N_{SSB}^{QCL}
scs15or60	32
scs30or120	64

For operation without shared spectrum channel access in FR2-2, a UE expects a MIB in a SS/PBCH block to provide *subCarrierSpacingCommon* = 'scs30or120'.

Upon detection of a SS/PBCH block, the UE determines from *MIB* that a CORESET for Type0-PDCCH CSS set, as described in clause 13, is present if $k_{SSB} < 24$ [4, TS 38.211] for FR1 or if $k_{SSB} < 12$ for FR2. The UE determines from *MIB* that a CORESET for Type0-PDCCH CSS set is not present if $k_{SSB} > 23$ for FR1 or if $k_{SSB} > 11$ for FR2; the CORESET for Type0-PDCCH CSS set may be provided by *PDCCH-ConfigCommon*.

For a serving cell without transmission of SS/PBCH blocks, a UE acquires time and frequency synchronization with the serving cell based on receptions of SS/PBCH blocks on the PCell, or on the PSCell, or on an SCell if applicable as described in [10, TS 38.133], of the cell group for the serving cell.

4.2 Transmission timing adjustments

A UE can be provided a value $N_{\mathrm{TA,offset}}$ of a timing advance offset for a serving cell by *n-TimingAdvanceOffset* for the serving cell. If the UE is not provided *n-TimingAdvanceOffset* for a serving cell, the UE determines a default value $N_{\mathrm{TA,offset}}$ of the timing advance offset for the serving cell as described in [10, TS 38.133].

If a UE is configured with two UL carriers for a serving cell, a same timing advance offset value $N_{\mathrm{TA,offset}}$ applies to both carriers.

Upon reception of a timing advance command for a TAG, the UE adjusts uplink timing for PUSCH/SRS/PUCCH transmission on all the serving cells in the TAG based on a value $N_{\mathrm{TA,offset}}$ that the UE expects to be same for all the serving cells in the TAG and based on the received timing advance command where the uplink timing for PUSCH/SRS/PUCCH transmissions is the same for all the serving cells in the TAG.

For a band with synchronous contiguous intra-band EN-DC in a band combination with non-applicable maximum transmit timing difference requirements as described in Note 1 of Table 7.5.3-1 of [10, TS 38.133], if the UE indicates *ul-TimingAlignmentEUTRA-NR* as 'required' and uplink transmission timing based on timing adjustment indication for a TAG from MCG and a TAG from SCG are determined to be different by the UE, the UE adjusts the transmission timing for PUSCH/SRS/PUCCH transmission on all serving cells part of the band with the synchronous contiguous intra-band EN-DC based on timing adjustment indication for a TAG from a serving cell in MCG in the band. The UE is not expected to transmit a PUSCH/SRS/PUCCH in one CG when the PUSCH/SRS/PUCCH is overlapping in time, even partially, with random access preamble transmitted in another CG.

For a SCS of $2^{\mu} \cdot 15$ kHz, the timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG in multiples of $16 \cdot 64 \cdot T_{\mathrm{c}}/2^{\mu}$. The start timing of the random access preamble is described in [4, TS 38.211].

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A timing advance command [11, TS 38.321] in case of random access response or in an absolute timing advance command MAC CE, T_{A}, for a TAG indicates N_{TA} values by index values of T_{A} = 0, 1, 2, ..., 3846, where an amount of the time alignment for the TAG with SCS of $2^{\mu} \cdot 15$ kHz is $N_{\mathrm{TA}} = T_{\mathrm{A}} \cdot 16 \cdot 64/2^{\mu}$. N_{TA} is defined in [4, TS 38.211] and is relative to the SCS of the first uplink transmission from the UE after the reception of the random access response or absolute timing advance command MAC CE.

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In other cases, a timing advance command [11, TS 38.321], T_{A}, for a TAG indicates adjustment of a current N_{TA} value, $N_{\mathrm{TA\_old}}$, to the new N_{TA} value, $N_{\mathrm{TA\_new}}$, by index values of T_{A} = 0, 1, 2,..., 63, where for a SCS of $2^{\mu} \cdot 15$ kHz, $N_{\mathrm{TA\_new}} = N_{\mathrm{TA\_old}} + (T_{\mathrm{A}} - 31) \cdot 16 \cdot 64/2^{\mu}$.

If a UE has multiple active UL BWPs, as described in clause 12, in a same TAG, including UL BWPs in two UL carriers of a serving cell, the timing advance command value is relative to the largest SCS of the multiple active UL BWPs. The applicable $N_{\mathrm{TA\_new}}$ value for an UL BWP with lower SCS may be rounded to align with the timing advance granularity for the UL BWP with the lower SCS while satisfying the timing advance accuracy requirements in [10, TS 38.133].

Adjustment of an N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a corresponding amount, respectively.

For a timing advance command received on uplink slot n and for a transmission other than a PUSCH scheduled by a RAR UL grant or a fallbackRAR UL grant as described in clause 8.2A or 8.3, or a PUCCH with HARQ-ACK information in response to a successRAR as described in clause 8.2A, the corresponding adjustment of the uplink transmission timing applies from the beginning of uplink slot $n + k + 1 + 2^{\mu} \cdot K_{\mathrm{offset}}$ where $k = \lceil N_{\mathrm{slot}}^{\mathrm{subframe},\mu} \cdot (N_{\mathrm{T,1}} + N_{\mathrm{T,2}} + N_{\mathrm{TA,max}} + 0.5)/T_{\mathrm{sf}} \rceil$, $N_{\mathrm{T,1}}$ is a time duration in msec of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured, $N_{\mathrm{T,2}}$ is a time duration in msec of N_2 symbols corresponding to a PUSCH preparation time for UE processing capability 1 [6, TS 38.214], $N_{\mathrm{TA,max}}$ is the maximum timing advance value in msec that can be provided by a TA command field of 12 bits, $N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ is the number of slots per subframe, T_{sf} is the subframe duration of 1 msec, and $K_{\mathrm{offset}} = K_{\mathrm{cell,offset}} - K_{\mathrm{UE,offset}}$, where $K_{\mathrm{cell,offset}}$ is provided by *cellSpecificKoffset* and $K_{\mathrm{UE,offset}}$ is provided by a Differential Koffset MAC CE command [11, TS 38.321]; otherwise, if not respectively provided, $K_{\mathrm{cell,offset}} = 0$ or $K_{\mathrm{UE,offset}} = 0$. N_1 and N_2 are determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG and of all configured DL BWPs for the corresponding downlink carriers. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214]. Slot n and $N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ are determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG. $N_{\mathrm{TA,max}}$ is determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG and for all configured initial UL BWPs provided by *initialUplinkBWP*. The uplink slot n is the last slot among uplink slot(s) overlapping with the slot(s) of PDSCH reception assuming $T_{TA} = 0$, where the PDSCH provides the timing advance command and T_{TA} is defined in [4, TS 38.211].

If a UE changes an active UL BWP between a time of a timing advance command reception and a time of applying a corresponding adjustment for the uplink transmission timing, the UE determines the timing advance command value based on the SCS of the new active UL BWP. If the UE changes an active UL BWP after applying an adjustment for the uplink transmission timing, the UE assumes a same absolute timing advance command value before and after the active UL BWP change.

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 described in [10, TS 38.133], the UE changes N_{TA} accordingly.

If two adjacent slots overlap due to a TA command, the latter slot is reduced in duration relative to the former slot. The UE does not change N_{TA} during an actual transmission time window for a PUSCH or a PUCCH transmission [6, TS 38.214].

Using higher-layer ephemeris parameters for a serving satellite, if provided, a UE pre-compensates the two-way transmission delay on the service link based on $N_{\mathrm{TA,adj}}^{\mathrm{UE}}$ that the UE determines using the serving satellite position and its own position. To pre-compensate the two-way transmission delay between the uplink time synchronization reference point and the serving satellite, the UE determines $N_{\mathrm{TA,adj}}^{\mathrm{common}}$ [4, TS 38.211] based on one-way propagation delay $\mathrm{Delay}_{\mathrm{common}}(\mathrm{t})$ that the UE determines as:

$$\mathrm{Delay}_{\mathrm{common}}(t) = \frac{TA_{\mathrm{Common}}}{2} + \frac{TA_{\mathrm{CommonDrift}}}{2} \times \left(t - t_{\mathrm{epoch}}\right) + \frac{TA_{\mathrm{CommonDriftVariant}}}{2} \times \left(t - t_{\mathrm{epoch}}\right)^2$$

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where TA_{Common}, $TA_{\mathrm{CommonDrift}}$, and $TA_{\mathrm{CommonDriftVariant}}$ are respectively provided by *ta-Common*, *ta-CommonDrift*, and *ta-CommonDriftVariant* and t_{epoch} is the epoch time of TA_{Common}, $TA_{\mathrm{CommonDrift}}$, and $TA_{\mathrm{CommonDriftVariant}}$ [12, TS 38.331]. $Delay_{common}(t)$ provides a distance at time t between the serving satellite and the uplink time synchronization reference point divided by the speed of light. The uplink time synchronization reference point is the point where DL and UL are frame aligned with an offset given by $N_{\mathrm{TA,offset}}$.

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4.3 Timing for secondary cell activation / deactivation

With reference to slots for PUCCH transmissions, when a UE receives in a PDSCH an activation command [11, TS 38.321] for a secondary cell ending in slot *n*, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133] and no earlier than slot $n+k$, except for the following:

- the actions related to CSI reporting on a serving cell that is active in slot $n+k$
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [11, TS 38.321] that the UE applies in slot $n+k$
- the actions related to CSI reporting on a serving cell which is not active in slot $n+k$ that the UE applies in the earliest slot after $n+k$ in which the serving cell is active.

The value of k is $m + 3\,N_{\mathrm{slot}}^{\mathrm{subframe},\mu} + 1$ where slot *n*+*m* is a slot indicated for PUCCH transmission with HARQ-ACK information for the PDSCH reception as described in clause 9.2.3 and $N_{\mathrm{slot}}^{\mathrm{subframe}\mu}$ is a number of slots per subframe for the SCS configuration μ of the PUCCH transmission as defined in [4, TS 38.211].

With reference to slots for PUCCH transmissions, if a UE receives a deactivation command [11, TS 38.321] for a secondary cell ending in slot n, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133], except for the actions related to CSI reporting on an activated serving cell which the UE applies in slot $n+k$.

If the *sCellDeactivationTimer* associated with the secondary cell expires in slot n, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133], except for the actions related to CSI reporting on an activated serving cell which the UE applies in the first slot that is after slot $n+3\cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ where μ is the SCS configuration for PDSCH reception on the secondary cell.