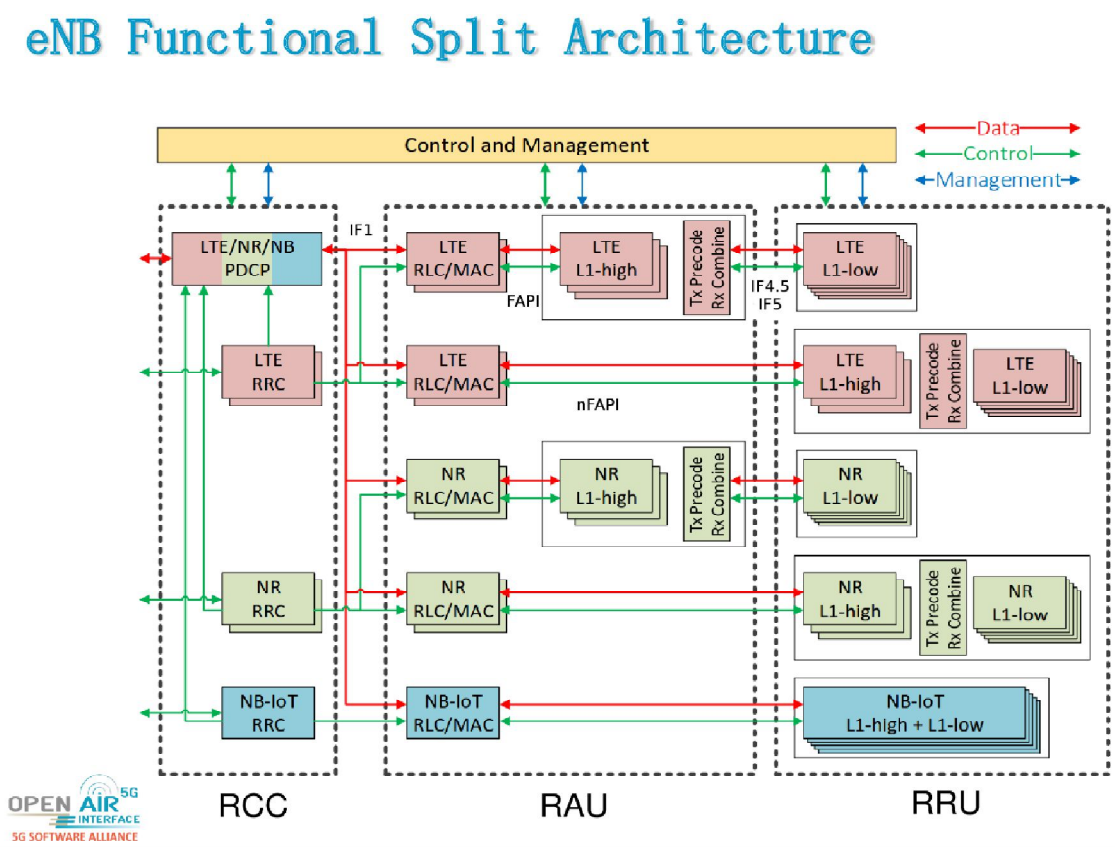
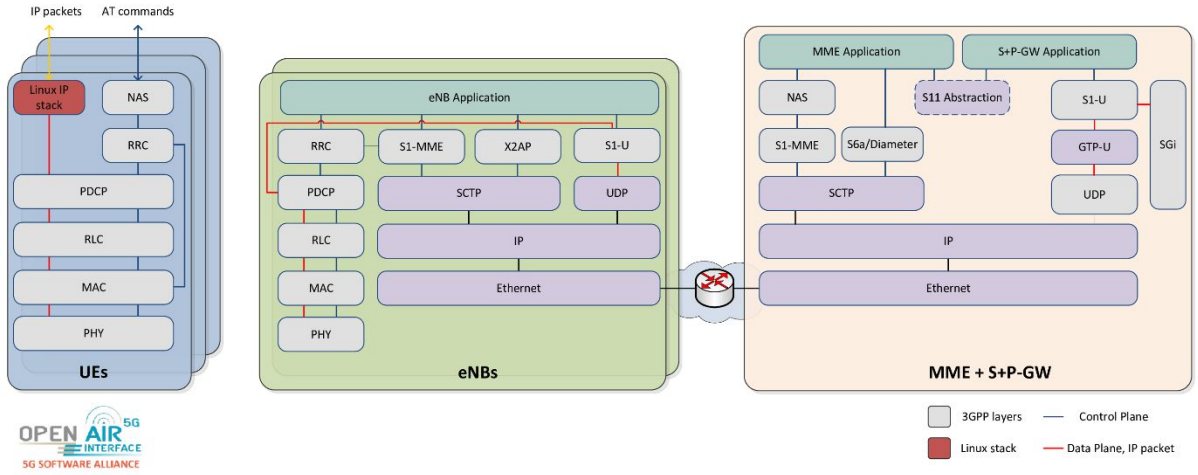
Załącznik nr 3. Funkcjonalność OpenAirInterface (openairinterface5g) w wersji 2023.w02

1 Functional Split Architecture

- RCC: Radio-Cloud Center
- RAU: Radio-Access Unit
- RRU: Remote Radio-Unit
- IF4.5 / IF5 : similar to IEEE P1914.1
- FAPI (IF2) : specified by Small Cell Forum (open-nFAPI implementation)
- IF1 : F1 in 3GPP Release 15



2 OpenAirInterface Block Diagram



OPENAIRINTERFACE FEATURES

3 OpenAirInterface 4G LTE eNB Feature Set

3.1 eNB PHY Layer

The Physical layer implements **3GPP 36.211**, **36.212**, **36.213** and provides the following features:

- LTE release 8.6 compliant, and implements a subset of release 10
- FDD and TDD configurations: 1 (experimental) and 3
- Bandwidth: 5, 10, and 20 MHz
- Transmission modes: 1, 2 (stable), 3, 4, 5, 6, 7 (experimental)
- Max number of antennas: 2
- CQI/PMI reporting: aperiodic, feedback mode 3 - 0 and 3 - 1
- PRACH preamble format 0
- Downlink (DL) channels are supported: PSS, SSS, PBCH, PCFICH, PHICH, PDCCH, PDSCH, PMCH, MPDCCH
- Uplink (UL) channels are supported: PRACH, PUSCH, PUCCH (format 1/1a/1b), SRS, DRS
- HARQ support (UL and DL)
- Highly optimized base band processing (including turbo decoder)
- Multi-RRU support: over the air synchro b/ multi RRU in TDD mode
- Support for CE-modeA for LTE-M. Limited support for repeatition, single-LTE-M connection, legacy-LTE UE attach is disabled.

3.2 eNB MAC Layer

The MAC layer implements a subset of the **3GPP 36.321** release v8.6 in support of BCH, DLSCH, RACH, and ULSCH channels.

- RRC interface for CCCH, DCCH, and DTCH
- Proportional fair scheduler (round robin scheduler soon), with the following improvements:
    - Up to 30 users tested in the L2 simulator, CCE allocation in the preprocessor ; the scheduler was also simplified and made more modular
    - Adaptative UL-HARQ
    - Remove out-of-sync UEs
    - No use of the `first_rb` in the UL scheduler ; respects `vrb_map_UL` and `vrb_map` in the DL
- DCI generation
- HARQ Support
- RA procedures and RNTI management
- RLC interface (AM, UM)
- UL power control
- Link adaptation
- Connected DRX (CDRX) support for FDD LTE UE. Compatible with R13 from 3GPP.

3.3 eNB RLC Layer

The RLC layer implements a full specification of the 3GPP 36.322 release v9.3.

- RLC TM (mainly used for BCCH and CCCH)
    - Neither segment nor concatenate RLC SDUs
    - Do not include a RLC header in the RLC PDU
    - Delivery of received RLC PDUs to upper layers
- RLC UM (mainly used for DTCH)
    - Segment or concatenate RLC SDUs according to the TB size selected by MAC
    - Include a RLC header in the RLC PDU
    - Duplication detection
    - PDU reordering and reassembly
- RLC AM, compatible with 9.3
    - Segmentation, re-segmentation, concatenation, and reassembly
    - Padding
    - Data transfer to the user
    - RLC PDU retransmission in support of error control and correction
    - Generation of data/control PDUs

3.4 eNB PDCP Layer

The current PDCP layer is header compliant with **3GPP 36.323** Rel 10.1.0 and implements the following functions:

- User and control data transfer
- Sequence number management
- RB association with PDCP entity
- PDCP entity association with one or two RLC entities
- Integrity check and encryption using the AES and Snow3G algorithms

3.5 eNB RRC Layer

The RRC layer is based on **3GPP 36.331** v15.6 and implements the following functions:

- System Information broadcast (SIB 1, 2, 3, and 13)
  - SIB1: Up to 6 PLMN IDs broadcast
- RRC connection establishment
- RRC connection reconfiguration (addition and removal of radio bearers, connection release)
- RRC connection release
- RRC connection re-establishment
- Inter-frequency measurement collection and reporting (experimental)
- eMBMS for multicast and broadcast (experimental)
- Handover (experimental)
- RRC inactivity timer (release of UE after a period of data inactivity)

3.6 eNB X2AP

The X2AP layer is based on **3GPP 36.423** v14.6.0 and implements the following functions:

- X2 Setup Request
- X2 Setup Response
- X2 Setup Failure
- Handover Request
- Handover Request Acknowledge
- UE Context Release
- X2 timers (t_reloc_prep, tx2_reloc_overall)
- Handover Cancel
- X2-U interface implemented
- EN-DC is implemented
- X2AP : Handling of SgNB Addition Request / Addition Request Acknowledge / Reconfiguration Complete
- RRC : Handling of RRC Connection Reconfiguration with 5G cell info, configuration of 5G-NR measurements
- S1AP : Handling of E-RAB Modification Indication / Confirmation

3.7 eNB/MCE M2AP

The M2AP layer is based on **3GPP 36.443** v14.0.1:

- M2 Setup Request
- M2 Setup Response
- M2 Setup Failure
- M2 Scheduling Information
- M2 Scheduling Information Response
- M2 Session Start Request
- M2 Session Start Response

3.8 MCE/MME M3AP

The M3AP layer is based on **3GPP 36.444** v14.0.1:

- M3 Setup Request
- M3 Setup Response
- M3 Setup Failure
- M3 Session Start Request
- M3 Session Start Response

4 OpenAirInterface 4G LTE UE Feature Set

4.1 LTE UE PHY Layer

The Physical layer implements **3GPP 36.211**, **36.212**, **36.213** and provides the following features:

- LTE release 8.6 compliant, and implements a subset of release 10
- FDD and TDD configurations: 1 (experimental) and 3
- Bandwidth: 5, 10, and 20 MHz
- Transmission modes: 1, 2 (stable)
- Max number of antennas: 2
- CQI/PMI reporting: aperiodic, feedback mode 3 - 0 and 3 - 1
- PRACH preamble format 0
- All downlink (DL) channels are supported: PSS, SSS, PBCH, PCFICH, PHICH, PDCCH, PDSCH, PMCH
- All uplink (UL) channels are supported: PRACH, PUSCH, PUCCH (format 1/1a/1b), SRS, DRS
- LTE MBMS-dedicated cell (feMBMS) procedures subset for LTE release 14 (experimental)
- LTE non-MBSFN subframe (feMBMS) Carrier Adquistion Subframe-CAS procedures (PSS/SSS/PBCH/PDSH) (experimental)
- LTE MBSFN MBSFN subframe channel (feMBMS): PMCH (CS@1.25KHz) (channel estimation for 25MHz bandwidth) (experimental)

4.2 LTE UE MAC Layer

The MAC layer implements a subset of the **3GPP 36.321** release v8.6 in support of BCH, DLSCH, RACH, and ULSCH channels.

- RRC interface for CCCH, DCCH, and DTCH
- HARQ Support
- RA procedures and RNTI management
- RLC interface (AM, UM)
- UL power control
- Link adaptation
- MBMS-dedicated cell (feMBMS) RRC interface for BCCH
- eMBMS and MBMS-dedicated cell (feMBMS) RRC interface for MCCH, MTCH

4.3 LTE UE RLC Layer

The RLC layer implements a full specification of the 3GPP 36.322 release v9.3.

4.4 LTE UE PDCP Layer

The current PDCP layer is header compliant with **3GPP 36.323** Rel 10.1.0.

4.5 LTE UE RRC Layer

The RRC layer is based on **3GPP 36.331** v14.3.0 and implements the following functions:

- System Information decoding
- RRC connection establishment
- MBMS-dedicated cell (feMBMS) SI-MBMS/SIB1-MBMS management

4.6 LTE UE NAS Layer

The NAS layer is based on **3GPP 24.301** and implements the following functions:

- EMM attach/detach, authentication, tracking area update, and more
- ESM default/dedicated bearer, PDN connectivity, and more

5 OpenAirInterface 5G-NR Feature Set

5.1 General Parameters

The following features are valid for the gNB and the 5G-NR UE.

- Static TDD,
- FDD
- Normal CP
- Subcarrier spacings: 15 and 30kHz (FR1), 120kHz (FR2)
- Bandwidths: 10, 20, 40, 80, 100MHz (273 Physical Resource Blocks)
- Intermediate downlink and uplink frequencies to interface with IF equipment
- Procedures for 2-layer DL MIMO
- Slot format: 14 OFDM symbols in UL or DL
- Highly efficient 3GPP compliant LDPC encoder and decoder (BG1 and BG2 supported)
- Highly efficient 3GPP compliant polar encoder and decoder
- Encoder and decoder for short blocks
- Support for UL transform precoding (SC-FDMA)

5.2 gNB PHY Layer

- 15kHz and 30kHz SCS for FR1 and 120kHz SCS for FR2
- Generation of NR-PSS/NR-SSS
- NR-PBCH supports multiple SSBs and flexible periodicity
- Generation of NR-PDCCH (including generation of DCI, polar encoding, scrambling, modulation, RB mapping, etc)
    - common search space
    - user-specific search space
    - DCI formats: 00, 10, 01 and 11
- Generation of NR-PDSCH (including Segmentation, LDPC encoding, rate matching, scrambling, modulation, RB mapping, etc).
    - PDSCH mapping type A and B
    - DMRS configuration type 1 and 2
    - Single and multiple DMRS symbols
    - PTRS support
    - Support for 1, 2 and 4 TX antennas
    - Support for up to 2 layers (currently limited to DMRS configuration type 2)
- NR-CSIRS Generation of sequence at PHY
- NR-PUSCH (including Segmentation, LDPC encoding, rate matching, scrambling, modulation, RB mapping, etc).
    - PUSCH mapping type A and B
    - DMRS configuration type 1 and 2
    - Single and multiple DMRS symbols
    - PTRS support
    - Support for up to 2 RX antenna
    - Support for up to 2 layers
- NR-PUCCH
    - Format 0 (2 bits, for ACK/NACK and SR)
    - Format 2 (up to 11 bits, mainly for CSI feedback)

- NR-SRS
    - SRS signal reception
    - Channel estimation (with T tracer real time monitoring)
    - Power noise estimation
- NR-PRS
    - Rel16 Positioning reference signal(PRS) generation and modulation
    - Multiple PRS resources, one per beam is supported in FR2 TDD mode
    - FR1 and FR2 support with config file
- NR-PRACH
    - Formats 0,1,2,3, A1-A3, B1-B3
- Highly efficient 3GPP compliant LDPC encoder and decoder (BG1 and BG2 are supported)
- Highly efficient 3GPP compliant polar encoder and decoder
- Encoder and decoder for short block

5.3 gNB Higher Layers

gNB MAC

- MAC -> PHY configuration using NR FAPI P5 interface
- MAC <-> PHY data interface using FAPI P7 interface for BCH PDU, DCI PDU, PDSCH PDU
- Scheduler procedures for SIB1
- Scheduler procedures for RA
    - Contention Free RA procedure
    - Contention Based RA procedure
        - Msg3 can transfer uplink CCCH, DTCH or DCCH messages
        - CBRA can be performed using MAC CE or C-RNTI
- Scheduler procedures for CSI-RS
- MAC downlink scheduler
    - phy-test scheduler (fixed allocation and usable also without UE)
    - regular scheduler with dynamic allocation
    - MCS adaptation from HARQ BLER
- MAC header generation (including timing advance)
- ACK / NACK handling and HARQ procedures for downlink
- MAC uplink scheduler
    - phy-test scheduler (fixed allocation)
    - regular scheduler with dynamic allocation
    - HARQ procedures for uplink
- Scheduler procedures for SRS reception
    - Periodic SRS reception
    - Channel rank computation up to 2x2 scenario
    - TPMI computation based on SRS up 4 antenna ports and 2 layers
- MAC procedures to handle CSI measurement report
    - evalution of RSRP report
    - evaluation of CQI report
- MAC scheduling of SR reception
- Bandwidth part (BWP) operation
    - Handle multiple dedicated BWPs
    - BWP switching through RRCReconfiguration method

gNB RLC

- Send/Receive operations according to 38.322 Rel.16
    - Segmentation and reassembly procedures
    - RLC Acknowledged mode supporting PDU retransmissions
    - RLC Unacknowledged mode
    - DRBs and SRBs establishment/handling and association with RLC entities
    - Timers implementation
    - Interfaces with PDCP, MAC
    - Interfaces with gtp-u (data Tx/Rx over F1-U at the DU)

gNB PDCP

- Send/Receive operations according to 38.323 Rel.16
    - Integrity protection and ciphering procedures
    - Sequence number management, SDU dicard and in-order delivery
    - Radio bearer establishment/handling and association with PDCP entities
    - Interfaces with RRC, RLC
    - Interfaces with gtp-u (data Tx/Rx over N3 and F1-U interfaces)

gNB SDAP

- Send/Receive operations according to 37.324 Rel.15
    - Establishment/Handling of SDAP entities.
    - Transfer of User Plane Data
    - Mapping between a QoS flow and a DRB for both DL and UL
    - Marking QoS flow ID in both DL and UL packets
    - Reflective QoS flow to DRB mapping for UL SDAP data PDUs

gNB RRC

- NR RRC (38.331) Rel 16 messages using new asn1c
- LTE RRC (36.331) also updated to Rel 15
- Generation of CellGroupConfig (for eNB) and MIB
- Generation of system information block 1 (SIB1)
- Generation of system information block 2 (SIB2)
- Application to read configuration file and program gNB RRC
- RRC can configure PDCP, RLC, MAC
- Interface with gtp-u (tunnel creation/handling for S1-U (NSA), N3 (SA) interfaces)
- Integration of RRC messages and procedures supporting UE 5G SA connection
    - RRCSetupRequest/RRCSetup/RRCSetupComplete
    - RRC Uplink/Downlink Information transfer carrying NAS messages transparently
    - RRC Reconfiguration/Reconfiguration complete
    - Paging
    - Support for master cell group configuration
    - Interface with NGAP for the interactions with the AMF
    - Interface with F1AP for CU/DU split deployment option
    - Periodic RRC measurements of serving cell (no A/B events)

gNB X2AP

- Integration of X2AP messages and procedures for the exchanges with the eNB over X2 interface supporting the NSA setup according to 36.423 Rel. 15
    - X2 setup with eNB
    - Handling of SgNB Addition Request / Addition Request Acknowledge / Reconfiguration Complete

gNB NGAP

- Integration of NGAP messages and procedures for the exchanges with the AMF over N2 interface according to 38.413 Rel. 15
    - NGAP Setup request/response
    - NGAP Initial UE message
    - NGAP Initial context setup request/response
    - NGAP Downlink/Uplink NAS transfer
    - NGAP UE context release request/complete
    - NGAP UE radio capability info indication
    - NGAP PDU session resource setup request/response
- Interface with RRC

gNB F1AP

- Integration of F1AP messages and procedures for the control plane exchanges between the CU and DU entities according to 38.473 Rel. 16
    - F1 Setup request/response
    - F1 DL/UL RRC message transfer
    - F1 Initial UL RRC message transfer
    - F1 UE Context setup request/response
    - F1 gNB CU configuration update
- Interface with RRC
- Interface with gtp-u (tunnel creation/handling for F1-U interface)

gNB GTP-U

- New gtp-u implementation supporting both N3 and F1-U interfaces according to 29.281 Rel.15
    - Interfaces with RRC, F1AP for tunnel creation
    - Interfaces with PDCP and RLC for data send/receive at the CU and DU respectively (F1-U interface)
    - Interface with SDAP for data send/receive, capture of GTP-U Optional Header, GTP-U Extension Header and PDU Session Container.

6 OpenAirInterface 5G-NR UE Feature Set

- Supporting "noS1" mode (DL and UL):
  - Creates TUN interface to PDCP to inject and receive user-place traffic
  - No connection to the core network
- Supporting Standalone (SA) mode:
  - UE can register with the 5G Core Network, establish a PDU Session and exchange user-plane traffic

6.1 NR UE PHY Layer

- Initial synchronization
  - the UE needs to know the position in frequency of the SSBs (via command line parameter in SA)
- Time tracking based on PBCH DMRS
- Frequency offset estimation based on PSS and SSS
- 15kHz and 30kHz SCS for FR1 and 120 kHz SCS for FR2
- Reception of NR-PSS/NR-SSS
- NR-PBCH supports multiple SSBs and flexible periodicity
  - RSRP measurement for the strongest SSB
- Reception of NR-PDCCH (including reception of DCI, polar decoding, de-scrambling, de-modulation, RB de-mapping, etc)
  - common search space configured by MIB
  - user-specific search space configured by RRC
  - DCI formats: 00, 10, 01 and 11
- Reception of NR-PDSCH (including Segmentation, LDPC decoding, rate de-matching, de-scrambling, de-modulation, RB de-mapping, etc).
  - PDSCH mapping type A and B
  - DMRS configuration type 1 and 2
  - Single and multiple DMRS symbols
  - PTRS support
  - Support for 1, 2 and 4 RX antennas
  - Support for up to 2 layers (currently limited to DMRS configuration type 2)
- Measurements based on NR-CSIRS
  - RSRP measurements
  - RI, PMI and CQI computation
  - Support for up to 4 RX antennas
  - Support for up to 2 layers
- NR-PUSCH (including Segmentation, LDPC encoding, rate matching, scrambling, modulation, RB mapping, etc).
  - PUSCH mapping type A and B
  - DMRS configuration type 1 and 2
  - Single and multiple DMRS symbols
  - PTRS support
  - Support for up to 2 TX antenna
  - Support for up to 2 layers
- NR-PUCCH
  - Format 0 (2 bits for ACK/NACK and SR)
  - Format 2 (up to 11 bits, mainly for CSI feedback)

    - Format 1, 3 and 4 present but old code never tested (need restructuring before verification)
- NR-SRS
    - Generation of sequence at PHY
    - SRS signal transmission
- NR-PRS
    - PRS based Channel estimation with T tracer dumps
    - Time of arrival(ToA) estimation based on channel impulse response(CIR)
    - Finer ToA estimation by 16x oversampled IDFT for CIR
    - Support for multiple gNB reception with gNBs synced via GPSDO
- NR-PRACH
    - Formats 0,1,2,3, A1-A3, B1-B3
- Highly efficient 3GPP compliant LDPC encoder and decoder (BG1 and BG2 are supported)
- Highly efficient 3GPP compliant polar encoder and decoder
- Encoder and decoder for short block

6.2 NR UE FAPI

- MAC -> PHY configuration via UE FAPI P5 interface
- Basic MAC to control PHY via UE FAPI P7 interface
- PHY -> MAC indication (needs some improvement)

6.3 NR UE Higher Layers

UE MAC

- Minimum system information (MSI)
    - MIB processing
    - Scheduling of system information block 1 (SIB1) reception
- Random access procedure (needs improvement, there is still not a clear separation between MAC and PHY)
    - Mapping SSBs to multiple ROs
    - Scheduling of PRACH
    - Processing of RAR
    - Transmission and re-transmission of Msg3
    - Msg4 and contention resolution
- DCI processing
    - format 10 (RA-RNTI, C-RNTI, SI-RNTI, TC-RNTI)
    - format 00 (C-RNTI, TC-RNTI)
    - format 11 (C-RNTI)
    - format 01 (C-RNTI)
- UCI processing
    - ACK/NACK processing
    - Triggering periodic SR
    - CSI measurement reporting
- DLSCH scheduler
    - Configuration of fapi PDU according to DCI
    - HARQ procedures

- ULSCH scheduler
    - Configuration of fapi PDU according to DCI
- NR-CSIRS scheduler
    - Scheduling of NR-CSIRS reception
    - Fill UCI for CSI measurement reporting
- Scheduler procedures for SRS transmission
    - Periodic SRS transmission
- Bandwidth part (BWP) operation
    - Operation in configured dedicated BWP through RRCSetup or RRCReconfiguration

UE RLC

- Tx/Rx operations according to 38.322 Rel.16
    - Segmentation and reassembly procedures
    - RLC Acknowledged mode supporting PDU retransmissions
    - RLC Unacknowledged mode
    - DRBs and SRBs establishment and handling
    - Timers implementation
    - Interfaces with PDCP, MAC

UE PDCP

- Tx/Rx operations according to 38.323 Rel.16
    - Integrity protection and ciphering procedures
    - Sequence number management, SDU dicard and in-order delivery
    - Radio bearer establishment/handling and association with PDCP entities
    - Interfaces with RRC, RLC

UE SDAP

- Tx/Rx operations operations according to 37.324 Rel.15

- Establishment/Handling of SDAP entities.
- Transfer of User Plane Data
- Reflective Mapping
- RRC Signaling Mapping

UE RRC

- Integration of RRC messages and procedures supporting UE 5G SA connection according to 38.331 Rel.16
    - RRCSetupRequest/RRCSetup/RRCSetupComplete
    - RRC Uplink/Downlink Information transfer carrying NAS messages transparently
    - RRC Reconfiguration/Reconfiguration complete
    - Support for master cell group configuration
    - Reception of UECapabilityEnquiry, encoding and transmission of UECapability
- Interface with PDCP: configuration, DCCH and CCCH message handling

- Interface with RLC and MAC for configuration

UE NAS

- Transfer of NAS messages between the AMF and the UE supporting the UE registration with the core network and the PDU session establishment according to 24.501 Rel.16
    - Identity Request/Response
    - Authentication Request/Response
    - Security Mode Command/Complete
    - Registration Request/Accept/Complete
    - PDU Session Establishment Request/Accept
    - NAS configuration and basic interfacing with RRC