**3GPP TSG-RAN WG2 Meeting #109-e *R2-200xxxx***

**Online, 24th February – 06th March 2020**

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| *CR-Form-v12.0* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  | **36.300** | **CR** | **1259** | **rev** | **1** | **Current version:** | **16.0.0** |  |
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| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network | **X** | Core Network |  |

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| ***Title:*** | Introduction of additional enhancements for NB-IoT in TS 36.300 | | | | | | | | | |
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| ***Source to WG:*** | Huawei | | | | | | | | | |
| ***Source to TSG:*** | R2 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | NB\_IOTenh3-Core | | | | |  | ***Date:*** | | | 2020/02/xx |
|  |  | | | |  | |  | | |  |
| ***Category:*** | **B** |  | | | | | ***Release:*** | | | Rel-16 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) Rel-12 (Release 12)* *Rel-13 (Release 13) Rel-14 (Release 14) Rel-15 (Release 15) Rel-16 (Release 16)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | Introduction of additional enhancements for NB-IoT | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | Introduction of additional enhancements for NB-IoT   * SON:   + Reporting of Cell Global Identity and strongest measured cell(s) (ANR)   + SON: Reporting of Random access performance   + SON: Reporting of Radio link failure (RLF) * Improved multi-carrier operation:   + DL channel quality reporting in MSG3   + DL channel quality reporting in connected mode   + NRS on non-anchor paging carrier * Mobility enhancements: Assistance information for idle mode inter-RAT cell selection for NB-IoT to and from LTE, LTE-MTC and GERAN * Connection to 5GC * Mobile Terminated Early Data Transmission (MT-EDT) * Transmission in Preconfigured Uplink Resource (PUR) * Multiple TB scheduling:   + Multiple TB scheduling in unicast mode   + Multiple TB scheduling for SC-PTM * UE-group Wake-Up Signal * Coexistence with NR | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | The additional enhancements for NB-IoT are not captured in TS 36.300 | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 2, 3.1, 3.2, 4.10, 7.1, 7.2, 7.3, 7.3a.1, 7.3a.2, 7.3a.3, 7.3b.1, 7.3b.2, 7.3b.3, 7.3x (new), 7.3y (new), 7.4, 8.1, 10.0, 10.1.3.0, 10.1.4, 10.1.5.1, 10.1.6, 10.2.x (new), 11.0, 11.1.1, 11.1.2, 11.7, 15.3.2, 6.1.x (new), 16.3, 22.3.2a, 22.3.4x (new), 22.4.2.x (new), 22.4.3, 22.4.5, 24.1, 24.2.1, 24.2.2, 24.3, 24.4, 24.5. | | | | | | | | |
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|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | | **X** |  | Other core specifications | | | | TS/TR TS 38.300 CR 0176  TS 36.331 CR 4192  TS 36.321 CR 1466  TS 36.304 CR 0783  TS 36.302 CR 1202  TS 36.306 CR 1731 | | |
| ***affected:*** | |  | **X** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **X** | O&M Specifications | | | | TS/TR ... CR ... | | |
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| ***Other comments:*** | | In this revision, author ‘NB/eMTC’ is used for text that is/should be common to NB-IoT/eMTC. Blue highlights indicate editorial updates for alignment with eMTC CR. Yellow highights indicate non-alignment between NB-IoT and eMTC CR.  This revision includes RAN3 TP in R3-201271, the changes are highlighted in green. | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | | R2-1910160, RAN2#106, Initial version  R2-1911591, RAN2#107, endorsed version after RAN2#107  R2-1912599, RAN2#107, endorsed version before RAN2#107bis  R2-1914094, RAN2#107bis, endorsed version after RAN2#107bis  R2-1915299, RAN2#108, endorsed version before RAN2#108  R2-1916567 RAN2#108, endorsed version after RAN2#108  R2-2000619 RAN2#109, version submitted at RAN2#109 | | | | | | | | |

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| First change |

# 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 TR 25.913: "Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN)".

[3] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; General description".

[4] 3GPP TS 36.211:"Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation".

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

[6] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[7] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".

[8] IETF RFC 4960 (09/2007): "Stream Control Transmission Protocol".

[9] 3GPP TS 36.302: "Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer".

[10] Void

[11] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode".

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

[13] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[14] 3GPP TS 36.322: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification".

[15] 3GPP TS 36.323: "Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification".

[16] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[17] 3GPP TS 23.401: "Technical Specification Group Services and System Aspects; GPRS enhancements for E-UTRAN access".

[18] 3GPP TR 24.801: "3GPP System Architecture Evolution (SAE); CT WG1 aspects".

[19] 3GPP TS 23.402: "3GPP System Architecture Evolution: Architecture Enhancements for non-3GPP accesses".

[20] 3GPP TS 24.301: "Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3".

[21] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); "Requirements for support of radio resource management".

[22] 3GPP TS 33.401: "3GPP System Architecture Evolution: Security Architecture".

[23] 3GPP TS 23.272: "Circuit Switched Fallback in Evolved Packet System; Stage 2".

[24] Void.

[25] 3GPP TS 36.413: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)".

[26] 3GPP TS 23.003: "Numbering, addressing and identification".

[27] 3GPP TR 25.922: "Radio Resource Management Strategies".

[28] 3GPP TS 23.216: "Single Radio voice Call continuity (SRVCC); Stage 2".

[29] 3GPP TS 32.421: "Subscriber and equipment trace: Trace concepts and requirements".

[30] 3GPP TS 32.422: "Subscriber and equipment trace; Trace control and configuration management".

[31] 3GPP TS 32.423: "Subscriber and equipment trace: Trace data definition and management".

[32] Void.

[33] 3GPP TS 22.220: "Service Requirements for Home NodeBs and Home eNodeBs".

[34] 3GPP TS 22.268: "Public Warning System (PWS) Requirements".

[35] IETF RFC 3168 (09/2001): "The Addition of Explicit Congestion Notification (ECN) to IP".

[36] 3GPP TS 25.446: "MBMS synchronisation protocol (SYNC)".

[37] 3GPP TS 22.168: "Earthquake and Tsunami Warning System (ETWS) requirements; Stage 1".

[38] Void.

[39] Void.

[40] 3GPP TS 29.274: "Tunnelling Protocol for Control Plane (GTPv2-C); Stage 3".

[41] 3GPP TS 29.061: "Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)".

[42] 3GPP TS 36.423: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)".

[43] 3GPP TS 37.320: "Universal Terrestrial Radio Access (UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRA); Radio measurement collection for Minimization of Drive Tests (MDT); Overall description; Stage 2".

[44] 3GPP TS 36.443: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP)".

[45] 3GPP TS 36.444: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M3 Application Protocol (M3AP)".

[46] 3GPP TS 36.420: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 general aspects and principles".

[47] 3GPP TS 29.281: "General Packet Radio System (GPRS) Tunnelling Protocol User Plane (GTPv1-U)"

[48] 3GPP TS 23.246: "Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description"

[49] 3GPP TS 26.346: "Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs"

[50] 3GPP TR 36.816: "Evolved Universal Terrestrial Radio Access (E-UTRA); Study on signalling and procedure for interference avoidance for in-device coexistence".

[51] 3GPP TS 36.305: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Stage 2 functional specifications of User Equipment (UE) positioning in E-UTRAN".

[52] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[53] 3GPP TS 33.320: "Security of Home Node B (HNB) / Home evolved Node B (HeNB)".

[54] 3GPP TS 23.251: "Technical Specification Group Services and System Aspects; Network Sharing; Architecture and functional description".

[55] 3GPP TS 23.139: "3GPP system – fixed broadband access network interworking".

[56] 3GPP TS 23.007: "Technical Specification Group Core Network and Terminals; Restoration procedures".

[57] 3GPP TS 23.682: "Architecture enhancements to facilitate communications with packet data networks and applications".

[58] 3GPP TS 24.312: "Access Network Discovery and Selection Function (ANDSF) Management Object (MO)".

[59] 3GPP TR 36.842: "Study on Small Cell enhancements for E-UTRA and E-UTRAN; Higher layer aspects"

[60] 3GPP TR 36.932: "Scenarios and Requirements for Small Cell Enhancements for E-UTRA and E-UTRAN".

[61] 3GPP TS 36.425: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 interface user plane protocol".

[62] 3GPP TS 23.303: "Technical Specification Group Services and System Aspects; Proximity-based services (ProSe)"

[63] 3GPP TS 36.314: "Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 - Measurements".

[64] 3GPP TR 36.889: "Study on Licensed-Assisted Access to Unlicensed Spectrum".

[65] IEEE 802.11, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, IEEE Std.".

[66] 3GPP TS 36.360: "LTE-WLAN Aggregation Adaptation Protocol (LWAAP) specification".

[67] 3GPP TS 24.302: "Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks".

[68] 3GPP TS 36.361: "LTE/WLAN Radio Level Integration Using IPsec Tunnel (LWIP) encapsulation; Protocol specification".

[69] 3GPP TS 36.463: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Wireless LAN (WLAN); Xw application protocol (XwAP)".

[70] 3GPP TS 33.402: "3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses".

[71] 3GPP TS 22.185: "Service requirements for V2X services; Stage 1".

[72] 3GPP TS 23.285: "Technical Specification Group Services and System Aspects; Architecture enhancements for V2X services".

[73] IETF RFC 7567 "IETF Recommendations Regarding Active Queue Management".

[74] 3GPP TS 26.114: "Technical Specification Group Services and System Aspects; IP Multimedia Subsystem (IMS); Multimedia Telephony; Media handling and interaction".

[75] 3GPP TS 24.386: "User Equipment (UE) to V2X control function; protocol aspects; Stage 3".

[76] 3GPP TS 37.340: "Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity".

[77] 3GPP TS 23.280: "Common functional architecture to support mission critical services; Stage 2".

[78] 3GPP TS 36.355: " Evolved Universal Terrestrial Radio Access (E-UTRA);LTE Positioning Protocol (LPP)".

[79] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description, Stage 2".

[80] 3GPP TS 37.324: "NR; Service Data Protocol (SDAP) specification".

[81] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".

[82] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".

[83] 3GPP TS 23.502: "Procedures for the 5G System; Stage 2".

[84] 3GPP TS 29.002: "Mobile Application Part (MAP) specification".

[85] 3GPP TS 25.412: "UTRAN Iu interface signalling transport".

[86] 3GPP TS 38.423: "NG-RAN; Xn Application Protocol (XnAP)".

[87] Void

[88] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[89] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities".

[90] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access".

[xx] 3GPP TS 24.501: "Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3"."

# 3 Definitions, symbols and abbreviations

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## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

**Access Control:** the process that checks whether a UE is allowed to access and to be granted services in a closed cell.

**Aerial UE communication**: functionality enabling Aerial UE function as defined in 23.17.

**Anchor carrier**: in NB-IoT, a carrier where the UE assumes that NPSS/NSSS/NPBCH/SIB-NB for FDD or NPSS/NSSS/NPBCH for TDD are transmitted.

**Carrier frequency**: center frequency of the cell.

**Cell:** combination of downlink and optionally uplink resources. The linking between the carrier frequency of the downlink resources and the carrier frequency of the uplink resources is indicated in the system information transmitted on the downlink resources.

**Cell Group**: in dual connectivity, a group of serving cells associated with either the MeNB or the SeNB.

**Control plane CIoT 5GS Optimisation**: Enables support of efficient transport of user data (IP, Ethernet and Unstructured) or SMS messages over control plane via the AMF without triggering user-plane resource establishment, as defined in TS 24.501 [xx]. In the context of this specification, a NB-IoT UE that only supports Control plane CIoT 5GS Optimisation is a UE that does not support User plane CIoT 5GS Optimisation and NG-U data transfer but may support other CIoT 5GS Optimisations.

**Control plane CIoT EPS optimization**: Enables support of efficient transport of user data (IP, non-IP or SMS) over control plane via the MME without triggering data radio bearer establishment, as defined in TS 24.301 [20]. In the context of this specification, a NB-IoT UE that only supports Control plane CIoT EPS optimization is a UE that does not support User plane CIoT EPS optimization and S1-U data transfer but may support other CIoT EPS optimizations.

**CSG Cell:** a cell broadcasting a CSG indicator set to true and a specific CSG identity.

**CSG ID Validation:** the process that checks whether the CSG ID received via handover messages is the same as the one broadcast by the target E-UTRAN.

**CSG member cell:** a cell broadcasting the identity of the selected PLMN, registered PLMN or equivalent PLMN and for which the CSG whitelist of the UE includes an entry comprising cell's CSG ID and the respective PLMN identity.

**DCN-ID:** DCN identity identifies a specific dedicated core network (DCN).

**Dual Connectivity**: mode of operation of a UE in RRC\_CONNECTED, configured with a Master Cell Group and a Secondary Cell Group.

**en-gNB**: as defined in TS 37.340 [76].

**E-RAB:** an E-RAB uniquely identifies the concatenation of an S1 Bearer and the corresponding Data Radio Bearer. When an E-RAB exists, there is a one-to-one mapping between this E-RAB and an EPS bearer of the Non Access Stratum as defined in [17].

**Frequency layer**: set of cells with the same carrier frequency.

**FeMBMS:** further enhanced multimedia broadcast multicast service.

**FeMBMS/Unicast-mixed cell**: cell supporting MBMS transmission and unicast transmission as SCell.

**Handover**: procedure that changes the serving cell of a UE in RRC\_CONNECTED.

**Hybrid cell**: a cell broadcasting a CSG indicator set to false and a specific CSG identity. This cell is accessible as a CSG cell by UEs which are members of the CSG and as a normal cell by all other UEs.

**Local Home Network**: as defined in TS 23.401 [17].

**LTE bearer**: in LTE-WLAN Aggregation, a bearer whose radio protocols are located in the eNB only to use eNB radio resources only.

**LWA bearer**: in LTE-WLAN Aggregation, a bearer whose radio protocols are located in both the eNB and the WLAN to use both eNB and WLAN resources.

**LWAAP PDU**: in LTE-WLAN Aggregation, a PDU with DRB ID generated by LWAAP entity for transmission over WLAN.

**Make-Before-Break HO/SeNB change**: maintaining source eNB/SeNB connection after reception of RRC message for handover or change of SeNB before the initial uplink transmission to the target eNB during handover or change of SeNB.

**Master Cell Group**: in dual connectivity, a group of serving cells associated with the MeNB, comprising of the PCell and optionally one or more SCells.

**Master eNB**: in dual connectivity, the eNB which terminates at least S1-MME.

**MBMS-dedicated cell**: cell dedicated to MBMS transmission.

**MBMS/Unicast-mixed cell**: cell supporting both unicast and MBMS transmissions.

**MCG bearer**: in dual connectivity, a bearer whose radio protocols are only located in the MeNB to use MeNB resources only.

**Membership Verification:** the process that checks whether a UE is a member or non-member of a hybrid cell.

**Multi-Connectivity**: Mode of operation whereby a multiple Rx/Tx UE in the connected mode is configured to utilise radio resources amongst E-UTRA and/or NR provided by multiple distinct schedulers connected via non-ideal backhaul.

**NB-IoT:** NB-IoT allows access to network services via E-UTRA with a channel bandwidth limited to 200 kHz.

**NB-IoT UE**: a UE that uses NB-IoT.

**ng-eNB:** node providing E-UTRA user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC.

**Non-anchor carrier**: in NB-IoT, a carrier where the UE does not assume that NPSS/NSSS/NPBCH/SIB-NB for FDD or NPSS/NSSS/NPBCH for TDD are transmitted.

**NR:** NR radio access

**PLMN ID Check:** the process that checks whether a PLMN ID is the RPLMN identity or an EPLMN identity of the UE.

**Power saving mode**: mode configured and controlled by NAS that allows the UE to reduce its power consumption, as defined in TS 24.301 [20], TS 23.401 [17], TS 23.682 [57].

**Primary PUCCH group:** a group of serving cells including PCell whose PUCCH signalling is associated with the PUCCH on PCell.

**Primary Timing Advance Group**: Timing Advance Group containing the PCell. In this specification, Primary Timing Advance Group refers also to Timing Advance Group containing the PSCell unless explicitly stated otherwise.

**ProSe-enabled Public Safety UE:** a UE that the HPLMN has configured to be authorized for Public Safety use, and which is ProSe-enabled and supports ProSe procedures and capabilities specific to Public Safety. The UE may, but need not, have a USIM with one of the special access classes {12, 13, 14}.

**ProSe Per-Packet Priority:** a scalar value associated with a protocol data unit that defines the priority handling to be applied for transmission of that protocol data unit.

**ProSe UE-to-Network Relay:** a UE that provides functionality to support connectivity to the network for Remote UE(s).

**ProSe UE-to-Network Relay Selection:** Process of identifying a potential ProSe UE-to Network Relay, which can be used for connectivity services (e.g. to communicate with a PDN).

**ProSe UE-to-Network Relay Reselection:** process of changing previously selected ProSe UE-to-Network Relay and identifying potential a new ProSe UE-to-Network Relay, which can be be used for connectivity services (e.g. to communicate with PDN).

**Public Safety ProSe Carrier:** carrier frequency for public safety sidelink communication and public safety sidelink discovery.

**PUCCH group:** either primary PUCCH group or a secondary PUCCH group.

**PUCCH SCell:** a Secondary Cell configured with PUCCH.

**RACH-less HO/SeNB change**: skipping random access procedure during handover or change of SeNB.

**Receive Only Mode:** See TS 23.246 [48].

**Remote UE:** a ProSe-enabled Public Safety UE, that communicates with a PDN via a ProSe UE-to-Network Relay.

**SCG bearer**: in dual connectivity, a bearer whose radio protocols are only located in the SeNB to use SeNB resources.

**Secondary Cell Group**: in dual connectivity, a group of serving cells associated with the SeNB, comprising of PSCell and optionally one or more SCells.

**Secondary eNB**: in dual connectivity, the eNB that is providing additional radio resources for the UE but is not the Master eNB.

**Secondary PUCCH group:** a group of SCells whose PUCCH signalling is associated with the PUCCH on the PUCCH SCell.

**Secondary Timing Advance Group**: Timing Advance Group containing neither the PCell nor PSCell.

**Short Processing Time**: For 1 ms TTI length, the operation with short processing time in UL data transmission and DL data reception.

**Short TTI:** TTI length based on a slot or a subslot.

**Sidelink**: UE to UE interface for sidelink communication, V2X sidelink communication and sidelink discovery. The Sidelink corresponds to the PC5 interface as defined in TS 23.303 [62].

**Sidelink Control period**: period over which resources are allocated in a cell for sidelink control information and sidelink data transmissions. The Sidelink Control period corresponds to the PSCCH period as defined in TS 36.213 [6].

**Sidelink communication**: AS functionality enabling ProSe Direct Communication as defined in TS 23.303 [62], between two or more nearby UEs, using E-UTRA technology but not traversing any network node. In this version, the terminology "sidelink communication" without "V2X" prefix only concerns PS unless specifically stated otherwise.

**Sidelink discovery**: AS functionality enabling ProSe Direct Discovery as defined in TS 23.303 [62], using E-UTRA technology but not traversing any network node.

**Split bearer**: in dual connectivity, a bearer whose radio protocols are located in both the MeNB and the SeNB to use both MeNB and SeNB resources.

**Split LWA bearer**: in LTE-WLAN Aggregation, a bearer whose radio protocols are located in both the eNB and the WLAN to use both eNB and WLAN radio resources.

**Switched LWA bearer**: in LTE-WLAN Aggregation, a bearer whose radio protocols are located in both the eNB and the WLAN but uses WLAN radio resources only.

**Timing Advance Group**: a group of serving cells that is configured by RRC and that, for the cells with an UL configured, use the same timing reference cell and the same Timing Advance value.

**User plane CIoT 5GS Optimisation**: Enables support for change from 5GMM-IDLE mode to 5GMM-CONNECTED mode without the need for using the Service Request procedure, as defined in TS 24.501 [xx].

**User plane CIoT EPS optimization**: Enables support for change from EMM-IDLE mode to EMM-CONNECTED mode without the need for using the Service Request procedure, as defined in TS 24.301 [20].

**V2X sidelink communication**: AS functionality enabling V2X Communication as defined in TS 23.285 [72], between nearby UEs, using E-UTRA technology but not traversing any network node.

**WLAN Termination**: the logical node that terminates the Xw interface on the WLAN side.

**User plane CIoT 5GS Optimisation**: Enables support for change from 5GMM-IDLE mode to 5GMM-CONNECTED mode without the need for using the Service Request procedure, as defined in TS 24.501 [xx].

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## 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].

1xCSFB Circuit Switched Fallback to 1xRTT

5GC 5G Core Network

ABS Almost Blank Subframe

AC Access Category

ACK Acknowledgement

ACLR Adjacent Channel Leakage Ratio

AM Acknowledged Mode

AMBR Aggregate Maximum Bit Rate

ANDSF Access Network Discovery and Selection Function

ANR Automatic Neighbour Relation

ARP Allocation and Retention Priority

ARQ Automatic Repeat Request

AS Access Stratum

AUL Autonomous Uplink

BCCH Broadcast Control Channel

BCH Broadcast Channel

BL Bandwidth reduced Low complexity

BR-BCCH Bandwidth Reduced Broadcast Control Channel

BSR Buffer Status Report

C/I Carrier-to-Interference Power Ratio

CA Carrier Aggregation

CAZAC Constant Amplitude Zero Auto-Correlation

CBC Cell Broadcast Center

CC Component Carrier

CG Cell Group

CIF Carrier Indicator Field

CIoT Cellular Internet of Things

CMAS Commercial Mobile Alert Service

CMC Connection Mobility Control

C-plane Control Plane

C-RNTI Cell RNTI

CoMP Coordinated Multi Point

CP Cyclic Prefix

CQI Channel Quality Indicator

CRC Cyclic Redundancy Check

CRE Cell Range Extension

CRS Cell-specific Reference Signal

CSA Common Subframe Allocation

CSG Closed Subscriber Group

CSI Channel State Information

CSI-IM CSI interference measurement

CSI-RS CSI reference signal

DC Dual Connectivity

DCCH Dedicated Control Channel

DCN Dedicated Core Network

DeNB Donor eNB

DFTS DFT Spread OFDM

DL Downlink

DMTC Discovery Signal Measurement Timing Configuration

DRB Data Radio Bearer

DRS Discovery Reference Signal

DRX Discontinuous Reception

DTCH Dedicated Traffic Channel

DTX Discontinuous Transmission

DwPTS Downlink Pilot Time Slot

E-CID Enhanced Cell-ID (positioning method)

E-RAB E-UTRAN Radio Access Bearer

E-UTRA Evolved UTRA

E-UTRAN Evolved UTRAN

EAB Extended Access Barring

ECGI E-UTRAN Cell Global Identifier

ECM EPS Connection Management

EDT Early Data Transmission

eHRPD enhanced High Rate Packet Data

eIMTA Enhanced Interference Management and Traffic Adaptation

EMM EPS Mobility Management

eNB E-UTRAN NodeB

EPC Evolved Packet Core

EPDCCH Enhanced Physical Downlink Control Channel

EPS Evolved Packet System

ETWS Earthquake and Tsunami Warning System

FDD Frequency Division Duplex

FDM Frequency Division Multiplexing

G-RNTI Group RNTI

GBR Guaranteed Bit Rate

GERAN GSM EDGE Radio Access Network

GNSS Global Navigation Satellite System

GP Guard Period

GRE Generic Routing Encapsulation

GSM Global System for Mobile communication

GUMMEI Globally Unique MME Identifier

GUTI Globally Unique Temporary Identifier

GWCN GateWay Core Network

GWUS Group Wake Up Signal

H-SFN Hyper System Frame Number

HARQ Hybrid ARQ

(H)eNB eNB or HeNB

HO Handover

HPLMN Home Public Land Mobile Network

HRPD High Rate Packet Data

HSDPA High Speed Downlink Packet Access

ICIC Inter-Cell Interference Coordination

IDC In-Device Coexistence

IP Internet Protocol

ISM Industrial, Scientific and Medical

KPAS Korean Public Alert System

L-GW Local Gateway

LAA Licensed-Assisted Access

LB Load Balancing

LBT Listen Before Talk

LCG Logical Channel Group

LCR Low Chip Rate

LCS LoCation Service

LHN Local Home Network

LHN ID Local Home Network ID

LIPA Local IP Access

LMU Location Measurement Unit

LPPa LTE Positioning Protocol Annex

LTE Long Term Evolution

LWA LTE-WLAN Aggregation

LWAAP LTE-WLAN Aggregation Adaptation Protocol

LWIP LTE WLAN Radio Level Integration with IPsec Tunnel

LWIP-SeGW LWIP Security Gateway

MAC Medium Access Control

MBMS Multimedia Broadcast Multicast Service

MBR Maximum Bit Rate

MBSFN Multimedia Broadcast multicast service Single Frequency Network

MCCH Multicast Control Channel

MCE Multi-cell/multicast Coordination Entity

MCG Master Cell Group

MCH Multicast Channel

MCS Modulation and Coding Scheme

MDT Minimization of Drive Tests

MeNB Master eNB

MGW Media Gateway

MIB Master Information Block

MIMO Multiple Input Multiple Output

MME Mobility Management Entity

MMTEL Multimedia telephony

MO-EDT Mobile Originated Early Data Transmission

MPDCCH MTC Physical Downlink Control Channel

MSA MCH Subframe Allocation

MSI MCH Scheduling Information

MSP MCH Scheduling Period

MT-EDT Mobile Terminated Early Data Transmission

MTC Machine-Type Communications

MTCH Multicast Traffic Channel

MTSI Multimedia Telephony Service for IMS

N2 Reference point between the NG-RAN and the AMF

NACK Negative Acknowledgement

NAS Non-Access Stratum

NB-IoT Narrow Band Internet of Things

NCC Next Hop Chaining Counter

NCGI NR Cell Global Identifier

NCR Neighbour Cell Relation

NG-RAN NG Radio Access Network

NH Next Hop key

NNSF NAS Node Selection Function

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

NPRS Narrowband Positioning Reference Signal

NPSS Narrowband Primary Synchronization Signal

NR NR Radio Access

NRT Neighbour Relation Table

NSSS Narrowband Secondary Synchronization Signal

OFDM Orthogonal Frequency Division Multiplexing

OFDMA Orthogonal Frequency Division Multiple Access

OPI Offload Preference Indicator

OTDOA Observed Time Difference Of Arrival (positioning method)

P-GW PDN Gateway

P-RNTI Paging RNTI

PA Power Amplifier

PAPR Peak-to-Average Power Ratio

PBCH Physical Broadcast CHannel

PBR Prioritised Bit Rate

PCC Primary Component Carrier

PCCH Paging Control Channel

PCell Primary Cell

PCFICH Physical Control Format Indicator CHannel

PCH Paging Channel

PCI Physical Cell Identifier

PDCCH Physical Downlink Control CHannel

PDCP Packet Data Convergence Protocol

PDN Packet Data Network

PDSCH Physical Downlink Shared CHannel

PDU Protocol Data Unit

PHICH Physical Hybrid ARQ Indicator CHannel

PHY Physical layer

PLMN Public Land Mobile Network

PMCH Physical Multicast CHannel

PMK Pairwise Master Key

PPPP ProSe Per-Packet Priority

PPPR ProSe Per-Packet Reliability

PRACH Physical Random Access CHannel

PRB Physical Resource Block

ProSe Proximity based Services

PSBCH Physical Sidelink Broadcast CHannel

PSC Packet Scheduling

PSCCH Physical Sidelink Control CHannel

PSCell Primary SCell

PSDCH Physical Sidelink Discovery CHannel

PSK Pre-Shared Key

PSM Power Saving Mode

PSSCH Physical Sidelink Shared CHannel

pTAG Primary Timing Advance Group

PTW Paging Time Window

PUCCH Physical Uplink Control CHannel

PUSCH Physical Uplink Shared CHannel

PWS Public Warning System

QAM Quadrature Amplitude Modulation

QCI QoS Class Identifier

QoE Quality of Experience

QoS Quality of Service

R-PDCCH Relay Physical Downlink Control CHannel

RA-RNTI Random Access RNTI

RAC Radio Admission Control

RACH Random Access Channel

RANAC RAN-based Notification Area code

RAT Radio Access Technology

RB Radio Bearer

RBC Radio Bearer Control

RCLWI RAN Controlled LTE-WLAN Interworking

RF Radio Frequency

RIBS Radio-interface based synchronization

RIM RAN Information Management

RLC Radio Link Control

RMTC RSSI Measurement Timing Configuration

RN Relay Node

RNA RAN-based Notification Area

RNAU RAN-based Notification Area Update

RNC Radio Network Controller

RNL Radio Network Layer

RNTI Radio Network Temporary Identifier

ROHC Robust Header Compression

ROM Receive Only Mode

RRC Radio Resource Control

RRM Radio Resource Management

RU Resource Unit

S-GW Serving Gateway

S-RSRP Sidelink Reference Signal Received Power

S1-MME S1 for the control plane

SAE System Architecture Evolution

SAP Service Access Point

SBCCH Sidelink Broadcast Control Channel

SC-FDMA Single Carrier – Frequency Division Multiple Access

SC-MCCH Single Cell Multicast Control Channel

SC-MTCH Single Cell Multicast Transport Channel

SC-N-RNTI Single Cell Notification RNTI

SC-PTM Single Cell Point To Multiploint

SC-RNTI Single Cell RNTI

SCC Secondary Component Carrier

SCell Secondary Cell

SCG Secondary Cell Group

SCH Synchronization Channel

SCTP Stream Control Transmission Protocol

SD-RSRP Sidelink Discovery Reference Signal Received Power

SDAP Service Data Adaptation Protocol

SDF Service Data Flow

SDMA Spatial Division Multiple Access

SDU Service Data Unit

SeGW Security Gateway

SeNB Secondary eNB

SFN System Frame Number

SI System Information

SI-RNTI System Information RNTI

S1-U S1 for the user plane

SIB System Information Block

SIPTO Selected IP Traffic Offload

SIPTO@LN Selected IP Traffic Offload at the Local Network

SL-BCH Sidelink Broadcast Channel

SL-DCH Sidelink Discovery Channel

SL-RNTI Sidelink RNTI

SL-SCH Sidelink Shared Channel

SPDCCH Short PDCCH

SPID Subscriber Profile ID for RAT/Frequency Priority

SPT Short Processing Time

SPUCCH Short PUCCH

SR Scheduling Request

SRB Signalling Radio Bearer

sTAG Secondary Timing Advance Group

STCH Sidelink Traffic Channel

SU Scheduling Unit

TA Tracking Area

TAG Timing Advance Group

TB Transport Block

TCP Transmission Control Protocol

TDD Time Division Duplex

TDM Time Division Multiplexing

TEID Tunnel Endpoint Identifier

TFT Traffic Flow Template

TM Transparent Mode

TMGI Temporary Mobile Group Identity

TNL Transport Network Layer

TTI Transmission Time Interval

U-plane User plane

UAC Unified Access Control

UDC Uplink Data Compression

UE User Equipment

UL Uplink

UM Unacknowledged Mode

UMTS Universal Mobile Telecommunication System

UpPTS Uplink Pilot Time Slot

UTRA Universal Terrestrial Radio Access

UTRAN Universal Terrestrial Radio Access Network

V2I Vehicle-to-Infrastructure

V2N Vehicle-to-Network

V2P Vehicle-to-Pedestrian

V2V Vehicle-to-Vehicle

V2X Vehicle-to-Everything

VRB Virtual Resource Block

WLAN Wireless Local Area Network

WT WLAN Termination

WUS Wake Up Signal

X2-C X2-Control plane

X2 GW X2 GateWay

X2-U X2-User plane

Xw-C Xw-Control plane

Xw-U Xw-User plane

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## 4.10 NB-IoT

NB-IoT provides access to network services using physical layer optimized for very low power consumption (e.g. full carrier bandwidth is 180 kHz, subcarrier spacing can be 3.75 kHz or 15 kHz).

As indicated in the relevant clauses in this specification, a number of E-UTRA protocol functions supported by all Rel-8 UEs are not used for NB-IoT and need not be supported by eNBs and UEs only using NB-IoT.

In this version of the specification, a number of functions including inter-RAT mobility, handover, measurement reports, public warning functions, GBR, CSG, support of HeNBs, relaying, carrier aggregation, dual connectivity, NAICS, real-time services, interference avoidance for in-device coexistence, RAN assisted WLAN interworking, sidelink communication/discovery, V2X sidelink communication, MDT, emergency call, CS fallback, ACB, EAB, ACDC, SSAC, aerial UE Communication, EN-DC and RRC\_INACTIVE are not supported for NB-IoT. This is not further stated in the corresponding procedures.

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| Next change |

# 7 RRC

## 7.0 General

This clause provides an overview on services and functions provided by the RRC sublayer.

## 7.1 Services and Functions

The main services and functions of the RRC sublayer include:

- Broadcast of System Information related to the non-access stratum (NAS);

- Broadcast of System Information related to the access stratum (AS);

- Paging;

- Establishment, maintenance and release of an RRC connection between the UE and E-UTRAN including:

- Allocation of temporary identifiers between UE and E-UTRAN;

- Configuration of signalling radio bearer(s) for RRC connection:

- Low priority SRB and high priority SRB;

- For NB-IoT, a UE dedicated SRB is supported before AS security is activated and only one UE dedicated SRB is supported after AS security is activated;

- For a NB-IoT UE that supports S1-U data transfer or User Plane CIoT EPS optimization, as defined in TS 24.301 [20]; or

- For a NB-IoT UE that supports NG-U data transfer or User Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx]

- One DRB is supported by default and up to two DRBs are supported optionally;

- For a UE that supports User Plane CIoT EPS optimization, as specified in TS 24.301 [20]; or

- For a UE that supports User Plane CIoT 5GS Optimisation, as specified in TS 24.501 [xx]:

- Suspension/resuming of the RRC connection;

- Security functions including key management;

- Establishment, configuration, maintenance and release of point to point Radio Bearers;

- Mobility functions including:

- UE measurement reporting and control of the reporting for inter-cell and inter-RAT mobility;

- Handover;

- UE cell selection and reselection and control of cell selection and reselection;

- Context transfer at handover.

- Notification and counting for MBMS services;

- Establishment, configuration, maintenance and release of Radio Bearers for MBMS services;

- QoS management functions;

- UE measurement reporting and control of the reporting;

- NAS direct message transfer to/from NAS from/to UE.

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## 7.2 RRC protocol states & state transitions

RRC uses the following states:

- **RRC\_IDLE**:

- PLMN selection;

- DRX configured by NAS;

- Broadcast of system information;

- Paging;

- Cell re-selection mobility;

- The UE shall have been allocated an id which uniquely identifies the UE in a tracking area;

- No RRC context stored in the eNB and ng-eNB (except for a UE that supports User Plane CIoT EPS optimizations, as specified in TS 24.301 [20] and User Plane CIoT 5GS optimisations, as specified in TS 24.501 [xx], where a context may be stored for the resume procedure);

Editor’s Note: FFS whether some additional information needs to be mentioned for PUR

- Sidelink communication transmission and reception;

- Sidelink discovery announcement and monitoring;

- V2X sidelink communication transmission and reception;

- MO-EDT;

- MT-EDT;

- Transmission using PUR.

- **RRC\_CONNECTED**:

- UE has an E-UTRAN-RRC connection;

- UE has context in E-UTRAN;

- E-UTRAN knows the cell which the UE belongs to;

- Network can transmit and/or receive data to/from UE;

- Network controlled mobility (handover and inter-RAT cell change order to GERAN with NACC);

- Neighbour cell measurements;

- Sidelink communication transmission and reception;

- Sidelink discovery announcement and monitoring;

- V2X sidelink communication transmission and reception;

- At PDCP/RLC/MAC level:

- UE can transmit and/or receive data to/from network;

- UE monitors control signalling channel for shared data channel to see if any transmission over the shared data channel has been allocated to the UE;

- UE also reports channel quality information and feedback information to eNB;

- DRX period can be configured according to UE activity level for UE power saving and efficient resource utilization. This is under control of the eNB.

E-UTRA connected to 5GC additionally supports RRC\_INACTIVE state, which has the same characteristics as RRC\_INACTIVE of NR connected to 5GC, as specified in TS 38.300 [79].

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## 7.3 Transport of NAS messages

The AS provides reliable in-sequence delivery of NAS messages in a cell. During handover, message loss or duplication of NAS messages can occur.

In E-UTRAN, NAS messages are either concatenated with RRC messages or carried in RRC without concatenation. Upon arrival of concurrent NAS messages for the same UE requiring both concatenation with RRC for the high priority queue and also without concatenation for the lower priority queue, the messages are first queued as necessary to maintain in-sequence delivery.

In downlink, when an EPS bearer (EPC) or PDU Session (5GC) establishment or release procedure is triggered, or for EDT in case of Control Plane CIoT EPS optimization or Control Plane CIoT 5GS Optimisation, the NAS message should normally be concatenated with the associated RRC message. When the EPS bearer (EPC) or PDU Session (5GC) is modified and when the modification also depends on a modification of the radio bearer, the NAS message and associated RRC message should normally be concatenated. Concatenation of DL NAS with RRC message is not allowed otherwise. In uplink, concatenation of NAS messages with RRC message is used only for transferring the initial NAS message during connection setup and for EDT in case of Control Plane CIoT EPS optimization or Control Plane CIoT 5GS Optimisation. Initial Direct Transfer is not used in E-UTRAN and no NAS message is concatenated with RRC connection request.

Multiple NAS messages can be sent in a single downlink RRC message during EPS bearer (EPC) or PDU Session (5GC) establishment or modification. In this case, the order of the NAS messages in the RRC message shall be kept the same as that in the corresponding S1-AP (EPC) or NG-AP (5GC) message in order to ensure the in-sequence delivery of NAS messages.

NOTE: NAS messages are integrity protected and ciphered by PDCP, in addition to the integrity protection and ciphering performed by NAS.

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## 7.3a CIoT signalling reduction optimizations

### 7.3a.1 General

Which solution of CIoT signalling reduction optimizations to be used is configured over NAS signalling between the UE and the MME or the AMF.

For NB-IoT, PDCP is not used while AS security is not activated.

### 7.3a.2 Control Plane CIoT EPS/5GS optimizations

The RRC connection established for Control Plane CIoT EPS optimizations, as defined in TS 24.301 [20], and Control Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], are characterized as below:

- A UL NAS signalling message or UL NAS message carrying data can be transmitted in a UL RRC container message (see Figure 7.3a.2-1). A DL NAS signaling or DL NAS data can be transmitted in a DL RRC container message;

- for NB-IoT:

- RRC connection reconfiguration is not supported;

- Data radio bearer (DRB) is not used;

- AS security is not used;

- A non-anchor carrier can be configured for all unicast transmissions during RRC connection establishment or re-establishment.

- There is no differentiation between the different data types (i.e. IP, non-IP or SMS) in the AS.



Figure 7.3a.2-1: The RRC connection established for Control Plane CIoT EPS/5GS Optimizations

### 7.3a.3 User Plane CIoT EPS/5GS optimizations

The RRC connection established for User Plane CIoT EPS optimization, as defined in TS 24.301 [20], and User Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], are characterized as below:

- A RRC connection suspend procedure is used at RRC connection release, the (ng-)eNB may request the UE to retain the UE AS context including UE capability in RRC\_IDLE;

- A RRC connection resume procedure is used at transition from RRC\_IDLE to RRC\_CONNECTED where previously stored information in the UE as well as in the (ng-)eNB is utilised to resume the RRC connection. In the message to resume, the UE provides a Resume ID (for EPS) or I-RNTI (for 5GS) to be used by the (ng-)eNB to access the stored information required to resume the RRC connection;

- At suspend-resume, security is continued. Re-keying is not supported in RRC connection resume procedure. The short MAC-I is reused as the authentication token at RRC connection reestablishment procedure and RRC connection resume procedure by the UE. For EPS, the eNB provides the NCC in the *RRCConnectionResume* message as well. And also the UE resets the COUNT;

- Multiplexing of CCCH and DTCH in the transition from RRC\_IDLE to RRC CONNECTED is not supported;

- For NB-IoT, a non-anchor carrier can be configured for all unicast transmissions when an RRC connection is re-established, resumed or reconfigured additionally when an RRC connection is established.

The RRC connection suspend and resume procedures are illustrated in Figures 7.3a.3-1/7.3a.3-1a and 7.3a.3-2/7.3a.3-2a, respectively. Note that the description here is only intended as an overview and all parameters are therefore not listed in the message flows.



Figure 7.3a.3-1: RRC Connection Suspend procedure in EPS



Figure 7.3a.3-1a: RRC Connection Suspend procedure in 5GS

1. Due to some triggers, e.g. the expiry of a UE inactivity timer, the (ng-)eNB decides to suspend the RRC connection.

2. In EPS, the eNB initiates the S1-AP UE Context Suspend procedure to inform the MME that the RRC connection is being suspended. In 5GS, the ng-eNB initiates the NG-AP UE Context Suspend procedure to inform the AMF that the RRC connection is being suspended.

3. In EPS, the MME requests the S-GW to release all S1-U bearers for the UE. In 5GS, the AMF requests the SMF to suspend the PDU session and the SMF requests the UPF to release the tunnel information for the UE.

4. MME/AMF Acks step 2.

5. The (ng-)eNB suspends the RRC connection by sending an *RRCConnectionRelease* message with the *releaseCause* set to *rrc-Suspend*. For EPS, the message includes the Resume ID which is stored by the UE and optionally, for EDT and transmission using PUR, the message also includes the *NextHopChainingCount* which is stored by the UE. For 5GS, the message includes the I-RNTI and NextHopChainingCount which are stored by the UE.

6. The UE stores the AS context, suspends all SRBs and DRBs, and enters RRC\_IDLE.



Figure 7.3a.3-2: RRC Connection Resume procedure in EPS



Figure 7.3a.3-2a: RRC Connection Resume procedure in 5GS

1. At some later point in time (e.g. when the UE is being paged or when new data arrives in the uplink buffer) the UE resumes the connection by sending an *RRCConnectionResumeRequest* to the (ng-)eNB. The UE includes its Resume ID (for EPS) or I-RNTI (for 5GS), the establishment cause, and authentication token. The authentication token is calculated in the same way as the short MAC-I used in RRC connection re-establishment and allows the (ng-)eNB to verify the UE identity. For 5GS, the UE resumes SRB1, derives new security keys using the *NextHopChainingCount* provided in the *RRCConnectionRelease* message of the previous RRC connection and re-establishes the AS security.

2. Provided that the Resume ID (for EPS) or I-RNTI (for 5GS) exists and the authentication token is successfully validated, the (ng-)eNB responds with an *RRCConnectionResume*. For EPS, the message includes the Next Hop Chaining Count (NCC) value which is required in order to re-establish the AS security.

3. For EPS, the UE resumes all SRBs and DRBs and re-establishes the AS security. For 5GS, the UE resumes all other SRBs and all DRBs. The UE is now in RRC\_CONNECTED.

4. The UE responds with an *RRCConnectionResumeComplete* confirming that the RRC connection was resumed successfully, along with an uplink Buffer Status Report, and/or UL data, whenever possible, to the eNB.

5. For EPS, the eNB initiates the S1-AP Context Resume procedure to notify the MME about the UE state change. For 5GS, the ng-eNB initiates the NG-AP Context Resume procedure to notify the AMF about the UE state change.

6. Fpr EPS, the MME requests the S-GW to activate the S1-U bearers for the UE. For 5GS, the AMF requests the SMF to resume the PDU session and the SMF requests the UPF to establish the tunnel information for the UE.

7. MME/AMF Acks step 5.

An RRC connection can also be resumed in an (ng-)eNB (the new (ng-)eNB) different from the one where the connection was suspended (the old (ng-)eNB). Inter (ng-)eNB connection resumption is handled using context fetching, whereby the new (ng-)eNB retrieves the UE context from the old (ng-)eNB over the X2/Xn interface. The new (ng-)eNB provides the Resume ID which is used by the old (ng-)eNB to identify the UE context. This is illustrated in Figure 7.3a.3-3/7.3a.3-3a.



Figure 7.3a.3-3: RRC Connection Resume procedure in different eNB in EPS



Figure 7.3a.3-3a: RRC Connection Resume procedure in different ng-eNB in 5GS

1. Same as step 1 in the intra (ng-)eNB connection resumption.

2. The new (ng-)eNB locates the old eNB using the Resume ID (for EPS) or I-RNTI (for 5GS) and retrieves the UE context by means of the X2-AP (for EPS) or Xn-AP (for 5GS) Retrieve UE Context procedure.

3. The old (ng-)eNB responds with the UE context associated with the Resume ID (for EPS) or I-RNTI (for 5GS).

4. Same as step 2 in the intra (ng-)eNB connection resumption.

5. Same as step 3 in the intra (ng-)eNB connection resumption.

6. Same as step 4 in the intra (ng-)eNB connection resumption.

7. For EPS, the new eNB initiates the S1-AP Path Switch procedure to establish a S1 UE associated signalling connection to the serving MME and to request the MME to resume the UE context. For 5GS, the AMF requests the SMF to resume the PDU session and the SMF requests the UPF to create the tunnel information for the UE and update the downlink path.

8. For EPS, the MME requests the S-GW to activate the S1-U bearers for the UE and updates the downlink path. For 5GS, the AMF requests the SMF to resume the PDU session and the SMF requests the UPF to create the tunnel information for the UE and update the downlink path.

9. MME/AMF Acks step 7.

10. For EPS, after the S1-AP Path Switch procedure the new eNB triggers release of the UE context at the old eNB by means of the X2-AP UE Context Release procedure. For 5GS, after the NG-AP Path Switch procedure the new ng-eNB triggers release of the UE context at the old ng-eNB by means of the Xn-AP UE Context Release procedure.

For a NB-IoT UE that supports Control Plane CIoT EPS optimization and S1-U data transfer or User Plane CIoT EPS optimization, as defined in TS 24.301 [20], and for a NB-IoT UE that supports Control Plane CIoT 5GS Optimisation and NG-U data transfer or User Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], PDCP is not used until AS security is activated.

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## 7.3b MO-EDT

### 7.3b.1 General

MO-EDT allows one uplink data transmission optionally followed by one downlink data transmission during the random access procedure.

MO-EDT is triggered when the upper layers have requested the establishment or resumption of the RRC Connection for Mobile Originated data (i.e., not signalling or SMS) and the uplink data size is less than or equal to a TB size indicated in the system information. MO-EDT is not used for data over the control plane when using the User Plane CIoT EPS/5GS optimizations.

MO-EDT is only applicable to BL UEs, UEs in Enhanced Coverage and NB-IoT UEs.

### 7.3b.2 MO-EDT for Control Plane CIoT EPS/5GS optimizations

MO-EDT for Control Plane CIoT EPS optimizations, as defined in TS 24.301 [20], and Control Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], are characterized as below:

- Uplink user data are transmitted in a NAS message concatenated in UL RRCEarlyDataRequest message on CCCH;

- Downlink user data are optionally transmitted in a NAS message concatenated in DL RRCEarlyDataComplete message on CCCH;

- There is no transition to RRC CONNECTED.

The MO-EDT procedure for Control Plane CIoT EPS optimizations and Control Plane CIoT 5GS Optimisations are illustrated in Figure 7.3b-1 and Figure 7.3b-1a respectively.



Figure 7.3b-1: MO-EDT for Control Plane CIoT EPS Optimizations



Figure 7.3b-1a: MO-EDT for Control Plane CIoT 5GS Optimisations

0. Upon connection establishment request for Mobile Originated data from the upper layers, the UE initiates the MO-EDTprocedure and selects a random access preamble configured for EDT.

1. UE sends *RRCEarlyDataRequest* message concatenating the user data on CCCH. For EPS if enabled in the cell, or for 5GS, the UE may indicate AS Release Assistance Information.

2. For EPS, the eNB initiates the S1-AP Initial UE message procedure to forward the NAS message and establish the S1 connection. For 5GS, the ng-eNB initiates the NG-AP Initial UE message procedure to forward the NAS message. The (ng-)eNB may indicate in this procedure that this connection is triggered for EDT.

3. For EPS, the MME requests the S-GW to re-activate the EPS bearers for the UE. For 5GS, the AMF determines the PDU session contained in the NAS message.

4. For EPS, the MME sends the uplink data to the S-GW. For 5GS, the AMF sends the PDU Session ID and the uplink data to the SMF and the SMF forwards the uplink data to the UPF.

5. For EPS, if downlink data are available, the S-GW sends the downlink data to the MME. For 5GS, if downlink data are available, the UPF forwards the downlink data to SMF and the SFM forwards the downlink data to AMF.

6. If downlink data are received from the S-GW or SMF, the MME or AMF forwards the data to the eNB or ng-eNB via DL NAS Transport procedure and may also indicate whether further data are expected. Otherwise, the MME or AMF may trigger Connection Establishment Indication procedure and also indicate whether further data are expected.

7. If no further data are expected, the (ng-)eNB can send the *RRCEarlyDataComplete* message on CCCH to keep the UE in RRC\_IDLE. If downlink data were received in step 6, they are concatenated in *RRCEarlyDataComplete* message.

8. For EPS, the S1 connection is released and the EPS bearers are deactivated.

NOTE 1: If the MME/AMF or the (ng-)eNB decides to move the UE in RRC\_CONNECTED mode, *RRCConnectionSetup* message is sent in step 7 to fall back to the legacy RRC Connection establishment procedure; the (ng-)eNB will discard the zero-length NAS PDU received in*RRCConnectionSetupComplete* message.

NOTE 2: If neither *RRCEarlyDataComplete* nor, in case of fallback, *RRCConnectionSetup* is received in response to *RRCEarlyDataRequest*, the UE considers the UL data transmission not successful.

### 7.3b.3 MO-EDT for User Plane CIoT EPS/5GS optimizations

MO-EDT for User Plane CIoT EPS optimizations, as defined in TS 24.301 [20], and for User Plane CIoT 5GS Optimisations, as defined in TS 24.501 [xx], are characterized as below:

- The UE has been provided with a *NextHopChainingCount* in the *RRCConnectionRelease* message with suspend indication;

- Uplink user data are transmitted on DTCH multiplexed with UL *RRCConnectionResumeRequest* message on CCCH;

- Downlink user data are optionally transmitted on DTCH multiplexed with DL *RRCConnectionRelease* message on DCCH;

- The short resume MAC-I is reused as the authentication token for *RRCConnectionResumeRequest* message and is calculated using the integrity key from the previous connection;

- The user data in uplink and downlink are ciphered. The keys are derived using the *NextHopChainingCount* provided in the *RRCConnectionRelease* message of the previous RRC connection;

- The *RRCConnectionRelease* message is integrity protected and ciphered using the newly derived keys;

- There is no transition to RRC CONNECTED.

The MO-EDT procedure for User Plane CIoT EPS optimizations is illustrated in Figure 7.3b-2.



Figure 7.3b-2: EDT for User Plane CIoT EPS Optimizations

0. Upon connection resumption request for Mobile Originated data from the upper layers, the UE initiates the MO-EDT procedure and selects a random access preamble configured for EDT.

1. The UE sends an *RRCConnectionResumeRequest* to the eNB, including its Resume ID, the establishment cause, and an authentication token. The UE resumes all SRBs and DRBs, derives new security keys using the *NextHopChainingCount* provided in the *RRCConnectionRelease* message of the previous connection and re-establishes the AS security. The user data are ciphered and transmitted on DTCH multiplexed with the *RRCConnectionResumeRequest* message on CCCH. If enabled, the UE may indicate AS Release Assistance Information.

2. The eNB initiates the S1-AP Context Resume procedure to resume the S1 connection and re-activate the S1-U bearers.

3. The MME requests the S-GW to re-activate the S1-U bearers for the UE.

4. The MME confirms the UE context resumption to the eNB.

5. The uplink data are delivered to the S-GW.

6. If downlink data are available, the S-GW sends the downlink data to the eNB.

7. If no further data are expected, the eNB can initiate the suspension of the S1 connection and the deactivation of the S1-U bearers.

8. The eNB sends the *RRCConnectionRelease* message to keep the UE in RRC\_IDLE. The message includes the *releaseCause* set to *rrc-Suspend*, the *resumeID,* the *NextHopChainingCount* and *drb-ContinueROHC* which are stored by the UE. If downlink data were received in step 6, they are sent ciphered on DTCH multiplexed with the *RRCConnectionRelease* message on DCCH.

The MO-EDT procedure for User Plane CIoT 5GS Optimisations is illustrated in Figure 7.3b-2a.



**Figure 7.3b-2a: MO-EDT for User Plane CIoT 5GS Optimisations**

0. Upon connection resumption request for Mobile Originated data from the upper layers, the UE initiates the MO-EDT procedure and selects a random access preamble configured for EDT.

1. The UE sends an *RRCConnectionResumeRequest* to the ng-eNB, including its I-RNTI, the resume cause, and an authentication token. The UE resumes all SRBs and DRBs, derives new security keys using the *NextHopChainingCount* provided in the *RRCConnectionRelease* message of the previous connection and re-establishes the AS security. The user data are ciphered and transmitted on DTCH multiplexed with the *RRCConnectionResumeRequest* message on CCCH. The UE may indicate AS Release Assistance Information.

2. The uplink data are delivered to the UPF.

3. The ng-eNB sends a NG-AP Context Resume Request message to the AMF to resume the connection. If the UE included AS Release Assistance information indicating No further UL/DL higher layer PDU in step 1, ng-eNB may request for immediate transition to RRC IDLE with Suspend.

4. If the AMF does not receive a request for immediate transition to RRC IDLE with Suspend in step 3 or the AMF is aware of downlink data or signalling pending, the AMF requests the SMF to resume the PDU session.

5. The AMF sends a NG-AP Context Resume Response to the ng-eNB. If the AMF receives a request for immediate transition to RRC IDLE with Suspend in step 3 and there is no downlink data or signalling pending, the AMF includes a Suspend indication, and keeps the UE in CM-IDLE with Suspend.

6. If the AMF includes Suspend indication in step 5, the ng-eNB proceeds to step 8. If the AMF does not include Suspend indication and the UE included AS Release Assistance information indicating Only a single Downlink Data transmission subsequent to the Uplink transmission in step 1, the ng-eNB may wait for the DL data to arrive, and proceeds to step 7.

7 The ng-eNB initiates the NG-AP UE Context Suspend procedure to inform the AMF that the RRC connection is being suspended. The AMF requests the SMF to suspend the PDU session and the SMF requests the UPF to release the tunnel information for the UE.

8. The eNB sends the *RRCConnectionRelease* message to keep the UE in RRC\_IDLE. The message includes the *releaseCause* set to *rrc-Suspend*, the *I-RNTI,* the *NextHopChainingCount* and *drb-ContinueROHC* which are stored by the UE. If downlink data were received in step 6, they are sent ciphered on DTCH multiplexed with the *RRCConnectionRelease* message on DCCH.

NOTE 1: If the MME/AMF or (ng-)eNB decides the UE to move in RRC\_CONNECTED mode, *RRCConnectionResume* message is sent in step 7 to fall back to the RRC Connection resume procedure. In that case, the *RRCConnectionResume* message is integrity protected and ciphered with the keys derived in step 1 and the UE ignores the *NextHopChainingCount* included in the *RRCConnectionResume* message. Downlink data can be transmitted on DTCH multiplexed with the *RRCConnectionResume* message. In addition, an *RRCConnectionSetup* can also be sent in step 7 to fall back to the RRC Connection establishment procedure.

NOTE 2: If neither *RRCConnectionRelease* nor, in case of fallback, *RRCConnectionResume* is received in response to *RRCConnectionResumeRequest* for MO-EDT,the UE considers the UL data transmission not successful.

For MO-EDT for User Plane CIoT EPS Optimizations and User Plane CIoT 5GS Optimisations, an RRC connection can also be resumed in an (ng-)eNB (the new (ng-)eNB) different from the one where the connection was suspended (the old eNB). Inter (ng-)eNB connection resumption is handled using context fetching, whereby the new eNB retrieves the UE context from the old eNB over the X2 (Xn) interface. The new (ng-)eNB provides the Resume ID for EPS or I-RNTI for 5GS which is used by the old (ng-)eNB to identify the UE context. This is illustrated in Figure 7.3b-3 for the case of User Plane CIoT EPS Optimisations and for the case of User Plane CIoT 5GS Optimisations respectively.



Figure: 7.3b-3: MO-EDT for User Plane CIoT EPS Optimizations in different eNB



Figure: 7.3b-3a: MO-EDT for User Plane CIoT 5GS Optimisations in different ng-eNB

1. Same as step 1 in the intra (ng-)eNB connection resumption.

2. The new (ng-)eNB locates the old (ng-)eNB using the Resume ID (for EPS) or I-RNTI (for 5GS) and retrieves the UE context by means of the X2-AP (for EPS) or Xn-AP (for 5GS) Retrieve UE Context procedure.

3. The old (ng-)eNB responds with the UE context associated with the Resume ID (for EPS) or I-RNTI (for 5GS).

4. For EPS, the new eNB initiates the S1-AP Path Switch procedure to establish a S1 UE associated signalling connection to the serving MME and to request the MME to resume the UE context. For 5GS, the new ng-eNB initiates the NG-AP Path Switch procedure to establish a NG UE associated signalling connection to the serving AMF and to request the AMF to resume the UE context.5. For EPS, the MME requests the S-GW to activate the S1-U bearers for the UE and updates the downlink path. For 5GS, the AMF requests requests the SMF to resume the PDU session and the SMF requests the UPF to create the tunnel information for the UE and update the downlink path.

6. MME/AMF Acks step 5.

7. For EPS, after the S1-AP Path Switch procedure the new eNB triggers release of the UE context at the old eNB by means of the X2-AP UE Context Release procedure. For 5GS, after the NG-AP Path Switch procedure the new ng-eNB triggers release of the UE context at the old ng-eNB by means of the Xn-AP UE Context Release procedure.

8. For EPS, same as step 5 in the intra eNB connection resumption. For 5GS, the uplink data are delivered to the UPF.

9. Same as step 6 in the intra (ng-)eNB connection resumption.

10. Same as step 7 in the intra (ng-)eNB connection resumption.

11. Same as step 8 in the intra (ng-)eNB connection resumption.

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## 7.3x MT-EDT

### 7.3x.1 General

MT-EDT is intended for one single downlink data transmission during the random access procedure.

MT-EDT is initiated by the MME if the UE and the network support MT-EDT and there is a single DL data transmission for the UE.

MT-EDT for Control Plane CIoT EPS Optimisations and for User Plane CIoT EPS Optimisations, as defined in TS 23.401 [17], is characterised as below:

- Support for MT-EDT for the Control Plane CIoT EPS Optimisation and/or for the User Plane CIoT EPS Optimisation is reported by UE at NAS level;

- DL data size is included in the S1-AP Paging message for the UE;

- MT-EDT indication is included in the *Paging* message for the UE over the Uu interface;

- For User Plane CIoT EPS Optimisation, the UE has been provided with a *NextHopChainingCount* in the *RRCConnectionRelease* message with suspend indication;

- In response to the *Paging* message including MT-EDT indication, the UE triggers the MO-EDT procedure for Control Plane CIoT EPS Optimisations or for User Plane CIoT EPS Optimisations if the upper layers request the establishment or resumption of the RRC Connection for Mobile Terminated Call;

- There is no transition to RRC CONNECTED.

MT-EDT is only applicable to BL UEs, UEs in enhanced coverage and NB-IoT UEs.

### 7.3x.2 MT-EDT for Control Plane CIoT EPS Optimisations

The MT-EDT procedure for Control Plane CIoT EPS Optimisations is illustrated in Figure 7.3x-1.



Figure 7.3x-1: MT-EDT for Control Plane CIoT EPS Optimisations

1. Upon arrival of downlink data, the SGW may send the DL data size to the MME for MT-EDT consideration by the MME.

2. The MME includes the DL data size in the S1-AP PAGING message to assist eNodeB in triggering MT-EDT.

3. If the data can fit in one single downlink transmission according to the UE category included in the UE Radio Capability for Paging provided in the S1-AP Paging message, the eNB includes *mt-EDT* indication in the *Paging* message for the UE.

4. The UE initiates the MO-EDT procedure for the Control Plane CIoT EPS Optimisations as described in subclause 7.3b.2 with the following differences:

- In step 1, the UE sends *RRCEarlyDataRequest* message with the establishment cause *mt-Access* andwithout user data.

- In step 7, in case of fallback to the RRC Connection establishment procedure, the downlink data may optionally be included in *RRCConnectionSetup* message

### 7.3x.3 MT-EDT for User Plane CIoT EPS Optimisations

The MT-EDT procedure for User Plane CIoT EPS Optimisations is illustrated in Figure 7.3x-2.



Figure 7.3x-2: MT-EDT for User Plane CIoT EPS Optimisations

1. Upon arrival of downlink data, the SGW may send the DL data size to the MME for MT-EDT consideration by the MME.

2. The MME may include the DL data size in the S1-AP PAGING message to assist eNodeB in triggering MT- EDT.

3. If the data can fit in one single downlink transmission according to the UE category included in the UE Radio Capability for Paging provided in the S1-AP Paging message, the eNB includes *mt-EDT* indication in the *Paging* message for the UE.

4. The UE may initiate the MO-EDT procedure for the User Plane CIoT EPS Optimisations as described in subclause 7.3b.3 with the following differences:

- In step 0, the UE selects a random access preamble not configured for EDT;

- In step 1, the UE sends *RRCConnectionResumeRequest* message with the resume cause *mt-EDT* and without user data.

- In step 4, the MME may include the Pending Data Indication in the S1AP UE Context Resume Response message to notify the eNB of further data traffic in excess of that initially signalled in step 2. The eNB may use this indication to decide whether to release the UE.

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## 7.3y Transmission using PUR

### 7.3y.1 General

Transmission using PUR allows one uplink transmission from RRC\_IDLE using a preconfigured uplink resource without performing the random access procedure.

Transmission using PUR is enabled by the (ng-)eNB if the UE and the (ng-)eNB support.

The UE may request to be configured with a PUR while in RRC\_CONNECTED mode. The (ng-)eNB decides to configure a PUR that may be based on UE’s request, UE’s subscription information and/or local policy. The PUR is only valid in the cell where the configuration was received.

Transmission using PUR is triggered when the upper layers request the establishment or resumption of the RRC Connection and the UE has a valid PUR for transmission and meets the TA validation criteria as specified in TS 36.331 [16].

Transmission using PUR is only applicable to NB-IoT UEs.

### 7.3y.2 PUR Configuration Request and PUR configuration

The procedure for PUR configuration request and PUR configuration is common to the Control Plane CIoT EPS/5GS optimisations and the User Plane CIoT EPS/5GS optimisations and are illustrated in Figure 7.3y-1.



Figure 7.3y-1: PUR Configuration Request and PUR Configuration

0. The UE is in RRC\_CONNECTED and PUR is enabled in the cell.

1. Based on indication from the upper layers, the UE may indicate to the (ng-)eNB that it is interested in being configured with PUR by sending *PURConfigurationRequest* message providing information about the requested resource (e.g. No. of occurences, periodicity, time offset, TBS, L1 Ack…).

2. When the (ng-)eNB moves the UE to RRC\_IDLE, based on a precedent UE’s request, subscription information and/or local policies, the (ng-)eNB may decide to provide a PUR resource to the UE or to release an existing PUR resource. The (ng-)eNB includes the details of the PUR configuration or a PUR release indication in the *RRCConnectionRelease* message.

Editor’s note: For the CP solution, FFS whether full configuration is kept in eNB or part of it in MME.

NOTE: The PUR configuration can be implicitly released at the UE and (ng-)eNB, when the UE accesses in another cell, when PUR is no longer enabled in the cell, or when the PUR resource has not been used for a configured number of consecutive occasions.

### 7.3y.3 Transmission using PUR for Control Plane CIoT EPS/5GS Optimisations

Transmission using PUR for Control Plane CIoT EPS Optimisations, as defined in TS 24.301 [20], and for Control Plane CIoT 5GS Optimisations, as defined in TS 24.501 [xx], is characterised as below:

- Uplink user data are transmitted using the PUR resource in a NAS message concatenated in *RRCEarlyDataRequest* message on CCCH;

- If there is no downlink data, the (ng-)eNB may terminate the procedure by sending a layer 1 acknowledgement optionally containing a Time Advance Command, a MAC Time advance Command or *RRCEarlyDataComplete* with no user data;

- Downlink user data, if any, are transmitted in a NAS message concatenated in *RRCEarlyDataComplete* message on CCCH;

- There is no transition to RRC CONNECTED.

The procedure for transmission using PUR for the Control Plane CIoT EPS optimisations and for the Control Plane CIoT 5GS optimisations is illustrated in Figure 7.3y-2.



Figure 7.3y-2: Transmission using PUR for the Control Plane CIoT EPS/5GS Optimisations

0. The UE has determined that the PUR resource can be used (e.g. PUR enabled in the cell, valid Time Alignment …).

1 Same as step 1 in MO-EDT for Control Plane CIoT EPS/5GS optimisations in Figure 7.3b-1 and 7.3b-1a except that the UE transmits over the PUR resource instead of a resource allocated in the random access response.

2..6 Same as MO-EDT for Control Plane CIoT EPS/5GS Optimisations in Figure 7.3b-1 and 7.3b-1a.

7a If the (ng-)eNB is aware that there is no pending downlink data or signalling, the (ng-)eNB can send a Layer 1 ACK optionally containing a Time Advance Adjustment to the UE to update the TA and terminate the procedure.

7b If the (ng-)eNB is aware that there is no further data or signalling, the (ng-)eNB can send a Time Advance Command to update the TA and terminate the procedure.

7c Same as step 7 in MO-EDT for Control Plane CIoT EPS/5GS Optimisations in Figure 7.3b-1 and 7.3b-1a except that a Time Advance Command can also be included.

NOTE 1: If the uplink data are too large to be included in *RRCEarlyDataRequest* in step 1, the UE can use the PUR resource to transmit *RRCConnectionRequest*. The procedure will fall back to the legacy RRC Connection establishment procedure, a new C-RNTI can be assigned.

NOTE 2: After step 1, the (ng-)eNB may request the UE to abort the transmission using PUR by sending a Layer 1 fallback indication. UE actions upon reception of Layer 1 fallback indication is left up to UE implementation.

NOTE 3: If the MME/AMF or the (ng-)eNB decides to move the UE in RRC\_CONNECTED mode, *RRCConnectionSetup* message is sent in step 7 to fall back to the legacy RRC Connection establishment procedure, a new C-RNTI can be assigned. The (ng-)eNB will discard the zero-length NAS PDU received in *RRCConnectionSetupComplete* message.NOTE 4: If none of Layer 1 Ack, MAC Time advance Command, *RRCEarlyDataComplete* and, in case of fallback, *RRCConnectionSetup* is received in response to *RRCEarlyDataRequest*, the UE considers the UL data transmission not successful.

7.3y.4 Transmission using PUR for User Plane CIoT EPS/5GS Optimisations

Transmission using PUR for User Plane CIoT EPS Optimisations, as defined in TS 24.301 [20], and for User Plane CIoT 5GS Optimisations, as defined in TS 24.501 [xx], are characterised as below:

- The UE is in RRC\_IDLE and has a valid PUR resource;

- The UE has been provided with a *NextHopChainingCount* in the *RRCConnectionRelease* message with suspend indication;

- Uplink user data are transmitted on DTCH multiplexed with *RRCConnectionResumeRequest* message on CCCH;

- Downlink user data are optionally transmitted on DTCH multiplexed with *RRCConnectionRelease* message on DCCH;

- The user data in uplink and downlink are ciphered. The keys are derived using the *NextHopChainingCount* provided in the *RRCConnectionRelease* message of the previous RRC connection;

- The *RRCConnectionRelease* message is integrity protected and ciphered using the newly derived keys;

- There is no transition to RRC CONNECTED.

The procedure for transmission using PUR for the User Plane CIoT EPS optimisations and for the User Plane CIoT 5GS optimisations is illustrated in Figure 7.3y-3 and Figure 7.3y-4 respectively.



Figure 7.3y-3: Transmission using PUR for the User Plane CIoT EPS Optimisations



**Figure 7.3y-4: Transmission using PUR for the User Plane CIoT 5GS Optimisations**

0. The UE has validated the PUR resource according to the configured criteria.

1 Same as step 1 in MO-EDT for User Plane CIoT EPS/5GS optimisations in Figure 7.3b-2 and 7.3b-2a except that the UE transmits over the PUR resource instead of a resource allocated in the random access response.

Editor’s Note: FFS whether AS RAI can be included with PUR transmission.

2..7 Same as MO-EDT for User Plane CIoT EPS/5GS optimisations in Figure 7.3b-2 and 7.3b-2a.

8 Same as step 8 in MO-EDT for user Plane CIoT EPS/5GS optimisations in Figure 7.3b-2 and 7.3b-2a except that a Time Advance Command can also be included.

NOTE 1: If the user data are too large to be fully included in the transmission using PUR in step 1, the UE can use PUR to transmit *RRCConnectionResumeRequest* and a segment of the user data. The procedure will fall back to the legacy RRC Connection Resume procedure; a new C-RNTI can be assigned.

NOTE 2: After step 1, the (ng-)eNB may request the UE to abort the transmission using PUR by sending a Layer 1 fallback indication. UE actions upon reception of Layer 1 fallback indication is left up to UE implementation.

NOTE 3: If the MME/AMF or the (ng-)eNB decides the UE to move in RRC\_CONNECTED mode, *RRCConnectionResume* message is sent in step 8 to fall back to the RRC Connection resume procedure. In that case, the *RRCConnectionResume* message is integrity protected and ciphered with the keys derived in step 1 and the UE ignores the *NextHopChainingCount* included in the *RRCConnectionResume* message; a new C-RNTI can be assigned. Downlink data can be transmitted on DTCH multiplexed with the *RRCConnectionResume* message. In addition, an *RRCConnectionSetup* can also be sent in step 8 to fall back to the RRC Connection establishment procedure.

NOTE 4: If neither *RRCConnectionRelease* nor, in case of fallback, *RRCConnectionResume* is received in response to *RRCConnectionResumeRequest* using PUR, the UE considers the UL data transmission not successful

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## 7.4 System Information

System information is divided into the *MasterInformationBlock* (MIB) and a number of *SystemInformationBlocks* (SIBs):

*- MasterInformationBlock* defines the most essential physical layer information of the cell required to receive further system information;

- *SystemInformationBlockPos* contains positioning assistance data;

- *SystemInformationBlockType1* and *SystemInformationBlockType1-BR* (for a BL UE or UE in enhanced coverage) contain information relevant when evaluating if a UE is allowed to access a cell and defines the scheduling of other system information blocks;

- *SystemInformationBlockType2* contains common and shared channel information;

- *SystemInformationBlockType3* contains cell re-selection information, mainly related to the serving cell;

- *SystemInformationBlockType4* contains information about the serving frequency and intra-frequency neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SystemInformationBlockType5* contains information about other E‑UTRA frequencies and inter-frequency neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SystemInformationBlockType6* contains information about UTRA frequencies and UTRA neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SystemInformationBlockType7* contains information about GERAN frequencies relevant for cell re-selection (including cell re-selection parameters for each frequency);

- *SystemInformationBlockType8* contains information about CDMA2000 frequencies and CDMA2000 neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SystemInformationBlockType9* contains a home eNB name (HNB name);

- *SystemInformationBlockType10* contains an ETWS primary notification;

- *SystemInformationBlockType11* contains an ETWS secondary notification;

- *SystemInformationBlockType12* contains a CMAS warning notification;

- *SystemInformationBlockType13* contains MBMS-related information;

- *SystemInformationBlockType14* contains information about Extended Access Barring for access control;

- *SystemInformationBlockType15* contains information related to mobility procedures for MBMS reception;

- *SystemInformationBlockType16* contains information related to GPS time and Coordinated Universal Time (UTC );

- *SystemInformationBlockType17* contains information relevant for traffic steering between E-UTRAN and WLAN;

- *SystemInformationBlockType18* contains information related to sidelink communication;

- *SystemInformationBlockType19* contains information related to sidelink discovery;

- *SystemInformationBlockType20* contains information related to SC-PTM;

- *SystemInformationBlockType21* contains information related to V2X sidelink communication;

- *SystemInformationBlockType24* contains information about NR frequencies and NR neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency);

- *SystemInformationBlockType25* contains information about UAC parameters;

- *SystemInformationBlockType26* contains additional information related to V2X sidelink communication;

- *SystemInformationBlockTypeXX* contains assistance information for inter-RAT cell selection to NB-IoT.

System information for NB-IoT is divided into the *MasterInformationBlock-NB* (MIB-NB) and a number of *SystemInformationBlocks-NB* (SIBs-NB):

- *MasterInformationBlock-NB* defines the most essential information of the cell required to receive further system information;

- *SystemInformationBlockType1-NB* contains information relevant when evaluating if a UE is allowed to access a cell and defines the scheduling of other system information blocks;

- *SystemInformationBlockType2-NB* contains common radio resource configuration information;

- *SystemInformationBlockType3-NB* contains cell re-selection information for intra-frequency, inter-frequency;

- *SystemInformationBlockType4-NB* contains neighboring cell related information relevant for intra-frequency cell re-selection;

- *SystemInformationBlockType5-NB* contains neighboring cell related information relevant for inter-frequency cell re-selection;

- *SystemInformationBlockType14-NB* contains information about access barring;

- *SystemInformationBlockType15-NB* contains information related to mobility procedures for MBMS reception;

- *SystemInformationBlockType16-NB* contains information related to GPS time and Coordinated Universal Time (UTC);

- *SystemInformationBlockType20-NB* contains information related to SC-PTM;

- *SystemInformationBlockType22-NB* contains common radio resource configuration information for paging and random access procedure on non-anchor carriers;

- *SystemInformationBlockType23-NB* contains common additional radio resource configuration information for random access procedure on anchor and non-anchor carriers;

- *SystemInformationBlockTypeXX-NB* contains assistance information for inter-RAT cell selection to E-UTRAN and/or GERAN.

On MBMS-dedicated cell, only system information relevant for receiving MBMS service is broadcasted. *MasterInformationBlock-MBMS* (MIB-MBMS) and *SystemInformationBlockType1-MBMS* (SIB1-MBMS) are used instead of MIB and SIB1 respectively:

*- MasterInformationBlock-MBMS* defines the most essential physical layer information of the cell required to receive further system information on MBMS-dedicated cell;

*- SystemInformationBlockType1-MBMS* contains information relevant for receiving MBMS service and defines the scheduling of other system information blocks on MBMS-dedicated cell;

The MIB is mapped on the BCCH and carried on BCH while all other SI messages are mapped on the BCCH and BR-BCCH, and carried on DL-SCH. Except for BL UEs, UEs in enhanced coverage and NB-IoT UEs, all other SI messages than the MIB which are dynamically carried on DL-SCH, can be identified through the SI-RNTI (System Information RNTI). Both the MIB and *SystemInformationBlockType1* (*SystemInformationBlockType1-BR* for BL UEs and UEs in enhanced coverage) use a fixed schedule with a periodicity of 40 and 80 ms respectively. The scheduling of other SI messages is flexible and indicated by *SystemInformationBlockType1* (*SystemInformationBlockType1-BR* for BL UEs and UEs in enhanced coverage, and *SystemInformationBlockType1-NB* for NB-IoT). For NB-IoT, the MIB-NB is mapped on the BCCH and carried on BCH while all other SI messages are mapped on the BCCH and carried on DL-SCH. Both the MIB-NB and *SystemInformationBlockType1-NB* use a fixed schedule with a periodicity of 640 and 2560 ms respectively. The MIB-NB contains all information required to acquire SIB1-NB and SIB1-NB contains all information required to acquire other SI messages.

On MBMS-dedicated cell, the MIB-MBMS and SIB1-MBMSuse a fixed schedule with a periodicity of 160 ms. Additionally, SIB1-MBMS may be scheduled in additional non-MBSFN subframes indicated in MIB-MBMS.

For NB-IoT, in TDD mode, the MIB-TDD-NB is transmitted on the same NB-IoT carrier as NPSS/NSSS, *SystemInformationBlockType1-NB* can be transmitted on NB-IoT carrier other than the MIB-NB, and the SI messages can be transmitted on a NB-IoT carrier other than the MIB-NB. At most two NB-IoT carriers are used to transmit the MIB-NB, *SystemInformationBlockType1-NB* and the SI messages.

Except for NB-IoT, the eNB may schedule DL-SCH transmissions concerning logical channels other than BCCH or BR-BCCH in the same subframe as used for BCCH or BR-BCCH. The minimum UE capability restricts the BCCH or BR-BCCH mapped to DL-SCH e.g. regarding the maximum rate.

The Paging message is used to inform UEs in RRC\_IDLE and UEs in RRC\_CONNECTED about a system information change. For NB-IoT UEs, BL UEs, and UEs in CE, the UE is not required to detect SIB changes when in RRC\_CONNECTED, and the network may release the NB-IoT UE, BL UE or UE in CE to RRC\_IDLE if it wants the NB-IoT UE, BL UE or UE in CE to acquire changed SIB(s).

Except for NB-IoT, system information may also be provided to the UE by means of dedicated signalling e.g. upon handover.

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# 8 E-UTRAN identities

## 8.1 E-UTRA related UE identities

The following E-UTRA related UE identities are used at cell level:

- C-RNTI: unique identification used for identifying RRC Connection and scheduling;

- Semi-Persistent Scheduling C-RNTI: unique identification used for semi-persistent scheduling;

- Temporary C-RNTI: identification used for the random access procedure;

- TPC-PUSCH-RNTI: identification used for the power control of PUSCH;

- TPC-PUCCH-RNTI: identification used for the power control of PUCCH;

- SL-RNTI: identification used for sidelink communication scheduling;

- SL-V-RNTI: identification used for V2X sidelink communication scheduling;

- Random value for contention resolution: during some transient states, the UE is temporarily identified with a random value used for contention resolution purposes;

- SRS-TPC-RNTI: identification used for triggering group SRS and power control of SRS for SRS-only SCells;

- SL Semi-Persistent Scheduling V-RNTI: identification used for semi-persistent scheduling for V2X sidelink communication;

- UL Semi-Persistent Scheduling V-RNTI: identification used for multiple semi-persistent scheduling for UE capable of V2X communication;

- AUL C-RNTI: unique identification used for autonomous uplink scheduling.

In DC, two C-RNTIs are independently allocated to the UE: one for MCG, and one for SCG.

The following UE identity is only used for E-UTRA connected to EPC:

- Resume ID: unique identification used for the RRC connection resume procedure;

The following UE identity is only used for E-UTRA connected to 5GC:

- I-RNTI: unique identification used for the RRC connection resume procedure in RRC\_INACTIVE or for the User Plane CIoT 5GS Optimisation as specified for NR connected to 5GC in TS 38.300 [79];

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# 10 Mobility

## 10.0 General

Load balancing is achieved in E-UTRAN with handover, redirection mechanisms upon RRC release, DC and through the usage of inter-frequency and inter-RAT absolute priorities and inter-frequency Qoffset parameters.

Measurements to be performed by a UE for mobility are classified in at least four measurement types:

- Intra-frequency E-UTRAN measurements;

- Inter-frequency E-UTRAN measurements;

- Inter-RAT measurements for UTRAN and GERAN;

- Inter-RAT measurements of CDMA2000 HRPD or 1xRTT frequencies.

For each measurement type one or several measurement objects can be defined (a measurement object defines e.g. the carrier frequency to be monitored).

For each measurement object one or several reporting configurations can be defined (a reporting configuration defines the reporting criteria). Three reporting criteria are used: event triggered reporting, periodic reporting and event triggered periodic reporting.

The association between a measurement object and a reporting configuration is created by a measurement identity (a measurement identity links together one measurement object and one reporting configuration of same RAT). By using several measurement identities (one for each measurement object, reporting configuration pair) it is possible:

- To associate several reporting configurations to one measurement object and;

- To associate one reporting configuration to several measurement objects.

The measurements identity is as well used when reporting results of the measurements.

Measurement quantities are considered separately for each RAT.

Measurement commands are used by E-UTRAN to order the UE to start measurements, modify measurements or stop measurements.

For NB-IoT:

- Handover, measurement reports and inter-RAT mobility are not supported;

- 10.1.1 Mobility Management in ECM-IDLE, 10.1.4 Paging and C-plane establishment, 10.1.5 Random Access Procedure, 10.1.6 Radio Link Failure, 10.1.7 Radio Access Network Sharing and all their clauses are applicable;

- 10.2.x Idle mode Inter-RAT Cell Selection to/from NB-IoT is supported;

- All other subclauses of clause 10 are not applicable.

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### 10.1.3 Measurements

#### 10.1.3.0 General

Measurements to be performed by a UE for intra/inter-frequency/inter-RAT mobility can be controlled by E-UTRAN, using broadcast or dedicated control. In RRC\_IDLE state, a UE shall follow the measurement parameters defined for cell reselection specified by the E-UTRAN broadcast. The use of dedicated measurement control for RRC\_IDLE state is possible through the provision of UE specific priorities (see clause 10.2.4). In RRC\_CONNECTED state, a UE shall follow the measurement configurations specified by RRC directed from the E-UTRAN (e.g. as in UTRAN MEASUREMENT\_CONTROL).

In RRC\_IDLE and RRC\_CONNECTED the UE may be configured to monitor some UTRA or E-UTRA carriers according to reduced performance requirements as specified in TS 36.133 [21].

In RRC\_IDLE, for NB-IoT UEs, BL UEs or UEs in enhanced coverage, the UE may further limit the intra-frequency and inter-frequency measurements when the relaxed monitoring criterion is fulfilled as specified in TS 36.304 [11].

In RRC\_IDLE, for NB-IoT UEs, when enabled in the cell and the relaxed monitoring criterion is fulfilled, the UE may perform serving cell measurements on the non-anchor paging carrier as specified in TS 36.133 [21].

For CSI-RS based discovery signals measurements, "cell" should be interpreted as "transmission point of the concerned cell" in the following descriptions.

Intra-frequency neighbour (cell) measurements, inter-frequency neighbour (cell) measurements and inter-RAT measurements are defined as follows:

- Intra-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are intra-frequency measurements when the current and target cell operates on the same carrier frequency.

- Inter-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are inter-frequency measurements when the neighbour cell operates on a different carrier frequency, compared to the current cell.

- Inter-RAT neighbour (cell) measurements: Neighbour cell measurements performed by the UE are inter-RAT measurements when the neighbour cell operates on a different RAT, compared to the current cell.

Whether a measurement is non gap assisted or gap assisted depends on the UE's capability and the current operating frequency. In non gap assisted scenarios, the UE shall be able to carry out such measurements without measurement gaps. In gap assisted scenarios, the UE may not be able to perform such measurements without measurement gaps. The UE determines whether a particular cell measurement needs to be performed in a transmission/reception gap and the scheduler needs to know whether gaps are needed:

- Same carrier frequency and cell bandwidths (Scenario A): an intra-frequency scenario; not measurement gap assisted.

- Same carrier frequency, bandwidth of the target cell smaller than the bandwidth of the current cell (Scenario B): an intra-frequency scenario; not measurement gap assisted.

- Same carrier frequency, bandwidth of the target cell larger than the bandwidth of the current cell (Scenario C): an intra-frequency scenario; not measurement gap assisted.

- Different carrier frequencies, bandwidth of the target cell smaller than the bandwidth of the current cell and bandwidth of the target cell within bandwidth of the current cell (Scenario D): an inter-frequency scenario; measurement gap-assisted scenario.

- Different carrier frequencies, bandwidth of the target cell larger than the bandwidth of the current cell and bandwidth of the current cell within bandwidth of the target cell (Scenario E): an inter-frequency scenario; measurement gap-assisted scenario.

- Different carrier frequencies and non-overlapping bandwidth, (Scenario F): an inter-frequency scenario; measurement gap-assisted scenario.

- Same carrier frequency, the operating frequency of the bandwidth reduced low complexity (BL) UE or the UE in Enhanced Coverage is not guaranteed to be aligned with the center frequency of the current cell (Scenario G): an intra-frequency scenario; measurement gap assisted scenario.







Figure 10.1.3-1: Inter and Intra-frequency measurements scenarios

Measurement gaps may be needed by the UE to carry out inter-RAT measurements on NR frequencies. UE may need measurement gaps to perform inter-RAT measurements on NR frequencies depending on the UE capability to support independent FR measurement as specified in TS 38.306 [89]. The UE may not be able to perform inter-RAT NR measurements without measurement gaps in the following cases:

- If the UE only supports per-UE gaps and the UE is required to measure NR frequencies:

- If the UE supports per-FR gaps and the UE is required to measure at least one NR frequency in FR1;

Measurement gaps patterns are configured and activated by RRC.

When CA is configured, the "current cell" above refers to any serving cell of the configured set of serving cells. For instance, for the definition of intra and inter frequency measurements, this means:

- Intra-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are intra-frequency measurements when one of the serving cells of the configured set and the target cell operates on the same carrier frequency. The UE shall be able to carry out such measurements without measurement gaps.

- Inter-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are inter-frequency measurements when the neighbour cell operates on a different carrier frequency than any serving cell of the configured set. The UE may not be able to perform such measurements without measurement gaps.

When DC is configured, the following principles are applied:

- The configured set of serving cells includes all the cells from MCG and SCG as for CA;

- The measurement procedure of serving cells belonging to the SeNB shall not be impacted due to RLF of SeNB;

- Common gap for the MeNB and the SeNB is applied;

- There is only a single measurement gap configuration for the UE which is controlled and informed by the MeNB.

- UE determines the starting point of the measurement gap based on the SFN, subframe number and subframe boundaries of the MCG serving cells.

When LAA is configured:

- The eNB configures the UE with one DMTC window for all neighbor cells as well as for the serving cell (if any) on one frequency;

- The UE is only expected to detect and measure cells transmitting DRS during the configured DRS DMTC window;

- For channel selection in an environment where hidden nodes may exist, UE may be configured with one RMTC per a frequency to perform RSSI measurement, and to report average RSSI and channel occupancy (percentage of measurement samples that RSSI value is above a threshold) in a reporting interval.

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### 10.1.4 Paging and C-plane establishment

Paging groups (where multiple UEs can be addressed) are used on PDCCH:

- Precise UE identity is found on PCH;

- DRX configurable via BCCH and NAS, for NB-IoT DRX configurable via BCCH only;

- Only one subframe allocated per paging interval per UE;

- The network may divide UEs to different paging occasions in time;

- There is no grouping within paging occasion;

- One paging RNTI for PCH.

When extended DRX (eDRX) is used in idle mode, the following are applicable:

- The DRX cycle is extended up to and beyond 10.24s in idle mode, with a maximum value of 2621.44 seconds (43.69 minutes); For NB-IoT, the maximum value of the DRX cycle is 10485.76 seconds (2.91 hours);

- The hyper SFN (H-SFN) is broadcast by the cell and increments by one when the SFN wraps around;

- Paging Hyperframe (PH) refers to the H-SFN in which the UE starts monitoring paging DRX during a Paging Time Window (PTW) used in ECM-IDLE. The PH is determined based on a formula that is known by the MME/AMF, UE and (ng-)eNB as a function of eDRX cycle and UE identity;

- During the PTW, the UE monitors paging for the duration of the PTW (as configured by NAS) or until a paging message is including the UE's NAS identity received for the UE, whichever is earlier. The possible starting offsets for the PTW are uniformly distributed within the PH and defined in TS 36.304 [11];

- MME/AMF uses the formulas defined in TS 36.304 [11] to determine the PH as well as the beginning of the PTW and sends the S1 paging request just before the occurrence of the start of PTW or during PTW to avoid storing paging messages in the (ng-)eNB;

- ETWS, CMAS, PWS requirement may not be met when a UE is in eDRX. For EAB, if the UE supports SIB14, when in extended DRX, it acquires SIB14 before establishing the RRC connection;

- When the eDRX cycle is longer than the system information modification period, the UE verifies that stored system information remains valid before establishing an RRC connection. Paging message can be used for system information change notification, when including *systemInfoModification-eDRX*, for a UE configured with eDRX cycle longer than the system information modification period.

NB-IoT UEs, BL UEs or UEs in enhanced coverage can use (G)WUS, when configured in the cell, to reduce the power consumption related to paging monitoring.

When GWUS is used in idle mode, the following are applicable:

- The eNB informs the MME whether it supports GWUS;

- Multiple WUS groups, possibly distributed over multiple GWUS resource, can be configured in the cell;

- If the UE supports WUS assistance information, the MME/AMF may provide the UE with UE paging probability information (see TS 24.301 [20] and TS 24.501 [xx]);

- UE selects one of the WUS group based on its UE paging probability information and /or its UE NAS identity as defined in TS 36.304 [11];

- A common WUS group is used to wake up all WUS groups monitoring the same GWUS resource.

When (G)WUS is used in idle mode, the following are applicable:

- The WUS or WUS group is used to indicate that the UE shall monitor MPDCCH or NPDCCH to receive paging in that cell;

- For a UE not configured with extended DRX, the WUS or WUS group is associated to one paging occasion (N = 1);

- For a UE configured with extended DRX, the WUS or WUS group can be associated to one or multiple paging occasion(s) (N ≥ 1) in a PTW;

- If UE detects the WUS or WUS group, the UE shall monitor the following N paging occasions unless it has received a paging message;

- The paging operation in the MME is not aware of the use of the WUS in the eNB.

The timing between WUS and the paging occasion (PO) is illustrated in Figure 10.1.4-1. The timing between GWUS and the paging occasion (PO) is illustrated in Figure 10.1.4-2 and Figure 10.1.4-3. The UE can expect (G)WUS repetitions during "Configured maximum WUS duration" but the actual (G)WUS transmission can be shorter, e.g. for UE in good coverage. The UE does not monitor (G)WUS during the non-zero "Gap".



Figure 10.1.4-1: Illustration of WUS timing

Gap

Configured maximum

WUS duration

PO

WUS 0

t

WUS 1

Configured maximum

WUS duration

Figure 10.1.4-2: Illustration of GWUS timing for NB-IoT UEs

Gap

Configured maximum

WUS duration

PO

WUS 0

t

Configured maximum

WUS duration

WUS 2

f

WUS 1

WUS 3

Figure 10.1.4-3: Illustration of GWUS timing for BL UEs and UEs in enhanced coverage

For NB-IoT, UE in RRC\_IDLE receives paging on the anchor carrier or on a non anchor carrier based on system information.

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#### 10.1.5.1 Contention based random access procedure

The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:



Figure 10.1.5.1-1: Contention based Random Access Procedure

The four steps of the contention based random access procedures are:

1) Random Access Preamble on RACH in uplink:

- There are two possible groups defined and one is optional. If both groups are configured the size of message 3 and the pathloss are used to determine which group a preamble is selected from. The group to which a preamble belongs provides an indication of the size of the message 3 and the radio conditions at the UE. The preamble group information along with the necessary thresholds are broadcast on system information.

2) Random Access Response generated by MAC on DL-SCH:

- Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;

- No HARQ;

- Addressed to RA-RNTI on PDCCH;

- Conveys at least RA-preamble identifier, Timing Alignment information for the pTAG, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon Contention Resolution);

- Intended for a variable number of UEs in one DL-SCH message.

3) First scheduled UL transmission on UL-SCH:

- Uses HARQ;

- Size of the transport blocks depends on the UL grant conveyed in step 2.

- For initial access:

- Conveys the RRC Connection Request generated by the RRC layer and transmitted via CCCH;

- Conveys at least NAS UE identifier but no NAS message;

- RLC TM: no segmentation.

- For RRC Connection Re-establishment procedure:

- Conveys the RRC Connection Re-establishment Request generated by the RRC layer and transmitted via CCCH;

- RLC TM: no segmentation;

- Does not contain any NAS message.

- After handover, in the target cell:

- Conveys the ciphered and integrity protected RRC Handover Confirm generated by the RRC layer and transmitted via DCCH;

- Conveys the C-RNTI of the UE (which was allocated via the Handover Command);

- Includes an uplink Buffer Status Report when possible.

- For other events:

- Conveys at least the C-RNTI of the UE;

- In the procedure to resume the RRC connection or in the EDT procedure for User Plane CIoT EPS/5GS Optimizations:

- Conveys the RRC Connection Resume Request generated by the RRC layer and transmitted via CCCH;

- Conveys a Resume ID (for EPS) or I-RNTI (for 5GS) to resume the RRC connection;

- For the MO-EDT procedure for User Plane CIoT EPS/5GS Optimizations:

- Conveys ciphered user data transmitted via DTCH;

- RLC UM/AM: no segmentation;

- Does not contain any NAS message.

- For NB-IoT:

- In the procedure to setup the RRC connection:

- An indication of the amount of data for subsequent transmission(s) on SRB or DRB can be indicated.

- For EDT for Control Plane CIoT EPS/5GS Optimizations:

- Conveys the RRC Early Data Request generated by the RRC layer and transmitted via CCCH;

- Conveys NAS UE identifier;

- For the MO-EDT procedure for Control Plane CIoT EPS/5GS Optimisations:

- Conveys user data concatenated in a NAS message;

- RLC TM: no segmentation.

4) Contention Resolution on DL:

- Early contention resolution shall be used i.e. eNB does not wait for NAS reply before resolving contention;

- For NB-IoT, for initial access, RRC connection resume procedure and RRC Connection Re-establishment procedure, eNB may transmit MAC PDU containing the UE contention resolution identity MAC control element without RRC response message;

NOTE: In Release 13, NB-IoT UEs do not support the MAC PDU containing the UE contention resolution identity MAC control element without RRC response message for initial access, RRC connection resume procedure and RRC Connection Re-establishment procedure.

- Not synchronised with message 3;

- HARQ is supported;

- Addressed to:

- The Temporary C-RNTI on PDCCH for initial access and after radio link failure;

- The C-RNTI on PDCCH for UE in RRC\_CONNECTED.

- HARQ feedback is transmitted only by the UE which detects its own UE identity, as provided in message 3, echoed in the Contention Resolution message;

- For initial access, RRC Connection Re-establishment procedure and EDT for Control Plane CIoT EPS/5GS Optimizations, no segmentation is used (RLC-TM).

The Temporary C-RNTI is promoted to C-RNTI for a UE which detects RA success and does not already have a C-RNTI; it is dropped by others. A UE which detects RA success and already has a C-RNTI, resumes using its C-RNTI.

When CA is configured, the first three steps of the contention based random access procedures occur on the PCell while contention resolution (step 4) can be cross-scheduled by the PCell.

When DC is configured, the first three steps of the contention based random access procedures occur on the PCell in MCG and PSCell in SCG. When CA is configured in SCG, the first three steps of the contention based random access procedures occur on the PSCell while contention resolution (step 4) can be cross-scheduled by the PSCell.

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### 10.1.6 Radio Link Failure

Two phases govern the behaviour associated to radio link failure as shown on Figure 10.1.6-1:

- First phase:

- started upon radio problem detection;

- leads to radio link failure detection;

- no UE-based mobility;

- based on timer or other (e.g. counting) criteria (T1).

- Second Phase:

- started upon radio link failure detection or handover failure;

- leads to RRC\_IDLE;

- UE-based mobility;

- Timer based (T2).



Figure 10.1.6-1: Radio Link Failure

Table 10.1.6-1 below describes how mobility is handled with respect to radio link failure:

Table 10.1.6-1: Mobility and Radio Link Failure

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| Cases | First Phase | Second Phase | T2 expired |
| UE returns to the same cell | Continue as if no radio problems occurred | Activity is resumed by means of explicit signalling between UE and eNB | Go via RRC\_IDLE |
| UE selects a different cell from the same eNB | N/A | Activity is resumed by means of explicit signalling between UE and eNB | Go via RRC\_IDLE |
| UE selects a cell of a prepared eNB (NOTE) | N/A | Activity is resumed by means of explicit signalling between UE and eNB | Go via RRC\_IDLE |
| UE selects a cell of a different eNB that is not prepared (NOTE) | N/A | Go via RRC\_IDLE | Go via RRC\_IDLE |
| NOTE: a prepared eNB is an eNB which has admitted the UE during an earlier executed HO preparation phase, or obtains the UE context during the Second Phase. | | | |

For a NB-IoT UE that only uses Control Plane CIoT EPS/5GS optimizations, as defined in TS 24.301 [20] and does not support RRC Connection re-establishment for the control plane as defined in TS 36.331 [16], at the end of the first phase, the UE enters RRC\_IDLE (there is no second phase).In the Second Phase, in order to resume activity and avoid going via RRC\_IDLE when the UE returns to the same cell or when the UE selects a different cell from the same eNB, or when the UE selects a cell from a different eNB, the following procedure applies:

- The UE stays in RRC\_CONNECTED;

- The UE accesses the cell through the random access procedure;

- Except for a NB-IoT UE using only Control Plane CIoT EPS/5GS optimizations, the UE identifier used in the random access procedure for contention resolution (i.e. C‑RNTI of the UE in the cell where the RLF occurred + physical layer identity of that cell + short MAC-I based on the keys of that cell) is used by the selected eNB to authenticate the UE and check whether it has a context stored for that UE:

- If the eNB finds a context that matches the identity of the UE, or obtains this context from the previously serving eNB, it indicates to the UE that its connection can be resumed;

- If the context is not found, RRC connection is released and UE initiates procedure to establish new RRC connection. In this case UE is required to go via RRC\_IDLE.

- For a NB-IoT UE using only Control Plane CIoT EPS/5GS optimizations, the UE identifier used in the random access procedure for contention resolution (i.e. S-TMSI (for EPS) or truncated 5G-S-TMSI (for 5GS) of the UE at the time where the RLF occurred + UL NAS MAC + UL NAS COUNT) is used by the selected (ng-)eNB to request the MME/AMF to authenticate the UE's re-establishment request and provide the UE context:

- If the authentication of the UE is successful and a context is provided, it indicates to the UE that its connection can be resumed;

- If no context is provided, the RRC connection is released and UE initiates procedure to establish new RRC connection. In this case UE is required to go via RRC\_IDLE.

The radio link failure procedure applies also for RNs, with the exception that the RN is limited to select a cell from its DeNB cell list. Upon detecting radio link failure, the RN discards any current RN subframe configuration (for communication with its DeNB), enabling the RN to perform normal contention-based RACH as part of the re-establishment. Upon successful re-establishment, an RN subframe configuration can be configured again using the RN reconfiguration procedure.

For DC, PCell supports above phases. In addition, the first phase of the radio link failure procedure is supported for PSCell. However, upon detecting RLF on the PSCell, the re-establishment procedure is not triggered at the end of the first phase. Instead, UE shall inform the radio link failure of PSCell to the MeNB.

NOTE: If the recovery attempt in the second phase fails, the details of the RN behaviour in RRC\_IDLE to recover an RRC connection are up to the RN implementation.

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### 10.2.x Idle mode Inter-RAT Cell Selection to/from NB-IoT

NB-IoT may provide assistance information for inter-RAT cell selection to E-UTRAN/GERAN and E-UTRAN may provide assistance information for inter-RAT cell selection to NB-IoT. A UE may use the assistance information provided by the network for cell selection to/from NB-IoT.

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# 11 Scheduling and Rate Control

## 11.0 General

In order to utilise the SCH resources efficiently, a scheduling function is used in MAC. In this clause, an overview of the scheduler is given in terms of scheduler operation, signalling of scheduler decisions, and measurements to support scheduler operation.

For NB-IoT, the Basic Scheduler Operation in 11.1, the uplink buffer status reports part in 11.3 and the DL channel quality reporting in 11.7 are applicable, the UE-AMBR part in 11.4 is applicable only for UE which is enabled to use S1-U data transfer or User Plane CIoT EPS optimization or for UE which is enabled to use NG-U data transfer or User Plane CIoT 5GS Optimisation, and all other subclauses of clause 11 are not applicable.

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### 11.1.1 Downlink Scheduling

In the downlink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible allocation when its downlink reception is enabled (activity governed by DRX when configured). When CA is configured, the same C-RNTI applies to all serving cells.

In addition, E-UTRAN can allocate semi-persistent downlink resources for the first HARQ transmissions to UEs:

- RRC defines the periodicity of the semi-persistent downlink grant;

- PDCCH indicates whether the downlink grant is a semi-persistent one i.e. whether it can be implicitly reused in the following TTIs according to the periodicity defined by RRC.

When required, retransmissions are explicitly signalled via the PDCCH(s). In the TTIs where the UE has semi-persistent downlink resource, if the UE cannot find its C-RNTI on the PDCCH(s), a downlink transmission according to the semi-persistent allocation that the UE has been assigned in the TTI is assumed. Otherwise, in the sub-TTIs where the UE has semi-persistent downlink resource, if the UE finds its C-RNTI on the PDCCH(s), the PDCCH allocation overrides the semi-persistent allocation for that TTI and the UE does not decode the semi-persistent resources.

Semi-persistent downlink resources can be configured per serving cell with the restriction that multiple DL SPS configurations per serving cell are not supported. SPS configurations can be active simultaneously for different cells. PDCCH allocations made on a given serving cell can only override the semi-persistent allocation for that serving cell.

For NB-IoT:

- Scheduling information for downlink data is transmitted on the downlink physical control channel NPDCCH. The scheduled downlink data is transmitted on the shared data channel NPDSCH;

- Only cross-subframe scheduling is supported, cross-carrier scheduling is not supported. The transmission duration in number of sub-frames for the NPDCCH and the NPDSCH is variable;

- The transmission duration in number of sub-frames is semi-static for the NPDCCH and is indicated for the NPDSCH as part of the scheduling information transmitted on the NPDCCH;

- The start time of the NPDSCH relative to the NPDCCH is signaled as part of the scheduling message.

For NB-IoT UEs, when multi-TB scheduling is configured, multiple downlink transmissions or multiple uplink transmissions, where each transmission corresponds to one HARQ process, can be scheduled via single NPDCCH.

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### 11.1.2 Uplink Scheduling

In the uplink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible allocation for uplink transmission when its downlink reception is enabled (activity governed by DRX when configured). When CA is configured, the same C-RNTI applies to all serving cells.

In addition, E-UTRAN can allocate a semi-persistent uplink resource or autonomous uplink resource for the first HARQ transmissions and potentially retransmissions to UEs:

- RRC defines the periodicity of the semi-persistent uplink grant or the bitmap of the autonomous uplink grant;

- PDCCH indicates whether the uplink grant is a semi-persistent one or an autonomous uplink one i.e. whether it can be implicitly reused in the following TTIs according to the periodicity or the bitmap defined by RRC.

In the TTIs where the UE has semi-persistent uplink resource or autonomous uplink resource, if the UE cannot find its C-RNTI on the PDCCH(s), an uplink transmission according to the semi-persistent allocation or autonomous uplink allocation that the UE has been assigned in the TTI can be made. The network performs decoding of the pre-defined PRBs according to the pre-defined MCS. Otherwise, in theTTIs where the UE has semi-persistent uplink resource or autonomous uplink resource, if the UE finds its C-RNTI on the PDCCH(s), the PDCCH allocation overrides the persistent allocation or autonomous uplink allocation for that TTI and the UE's transmission follows the PDCCH allocation, not the semi-persistent allocation or autonomous uplink. Retransmissions are either implicitly allocated in which case the UE uses the semi-persistent uplink allocation or autonomous uplink allocation, or explicitly allocated via PDCCH(s) in which case the UE does not follow the semi-persistent allocation or autonomous uplink allocation. The UE is not allowed to use autonomous uplink resource for retransmission of dynamically scheduled transmission.

NOTE: there is no blind decoding in uplink and when the UE does not have enough data to fill the allocated resource, padding is used.

When the UE is provided with valid uplink grants in several serving cells in one TTI, the order in which the grants are processed during logical channel prioritisation and whether joint or serial processing is applied are left up to UE implementation, while adhering to transmission restrictions of a logical channel via LAA SCells.

Similar to the downlink, semi-persistent uplink resources can be configured. Multiple UL SPS configurations are supported per Serving Cell. On one Serving Cell, multiple such configurations can be active simultaneously only for the same TTI length. SPS configurations can also be active simultaneously for different cells. PDCCH allocations made on a given serving cell can only override the semi-persistent allocation for that serving cell.

When UL skipping is configured, the UE will not transmit a MAC PDU with only padding BSR and padding if no data is available for transmission in the UE buffer. When UL Skippping and an SPS interval shorter than 10ms is configured, a retransmission is prioritised over a new transmission on semi-persistent uplink resources if no dynamic grant is allocated for that subframe.

For a UE capable of V2X communication, multiple semi-persistent configurations can be configured in uplink, regardless of the specific services the UE is operating. The uplink resources for each semi-persistent configuration can only be configured for the PCell. When DC is configured, the uplink resources for each semi-persistent configuration can only be configured for the PCell or PSCell.

Autonomous uplink allocation can be configured for LAA SCell(s). The UE will not transmit on autonomous uplink resources if no data is available for transmission.

For NB-IoT:

- Scheduling information for uplink data is transmitted on the downlink physical control channel NPDCCH. The scheduled uplink data is transmitted on the shared data channel NPUSCH;

- The transmission duration in number of sub-frames for the NPUSCH is variable;

- The transmission duration in number of sub-frames is semi-static for the NPDCCH and is indicated for the NPUSCH as part of the scheduling information transmitted on the NPDCCH;

- The start time of the NPUSCH relative to the NPDCCH is signaled as part of the scheduling message;

- E-UTRAN can allocate semi-persistent uplink resource for sending a BSR acting as a Scheduling Request.- E-UTRAN can allocate preconfigured uplink resources to be used in RRC\_IDLE for transmission using PUR, see clause 7.3y.

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## 11.7 DL channel quality reporting in NB-IoT

The DL channel quality report in RRC\_IDLE is defined by the following characteristics:

- The reporting is configured by eNB via system information;

- The report is related to the DL carrier used for the initial random access procedure;

- The report is carried in the RRC message during the random access procedure.

The DL channel quality report in RRC\_CONNECTED is defined by the following characteristics:

- The reporting is triggered by the eNB via a MAC Control Element;

- The report is related to the configured DL carrier used in unicast transmission;

- The report is carried in a MAC Control Element.

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## 15.3 MBMS Transmission

### 15.3.1 General

Transmission of a MBMS in E-UTRAN uses either MBSFN transmission or SC-PTM transmission. The MCE makes the decision on whether to use SC-PTM or MBSFN for each MBMS session.

### 15.3.2 Single-cell transmission

Single-cell transmission of MBMS is characterized by:

- MBMS is transmitted in the coverage of a single cell;

- One SC-MCCH and one or more SC-MTCH(s) are mapped on DL-SCH;

- Scheduling is done by the eNB;

- SC-MCCH and SC-MTCH transmissions are each indicated by a logical channel specific RNTI on PDCCH (there is a one-to-one mapping between TMGI and G-RNTI used for the reception of the DL-SCH to which a SC-MTCH is mapped);

- A single transmission is used for DL-SCH (i.e. neither blind HARQ repetitions nor RLC quick repeat) on which SC-MCCH or SC-MTCH is mapped;

- SC-MCCH and SC-MTCH use the RLC-UM mode.

For each SC-MTCH, the following scheduling information is provided on SC-MCCH:

- **SC-MTCH scheduling cycle**;

- **SC-MTCH on-duration**: duration in downlink subframes that the UE waits for, after waking up from DRX, to receive PDCCHs. If the UE successfully decodes a PDCCH indicating the DL-SCH to which this SC-MTCH is mapped, the UE stays awake and starts the inactivity timer;

- **SC-MTCH inactivity-timer**: duration in downlink subframes that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH indicating the DL-SCH to which this SC-MTCH is mapped, failing which it re-enters DRX. The UE shall restart the inactivity timer following a single successful decoding of a PDCCH.

NOTE 1: The SC-PTM reception opportunities are independent of the unicast DRX scheme.

NOTE 2: The SC-MTCH inactivity-timer may be set to 0.

NOTE 3: Although the above parameters are per SC-MTCH (i.e. per MBMS service), the network may configure the same scheduling pattern for multiple SC-MTCHs (i.e. multiple MBMS services).

NOTE 4: For NB-IoT UEs, the definition of the above parameters does not apply.

NOTE 5: For BL UEs and UEs in enhanced coverage, the definition of the above parameters does not apply.

For NB-IoT UEs, when multi-TB scheduling is configured, multiple downlink transmissions can be scheduled via single NPDCCH.

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### 16.1.x Resource reservation for co-existence with NR

E-UTRAN may reserve resources in uplink and downlink on a NB-IoT non-anchor carrier to avoid resource overlap with NR when NB-IoT is deployed within an NR carrier. The resource reservation signalled to the UE is carrier specific and is for use in unicast transmission.

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## 16.3 UE assistance information for RRM, and UE power optimisations and UE overheating

Except for NB-IoT UEs, in order to optimise the user experience and (for instance) to assist the eNB in configuring connected mode parameters and connection release handling, the UE may be configured to send assistance information to the eNB comprising:

- UE preference for power optimised configuration (1 bit):

- When this bit is sent by the UE, the UE shall set this in accordance with its preference for a configuration that is primarily optimised for power saving (e.g. a long value for the long DRX cycle or RRC connection release) or not;

- The details regarding how the UE sets the indicator are left to UE implementation.

- UE bandwidth preference on maximum PDSCH/PUSCH bandwidth:

- When this information is sent by the UE that supports CE mode, the UE shall set this in accordance with its preference on maximum PDSCH/PUSCH bandwidth to assist the eNB for a reconfiguration of the CE mode for the UE in RRC\_CONNECTED state;

- The details regarding how the UE sets the bandwidth preference are left to UE implementation.

- UE indication on detected overheating:

- When this information is send by the UE, the UE shall set this information to inform the eNB about UE internal overheating caused by configurations concerning carrier aggregation/dual connectivity, MIMO transmissions, and/or modulation schemes being concurrently configured. The eNB may mitigate the indicated overheating by downgrading the UE configuration. Details regarding how the eNB mitigates the overheating are left to implementation (e.g. the eNB may choose to mitigate overheating by downgrading E-UTRA configuration and/or NR in case of EN-DC taking into account the assistance information provided by the UE). If the eNB does not provide any mitigation, the UE may need to mitigate the indicated overheating based on UE implementation.

- The details regarding how the UE detects the internal overheating are left to UE implementation.

In 5GS and, if configured, in EPS, aNB-IoT UE or BL UE may send assistance information to the eNB to assist the eNB in connection release handling.

The network response to the UE assistance information is left to network implementation. The eNB ensures that an appropriate QoS level is provided irrespective of received power preference indication or the bandwidth preference.

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### 22.3.2a Automatic Neighbour Relation Function

The purpose of the **Automatic Neighbour Relation** (ANR) function is to relieve the operator from the burden of manually managing Neighbour Cell Relations (NCRs). Figure 22.3.2a-1 shows ANR and its environment:



Figure 22.3.2a-1: Interaction between eNB and O&M due to ANR

The ANR function resides in the eNB and manages the conceptual Neighbour Cell Relation Table (NCRT). Located within ANR, the Neighbour Detection Function finds new neighbours and adds them to the NCRT. ANR also contains the Neighbour Removal Function which removes outdated NCRs. The Neighbour Detection Function and the Neighbour Removal Function are implementation specific.

A **Neighbour Cell Relation** (NCR) in the context of ANR is defined as follows:

An existing Neighbour Relation from a source cell to a target cell means that eNB controlling the source cell:

a) Knows the ECGI/CGI and PCI of the target cell.

b) Has an entry in the Neighbour Cell Relation Table for the source cell identifying the target cell.

c) Has the attributes in this Neighbour Cell Relation Table entry defined, either by O&M or set to default values.

For each cell that the eNB has, the eNB keeps a NCRT, see Figure 22.3.2a-1. For each NCR, the NCRT contains the Target Cell Identifier (TCI), which identifies the target cell. For E-UTRAN, the TCI corresponds to the E-UTAN Cell Global Identifier (ECGI) and Physical Cell Identifier (PCI) of the target cell. Furthermore, each NCR has three attributes, the NoRemove, the NoHO and the NoX2 attribute. These attributes have the following definitions:

**- No Remove**: If checked, the eNB shall not remove the Neighbour Cell Relation from the NRT.

**- No HO**: If checked, the Neighbour Cell Relation shall not be used by the eNB for handover reasons.

**- No X2:** If checked, the Neighbour Relation shall not use an X2 interface in order to initiate procedures towards the eNB parenting the target cell.

Neighbour Cell Relations are cell-to-cell relations, while an X2 link is set up between two eNBs. Neighbour Cell Relations are unidirectional, while an X2 link is bidirectional.

NOTE: The neighbour information exchange, which occurs during the X2 Setup procedure or in the eNB Configuration Update procedure, may be used for ANR purpose.

The ANR function also allows O&M to manage the NCRT. O&M can add and delete NCRs. It can also change the attributes of the NCRT. The O&M system is informed about changes in the NCRT.

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22.3.4x Automatic Neighbour Relation Function in NB-IoT

The ANR (Automatic Neighbour Relation) function relies on cells broadcasting their identity on global level, E-UTRAN Cell Global Identifier (ECGI).

**Figure 22.3.4x-1: Automatic Neighbour Relation Function in case of NB-IoT**

The purpose of SON/ANR reporting in NB-IoT is network optimisation. The measurements are performed when the UE is in RRC\_IDLE and reported next time the UE enters RRC\_CONNECTED. ANR measurement reporting is not supported when the UE uses the Control Plane CIoT EPS Optimisation.

The function works as follows:

The eNB serving cell A has an ANR function. During connected mode, the eNB can configure the UE to perform measurements on a frequency and read the CGI of the strongest cell if the quality is above a given RSRP threshold. The eNB may use different policies for instructing the UE to do measurements.

1 When releasing the RRC connection, the eNB configures the UE to perform ANR measurements on one or more frequencies. The RRC connection is released and the UE enters RRC\_IDLE.

When the UE is in RRC\_IDLE and remains camped on the cell from which the ANR measurement configuration was received, the UE performs the ANR measurements requested by the eNB:

2a For each of the configured frequency, the UE performs measurements, identifies the strongest cell and stores the cell measurement results for later reporting.

2b For each of the configured frequency, if the NRSRP of the strongest cell is above the configured threshold, the UE reads the ECGI, the TAC and all available PLMN ID(s) of the related neighbour cell and stores the information for later reporting.

NOTE: While performing an ANR measurement, the UE performs inter-frequency measurements on the configured frequency regardless of the measurement rules for cell re-selection and the relaxed monitoring measurement rules as specified in TS 36.304 [11].

When the UE establishes or resumes the RRC connection:

3 The UE reports the availability of an ANR report.

When the eNB receives the indication of the ANR report availability, the following sequence may be used whilst UE is in RRC\_CONNECTED mode:

4 The eNB requests the UE to provide the report.

5 The UE reports the stored cells and associated information.

When the UE returns to RRC\_IDLE, if the UE has indicated the availability of the ANR report, the UE discards the old ANR configuration and ANR report.

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#### 22.4.2.x Connection failure due to Radio Link Failure in NB-IoT

In NB-IoT, the function of Mobility Robustness Optimization is to detect connection failures due to radio link failure.

Solution for failure scenarios consists of one or more of following functions:

- Detection of the failure after RRC re-establishment attempt;

- Detection of the failure after RRC connection setup;

- Retrieval of information needed for problem analysis.

Triggering of each of these functions is optional and depends on situation and implementation.

**Detection of the failure after RRC re-establishment attempt:**

UE provides the RLF Report to the eNB after successful RRC connection re-establishment.

**Detection of the failure after RRC connection setup:**

In case the RRC connection re-establishment fails or the UE does not perform any RRC connection re-establishment, the UE makes the RLF Report available to the eNB after reconnecting from idle mode. Availability of the RLF Report at the RRC connection setup procedure is the indication that a RLF failure occured and that the RLF Report from this occurence could be obtained by the network.

**Retrieval of information needed for problem analysis**

The information needed for detailed problem analysis may be retrieved from both, the UE and the network sides. The information that is collected at the UE is provided to the network with the RLF Report.

The RLF Report from the UE includes the following information:

- The E-CGI of the last cell that served the UE.

- The radio measurements of the last cell that served the UE.

- Time elapsed from the connection failure till RLF Report signalling.

The eNB receiving the RLF Report from the UE may forward the report to the eNB that served the UE before the reported connection failure using the RLF INDICATION message.

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### 22.4.3 Support for RACH Optimisation

The setting of RACH parameters that can be optimized are:

- RACH configuration (resource unit allocation);

- RACH preamble split (among dedicated, group A, group B, RSRP level, NRSRP level (for NB-IoT), NPRACH resource pools (for NB-IoT), EDT);

- RACH backoff parameter value;

- RACH transmission power control parameters.

RACH optimization is supported by UE reported information and by PRACH parameters exchange or NPRACH parameters (for NB-IoT) between eNBs.

UEs which receive polling signalling shall report the below information:

- Number of RACH preambles sent until the successful RACH completion;

- Contention resolution failure;

- For BL UE or UE in enhanced coverage or NB-IoT UE, the RSRP (NRSRP for NB-IoT) level in which the UE started the random access procedure;

- For BL UE or UE in enhanced coverage or NB-IoT UE, an EDT fallback indication.

UE reporting of RACH information is not supported for a NB-IoT UE using the Control Plane CIoT EPS Optimisation,

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| Next change |

### 22.4.5 Radio Link Failure report

The RLF Report from the UE can be used for both coverage optimization and mobility robustness optimization.

The UE stores the latest RLF or, except for NB-IoT, handover failure related information, and indicates RLF report availability at each subsequent LTE RRC connection (re-)establishment and, except for NB-IoT, handover to an LTE cell until the RLF report is fetched by the network or for 48 hours after the RLF or, except for NB-IoT, handover failure is detected.

The UE keeps the information during state transitions and RAT changes, and indicates RLF report availability again after it returns to the LTE RAT.

The UE only indicates RLF report availability and only provides the RLF report to the network if the current RPLMN is a PLMN that was present in the UE's EPLMN List or was the RPLMN at the time the RLF or handover failure was detected.

UE reporting of RLF information is not supported for a NB-IoT UE using the Control Plane CIoT EPS Optimisation

Editor’s Note: It is FFS whether the RLF report is kept during state transitions and RAT changes for NB-IoT.

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## 23.13 Optimising signalling load and resource usage for paging

### 23.13.1 General paging optimisation

Paging can be optimised by the MME and the E-UTRAN as described in TS 23.401 [17].

As a part of this, an eNB may inform the MME about a list of recommended eNBs for paging. If a recommended eNB in this list is a HeNB behind a HeNB GW, the paging target is identified by the TAI instead of the eNB identity.

Paging Attempt Information consists of a Paging Attempt Count and the Intended Number of Paging Attempts and may include the Next Paging Area Scope. If Paging Attempt Information is included in the Paging message, each paged eNB receives the same information during a paging attempt. The Paging Attempt Count shall be increased by one at each new paging attempt. The Next Paging Area Scope, when present, indicates whether the MME plans to modify the paging area currently selected at next paging attempt. If the UE has changed its mobility state to ECM CONNECTED the Paging Attempt Count is reset.

### 23.13.2 Paging optimisation for UEs in enhanced coverage

Information on the coverage enhancement (CE) level, if available for the UE, is provided transparently by the serving eNB to the MME at transition to ECM\_IDLE together with the respective cell identifier and is provided to the E-UTRAN during paging. The Paging Attempt Information, as defined in 23.13.1, is always provided to all paged eNBs for UEs for which the information on the coverage enhancement level has been received.

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# 24 Support for 5GC

## 24.1 General

The E-UTRA connected to 5GC is supported as part of NG-RAN. The E-UTRA can be connected to both EPC and 5GC.

The overall architecture of E-UTRA connected to 5GC as part of NG-RAN is described in TS 38.300 [79], where the term "ng-eNB" is used for E-UTRA connected to 5GC. However, in this specification the term "eNB" is used for both cases unless there is a specific need to disambiguate between eNB and ng-eNB.

E-UTRA connected to 5GC supports the following functions:

- 5G NAS message transport (see clause 7.3);

- 5G security framework (see TS 38.300 [79]), except that data integrity protection is not supported;

- Access Control (see TS 38.300 [79]);

- Flow-based QoS (see TS 38.300 [79]);

- Network slicing (see TS 38.300 [79]);

- SDAP (see TS 37.324 [80]), except for NB-IoT;

- NR PDCP (see TS 38.323 [81]), except for NB-IoT;

- Support of UEs in RRC\_INACTIVE state, except for NB-IoT;

- CIoT 5GS optimisations for NB-IoT UEs (see clause 7.3a);

- MO-EDT for NB-IoT UEs (see clause 7.3b);

- Transmission using PUR for NB-IoT UEs (see clause 7.3y).

## 24.2 Radio Protocol Architecture

### 24.2.1 User Plane

Except for NB-IoT, the figure below shows the protocol stack for the user plane, where SDAP, NR PDCP, RLC and MAC sublayers perform the functions listed in clause 6.5 of TS 38.300 [79], clause 6.4 of TS 38.300 [79], clause 6.3, and clause 6.2 respectively.



Figure 24.2.1-1: User Plane Protocol Stack

For NB-IoT, the protocol stack for the user plane is described in clause 4.3 where eNB should be understood as ng-eNB. PDCP, RLC and MAC sublayers perform the functions listed in clause 6.3, clause 6.2 and clause 6.1 respectively.

NOTE 1: For a NB-IoT UE that only supports Control Plane CIoT 5GS Optimisation, as defined in TS 25.401 [xx], PDCP is bypassed and DTCH is not supported.

NOTE 2: For a NB-IoT UE that supports Control Plane CIoT 5GS Optimisation and NG-U data transfer or User Plane CIoT 5GS Optimisation, as defined in TS 25.401 [xx], PDCP is also bypassed (i.e. not used) until AS security is activated.

### 24.2.2 Control Plane

Except for NB-IoT, the figure below shows the protocol stack for the control plane, where:

- NR PDCP sublayer (terminated in ng-eNB on the network side) performs the functions listed for the control plane in clause 6.4 of TS 38.300 [79]. The UE uses only NR PDCP for both SRBs and DRBs when connected to 5GC;

- RLC and MAC sublayers (terminated in ng-eNB on the network side) perform the functions listed in clause 6.2 and 6.1;

- RRC (terminated in ng-eNB on the network side) performs the functions listed in clause 7;

- NAS control protocol (terminated in AMF on the network side) performs the functions listed in TS 23.501 [82], for instance: authentication, mobility management, security control.



Figure 24.2.2-1: Control Plane Protocol Stack

For NB-IoT, the protocol stack for the control plane is described in clause 4.3 where eNB and MME should be understood as ng-eNB and AMF respectively.

- PDCP sublayer (terminated in ng-eNB on the network side) performs the functions listed for the control plane in clause 6.3;

- RLC and MAC sublayers (terminated in ng-eNB on the network side) performs the functions listed for the control plane in clause 6.2 and clause 6.1 respectively;

- RRC (terminated in ng-eNB on the network side) performs the functions listed in clause 7;

- NAS control protocol (terminated in AMF on the network side) performs the functions listed in TS 24.501 [xx].

NOTE: For a NB-IoT UE that only supports Control Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], PDCP is bypassed. For a NB-IoT UE that supports Control Plane CIoT 5GS Optimisation and NG-U data transfer or User Plane CIoT 5GS Optimisation, as defined in TS 24.501 [xx], PDCP is not used until AS security is activated.

## 24.3 Layer 2

Except for NB-IoT, the layer 2 of E-UTRA connected to 5GC is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC), NR Packet Data Convergence Protocol (PDCP) and Service Data Adaptation Protocol (SDAP).

- The physical layer offers to the MAC sublayer transport channels, see clause 5;

- The MAC sublayer offers to the RLC sublayer logical channels, see clause 6.1;

- The RLC sublayer offers to the NR PDCP sublayer RLC channels, see clause 6.2;

- The NR PDCP sublayer offers to the SDAP sublayer data radio bearers, and offers to the RRC sublayer signalling radio bearers, see TS 38.323 [81];

- The SDAP sublayer offers to 5GC QoS flows, see TS 37.324 [80].

For NB-IoT, the layer 2 of E-UTRA connected to 5GC is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP).

- The physical layer offers to the MAC sublayer transport channels, see clause 5;

- The MAC sublayer offers to the RLC sublayer logical channels, see clause 6.1;

- The RLC sublayer offers to the PDCP sublayer RLC channels, see clause 6.2;

- The PDCP sublayer offers to the 5GC QoS flows data radio bearers, and offers to the RRC sublayer signalling radio bearers, see clause 6.3.

## 24.4 CN Selection

For a cell that provides E-UTRA connectivity to both 5GC and EPC within a PLMN, the UE upper layer performs CN selection between EPC and 5GC. The UE AS layer indicates available CN type(s) to upper layers for CN type selection and in addition for NB-IoT, the supported CIoT features. The UE NAS layer indicates selected CN type (if available) with selected PLMN during PLMN selection procedure, as defined in TS 36.304 [11].

## 24.5 Mobility

Intra-EUTRA inter-system Handover (i.e., handover between E-UTRA connected to 5GC and E-UTRA connected to EPC) is described in clause 10.2.2c and in TS 23.502 [83].

The inter-RAT intra-5GC Handover (i.e., handover between E-UTRA connected to 5GC and NR connected to 5GC) is described in clause 9.3.1.2 of TS 38.300 [79].

Inter-RAT handover to/from GERAN/UTRAN/CDMA2000 and cell change order to GERAN with NACC are not supported, and CS fallback described in clause 10.2.5 is not applied except for the functionality of release with redirection to GERAN/UTRAN.

The following mobility procedures are supported:

- RRC Connection Release with Redirection to GERAN/UTRAN/CDMA2000/EUTRAN;

- Cell Change Order to GERAN without NACC.

When the UE is connected to E-UTRA/5GC, inter system fallback towards E-UTRAN is performed when 5GC does not support some services, see TS 23.501 [82]. Depending on factors such as CN interface availability, network configuration and radio conditions, the fallback procedure results in either RRC CONNECTED state mobility (handover procedure) or RRC IDLE state mobility (redirection), see TS 23.501 [82] and TS 36.331 [16].

Except for NB-IoT, in the N2 signalling procedure, the AMF based on support for emergency services, voice service, any other services or for load balancing etc, may indicate the target CN type as EPC or 5GC to the ng-eNB node. When the target CN type is received by ng-eNB, the target CN type is also conveyed to the UE in RRC Connection Release message.

The mobility in RRC\_INACTIVE is described in clause 10.1.9.

For E-UTRA connected to 5GC, in RRC\_IDLE the UE monitors the PCCH for CN-initiated paging information, in RRC\_INACTIVE, except for NB-IoT, the UE monitors the PCCH for RAN-initiated and CN-initiated paging information. The RAN-initiated and CN-initiated paging occasions overlap and the same paging mechanism is used for both. Except for NB-IoT UEs, the extended DRX (eDRX) is not used for E-UTRA connected to 5GC. The paging optimisation in clause 23.13 is also applicable, where AMF shall be considered instead of MME and ng-eNB shall be considered instead of eNB.