5G/LTE data transmission devices with equipment for PL-5G project

5G NR/LTE Digital Data Transmission Device Variant 1, USB-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 1 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 20 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-20 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 40.
- Support for at least 500 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA mode,
    - FDD and FDD communication in FR1 band,

    - ability process at least 2 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.
- Tools allowing monitoring of the device from a commandline.

- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.

- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.
- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).

- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 10 x 25 x 30 cm, suitable for indoor use.
- Weight of the device not exceeding 3 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 1 dedicated Software Defined Radio (SRD) card installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 20 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the change of its hardware platform must be possible using a hardware device connected to an USB port.

The device must be new (cannot be a refurbished device).

The device must include at least 5 years of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 15 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 1, server-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 1 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 20 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-20 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 40.
- Support for at least 500 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA mode,
    - FDD and FDD communication in FR1 band,

    - ability process at least 2 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.
- Tools allowing monitoring of the device from a commandline.

- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.

- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.
- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).

- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 10 x 25 x 30 cm, suitable for indoor use.
- Weight of the device not exceeding 3 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 1 dedicated Software Defined Radio (SRD) card installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 20 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the

change of its hardware platform must be possible using IP communication with a licensing server (provided by the manufacturer of the device as a software solution possible to deploy in user's infrastructure on a Linux operating system).

The device must be new (cannot be a refurbished device).

The device must include at least 5 years of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 15 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 1A, USB-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 1 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 20 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-20 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 40.
- Support for at least 500 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA mode,
    - FDD and FDD communication in FR1 band,

    - ability process at least 2 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.
- Tools allowing monitoring of the device from a commandline.

- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.

- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.
- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).

- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 10 x 25 x 30 cm, suitable for indoor use.
- Weight of the device not exceeding 3 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 1 dedicated Software Defined Radio (SRD) card installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 20 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the change of its hardware platform must be possible using a hardware device connected to an USB port.

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 15 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 1A, server-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 1 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 20 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-20 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 40.
- Support for at least 500 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA mode,
    - FDD and FDD communication in FR1 band,

    - ability process at least 2 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.
- Tools allowing monitoring of the device from a commandline.

- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.

- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.
- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).

- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 10 x 25 x 30 cm, suitable for indoor use.
- Weight of the device not exceeding 3 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 1 dedicated Software Defined Radio (SRD) card installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 20 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the

change of its hardware platform must be possible using IP communication with a licensing server (provided by the manufacturer of the device as a software solution possible to deploy in user's infrastructure on a Linux operating system).

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 15 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 2

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 3 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 50 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-50 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 120.
- Support for at least 1000 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA and NSA modes,
    - FDD and FDD communication in FR1 band,

    - ability process at least 4 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Carrier Aggregation in SA and NSA modes (at least up to **3 DL** carriers),
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.

- Tools allowing monitoring of the device from a commandline.
- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.

- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.
- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.

- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an

equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 35 x 30 x 40 cm, suitable for indoor use.
- Weight of the device not exceeding 12 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 3 dedicated Software Defined Radio (SRD) cards installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 50 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as Radio head (wireless data transmission device) type A" and "Radio head (wireless data transmission device) type B".
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be new (cannot be a refurbished device).

The device must include at least 5 years of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 30 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 2, server-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 3 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 50 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-50 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 120.
- Support for at least 1000 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA and NSA modes,
    - FDD and FDD communication in FR1 band,

    - ability process at least 4 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Carrier Aggregation in SA and NSA modes (at least up to **3 DL** carriers),
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.

- Tools allowing monitoring of the device from a commandline.
- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.

- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.
- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.

- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an

equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 35 x 30 x 40 cm, suitable for indoor use.
- Weight of the device not exceeding 12 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 3 dedicated Software Defined Radio (SRD) cards installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 50 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as Radio head (wireless data transmission device) type A" and "Radio head (wireless data transmission device) type B".
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the change of its hardware platform must be possible using IP communication with a licensing server (provided by the manufacturer of the device as a software solution possible to deploy in user's infrastructure on a Linux operating system).

The device must be new (cannot be a refurbished device).

The device must include at least 5 years of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 30 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 2A, server-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 3 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 50 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-50 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 120.
- Support for at least 1000 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA and NSA modes,
    - FDD and FDD communication in FR1 band,

    - ability process at least 4 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Carrier Aggregation in SA and NSA modes (at least up to **3 DL** carriers),
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.

- Tools allowing monitoring of the device from a commandline.
- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.

- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.
- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.

- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an

equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 35 x 30 x 40 cm, suitable for indoor use.
- Weight of the device not exceeding 12 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 3 dedicated Software Defined Radio (SRD) cards installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 50 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 56 MHz frequency width,
    - ADC/DAC sample rate at least 61 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 2 ppm,
    - transmitter power at least 2.5 dBm for f=500 MHz and -6 for f=3500 MHz,
    - connected by a PCIe 1x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 6 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as Radio head (wireless data transmission device) type A" and "Radio head (wireless data transmission device) type B".
- At least **1 RJ45** GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the change of its hardware platform must be possible using IP communication with a licensing server (provided by the manufacturer of the device as a software solution possible to deploy in user's infrastructure on a Linux operating system).

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 30 SIM cards preconfigured to work with the device.

5G NR/LTE Digital Data Transmission Device Variant 3, server-based floating license

A data transmission device able to perform functions of:

- an LTE (eNodeB and ng-eNodeB) base station and 5G New Radio (gNodeB) base station,
- a 5G and EPC core network,

and provide a set of high-level services for end users.

The base station functionality must include the following functions:

- An ability to function as an LTE (eNodeB and ng-eNodeB) and 5G (gNodeB) base station compatible with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base station and the core network.
- An ability to support at least 8 independent cells, each of which can be a 5G cell.
- Maximum width of used frequency channel must be at least 100 MHz, but it must be possible to use narrower channels, including 1.4, 3, 5, 10, 15 and 20 MHz in LTE, 200 kHz in NB-IoT and 5-100 MHz in 5G NR.
- The product of multiplication of the number of supported MIMO layers and supported channel width (in MHz) must be at least 1600.
- Support for at least 1000 of active UEs simultaneously.
- Support for at least the following types of handover procedure: intra eNodeB, S1, X2, intra ng-eNodeB, intra gNodeB, NG, Xn, EPS to 5GS, 5GS to EPS.
- Support of at least the following interfaces:
    - eNodeB: S1AP and GTP-U to EPC, X2AP between eNodeBs,
    - ng-eNodeB/gNodeB: NGAP and GTP-U to 5GC, XnAP between ng-eNodeB/gNodeB,
    - M1 i M2 to eMBMS,
    - multiple PLMNs and S1/NG interfaces can be used simultaneously.
- Support for IPv6 protocol.
- Support for at least the following LTE PHY functions:
    - TDD and FDD transmission,
    - LTE transmission modes 1-10,
    - multiple cells in inter-band and intra-band configuration,
    - HARQ protocol,
    - wideband CQI/PMI reporting,
    - UE power control in a closed-loop mode,
    - an optimized implementation of turbo-coding,
    - PRS signals,
    - PRACH-based timing measurements,
    - a frequency-based MMSE equalizer,
    - CSI-RS mechanisms,
    - Carrier Aggregation, including:
        - cross-carrier scheduling (at least 8 DL channel maximum),
        - mixed FDD-TDD mode.
    - Peak to Average Power Ratio reduction mechanisms,
    - ability to use different types of Radio Heads when appropriate drivers are available,
    - LTE resource allocation mechanisms for PUSCH in multi-cluster mode,
    - PUCCH3 I PUCCH support,
    - CoMP mechanisms: DMRS scrambling identity and QCL parameters selection,

    - 1024QAM modulation for PDSCH DL transmission,
    - 256QAM for DL transmission in PDSCH and MBMS;
    - 256QAM for UL transmission in PUSCH.
- Support of at least the following LTE protocol layer functions:
    - MAC, RLC, PDCP, RRC layers,
    - compatibility with client devices operating in full- and half-dupex modes,
    - proportionally-fair scheduler with QoS support,
    - semi-persistent scheduling (SPS) mode,
    - lack of limitations regarding the number of active users, except as a result of limited resources,
    - fully Configurable System Information Blocks,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - confidentiality and integrity protection of data traffic,
    - at least the following cryptographic algorithms: AES, Snow3G and ZUC,
    - RRC monitoring with measurement gap support,
    - QoS mechanisms with user-configurable DRB for each QCI,
    - ROHC support, with at least RTP, UDP and IP v1 profiles, unidirectional mode (lack of support for RTP CSRC, IP extensions and outer/inner IP is permitted),
    - Multimedia Broadcast Multicast Services (MBMS) services,
    - ETWS and CMAS Public Warning System support,
    - compatibility with category 0 client devices,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode,
    - RRC release procedure with redirection to NR SA cell,
    - TTI bundling mechanism,
    - PDCCH signaling over PRACH channel.
- Support for at least the following LTE-M mechanisms and functions:
    - FDD, HD-FDD and TDD communication,
    - TM6 and TM9 modes,
    - compatibility with category M1 client devices,
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - Coverage Enhancement Mode A,
    - message repetition mechanisms for MPDCCH, PDSCH, PUCCH, PUSCH and PRACH,
    - MPDCCH transmission in localized and distributed modes.
- Support for at least the following NB-IoT mechanisms and functions:
    - compatibility with both single-tone and multi-tone NB1 and NB2 client devices,
    - subcarrier spacing of 3.75 and 15 kHz,
    - in-band, guard band and standalone operation modes,
    - all 3GPP rel. 16 NPDCCH, NPDSCH, NPUSCH and NPRACH configurations (including NPRACH Format 2),
    - Discontinuous Reception (DRX) and Extended Discontinuous Reception (eDRX) mode,
    - CIoT control plane optimizations,
    - Multi-DRB mode,
    - PDCC Order PRACH function.
- Ability to simultaneously maintain multiple NB-IoT and LTE cells within the same eNodeB.
- Support for at least the following 5G New Radio mechanisms and functions:
    - SA and NSA modes,
    - FDD and FDD communication in FR1 band,

    - ability process at least 4 MIMO streams in both uplink and downlink (regardless of limitations of the hardware platform regarding the number of MIMO streams possible to send and receive),
    - 256QAM modulation in both uplink and downlink,
    - all PUCCH and PRACH formats defined by 3GPP rel. 16 standards,
    - two-step RACH procedure,
    - user-configurable TDD Ul/DL patterns, with automatic and manual selection of k0, k1, k2 parameters,
    - PDCCH channel supporting at least the following DCI formats: 0_0, 0_1, 1_0 and 1_1,
    - PHY layer test mode with continuous transmission over PDSCH and PUSCH channels,
    - EUTRAN-NR Dual Connectivity (EN-DC) mode and NR-NR Dual Connectivity (NR-DC) mode with automatic and manual activation/deactivation,
    - dynamic reconfiguration of DRB for LTE/NR,
    - user configurable DRB for each QCI/5QI,
    - Discontinuous Reception (DRX) mode,
    - RRC monitoring with measurement gap function,
    - PScell change support,
    - ETWS and CMAS Public Warning System support,
    - Carrier Aggregation in SA and NSA modes (at least up to 8 DL carriers),
    - Multi-BWP z obsługą zmiany BWP na podstawie RCC i DCI,
    - SUL (Supplementary Uplink),
    - RRC Inactive mode,
    - EPS fallback,
    - Network slicing,
    - RRC release with redirection to EUTRA cell,
    - PDCCH Order,
    - CSI-RS i TRS,
    - Scheduling Request,
    - Dynamic Spectrum Sharing,
    - Positioning Reference Signals (PRS).
- A communication channel emulator function allowing the real-world communication channel between base station and client to be modified, with at least the following functions:
    - real-time processing of base station signals,
    - white-noise generator,
    - support for at least the following channel models: AWGN, EPA, EVA, ETU, TDLA30, TDLB100, TDLC300 i MBSFN 3GPP,
    - support for MIMO communication and 3GPP correlation matrices,
    - support for Rayleight fading with dedicated MIMO 3GPP correlation matrices.
- Support for localization protocols:
    - Location Positioning Protocol (LPP) with E-CID and OTDOA methods,
    - New Radio Positioning Protocol (NRPP) with E-CID and OTDOA methods.
- Configurable event and message logging system (including decode to text mechanisms) for at least the following layers: PHY, RLC, PDCP, NAS, MAC, RRC and at least the following interfaces: S1AP, NGAP, X2AP, XnAP.
- Ability to capture and analyze network traffic using pcap format for communication conducted over at least the following interfaces: S1, NG, M2, X2, Xn.
- Ability to generate QAM constellation plots and channel response plots.
- Websocket API for remote monitoring and managing of the device.

- Tools allowing monitoring of the device from a commandline.
- Ability of the administrator to issue commands resulting in:
    - handover procedure initiation,
    - dynamic (with no assured service disruption) change of transmission power level for each of supported cells.
- Compatibility with a 5G/EPC core network both from the same and other manufacturers.
- Ability to integrate the base station with:
    - elements of 5G and EPC core network from the same manufacturer, operating both on the same hardware platform (the same device) as the base station and outside the hardware platform, reachable by an IP network,
    - elements of 5G and EPC core network from other manufacturers, operating outside the hardware platform (device) running the base station, reachable by a network utilizing an IP protocol.
- Ability to generate and receive radio signals using:
    - dedicated SRD cards designed by the manufacturer of the base station and included as a part of the provided hardware platform,
    - external, third-party SDR devices (not included in the provided hardware platform), possible to connect to the provided hardware platform by USB or Ethernet interfaces,
    - external data transmission devices (not included in the provided hardware platform) which can be connected to the device using CPRI interface (split 8) cards (installed in place of the dedicated SDR cards) – especially devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B”.

The EPC core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the eNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of an EPC core: MME, SGW, PGW, ePDG, PCRF, HSS and EIR.
- Ability to simultaneously support multiple eNodeB base stations using S1 interface (including S1AP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
- Implementation of at least the following UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Support for Multi-PDN configuration and dynamic configuration of E-UTRAN Radio Access Bearers (E-RABs) for VoLTE/IMS services.
- Transparent traffic forwarding between UE and an external IP network, without a need for external SGW/PGW elements.

- Configurable APN names, IP address ranges, DNS configuration and QoS parameters for E-RABs.
- Ability to send ETWS/CMAS messages.
- Support for IPv6 protocol.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the EPC.
- Tools allowing monitoring of the EPC from a commandline.
- Support for:
    - power saving modes: PSM and eDRX,
    - Location Services Application Protocol (LCS-AP),
    - multiple IMS servers using Rx interface,
    - CIoP EPS control plane optimizations, including:
        - Non-IP data delivery,
        - Attach without PDN Connectivity.
- Support for NB-IoT RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - S6a interface and an external HSS,
    - S13 interface and an external EIR,
    - SGsAP interface and an external VLR/MSC,
    - SBcAP interface and an external CBC.
- Support for and ability to forward broadcast and multicast traffic between the EPS and a PDN network.
- Support for client devices operating in Dual Connectivity with New Radio mode (DCNR).

The 5G core network functionality must include the following functions:

- Compliance with 3GPP rel. 16 specification, especially in terms of compatibility between client terminals, the base stations and the core network.
- Compatibility with the ng-eNodeB/gNodeB base station specified above, which is a part of the functionality of the device.
- Implementation of the functionality of at least the following components of a 5G core: AMF, SMF, AUSF, UPF, UDM and 5G-EIR.
- Ability to simultaneously support multiple ng-eNodeB/gNodeB base stations and N3IWF elements using NG interface (including NGAP and GTP-U protocols).
- Ability to protect integrity and confidentiality of NAS communication using an algorithm selected from a group containing at least: AES, Snow3G and ZUC.
- Support for USIM authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK 5G-AKA.
- Implementation of at least the following UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Support for multi-PDU sessions with dynamic QoS flow creation for VoNR/IMS services.
- Transparent IP forwarding to external IP network, without a need for external UPF elements.
- Configurable APN names, IP address ranges, DNS configuration and QoS flows.

- Forwarding of IPv4, IPv4v6, IPv6 and unstructured-PDU traffic.
- Configurable event and message logging system (including decode to text mechanisms).
- Websocket API for remote monitoring and managing of the 5G core.
- Tools allowing monitoring of the 5G core from a commandline.
- Support for:
    - energy efficient modes, at least: MICO and eDRX,
    - multiple IMS servers using Rx interface,
    - CIoT 5GS control plane optimization mechanisms, including Non-IP forwarding feature,
    - Network Slicing mechanisms,
    - NL1 interface.
- Support of NB-IoT, LTE and non-3GPP RAT access systems.
- Ability to use an internal user database, and functioning without the need for an external HSS element.
- Support for and ability to forward broadcast and multicast traffic in created PDU sessions.
- Ability to send ETWS/CMAS messages.
- Access to the following interfaces and the ability to integrate external elements compatible with them, by employing IP communication:
    - N12 interface and an external AUSF,
    - N8 interface and an external UDM,
    - N17 interface and an external 5G-EIR,
    - N50 interface and an external CBC.

The device must also provide the following, high level service functionality for end users:

- Implementation of at least the following IMS system elements in a form of an integrated service system: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), Serving-CSCF (S-CSCF) and Home Subscriber Server (HSS).
    - The system must provide at least the following services: Voice call, Video call, Voice echo test, Call hold, SMS over SIP and SMS over SG.
    - Support for authentication using algorithm selected from a group containing at least: XOR, Milenage and TUAK.
    - Support for at least the following security mechanisms for IPSec-based protection of network traffic generated by the services: MD5, AKAv1, AKAv2.
    - Employment of Rx interface and dedicated bearers for carrying network traffic generated by services.
    - An ability to use Cx interface and external user authentication solutions.
    - Ability to employ both IPv4 and IPv6 protocols.
- Implementation of eMBMS services:
    - Implementation of at least the following eMBMS service elements: LTE eMBMS Gateway (eMBMS-GW) and Multi-cell Coordination Entity (MCU).
    - Support for M1 and M2AP interfaces.

The elements of the device providing base station functions must additionally be delivered in form allowing their installation and use in an environment of a newly installed Linux system or an

equivalent operating system. The equivalent operating system is defined as operating system employing the same system kernel.

The device must be delivered with authentication information allowing administrative access to its operating system.

The hardware platform of the device must fulfill the following requirements:

- A Tower-type chassis no larger than 50 x 25 x 60 cm, suitable for indoor use.
- Weight of the device not exceeding 15 kg.
- Power supply compatible with the 230V AC power grid.
- Computational, memory and mass storage resources allowing the device to provide the functionality specified above.
- At least 4 dedicated Software Defined Radio (SRD) cards installed in PCIe ports, allowing processing and generation of radio signals necessary for base station operation. Each of the cards must additionally fulfill the following requirements:
    - support for LTE/5G channels of at least 100 MHz width and 4x4 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 300 MHz to 6 GHz range,
    - integrated TX/RX switch allowing TDD mode operation,
    - 8 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna,
    - in and out connectors for Clock/PPS signals,
    - ability to process signals of at least 100 MHz frequency width,
    - ADC/DAC sample rate at least 120 MS/s,
    - ADC/DAC resolution at least 12 bits,
    - frequency accuracy at least 1 ppm,
    - transmitter power at least 11 dBm for f=500 MHz and 2.5 for f=3500 MHz,
    - connected by a PCIe 8x (or compatible) slot,
    - 12V DC power input from PCIe slot and power consumption not exceeding 35 W.
- Ability to install CPRI cards in place of the above SDR cards, allowing the use of radio heads compatible with CPRI interface, especially these specified as Radio head (wireless data transmission device) type A" and "Radio head (wireless data transmission device) type B".
- At least 2 RJ45 GigabitEthernet interfaces.
- Preinstalled Linux operating system with administrative access (root access) and all other elements necessary for functioning of the device.

The device must be possible to operate using an alternate hardware platform in form of a computational server equipped with a general use processor (for example an x86 processor), without the need for installation of dedicated hardware elements, except these necessary for reception and generation of radio signals.

A change of the hardware platform must be possible for the user without the need to contact other parties (such as manufacturer or supplier of the device). Activation of device functionality after the change of its hardware platform must be possible using IP communication with a licensing server (provided by the manufacturer of the device as a software solution possible to deploy in user's infrastructure on a Linux operating system).

The device must be new (cannot be a refurbished device).

The device must include at least 6 years of support provided by the manufacturer, including access to updates and new features.

The device must be delivered with at least 30 SIM cards preconfigured to work with the device.

Radio head (wireless data transmission device) type A

The subject of the specification is a brand new Remote Radio Head (RRH) allowing operation in accordance with 5G NR and LTE specifications able to be connected with Baseband Unit using CPRI protocol.

CPRI card with appropriate software, capable of being installed as part of the device's hardware platform (in place of the dedicated SDR card), allowing it to use the radio head to communicate with 5G/LTE client devices:

- the card should have the ability to connect to the radio head with fiber - a dedicated SM/LC port or SFP port with a suitable optical module.

It is required that the delivered device will be compatible with the device described as 5G NR/LTE Base Station (data transmission device), through the use of CPRI cards allowing such integration and attached to the radio head.

Technical specification:

- Number of antenna sockets: no less than 4
- MIMO: at least 4x4
- Maximum output (transmission) power: at least 2 W
- Transmission power adjustment: at least with 1 dB step and in range between **25 dBm** and 33 dBm
- Frequency range (at least):
  - For 5G NR: 3800 MHz – 4100 MHz (N77)
- 5G NR characteristic
  - Number of carriers: at least 1
  - Channel bandwidth adjustment: at least in a range 10 MHz – 100 MHz
  - Sensitivity:
    - Reference sensitivity 5/10/15 MHz (SBS 15 kHz) lower than -103.7 dBm
    - Reference sensitivity 5/10/15 MHz (SBS 30 kHz) lower than **-101.9** dBm
    - Reference sensitivity 5/10/15 MHz (SBS 60 kHz) lower than **-98.3** dBm
  - Error vector magnitude:
    - For QAM256 not worse than 3.5%
    - For QAM64 not worse than 6%
    - For QAM16 not worse than 10.5%
    - For QPSK not worse than 14.5%
- I/Q interfaces: minimum 2 CPRI interfaces with line rate not lower than 8
- Power supply: DC in the range of 43-52 V provided by the included PSU with sufficient power to use all the capabilities of the device with a 25 m cable (between the supply and the head)
- Weight: not heavier than 15 kg
- Operation temperature in a range of at least **-40°C** - 50°C
- Management:
  - Local 1GbE port dedicated for management

    - Management objects defined by ETSI GS ORI standard at least from set: RE, TxSigPath_EUTRA, RxSigPath_EUTRA, TxSigPath_NR, RxSigPath_NR, oriLink , antPort
- SFP+ modules possible to be installed in CPRI ports of the radio head and adapted to use SM fiber with LC connectors.
    - Additionally two spare SFP+ modules described above.
- Two SM fiber cables, 30 m long, appropriate for outdoor installation, suitable for connecting the radio head to the CPRI card installed as part of the hardware platform,
    - the connectors on the radio head side must be weather resistant.
- Two complete sets of low-loss signal cables, 1.5 m long, allowing connecting the radio head and an antenna
- Mounting bracket allowing to mount the radio head on a pole with diameter in a range 5-7 cm
- GPS antenna with 5 m long cable.
- The device must be new (cannot be a refurbished device).

Radio head (wireless data transmission device) type B

The subject of the specification is a brand new Remote Radio Head (RRH) allowing operation in accordance with LTE specifications able to be connected with Baseband Unit using CPRI protocol.

CPRI card with appropriate software, capable of being installed as part of the device's hardware platform (in place of the dedicated SDR card), allowing it to use the radio head to communicate with 5G/LTE client devices:

- the card should have the ability to connect to the radio head with fiber - a dedicated SM/LC port or SFP port with a suitable optical module.

It is required that the delivered device will be compatible with the device described as 5G NR/LTE Base Station (data transmission device), through the use of CPRI cards allowing such integration and attached to the radio head.

Technical specification:

- Number of antenna sockets: no less than 2
- MIMO: at least 2x2
- Maximum output (transmission) power: at least 20 W
- Transmission power adjustment: at least with 1 dB step and in range between 25 dBm and 43 dBm
- Transmission power adjustment: at least 0.5 dBm in operation temperature between 10-40^{o}C
- Frequency range (at least):
  - For LTE: 2300 MHz – 2400 MHz
- LTE characteristic
  - Number of carriers: at least 1
  - Channel bandwidth adjustment at least from set: 5 MHz, 10 MHz, 15 MHz, 20 MHz
  - Sensitivity:
    - Reference signal sensitivity in 5 kHz channel: no more than -101.5 dBm
    - Reference signal sensitivity in 10 kHz channel: no more than -101.5 dBm
    - Reference signal sensitivity in 15 kHz channel: no more than -101.5 dBm
  - Error vector magnitude:
    - For QAM64 not worse than 8%
    - For QAM16 not worse than 12.5%
    - For QPSK not worse than 17.5%
- I/Q interfaces: minimum 2 CPRI interfaces with line rate not lower than 6
- Power supply: DC in the range of 36-75 V provided by the included PSU with sufficient power to use all the capabilities of the device with a 25 m cable (between the supply and the head)
- Weight: not heavier than 12 kg
- Operation temperature in a range of at least **-40^{o}C** - 50^{o}C
- Management:
  - Local 1GbE port dedicated for management
  - Management objects defined by ETSI GS ORI standard at least from set: RE, TxSigPath_EUTRA, RxSigPath_EUTRA, oriLink , antPort, HealthCheck

- SFP+ modules possible to be installed in CPRI ports of the radio head and adapted to use SM fiber with LC connectors.
    - Additionally two spare SFP+ modules described above.
- Two SM fiber cable, 30 m long, appropriate for outdoor installation, suitable for connecting the radio head to the CPRI card installed as part of the hardware platform,
    - the connector on the radio head side must be weather resistance.
- Two complete sets of low-loss signal cables, 1.5 m long, allowing connecting the radio head and an antenna.
- Mounting bracket allowing to mount the radio head on a pole with diameter in a range 5-7 cm
- GPS antenna with 5 m long cable.
- The device must be new (cannot be a refurbished device).

Antenna type A

Panel antenna with mounting bracket, designed for outdoor installation and operation in the 3700-4200 MHz band. The antenna should meet the following technical specification:

- Frequency range: 3700-4200 MHz.
- Ability to provide MIMO 4x4 communication.
- 4 connectors type 4.3-10 (female) located at the bottom of the antenna.
- Polarization: +/- 45° (slant linear).
- Average antenna gain in the band: not less than 17 dBi (each port)
- Maximum antenna gain not lower than: 18 dBi
- 3 dB horizontal beam width: 33° ±3°
- 3 dB vertical beam width: 6.5° ±0.5°
- Impedance: 50 Ω
- VSWR: < 1.45
- Return loss: > 14 dB
- Port-to-port isolation: > 25 dB
- Front-to-back ratio (total power +/-30°): > 30 dB
- Passive intermodulation: < -150 dBc
- Upper Sidelobe Suppression (peak to +/-20°): > 18 dB
- Cross-Polar Discrimination: > 16 dB
- Maximum effective power: no lower than 100W (each port)
- Dimensions of the antenna without connectors, adjusting elements and mounting brackets not exceeding 85 cm x 35 cm x 15 cm
- Weight not heavier than 13 kg including mounting bracket
- Survival Wind Speed: 200 km/h
- Windload frontal (rated wind speed 150km/h): not greater than 280 N
- Windload lateral(rated wind speed 150km/h): not greater than 120 N
- Housing material: UV-resistant.
- Operating temperature at least in the range of -40-70°C.
- Stainless steel mounting bracket allowing for installations on a vertical pole mast with a diameter in the range of at least 5-11 cm. The mount must also allow for easy and repeated manual change of the antenna's downtilt in the range of at least from +2° to -10°.
- The antenna must support the eRET mechanism, with 2 RCU elements (tilt adjustment separately in the two pairs of RF ports) controllable with a single AISG 2.0 M/F component,
    - electrical downtilt at least in a range: 0-10°
    - internal RET controller inside antenna housing
    - 2 ASIG - 8 pin DIN connectors (1 male, 1 female), located on the bottom of the antenna
    - acceptable input voltage in a range10-30 V and maximum power consumption lower than 11 W
- Lightning Protection: DC grounded.
- The device must be new (cannot be a refurbished device).

Antenna type B

Panel antenna with mounting bracket, designed for outdoor installation and operation in the 3300-4200 MHz band. The antenna should meet the following technical specification:

- Frequency range: 3300-4200 MHz.
- Ability to provide MIMO 4x4 communication.
- 4 connectors type 4.3-10 (female) located at the bottom of the antenna.
- Polarization: +/- 45° (slant linear).
- Average antenna gain in the band: not less than 17 dBi (each port)
- Maximum antenna gain not lower than: 18 dBi
- 3 dB horizontal beam width: 65° ±3°
- 3 dB vertical beam width: 7° ±0.5°
- Impedance: 50 Ω
- VSWR: < 1.5
- Return loss: > 14 dB
- Port-to-port isolation: > 25 dB
- Front-to-back ratio (total power +/-30°): > 30 dB
- Upper Sidelobe Suppression (peak to +/-20°): > 18 dB
- Cross-Polar Discrimination: > 16 dB
- Maximum effective power: no lower than 150 W (each port)
- Dimensions of the antenna without connectors, adjusting elements and mounting brackets not exceeding 78 cm x 30 cm x 9 cm
- Weight not heavier than 6 kg including mounting bracket
- Survival Wind Speed: 200 km/h
- Windload frontal (rated wind speed 150km/h): not greater than 220 N
- Windload lateral(rated wind speed 150km/h): not greater than 80 N
- Housing material: UV-resistant.
- Operating temperature at least in the range of -40-70°C.
- Stainless steel mounting bracket allowing for installations on a vertical pole mast with a diameter in the range of at least 5-11 cm. The mount must also allow for easy and repeated manual change of the antenna's downtilt in the range of at least from +2° to -10°.
- Lightning Protection: DC grounded.
- The device must be new (cannot be a refurbished device).

Antenna type C

Omnidirectional antenna with mounting bracket, designed for outdoor installation and operation in the frequency 3300-4200 MHz (N77 band). The antenna should meet the following technical specification:

- Frequency range: 3300-4200 MHz (N77).
- Ability to provide MIMO 4x4 communication.
- 4 connectors type 4.3-10 (female) located at the bottom of the antenna.
- Polarization: +/- 45° (slant linear).
- Average antenna gain in the band: not less than 5.7 dBi +/- 0.5 dB
- Maximum antenna gain not lower than: 6.7 dBi +/- 0.3 dB
- 3 dB horizontal beam width: 360° (omnidirectional)
- 3 dB vertical beam width: 21° ±2°
- Impedance: 50 Ω
- VSWR: < 1.5
- Return loss: > 14 dB
- Port-to-port isolation: > 25 dB
- Front-to-back ratio (total power +/-30°): > 25 dB
- Cross-Polar Discrimination: > 10 dB
- Maximum effective power: no lower than 150 W (each port)
- Dimensions of the antenna without connectors, adjusting elements and mounting brackets not exceeding 35 cm (height) and 23 cm (diameter)
- Weight not heavier than 5.1 kg including mounting bracket
- Survival Wind Speed: 200 km/h
- Windload (rated wind speed 150km/h): not greater than 60 N
- Housing material: UV-resistant.
- Operating temperature at least in the range of -40-70°C.
- Stainless steel mounting bracket allowing for installations on a vertical pole mast with a diameter in the range of at least 16-25 cm.
- Lightning Protection: DC grounded.
- The device must be new (cannot be a refurbished device).

Antenna type D

Panel antenna with mounting bracket, designed for outdoor installation and operation in the 3300-4200 MHz band. The antenna should meet the following technical specification:

- Frequency range: 3300-4200 MHz.
- Ability to provide MIMO 4x4 communication.
- 4 connectors type 4.3-10 (female) located at the bottom of the antenna.
- Polarization: +/- 45° (slant linear).
- Average antenna gain in the band: not less than: 12 dBi ± 1 dB
- Maximum antenna gain not lower than: 12.5 dBi ± 1 dB
- 3 dB horizontal beam width: 65° ±3°
- 3 dB vertical beam width: 22° ±2°
- Impedance: 50 Ω
- VSWR: < 1.5
- Return loss: > 14 dB
- Port-to-port isolation: > 25 dB
- Front-to-back ratio (total power +/-30°): > 25 dB
- Cross-Polar Discrimination: > 16 dB
- Maximum effective power: no lower than 50 W (each port)
- Dimensions of the antenna without connectors, adjusting elements and mounting brackets not exceeding 29 cm x 29 cm x 9 cm
- Weight not heavier than 4.2 kg including mounting bracket
- Survival Wind Speed: 200 km/h
- Windload frontal (rated wind speed 150km/h): not greater than 110 N
- Windload lateral(rated wind speed 150km/h): not greater than 40 N
- Housing color: UV-resistant
- Operating temperature at least in the range of -40-70°C.
- Stainless steel mounting bracket allowing for installations on a vertical pole mast with a diameter in the range of at least 5-11 cm. The mount must also allow for easy and repeated manual change of the antenna's downtilt in the range of at least from +1° to -7°.
- Lightning Protection: DC grounded.
- The device must be new (cannot be a refurbished device).

Antenna type E

Panel antenna with mounting bracket, designed for outdoor installation and operation in frequency range 2300-2700 MHz (B38, B40, B41 bands). The antenna should meet the following technical specification:

- Frequency range: 2300-2700 MHz (B38, B40, B41).
- Ability to provide MIMO 2x2 communication.
- 2 connectors type 4.3-10 (female) located at the bottom of the antenna.
- Polarization: +/- 45° (slant linear).
- Average antenna gain in the band: not less than: 16.5 dBi ± 0.5 dB
- Maximum antenna gain not lower than: 17 dBi
- 3 dB horizontal beam width: 90° ±3°
- 3 dB vertical beam width: 7° ±0.5°
- Impedance: 50 Ω
- VSWR: < 1.5
- Return loss: > 14 dB
- Port-to-port isolation: > 28 dB
- Front-to-back ratio (total power +/-30°): > 30 dB
- Upper Sidelobe Suppression (peak to +/-20°): > 18 dB
- Cross-Polar Discrimination: > 16 dB
- Maximum effective power: no lower than 150 W (each port)
- Dimensions of the antenna without connectors, adjusting elements and mounting brackets not exceeding 110 cm x 17 cm x 9 cm
- Weight not heavier than 5 kg including mounting bracket
- Survival Wind Speed: 200 km/h
- Windload frontal (rated wind speed 150km/h): not greater than 210 N
- Windload lateral(rated wind speed 150km/h): not greater than 110 N
- Housing material: UV-resistant.
- Operating temperature at least in the range of -40-70°C.
- Stainless steel mounting bracket allowing for installations on a vertical pole mast with a diameter in the range of at least 5-11 cm. The mount must also allow for easy and repeated manual change of the antenna's downtilt in the range of at least from +0° to -10°.
- Lightning Protection: DC grounded.
- The device must be new (cannot be a refurbished device).

Data Transmission Device Emulating LTE/5G User Equipment, Variant 1

A data transmission device allowing emulation of a number of 4G, 5G NR, NB-IoT and LTE-M client devices (User Equipment - UEs). The device must meet the following technical requirements:

- Ability to emulate 4G, 5G NR, NB-IoT and LTE-M UEs.
- Ability to simultaneously emulate UEs connected to different network cells, at least in each of the following scenarios:
    - at least 2 5G NR cells,
    - at least 4 MIMO 2x2 4G cells,
    - at least 2 MIMO 4x4 4G cells.
- Number of emulated clients: at least 64.
- Support for configuration of emulation process by using API and WebGUI interfaces or by editing text configuration files.
- Ability to differentiate propagation conditions for emulated clients by employing a radio channel simulator capable of modifying at least:
    - PER parameter values for PDSCH and PDCCH channels,
    - RSRP and CQI parameter values,
    - strength of transmitted signal.
- Ability to generate traffic at least at the level of protocols from the set of TCP, UDP, RTP, HTTP, ability to emulate VoIP traffic and ability to run external applications for traffic generation per client, including applications executed on external devices and connected with Ethernet network.
- Ability to configure and execute test scenarios utilizing scheduled client activities.
- Generation and processing of radio signals realized using at least 4 dedicated Software Defined Radio (SRD) cards installed in PCIe ports. Each of the cards must additionally fulfill the following requirements:
    - support for 4G/5G channels of at least 50 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna.
- Ability to employ 2 SDR cards to allow emulation of MIMO 4x4 UEs.
- At least two GigabitEthernet (RJ45) connectors.
- Linux operating system.
- User access to operating system with administrative rights.
- Power supply: 230 V AC.
- Weight less than 15 kg.

Technical parameters of emulated 5G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 15.
- Support for FDD and TTD modes in any frequency from at least 500 MHz – 6 GHz range.

- Emulated UEs supporting channel widths of at least 50 MHz with ability to use narrower channels.
- Supported modulations: at least QAM 256 for both uplink and downlink
- Ability to emulate clients connecting to SA and NSA networks.
- Support for Split bearer mechanisms in at least the following modes: 3, 3a, 3x.

Technical parameters of emulated 4G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 8.
- Operation in TDD and FDD on freely selectable frequency in, at least, 500 MHz to 6 GHz range.
- Supported channel widths: at least 1.4, 3, 5, 10, 15, 20 MHz for LTE and 200 kHz for NB-IoT.
- Emulation of LTE network clients operating in, at least, the following modes: cat. 0, cat. 1, cat. 3, cat. 4, cat. 15 and cat 13.
- Emulation of IoT network clients operating in, at least, the following modes: LTE cat. 0, LTE cat. 1, LTE-M cat M1, NB-IoT cat NB1, and NB2.
- Supported modulations: at least up to QAM 256 for uplink and downlink.
- Ability to protect the integrity and confidentiality of communications using an algorithm selected from a group including at least AES, Snow3G and ZUC algorithms.
- Emulation of at least the following handover scenarios: Intra-freq, inter-freq and inter-band.
- Support for Carrier aggregation: at least up to 4 CCs for downlink, at least up to 2 CCs for uplink.

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

Data Transmission Device Emulating LTE/5G User Equipment, Variant 2

A data transmission device allowing emulation of a number of 4G, 5G NR, NB-IoT and LTE-M client devices (User Equipment - UEs). The device must meet the following technical requirements:

- Ability to emulate 4G, 5G NR, NB-IoT and LTE-M UEs.
- Ability to simultaneously emulate UEs connected to different network cells, at least in each of the following scenarios:
    - at least 2 5G NR cells,
    - at least 4 MIMO 2x2 4G cells,
    - at least 2 MIMO 4x4 4G cells.
- Number of emulated clients: at least 128.
- Support for configuration of emulation process by using API and WebGUI interfaces or by editing text configuration files.
- Ability to differentiate propagation conditions for emulated clients by employing a radio channel simulator capable of modifying at least:
    - PER parameter values for PDSCH and PDCCH channels,
    - RSRP and CQI parameter values,
    - strength of transmitted signal.
- Ability to generate traffic at least at the level of protocols from the set of TCP, UDP, RTP, HTTP, ability to emulate VoIP traffic and ability to run external applications for traffic generation per client, including applications executed on external devices and connected with Ethernet network.
- Ability to configure and execute test scenarios utilizing scheduled client activities.
- Generation and processing of radio signals realized using at least 4 dedicated Software Defined Radio (SRD) cards installed in PCIe ports. Each of the cards must additionally fulfill the following requirements:
    - support for 4G/5G channels of at least 50 MHz width and 2x2 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - 4 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna.
- Ability to employ 2 SDR cards to allow emulation of MIMO 4x4 UEs.
- At least two GigabitEthernet (RJ45) connectors.
- Linux operating system.
- User access to operating system with administrative rights.
- Power supply: 230 V AC.
- Weight less than 15 kg.

Technical parameters of emulated 5G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 15.
- Support for FDD and TTD modes in any frequency from at least 500 MHz – 6 GHz range.

- Emulated UEs supporting channel widths of at least 50 MHz with ability to use narrower channels.
- Supported modulations: at least QAM 256 for both uplink and downlink
- Ability to emulate clients connecting to SA and NSA networks.
- Support for Split bearer mechanisms in at least the following modes: 3, 3a, 3x.

Technical parameters of emulated 4G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 8.
- Operation in TDD and FDD on freely selectable frequency in, at least, 500 MHz to 6 GHz range.
- Supported channel widths: at least 1.4, 3, 5, 10, 15, 20 MHz for LTE and 200 kHz for NB-IoT.
- Emulation of LTE network clients operating in, at least, the following modes: cat. 0, cat. 1, cat. 3, cat. 4, cat. 15 and cat 13.
- Emulation of IoT network clients operating in, at least, the following modes: LTE cat. 0, LTE cat. 1, LTE-M cat M1, NB-IoT cat NB1, and NB2.
- Supported modulations: at least up to QAM 256 for uplink and downlink.
- Ability to protect the integrity and confidentiality of communications using an algorithm selected from a group including at least AES, Snow3G and ZUC algorithms.
- Emulation of at least the following handover scenarios: Intra-freq, inter-freq and inter-band.
- Support for Carrier aggregation: at least up to 4 CCs for downlink, at least up to 2 CCs for uplink.

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

Data Transmission Device Emulating LTE/5G User Equipment, Variant 3

A data transmission device allowing emulation of a number of 4G, 5G NR, NB-IoT and LTE-M client devices (User Equipment - UEs). The device must meet the following technical requirements:

- Ability to emulate 4G, 5G NR, NB-IoT and LTE-M UEs.
- Ability to simultaneously emulate UEs connected to different network cells, at least in each of the following scenarios:
    - at least 2 5G NR cells,
    - at least 4 MIMO 2x2 4G cells,
    - at least 2 MIMO 4x4 4G cells.
- Number of emulated clients: at least 64.
- Support for configuration of emulation process by using API and WebGUI interfaces or by editing text configuration files.
- Ability to differentiate propagation conditions for emulated clients by employing a radio channel simulator capable of modifying at least:
    - PER parameter values for PDSCH and PDCCH channels,
    - RSRP and CQI parameter values,
    - strength of transmitted signal.
- Ability to generate traffic at least at the level of protocols from the set of TCP, UDP, RTP, HTTP, ability to emulate VoIP traffic and ability to run external applications for traffic generation per client, including applications executed on external devices and connected with Ethernet network.
- Ability to configure and execute test scenarios utilizing scheduled client activities.
- Generation and processing of radio signals realized using at least 2 dedicated Software Defined Radio (SRD) cards installed in PCIe ports. Each of the cards must additionally fulfill the following requirements:
    - support for 4G/5G channels of at least 100 MHz width and 4x4 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - 8 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna.
- At least one GigabitEthernet (RJ45) and at least one 10 GigabitEthernet (RJ45) connector .
- Linux operating system.
- User access to operating system with administrative rights.
- Power supply: 230 V AC.
- Weight less than 15 kg.

Technical parameters of emulated 5G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 15.
- Support for FDD and TTD modes in any frequency from at least 500 MHz – 6 GHz range.
- Emulated UEs supporting channel widths of at least 100 MHz with ability to use narrower channels.

- Supported modulations: at least QAM 256 for both uplink and downlink
- Ability to emulate clients connecting to SA and NSA networks.
- Support for Split bearer mechanisms in at least the following modes: 3, 3a, 3x.

Technical parameters of emulated 4G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 8.
- Operation in TDD and FDD on freely selectable frequency in, at least, 500 MHz to 6 GHz range.
- Supported channel widths: at least 1.4, 3, 5, 10, 15, 20 MHz for LTE and 200 kHz for NB-IoT.
- Emulation of LTE network clients operating in, at least, the following modes: cat. 0, cat. 1, cat. 3, cat. 4, cat. 15 and cat 13.
- Emulation of IoT network clients operating in, at least, the following modes: LTE cat. 0, LTE cat. 1, LTE-M cat M1, NB-IoT cat NB1, and NB2.
- Supported modulations: at least up to QAM 256 for uplink and downlink.
- Ability to protect the integrity and confidentiality of communications using an algorithm selected from a group including at least AES, Snow3G and ZUC algorithms.
- Emulation of at least the following handover scenarios: Intra-freq, inter-freq and inter-band.
- Support for Carrier aggregation: at least up to 4 CCs for downlink, at least up to 2 CCs for uplink.

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

Data Transmission Device Emulating LTE/5G User Equipment, Variant 4

A data transmission device allowing emulation of a number of 4G, 5G NR, NB-IoT and LTE-M client devices (User Equipment - UEs). The device must meet the following technical requirements:

- Ability to emulate 4G, 5G NR, NB-IoT and LTE-M UEs.
- Ability to simultaneously emulate UEs connected to different network cells, at least in each of the following scenarios:
    - at least 2 5G NR cells,
    - at least 4 MIMO 2x2 4G cells,
    - at least 2 MIMO 4x4 4G cells.
- Number of emulated clients: at least 128.
- Support for configuration of emulation process by using API and WebGUI interfaces or by editing text configuration files.
- Ability to differentiate propagation conditions for emulated clients by employing a radio channel simulator capable of modifying at least:
    - PER parameter values for PDSCH and PDCCH channels,
    - RSRP and CQI parameter values,
    - strength of transmitted signal.
- Ability to generate traffic at least at the level of protocols from the set of TCP, UDP, RTP, HTTP, ability to emulate VoIP traffic and ability to run external applications for traffic generation per client, including applications executed on external devices and connected with Ethernet network.
- Ability to configure and execute test scenarios utilizing scheduled client activities.
- Generation and processing of radio signals realized using at least 2 dedicated Software Defined Radio (SRD) cards installed in PCIe ports. Each of the cards must additionally fulfill the following requirements:
    - support for 4G/5G channels of at least 100 MHz width and 4x4 MIMO for both TDD and FDD transmissions,
    - ability to operate on any frequency in at least 500 MHz to 6 GHz range,
    - 8 female SMA connectors for external antennas,
    - external antennas for all of the above SDR card connectors:
        - on a magnetic stand,
        - dimensions not exceeding 5 x 5 x 20 cm,
        - equipped with a **0.5-3** m signal cable (the same length for each antenna) including a connector necessary for use with the above SDR cards,
    - build-in GPS receiver and 1 external female SMA connector for external GPS antenna.
- At least one GigabitEthernet (RJ45) and at least one 10 GigabitEthernet (RJ45) connector .
- Linux operating system.
- User access to operating system with administrative rights.
- Power supply: 230 V AC.
- Weight less than 15 kg.

Technical parameters of emulated 5G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 15.
- Support for FDD and TTD modes in any frequency from at least 500 MHz – 6 GHz range.
- Emulated UEs supporting channel widths of at least 100 MHz with ability to use narrower channels.

- Supported modulations: at least QAM 256 for both uplink and downlink
- Ability to emulate clients connecting to SA and NSA networks.
- Support for Split bearer mechanisms in at least the following modes: 3, 3a, 3x.

Technical parameters of emulated 4G network clients:

- Functionality compatible with 3GPP specification of at least Rel. 8.
- Operation in TDD and FDD on freely selectable frequency in, at least, 500 MHz to 6 GHz range.
- Supported channel widths: at least 1.4, 3, 5, 10, 15, 20 MHz for LTE and 200 kHz for NB-IoT.
- Emulation of LTE network clients operating in, at least, the following modes: cat. 0, cat. 1, cat. 3, cat. 4, cat. 15 and cat 13.
- Emulation of IoT network clients operating in, at least, the following modes: LTE cat. 0, LTE cat. 1, LTE-M cat M1, NB-IoT cat NB1, and NB2.
- Supported modulations: at least up to QAM 256 for uplink and downlink.
- Ability to protect the integrity and confidentiality of communications using an algorithm selected from a group including at least AES, Snow3G and ZUC algorithms.
- Emulation of at least the following handover scenarios: Intra-freq, inter-freq and inter-band.
- Support for Carrier aggregation: at least up to 4 CCs for downlink, at least up to 2 CCs for uplink.

The device must be new (cannot be a refurbished device).

The device must include at least 1 year of support provided by the manufacturer, including access to updates and new features.

PCIe Driver for Radio Devices

A license allowing the use of a software hardware driver necessary for use of devices specified as “Radio head (wireless data transmission device) type A” and “Radio head (wireless data transmission device) type B” with all devices specified as “5G NR/LTE Digital Data Transmission Device” (in all their variants).

SIM Card Programming Device

A device allowing SIM cards to be programmed in a way, which allows them to be used with devices specified as “5G NR/LTE Digital Data Transmission Device” (in all their variants), when functioning in at least LTE and 5G NR modes.

The device must be delivered with a software capable of running under Windows or Linux operating systems, allowing the device to be used by an operator.

5G UE data transmission device

A data transmission device capable of connecting to a 5G network and providing data transfer, voice and video communication and exchanging text and multimedia messages. The device must utilize an operating system utilizing a Linux system kernel and must allow additional applications to be installed by users.

The device must be able to operate with devices specified as “5G NR/LTE Digital Data Transmission Device” in all of its variants, including a scenario when “Radio head (wireless data transmission device) type A” or “Radio head (wireless data transmission device) type B” is used for radio communication. The client device must be able to use at least the following high level services offered by these devices: Voice call, Video call, SMS.

The device must also fulfill the following technical requirements:

- Operate in at least the following frequency bands:
  - 5G Band: 1, 3, 5, 7, 8, 28, 38, 40, 41, 77, 78,
  - 4G Band: 1, 2, 3, 4, 5, 7, 8, 12, 17, 20, 28, 38, 39, 40, 41,
- Support both 5G SA and NSA modes.
- Can connect and operate in 5G network identified by any PLMNID (including testing and private identifiers).
- Dual SIM operation support (Nano-SIM, eSIM, dual stand by).
- At least 8-core CPU.
- RAM: at least 8 GB.
- Flash memory: at least 256 GB.
- Touch sensitive screen:
  - at least 6.4” and resolution at least 1080x2400 pixels,
  - at least 90 Hz refresh rate.
- Camera allowing pictures of at least 50 MP resolution to be taken in normal mode and of at least 13 MP resolution in wide mode.
- Additional camera of at least 16 MP resolution.
- Support for at least the following, additional communication technologies:
  - WLAN: Wi-Fi 802.11 a/b/g/n/ac/ ax (or ax-ready), dual-band,
  - Bluetooth: 5.1, A2DP, LE, aptX HD,
  - NFC.
- Battery of at least 4200 mAh capacity.
- Color: dark (e.g. black, graphite).
- Dimmensions not exceeding: 17 cm x 8 cm x 1 cm.
- Weight not exceeding 250 g.

The device must be new (cannot be refurbished).