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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 TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[9] 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)".

[10] 3GPP TS 36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".

[11] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

[13] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access".

[14] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode".

[15] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[16] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[17] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

3 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_{cells}^{DL}	Number of configured cells
$N_{\mathrm{RB}}^{\mathrm{DL}}$	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 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].

ACK	Acknowledgement
AUL	Autonomous Uplink
AUL-DFI	AUL downlink feedback information
BCH	Broadcast Channel
CCE	Control Channel Element
CDD	Cyclic Delay Diversity
CG	Cell Group
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CRI	CSI-RS Resource Indicator
CSI	Channel State Information
CSI-IM	CSI-interference measurement
DAI	Downlink Assignment Index
DC	Dual Connectivity
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
DTX	Discontinuous Transmission
EDT	Early Data Transmission
EN-DC	E-UTRA NR Dual Connectivity with MCG using E-UTRA and SCG using NR
EPDCCH	Enhanced Physical Downlink Control Channel
EPRE	Energy Per Resource Element
MCG	Master Cell Group
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
NE-DC	NR E-UTRA Dual Connectivity with MCG using NR and SCG using E-UTRA
NPBCH	Narrowband Physical Broadcast CHannel
NPDCCH	Narrowband Physical Downlink Control CHannel
NPDSCH	Narrowband Physical Downlink Shared CHannel
NPRACH	Narrowband Physical Random Access CHannel
NPUSCH	Narrowband Physical Uplink Shared CHannel

NPSS	Narrowband Primary Synchronization Signal
NSSS	Narrowband Secondary Synchronization Signal
NRS	Narrowband Reference Signal
NTN	Non-Terrestrial Network
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 Signal
PRB	Physical Resource Block
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSCell	Primary Secondary cell
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel
PSSS	Primary Sidelink Synchronisation Signal
PUCCH	Physical Uplink Control Channel
PUCCH-SCell	PUCCH SCell
PUR	Preconfigured Uplink Resource
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
RBG	Resource Block Group
RE	Resource Element
RI	Rank Indication
RS	Reference Signal
RSS	Resynchronization Signal
SCG	Secondary Cell Group
SINR	Signal to Interference plus Noise Ratio
SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
SSSS	Secondary Sidelink Synchronisation Signal
TAG	Timing Advance Group
TBS	Transport Block Size
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronization 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.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

For a BL/CE UE, if the UE is configured with higher layer parameter *RSS-Config*, the UE can use the resynchronization signal (as defined in [3]) to re-acquire time and frequency synchronization with the cell.

4.2 Timing synchronization

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.

If the UE is configured with a SCG [11] and the parameter *rlf-TimersAndConstantsSCG* is provided by the higher layers and is not set to release, the downlink radio link quality of the PSCell [11] of the SCG 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 synchronization

No functionality is specified in this clause in this release.

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command or a timing adjustment indication for a TAG containing the primary cell or PSCell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell or PSCell based on the received timing advance command or a timing adjustment indication.

The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell if the secondary cell and the primary cell belong to the same TAG. If the primary cell in a TAG has a frame structure type 1 and a secondary cell in the same TAG has a frame structure type 2 or frame structure 3, UE may assume that $N_{TA} \geq 624$.

If the UE is configured with a SCG, the UL transmission timing for PUSCH/SRS of a secondary cell other than the PSCell is the same as the PSCell if the secondary cell and the PSCell belong to the same TAG.

Upon reception of a timing advance command or a timing adjustment indication for a TAG not containing the primary cell or PSCell, if all the serving cells in the TAG have the same frame structure type, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG based on the received timing advance command or a timing adjustment indication where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG.

Upon reception of a timing advance command or a timing adjustment indication for a TAG not containing the primary cell or PSCell, if a serving cell in the TAG has a different frame structure type compared to the frame structure type of another serving cell in the same TAG, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG by using $N_{TAoffset}$ = 624 regardless of the frame structure type of the serving cells and based on the received timing advance command or a timing adjustment indication where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG. $N_{TAoffset}$ is described in [3].

The timing adjustment indication specified in [11] indicates the initial N_{TA} used for a TAG.The timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG as multiples of $16\,T_s$. The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], T_A, for a TAG indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 256 if the UE is configured with a SCG, and T_A = 0, 1, 2, ..., 1282 otherwise, where an amount of the time alignment for the TAG is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, a 6-bit timing advance command [8] or the Timing advance adjustment field in DCI format 6-0A/B if present [4], T_A, for a TAG 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 for the TAG by a given amount respectively.

For a non-BL/CE UE, for a timing advance command received on

- subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the beginning of subframe *n*+5 if the UE is configured with higher layer parameter *shortProcessingTime* and the corresponding PDCCH with CRC scrambled by C-RNTI is in the UE-specific search space, *n+6* otherwise.

- slot *n*, the corresponding adjustment of the uplink transmission timing shall apply from the first subframe boundary no earlier than slot *[n+8]*.

- subslot *n*, the corresponding adjustment of the uplink transmission timing shall apply from the first subframe boundary no earlier than

  - subslot *[n+16]* if higher layer parameter *proc-TimeAdv-r15*= '*nplus4set1*'.

  - subslot *[n+18]* if higher layer parameter *proc-TimeAdv-r15*= '*nplus6set1*'or '*nplus6set2*'.

  - subslot *[n+20]* if higher layer parameter *proc-TimeAdv-r15*= '*nplus8set2*'.

For serving cells in the same TAG, 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 complete transmission of subframe *n* and not transmit the overlapped part of subframe *n*+1.

For a BL/CE UE, for a timing advance command received on subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply for the uplink PUCCH/PUSCH/SRS transmissions in subframe $n+6+K_{offset}$. When the BL/CE UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are on the same narrowband and are overlapped due to the timing adjustment, the UE shall complete transmission of subframe *n* and is not required to transmit in subframe *n+1* until the first available symbol that has no overlapping portion with subframe *n*. When the BL/CE UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are on different narrowbands, and the timing adjustment occurs in the guard period for narrowband retuning, the UE is not required to transmit in subframe *n+1* until the first available symbol that has no overlapping portion with subframe *n* and which does not reduce the guard period. The value of K_{offset} is given by,

- if the UE is configured with the higher layer parameter *k-Offset,*

  - $K_{\text{offset}} = K_{\text{cell\_offset}} - K_{\text{UE\_offset}}$ where

    $K_{\text{cell\_offset}}$ is the parameter *k-Offset* provided by higher layers, and

$K_{\text{UE\_offset}}$ is the parameter *Differential Koffset* provided by higher layers, otherwise $K_{\text{UE\_offset}} = 0$

- otherwise,
  - $K_{\text{offset}} = 0$.

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.

For a BL/CE UE in a NTN serving cell, using serving satellite higher-layer ephemeris parameters, if configured, the BL/CE UE determines $N_{\text{TA,adj}}^{\text{UE}}$ (defined in [3]) using the serving satellite position and its own position to pre-compensate the two-way transmission delay on the service link. To pre-compensate the two-way transmission delay between the uplink time synchronization reference point and the serving satellite, the BL/CE UE determines $N_{\text{TA,adj}}^{\text{common}}$ (defined in [3]) based on one-way propagation delay $Delay_{\text{common}}(t)$ which can be obtained as:

$$Delay_{\text{common}}(t) = \frac{1}{2}\left[N_{\text{TA}}^{\text{common}} + N_{\text{TA}}^{\text{commonDrift}} \times \left(t - t_{\text{epoch}}\right) + N_{\text{TA}}^{\text{commonDriftVariation}} \times \left(t - t_{\text{epoch}}\right)^2\right]$$

where $N_{\text{TA}}^{\text{common}}$, $N_{\text{TA}}^{\text{commonDrift}}$, and $N_{\text{TA}}^{\text{commonDriftVariation}}$ are given by the higher layer parameters *nta-Common*, *nta-CommonDrift*, and *nta-CommonDriftVariation* respectively, and t_{epoch} is the epoch time given by the higher layer parameter *epochTime*. $Delay_{\text{common}}(t)$ 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 $N_{\text{TA,offset}}$.

For a BL/CE UE communicating over NTN, time and frequency pre-compensation is adjusted per uplink segment with a transmission duration of $N_{\text{segment}}^{\text{precompensation}}$ time units, where the quantity $N_{\text{segment}}^{\text{precompensation}}$ is provided by higher layers, as specified in 3GPP TS 36.331 [11].

4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation command [8] for a secondary cell in subframe *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [10] and no earlier than subframe n+8, except for the following:

- the actions related to CSI reporting on a serving cell which is active in subframe n+8
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [8]

which shall be applied in subframe *n+8*.

- the actions related to CSI reporting on a serving cell which is not active in subframe n+8

which shall be applied in the earliest subframe after n+8 in which the serving cell is active.

When a UE receives an RRC configuration which configures secondary cell as activated [11] in subframe *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [10] and no earlier than subframe *n+20*, except for the following:

- the actions related to CSI reporting on a serving cell which is active in subframe *n+20*
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [8]

which shall be applied in subframe *n+20*.

- the actions related to CSI reporting on a serving cell which is not active in subframe *n+20*

which shall be applied in the earliest subframe after *n+20* in which the serving cell is active.

If a UE has been configured with *cqi-ShortPeriodicSCell* for a secondary cell, parameters *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* in clause 7.2 are given by *cqi-ShortPeriodicSCell* from subframe *n*+8 until subframe *n*+34.

When a UE receives a deactivation command [8] for a secondary cell or the *sCellDeactivationTimer* associated with the secondary cell expires in subframe *n*, the corresponding actions in [8] shall apply no later than the minimum