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(54) **Title:** HIGH LEVEL OPERATING SYSTEM (HLOS) INTERFACE FOR LOCAL AREA DATA NETWORK (LADN) SERVICE

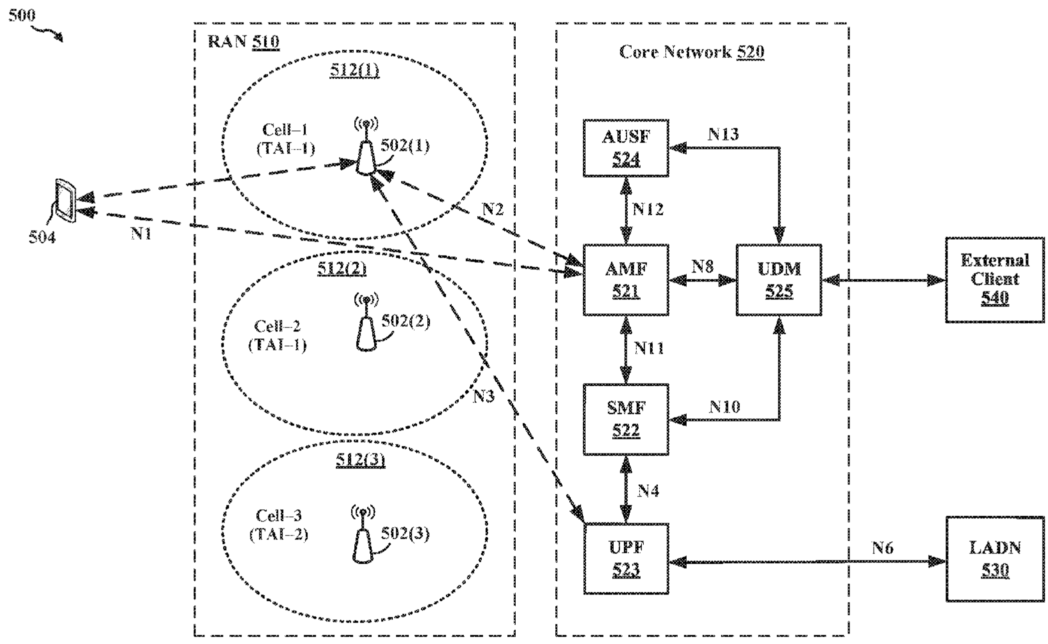

Figure 5

(57) **Abstract:** This disclosure provides systems, methods and apparatus, including computer programs encoded on computer storage media, for a user equipment (UE) to establish a protocol data unit (PDU) session with a local area data network (LADN) service. In some implementations, the UE may register with the LADN service and obtain a tracking area identity (TAI) associated with a data network name (DNN) of the LADN service. The TAI of the DNN may be stored in the UE, and may be used to determine when the LADN service is available to the UE. The UE may compare one or more TAIs received in broadcast messages from a serving cell with the TAI of the DNN to determine whether the UE is located within the LADN service area. When the UE is determined to be within the LADN service area the UE request and establish a PDU Session with the DNN of the LADN service.

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HIGH LEVEL OPERATING SYSTEM (HLOS) INTERFACE FOR LOCAL AREA DATA NETWORK (LADN) SERVICE

TECHNICAL FIELD

[0001] This disclosure relates generally to wireless communications and, more specifically, to establishing a protocol data unit (PDU) session with a local area data network (LADN) service.

DESCRIPTION OF THE RELATED TECHNOLOGY

[0002] Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (such as time, frequency, and power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, and orthogonal frequency division multiple access (OFDMA) systems (such as a Long Term Evolution (LTE) system or a Fifth Generation (5G) New Radio (NR) system). A wireless multiple-access communications system may include a number of base stations or access network nodes, each simultaneously supporting communication for multiple communication devices, which may be otherwise known as user equipment (UE).

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR), which is part of a continuous mobile broadband evolution promulgated by the Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability, and other requirements. 5G NR includes services associated with enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low latency communications (URLLC). There exists a need for further improvements in 5G NR technology. These improvements also may be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0004] The systems, methods and devices of this disclosure each have several innovative aspects, no single one of which is solely responsible for the desirable attributes disclosed herein.

[0005] One innovative aspect of the subject matter described in this disclosure can be implemented as a method for wireless communication. The method may be performed by a user equipment (UE) including at least a modem and a high-level operating system (HLOS) configured to execute an application on the UE, and may include sending a local area data network (LADN) Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least a data network name (DNN) of the LADN service; transmitting, to a core network associated with a radio access network (RAN), a registration request message including a request to register the application with the LADN service and indicating the DNN of the LADN service; receiving, from the core network, a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN; sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service; receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS; determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination.

[0006] The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some instances, establishing the PDU session may include transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0007] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, determining whether the UE is within the LADN service area also may be based on a cell identity (ID) of the BS.

[0008] In some implementations, the method also may include sending a setup request from the application to the modem via the HLOS, and sending a setup response from the modem to the application via the HLOS. In some instances, the setup request may include the DNN of the LADN service and a request to register the application with the LADN service, and the setup response may indicate successful establishment of the PDU session with the DNN of the LADN service.

[0009] Another innovative aspect of the subject matter described in this disclosure can be implemented in a UE. The UE may include one or more processors, a memory, a modem, and a high-level operating system (HLOS) configured to execute an application on the UE. The memory may be coupled to the one or more processors, and may store instructions that, when executed by the one or more processors, cause the UE to perform a number of operations. In some implementations, the number of operations may include sending a local area data network (LADN) Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least a data network name (DNN) of the LADN service; transmitting, to a core network associated with a radio access network (RAN), a registration request message including a request to register the application with the LADN service and indicating the DNN of the LADN service; receiving, from the core network, a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN; sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service; receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS; determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination. The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some implementations, establishing the PDU session may include transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0010] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, determining whether the UE is within the LADN service area also may be based on a cell identity (ID) of the BS.

[0011] In some implementations, execution of the instructions may cause the UE to perform operations further including sending a setup request from the application to the modem via the HLOS, and sending a setup response from the modem to the application via the HLOS. In some instances, the setup request may include the DNN of the LADN service and a request to register the application with the LADN service, and the setup response may indicate successful establishment of the PDU session with the DNN of the LADN service.

[0012] Another innovative aspect of the subject matter described in this disclosure can be implemented as a method for wireless communication. The method may be performed by a user equipment (UE) including at least a modem and a high-level operating system (HLOS) configured to execute an application on the UE, and may include sending a Request and Setup message from the application to the modem via the HLOS; and transmitting, to a core network associated with a radio access network (RAN), a message including a request to register the application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with a data network name (DNN) of the LADN service when available to the UE, and the DNN of the LADN service. The Request and Setup message may include a request to register the application with the LADN service, a request to setup the PDU session with the LADN service when available to the UE, and the DNN of the LADN service.

[0013] The method also may include receiving, from the core network, an accept message; determining that the LADN service is available to the UE; and establishing the PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session. The accept message may include the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service. In some instances, determining that the LADN service area is available to the UE may include receiving a UE Presence Indication from the core network.

[0014] The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some implementations, establishing the PDU session may include transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0015] Another innovative aspect of the subject matter described in this disclosure can be implemented in a UE. The UE may include one or more processors, a memory, a modem, and a high-level operating system (HLOS) configured to execute an application on the UE. The memory may be coupled to the one or more processors, and may store instructions that, when executed by the one or more processors, cause the UE to perform a number of operations. In some implementations, the number of operations may include sending a Request and Setup message from the application to the modem via the HLOS; and transmitting, to a core network associated with a radio access network (RAN), a message including a request to register the application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with a data network name (DNN) of the LADN service when available to the UE, and the DNN of the LADN service. The Request and Setup message may include a request to register the application with the LADN service, a request to setup the PDU session with the LADN service when available to the UE, and the DNN of the LADN service.

[0016] In some implementations, execution of the instructions may cause the UE to perform operations further including receiving, from the core network, an accept message; determining that the LADN service is available to the UE; and establishing the PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session. The accept message may include the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service. In some instances, determining that the LADN service area is available to the UE may include receiving a UE Presence Indication from the core network.

[0017] The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some implementations, establishing the PDU session may include transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0018] Another innovative aspect of the subject matter described in this disclosure can be implemented as a method for wireless communication. The method may be performed by a user equipment (UE), and may include transmitting a registration request message including a request to register a UE application with a local area data network (LADN) service and indicating at least a data network name (DNN) of the LADN service; receiving a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN; receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS; determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination indicating that the UE is within a service area of the LADN.

[0019] The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some instances, establishing the PDU session may include transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service;

and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0020] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, determining whether the UE is within the LADN service area also may be based on a cell identity (ID) of the BS.

[0021] In some implementations, the UE also may include at least a modem and a high-level operating system (HLOS) configured to execute the application, and the method also may include sending a LADN Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least the DNN of the LADN service; and sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service. In some other implementations, the method also may include sending a setup request from the application to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to register the UE application with the LADN service; and sending a setup response from the modem to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

[0022] Another innovative aspect of the subject matter described in this disclosure can be implemented in a UE. The UE may include one or more processors coupled to a memory. The memory may store instructions that, when executed by the one or more processors, cause the UE to perform a number of operations. In some implementations, the number of operations may include transmitting a registration request message including a request to register a UE application with a local area data network (LADN) service and indicating at least a data network name (DNN) of the LADN service; receiving a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN; receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS; determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination indicating that the UE is within a service area of the LADN.

[0023] The broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH). In some instances, establishing the PDU session may include transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0024] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, determining whether the UE is within the LADN service area also may be based on a cell identity (ID) of the BS.

[0025] In some implementations, the UE also may include at least a modem and a high-level operating system (HLOS) configured to execute the application, and the number of operations also may include sending a LADN Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least the DNN of the LADN service; and sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service. In some other implementations, the number of operations also may include sending a setup request from the application to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to register the UE application with the LADN service; and sending a setup response from the modem to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

[0026] Another innovative aspect of the subject matter described in this disclosure can be implemented as a method for wireless communication. The method may be performed by a user equipment (UE), and may include transmitting a message including a request to register a UE application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with a data network name (DNN) of the LADN service when available to the UE, and the DNN of the LADN service; receiving an accept message including the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service; determining that the LADN service is available to the UE; and establishing the PDU session with the DNN of the LADN based on the determination and the request to setup the PDU session. In some implementations, establishing the PDU session may include transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0027] In some implementations, the method also may include receiving a system information block (SIB) broadcast from a base station (BS), and determining that the LADN service is available to the UE may be based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a tracking area identity (TAI) or a cell identifier (ID). In some other implementations, determining that the LADN service is available to the UE may include receiving a UE Presence Indication from a core network.

[0028] In some implementations, the UE also may include at least a modem and a high-level operating system (HLOS) configured to execute the application, and the method also may include sending a Request and Setup message from the application to the modem via the HLOS, the Request and Setup message including the request to register the UE application, the request to setup the PDU session, and the DNN of the LADN service; and sending a setup response message from the modem to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the LADN service.

[0029] Another innovative aspect of the subject matter described in this disclosure can be implemented in a UE. The UE may include one or more processors coupled to a memory. The memory may store instructions that, when executed by the one or more processors, cause the UE to perform a number of operations. In some implementations, the number of operations may include transmitting a message including a request to register a UE application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with a data network name (DNN) of the LADN service when available to the UE, and the DNN of the LADN service; receiving an accept message including the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service; determining that the LADN service is available to the UE; and establishing the PDU session with the DNN of the LADN based on the determination and the request to setup the PDU session. In some implementations, establishing the PDU session may include transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0030] In some implementations, the number of operations also may include receiving a system information block (SIB) broadcast from a base station (BS), and determining that the LADN service is available to the UE may be based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a tracking area identity (TAI) or a cell identifier (ID). In some other implementations, determining that the LADN service is available to the UE may include receiving a UE Presence Indication from a core network.

[0031] In some implementations, the UE also may include at least a modem and a high-level operating system (HLOS) configured to execute the application, and the number of operations also may include sending a Request and Setup message from the application to the modem via the HLOS, the Request and Setup message including the request to register the UE application, the request to setup the PDU session, and the DNN of the LADN service; and sending a setup response message from the modem to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the LADN service.

[0032] Details of one or more implementations of the subject matter described in this disclosure are set forth in the accompanying drawings and the description below.

Other features, aspects, and advantages will become apparent from the description, the drawings and the claims. Note that the relative dimensions of the following figures may not be drawn to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Figure 1 shows a diagram illustrating an example wireless communications system.

[0034] Figure 2A shows an example of a first 5G NR frame.

[0035] Figure 2B shows example downlink (DL) channels within a 5G NR slot.

[0036] Figure 2C shows an example of a second 5G NR frame.

[0037] Figure 2D shows example uplink (UL) channels within a 5G NR slot.

[0038] Figure 3 shows a diagram illustrating an example base station and user equipment (UE) in an access network.

[0039] Figure 4 shows a block diagram of an example user equipment (UE).

[0040] Figure 5 shows a diagram illustrating another example wireless communications system.

[0041] Figure 6 shows a sequence diagram for wireless communication that supports establishing a protocol data unit (PDU) session between a UE and a local area data network (LADN) service.

[0042] Figure 7 shows another sequence diagram for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0043] Figure 8 shows a flowchart depicting an example operation for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0044] Figures 9A–9B show flowcharts depicting example operations for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0045] Figure 10 shows a flowchart depicting an example operation for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0046] Figures 11A–11C show flowcharts depicting example operations for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0047] Figure 12 shows a flowchart depicting an example operation for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0048] Figures 13A–13D show flowcharts depicting example operations for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0049] Figure 14 shows a flowchart depicting an example operation for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0050] Figures 15A–15C show flowcharts depicting example operations for wireless communication that supports establishing a PDU session between a UE and a LADN service.

[0051] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0052] The following description is directed to some particular implementations for the purposes of describing innovative aspects of this disclosure. However, a person having ordinary skill in the art will readily recognize that the teachings herein can be applied in a multitude of different ways. The described implementations can be implemented in any device, system or network that is capable of transmitting and receiving radio frequency (RF) signals according to one or more of the Long Term Evolution (LTE), 3G, 4G or 5G (New Radio (NR)) standards promulgated by the 3rd Generation Partnership Project (3GPP), the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards, the IEEE 802.15 standards, or the Bluetooth® standards as defined by the Bluetooth Special Interest Group (SIG), among others. The described implementations can be implemented in any device, system or network that is capable of transmitting and receiving RF signals according to one or more of the following technologies or techniques: code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), single-user (SU) multiple-input multiple-output (MIMO) and multi-user (MU) MIMO. The described implementations also can be implemented using other wireless communication protocols or RF signals suitable for use in one or more of a wireless wide area network (WWAN), a wireless personal area network (WPAN), a wireless local area network (WLAN), or an internet of things (IOT) network.

[0053] Implementations of the subject matter described in this disclosure may allow UEs to establish a protocol data unit (PDU) session with a LADN service. In accordance with various aspects of the present disclosure, a UE application seeking access to a local area data network (LADN) service may register with the LADN service and obtain the tracking area identity (TAI) of a data network name (DNN) associated with the LADN service. The TAI of the DNN may be stored in the UE, and may be used to determine when the LADN service is available to the UE. In some implementations, the UE may compare one or more TAIs received in broadcast messages from a serving cell with the TAI of the DNN to determine whether the UE is located within the LADN service area.

[0054] A match between the TAI of the DNN and one of the TAIs contained in the broadcast messages may indicate that the UE is within the tracking area identified by the matching TAIs, and therefore also may be located in the LADN service area. A mismatch between the TAI of the DNN and all of the TAIs contained in the broadcast messages may indicate that the UE is not within the tracking area identified by the matching TAIs, and therefore may be located outside of the LADN service area. When there is a match between the TAI of the DNN and one of the TAIs contained in the broadcast messages, the UE may determine that the LADN service is available, and may request and establish a PDU Session with the DNN of the LADN service. When there is a mismatch between the TAI of the DNN and all of the TAIs contained in the broadcast messages, the UE may determine that the LADN service is not available, and may refrain from requesting or establishing the PDU Session with the DNN of the LADN service.

[0055] Particular implementations of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. By sending requests to establish a PDU session with a LADN service based on a determination that the UE is located within a service area of the LADN, the likelihood of successfully establishing the PDU session with the LADN service is increased, for example, as compared with wireless communication devices that send repeated PDU session requests when the LADN service is not available. Among other advantages, increasing the likelihood of successfully establishing PDU sessions with LADN services may reduce power consumption of the UE, and also may reduce signaling overhead in the radio access network.

[0056] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0057] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0058] Accordingly, in one or more example implementations, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can include a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

[0059] Figure 1 shows a diagram of an example wireless communications system 100. The wireless communications system 100, which may be a Next Generation RAN (NG-RAN), includes base stations 102, UEs 104, an Evolved Packet Core (EPC) 160, and another core network 190. The base stations 102 may include macrocells (high power cellular base station) or small cells (low power cellular base station). The macrocells include base stations. The small cells include femtocells, picocells, and microcells.

[0060] The base stations 102 configured for 4G LTE (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) may interface with the EPC 160 through backhaul links 132 via S1 interfaces, and the base stations 102 configured for 5G NR may interface with the core network 190 through backhaul links 184. In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (such as handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (such as through the EPC 160 or the core network 190) with each other over backhaul links 134 (such as the X2 interface). The backhaul links 134 may be wired or wireless.

[0061] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macrocells may be known as a heterogeneous network. A heterogeneous network also may include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, or transmit diversity. The communication links may be through one or more carriers. The base stations 102 and UEs 104 may use spectrum up to Y MHz (such as 5 MHz, 10 MHz, 15 MHz, 20 MHz, 100 MHz, 400 MHz, etc.) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (such as more or fewer carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

[0062] Some UEs 104 may communicate with each other using device-to-device (D2D) communication link 158. The D2D communication link 158 may use the DL/UL WWAN spectrum. The D2D communication link 158 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.

[0063] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 2.4 GHz unlicensed frequency spectrum, a 5 GHz unlicensed frequency spectrum, or both. When communicating in an unlicensed frequency spectrum, the STAs 152 and the AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.

[0064] The small cell 102' may operate in a licensed or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102,' employing NR in an unlicensed frequency spectrum, may boost coverage to or increase capacity of the access network.

[0065] A base station 102, whether a small cell 102' or a large cell (such as a macro base station), may include an eNB, gNodeB (gNB), or another type of base station. Some base stations, such as gNB 180, may operate in a traditional sub 6 GHz spectrum, in millimeter wave (mmW) frequencies, or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as a millimeter wave or mmW base station. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW or near mmW radio frequency band (such as between 3 GHz – 300 GHz) has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 182 with the UE 104 to compensate for the extremely high path loss and short range.

[0066] The base station 180 may transmit a beamformed signal to the UE 104 in one or more transmit directions 182'. The UE 104 may receive the beamformed signal from the base station 180 in one or more receive directions 182''. The UE 104 also may transmit a beamformed signal to the base station 180 in one or more transmit directions. The base station 180 may receive the beamformed signal from the UE 104 in one or more receive directions. The base station 180 and UE 104 may perform beam training to determine the best receive and transmit directions for each of the base station 180 and UE 104. The transmit and receive directions for the base station 180 may or may not be the same. The transmit and receive directions for the UE 104 may or may not be the same.

[0067] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting MBMS related charging information.

[0068] The core network 190 may include an Access and Mobility Management Function (AMF) 192, other AMFs 193, a Session Management Function (SMF) 194, and a User Plane Function (UPF) 195. The AMF 192 may be in communication with a Unified Data Management (UDM) 196. The AMF 192 is the control node that processes the signaling between the UEs 104 and the core network 190. Generally, the AMF 192 provides QoS flow and session management. All user Internet protocol (IP) packets are transferred through the UPF 195. The UPF 195 provides UE IP address allocation as well as other functions. The UPF 195 is connected to the IP Services 197. The IP Services 197 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, or other IP services.

[0069] The base station also may be referred to as a gNB, Node B, evolved Node B (eNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set

(ESS), a transmit reception point (TRP), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 or the core network 190 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (such as an MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT devices (such as a parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE 104 also may be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0070] Figure 2A shows an example of a first slot 200 within a 5G NR frame structure. Figure 2B shows an example of DL channels 230 within a 5G NR slot. Figure 2C shows an example of a second slot 250 within a 5G NR frame structure. Figure 2D shows an example of UL channels 280 within a 5G NR slot. In some instances, the 5G NR frame structure may be FDD in which, for a particular set of subcarriers (carrier system bandwidth), slots within the set of subcarriers are dedicated for either DL or UL transmissions. In some other instances, the 5G NR frame structure may be TDD in which, for a particular set of subcarriers (carrier system bandwidth), slots within the set of subcarriers are dedicated for both DL and UL transmissions. In the examples shown in Figures 2A and 2C, the 5G NR frame structure is based on TDD, with slot 4 configured with slot format 28 (with mostly DL), where D indicates DL, U indicates UL, and X indicates that the slot is flexible for use between DL and UL, and with slot 3 configured with slot format 34 (with mostly UL). While slots 3 and 4 are shown with slot formats 34 and 28, respectively, any particular slot may be configured with any of the various available slot formats 0–61. Slot formats 0 and 1 are all DL and all UL, respectively. Other slot formats 2–61 include a mix of DL, UL, and flexible symbols. UEs may be configured with the slot format, either dynamically through downlink control information (DCI) or semi-statically through radio resource control

(RRC) signaling by a slot format indicator (SFI). The configured slot format also may apply to a 5G NR frame structure that is based on FDD.

[0071] Other wireless communication technologies may have a different frame structure or different channels. A frame may be divided into a number of equally sized subframes. For example, a frame having a duration of 10 microseconds (ms) may be divided into 10 equally sized subframes each having a duration of 1 ms. Each subframe may include one or more time slots. Subframes also may include mini-slots, which may include 7, 4, or 2 symbols. Each slot may include 7 or 14 symbols, depending on the slot configuration. For slot configuration 0, each slot may include 14 symbols, and for slot configuration 1, each slot may include 7 symbols. The symbols on DL may be cyclic prefix (CP) OFDM (CP-OFDM) symbols. The symbols on UL may be CP-OFDM symbols (such as for high throughput scenarios) or discrete Fourier transform (DFT) spread OFDM (DFT-s-OFDM) symbols (also referred to as single carrier frequency-division multiple access (SC-FDMA) symbols) (such as for power limited scenarios).

[0072] The number of slots within a subframe is based on the slot configuration and the numerology. For slot configuration 0, different numerologies (μ) 0 to 5 allow for 1, 2, 4, 8, 16, and 32 slots, respectively, per subframe. For slot configuration 1, different numerologies 0 to 2 allow for 2, 4, and 8 slots, respectively, per subframe. Accordingly, for slot configuration 0 and numerology μ, there are 14 symbols per slot and 2μ slots per subframe. The subcarrier spacing and symbol length/duration are a function of the numerology. The subcarrier spacing may be equal to 2^μ*15 kHz, where μ is the numerology 0 to 5. As such, the numerology μ=0 has a subcarrier spacing of 15 kHz, and the numerology μ=5 has a subcarrier spacing of 480 kHz. The symbol length/duration is inversely related to the subcarrier spacing. Figures 2A–2D provide an example of slot configuration 0 with 14 symbols per slot and numerology μ=0 with 1 slot per subframe. The subcarrier spacing is 15 kHz and symbol duration is approximately 66.7 microseconds (μs).

[0073] A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as a physical RB (PRB)) that extends across 12 consecutive subcarriers and across a number of symbols. The intersections of subcarriers and across 14 symbols. The intersections of subcarriers and of the RB define multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.

[0074] As illustrated in Figure 2A, some of the REs carry a reference signal (RS) for the UE. In some configurations, one or more REs may carry a demodulation reference signal (DM-RS) (indicated as Rx for one particular configuration, where 100x is the port number, but other DM-RS configurations are possible). In some configurations, one or more REs may carry a channel state information reference signal (CSI-RS) for channel measurement at the UE. The REs also may include a beam measurement reference signal (BRS), a beam refinement reference signal (BRRS), and a phase tracking reference signal (PT-RS).

[0075] Figure 2B illustrates an example of various DL channels within a subframe of a frame. The physical downlink control channel (PDCCH) carries DCI within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A primary synchronization signal (PSS) may be within symbol 2 of particular subframes of a frame. The PSS is used by a UE 104 to determine subframe or symbol timing and a physical layer identity. A secondary synchronization signal (SSS) may be within symbol 4 of particular subframes of a frame. The SSS is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DM-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form a synchronization signal (SS)/PBCH block. The MIB provides a number of RBs in the system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

[0076] As illustrated in Figure 2C, some of the REs carry DM-RS (indicated as R for one particular configuration, but other DM-RS configurations are possible) for channel estimation at the base station. The UE may transmit DM-RS for the physical uplink control channel (PUCCH) and DM-RS for the physical uplink shared channel (PUSCH). The PUSCH DM-RS may be transmitted in the first one or two symbols of the PUSCH. The PUCCH DM-RS may be transmitted in different configurations depending on whether short or long PUCCHs are transmitted and depending on the particular PUCCH format used. Although not shown, the UE may transmit sounding reference signals (SRS). The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

[0077] Figure 2D illustrates an example of various UL channels within a subframe of a frame. The PUCCH may be located as indicated in one configuration. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), or UCI.

[0078] Figure 3 shows a block diagram of an example base station 310 and UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (such as the MIB and SIBs), RRC connection control (such as RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0079] The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (such as binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (such as a pilot signal) in the time or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially pre-coded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

[0080] At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal includes a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358.

The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0081] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK or NACK protocol to support HARQ operations.

[0082] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (such as the MIB and SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0083] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0084] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver

318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0085] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK or NACK protocol to support HARQ operations. Information to be wirelessly communicated (such as for LTE or NR based communications) is encoded and mapped, at the PHY layer, to one or more wireless channels for transmission.

[0086] In the example of Figure 3, each antenna 352 of the UE 350 is coupled to a respective transmitter 354TX. However, in some other implementations, the UE 350 may include fewer transmitters (or transmit chains) than receive (RX) antennas. Although not shown for simplicity, each transmitter may be coupled to a respective power amplifier (PA) which amplifies the signal to be transmitted. The combination of a transmitter and a PA may be referred to herein as a "transmit chain" or "TX chain." To save on cost or die area, the same PA may be reused to transmit signals over multiple RX antennas. In other words, one or more TX chains of a UE may be selectively coupled to multiple RX antennas ports.

[0087] Figure 4 shows a block diagram of an example UE 400. The UE 400 may be one example of the UE 104 of Figure 1 or the UE 350 of Figure 3. The UE 400 may include an application layer 410, a modem control interface (MCI) 420, and a modem 430. The application layer 410 may include hardware or a processor executing software (or both) that can store and execute one or more applications on the UE 400, and may include protocols for exchanging communications across an Internet Protocol (IP) network. The application layer 410 includes an application processor 412 and a memory 414 coupled one another by a bus 415. The application layer 410 is coupled to the modem 430 by the MCI 420, and may be responsible for executing one or more software applications on the UE 400. The application layer 410 also may be used to provide end-to-end services between applications executing in the UE 400 and one or more other devices, entities, or networks according to any number of suitable communication protocols.

[0088] The memory 414 may be any suitable type of memory that can store computer-readable, computer-executable software code containing instructions that, when executed by the application processor 412, causes the UE 400 to perform various functions or operations. In some implementations, the memory 414 may store a number of UE applications 416, a high-level operating system (HLOS) 418, and data generated by one or more of the application processor 412, the applications 416, or the HLOS 418. The HLOS 418 may be a set of software that manages hardware resources on the UE 400, provides common services for applications residing in the application layer 410, and performs various other high-level functions and operations for the UE 400.

[0089] The application processor 412, which may be a specially-configured processor designed to support applications running in a mobile operating system environment, can be implemented as a general purpose processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. In some implementations, the application processor 412 and the memory 414 may implement the HLOS 418.

[0090] The modem 430 may include a plurality of radios 432(1)–432(N) that may be used to communicate with other devices, systems, networks, entities, and nodes any number of suitable communication protocols. In some implementations, a first radio 432(1) may be configured for cellular communications, a second radio 432(2) may be configured for WLAN communications, and a third radio 432(3) may be configured for Bluetooth communications.

[0091] The MCI 420 may be distributed between the radios 432(1)–432(N) and the application layer 410, and may manage connection points between one or more of the radios 432(1)–432(N) and the HLOS 418. Although not shown for simplicity, the application layer 410 may include a number of application program interfaces (API) and corresponding drivers that can establish connection points between applications residing in the memory 414 and one or more of the radios 432(1)–432(N). In some implementations, a first driver may be a Mobile Broadband driver and a first API may be a Mobile Broadband API set, a second driver may be a WLAN driver and a second

API may be a WLAN API set, and a third driver may be a Bluetooth driver and a third API may be a Bluetooth API set. In some instances, the connection points may be established via a radio interface layer (RIL), which is a layer in the HLOS 418 that provides an interface to radio resources of the modem 430.

[0092] Figure 5 shows a diagram of an example wireless communications system 500. The wireless communications system 500, which may be one implementation of the wireless communications system 100 of Figure 1, includes a radio access network (RAN) 510, a core network 520, and a local area data network (LADN) 530. The RAN 510 may include a plurality of base stations 502(1)–502(3) that can wirelessly communicate with a number of wireless communication devices (such as a UE 504), and may provide access points for the wireless communication devices to connect to the core network 520 and the LADN 530. The base stations 502(1)–502(3) may be one example of the base station 102 of Figure 1 or the base station 310 of Figure 3, and the UE 504 may be one example of the UE 104 of Figure 1, the UE 350 of Figure 3, or the UE 400 of Figure 4. Although only three base stations 502(1)–502(3) are shown in Figure 5 for simplicity, the RAN 510 may include any suitable number of base stations. The radio access network may be any suitable RAN including, for example, a 5G NR access network.

[0093] Each of the base stations 502(1)–502(3) may provide communication coverage for a respective geographic area or cell. For the example of Figure 5, the first base station 502(1) may provide communication coverage for a first geographic area 512(1), the second base station 502(2) may provide communication coverage for a second geographic area 512(2), and the third base station 502(3) may provide communication coverage for a third geographic area 512(3). The first geographic area 512(1) may be referred to as cell–1, and may correspond to a first tracking area (TA) identified by a first tracking area identity (TAI–1). The second geographic area 512(2) may be referred to as cell–2, and also may correspond to the first tracking area TAI–1. The third geographic area 512(3) may be referred to as cell–3, and may correspond to a second TA identified by TAI–2. As such, the first tracking area TAI–1 may include cell–1 and cell–2, and the second tracking area TAI–2 may include cell–3.

[0094] The core network 520 may include an Access and Mobility Management Function (AMF) 521, a Session Management Function (SMF) 522, a User Plane Function (UPF) 523, an Authentication Server Function (AUSF) 524, and a Unified

Data Management (UDM) 525. Although not shown in Figure 5 for simplicity, the core network 520 also may include a Policy Control Function (PCF), an Application Function (AF), and other components, devices, and functions in accordance with one or more releases of the 3GPP Technical Specifications. In some implementations, the core network 520 may be a 5G Core Network (5G CN) in communication with an EPC (not shown for simplicity).

[0095] The AMF 521 is connected to the SMF 522 at reference point N11, is connected to the AUSF 524 at reference point N12, and is connected to the UDM at reference point N8. The AMF 521 may support mobility functions for the UE 504 such as, for example, terrestrial cell change and handovers. The AMF 521 also may provide a signaling connection to the UE 504 via the N1 interface, and provide a signaling connection to each of the base stations 502(1)–502(3) via the N2 interfaces (only one N2 interface shown for simplicity). In some implementations, the AMF 521 may configure the service area of the LADN 530, and may manage Protocol Data Unit (PDU) sessions between the UE 504 and the LADN 530 on behalf of the SMF 522.

[0096] The SMF 522 is connected to the UPF 523 at reference point N4, and provides a connection between the AMF 521 and the UPF 523. The SMF 522 is responsible for managing the establishment, modification, and release of PDU sessions for the UE 504. The SMF 522 may perform IP address allocation and management for UE 504, and may act as a Dynamic Host Configuration Protocol (DHCP) server for the UE 504. The SMF 522 also may select and control the UPF 523 on behalf of the UE 504.

[0097] The UPF 523 is connected to the LADN 530 at reference point N6, and may provide a signaling connection to each of the base stations 502(1)–502(3) via the N3 interfaces (only one N3 interface shown for simplicity). The UPF 523 is responsible for packet routing, packet forwarding, downlink packet buffering, and downlink data notifications triggering. In some implementations, the UPF 523 may support voice and data bearers for the UE 504, and may enable the UE 504 to access other networks such as the LADN 530. In some instances, the UPF 523 may provide an interconnect point for PDU sessions between the UE 504 and the LADN 530, may enforce policy rules for the user plane, and may provide Quality of Service (QoS) for the user plane.

[0098] Although not shown in Figure 5 for simplicity, the core network 520 also may include a location management function (LMF) and a Gateway Mobile Location

Center (GMLC). The LMF may determine positioning information of the UE 504 using various positioning techniques such as Assisted GNSS (A-GNSS), Observed Time Difference of Arrival (OTDOA), Precise Point Positioning (PPP), Enhanced Cell ID (ECID), Round Trip Time (RTT), and other positioning procedures. In some implementations, the LMF may process location services requests received from an external client 540, and the GMLC may support positioning functions for the external client 540.

[0099] The LADN 530 may be a data network that provides one or more services (such as operator services, Internet access, and 3rd party services) to UEs that establish a connection with the LADN 530 through the core network 520. The data network may be identified by a data network name (DNN) or an access point name (APN), and may be available within a specified service area. The service area of the data network may correspond to a single cell, a group of cells, or an entire registration area. In some implementations, the service area of the data network may correspond to one or more tracking areas. The tracking areas of data networks associated with the LADN 530 may collectively define a service area of the LADN 530, and the TAIs of the tracking areas may be grouped together in a TAI list indicative of the service area of the LADN 530.

[0100] When the UE 504 initially registers with the core network 520, the AMF 521 may allocate a registration area that includes one or more tracking areas associated with the RAN 510, and may identify the LADNs which are available within the UE's registration area. The AMF 521 may indicate the available LADNs to the UE 504 by sending data network information to the UE using NAS signaling. The data network information may include DNNs, TAI lists, cell IDs, and PLMN IDs associated with the available data networks. The UE may use the data network information received from the AMF 521 to establish a PDU session with the LADN 530.

[0101] Specifically, when a UE application seeks access to a particular LADN service, the UE application may send a LADN setup request message to the UE's modem. The UE may generate a PDU Session ID, determine the DNN associated with the requested LADN service, and transmit a PDU Session Establishment Request message that requests the core network 520 to establish a PDU session between the UE and the LADN service. The PDU Session Establishment Request message may include the DNN of the requested LADN service, the PDU Session ID, a PDU session type, Single Network Slice Selection Assistance Information (S-NSSAI), and a Service and Session Continuity (SSC) mode.

[0102] The AMF 521 receives the PDU Session Establishment Request message from the UE, and may forward some or all of the PDU Session Establishment Request message to the SMF 522. The SMF 522 may determine whether the PDU Session Establishment Request is compliant with the user's subscriptions and local policies, and also may determine whether the UE is located within the LADN service area based on user location information provided by the AMF 521. If the user location information does not indicate that the UE is located within the LADN service area, the SMF 522 may reject the PDU Session Establishment Request (such as because the UE is outside of the LADN service area), and the AMF 521 may send a PDU Session Establishment failure indication to the UE.

[0103] In response to receiving the PDU Session Establishment failure indication, the UE application may repeatedly send LADN setup request messages to the UE's modem, which prompts the UE to repeatedly transmit PDU Session Establishment Request messages to the core network 520. As long as the UE remains outside of the LADN service area, the core network 520 may continue sending failure indications to the UE. Repeatedly requesting and failing to establish a PDU session with the LADN service not only consumes power of the UE, but also consumes signaling overhead of the RAN 510.

[0104] In accordance with some aspects of the present disclosure, a UE application seeking access to a LADN service may register with the LADN service and obtain the TAI of a DNN associated with the LADN service. The TAI of the DNN may be stored in the UE, and may be used to determine when the LADN service is available to the UE. In some implementations, the UE may compare one or more TAIs received in broadcast messages from a serving cell with the TAI of the DNN to determine whether the UE is located within the LADN service area. When there is a match between the TAI of the DNN and one of the TAIs contained in the broadcast messages received from the serving cell, the UE may determine that the LADN service is available, and thereafter request and establish a PDU Session with the DNN of the LADN service.

[0105] Figure 6 shows a sequence diagram depicting an example message exchange 600 between a UE 610 and a core network 620. The core network 620 may be associated with a radio access network (RAN) that includes a plurality of base stations such as base station 630. The UE 610 may be one example of the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, or the UE 504 of Figure 5. The base station 630 may be one example of the base station 102 of Figure 1, the base station 310 of Figure 3, or the base stations 502(1)–502(3) of Figure 5. The base station 630 may be any suitable base station or node including, for example, a gNB or an eNB. The RAN may be any suitable radio access network, and may include any suitable radio access technology. In some implementations, the RAN may be one example of the RAN 510 of Figure 5. The core network 620 may be any suitable core network including, for example, a 5G Core Network (5G CN) in communication with an EPC (not shown for simplicity). In some implementations, the core network 620 may be one example of the core network 520 of Figure 5.

[0106] The UE 610 is shown to include a HLOS 612, a modem 614, and an MCI (other components of the UE 610 are not shown for simplicity). The HLOS 612 may reside in an application processor of the UE 610, and is coupled to the modem 614 via the MCI. In some implementations, the HLOS 612 may be one example of the HLOS 418 of Figure 4, the modem 630 may be one example of the modem 430 of Figure 4, and the MCI may be one example of the MCI 420 of Figure 4.

[0107] An application executed by the HLOS 612 may select or otherwise identify a LADN service with which to establish a connection through the core network 620, and the UE 610 may register the application with the identified LADN service before attempting to establish a PDU session with the identified LADN service. In some implementations, the application sends a LADN Registration Request to the modem 614 via the MCI. The LADN Registration Request may include at least a data network name (DNN) of the LADN service, and may prompt the modem 614 to initiate a registration procedure with the LADN service.

[0108] The modem 614 receives the LADN Registration Request, and transmits a registration request (REG REQ) message to the core network 620. The REG REQ message may include a request to register the application with the LADN service, and may indicate the DNN of the LADN service. The core network 620 accepts the registration request, registers the application with the identified LADN service, and sends a Registration Accept (REG ACCEPT) message to the UE 610. The REG ACCEPT message indicates that the application has been registered with the identified

LADN service, and may include the DNN of the LADN service and a TAI associated with the DNN. The modem 614 receives the REG ACCEPT message, and may store the TAI of the DNN in a suitable memory within the UE 610.

[0109] The modem 614 receives, from the base station 630, a System Information Block (SIB) containing a TAI list that includes one or more TAIs. In some implementations, the base station 630 may periodically or aperiodically broadcast SIBs containing TAIs or a TAI list. Each of the TAIs contained in the SIB may identify a corresponding tracking area, and the tracking areas identified by the TAIs contained in the SIB may collectively indicate the service area of the base station 630. With reference to Figure 5, the first base station 502(1) may broadcast a SIB containing TAI–1 to indicate that the tracking area identified by TAI–1 includes or corresponds to Cell–1, the second base station 502(2) may broadcast a SIB containing TAI–1 to indicate that the tracking area identified by TAI–1 includes or corresponds to Cell–2, and the third base station 502(3) may broadcast a SIB containing TAI–2 to indicate that the tracking area identified by TAI–2 includes or corresponds to Cell–3.

[0110] In some implementations, the UE 610 may compare the TAIs contained in the SIB with the TAI of the DNN to determine whether the UE 610 is located within the LADN service area. A match between the TAI of the DNN and one of the TAIs contained in the broadcast TAI list may indicate that the UE 610 is within the tracking area identified by the matching TAIs, and therefore also may indicate that the UE 610 is within the service area of the LADN. A mismatch between the TAI of the DNN and the TAIs contained in the broadcast TAI list may indicate that the UE 610 is not located within the tracking area identified by the matching TAIs, and therefore also may indicate that the UE 610 is not located within the service area of the LADN. For the example of Figure 6, the TAI of the DNN matches one of the TAIs contained in SIB received from the base station 630, and the UE 610 determines that it is located within the service area of the identified LADN.

[0111] The modem 614 sends a LADN indication message to the application via the HLOS 612 based on the determination that the UE 610 is located within the service area of the identified LADN. The LADN indication message may indicate that the UE application is registered with the identified LADN service, and may include the DNN of the identified LADN service and the TAI associated with the DNN of the LADN service. In some other implementations, the modem 614 may determine when the UE

610 is within a vicinity of the service area of the identified LADN based on the TAIs contained in the SIB, and may indicate the proximity of the DNN of the identified LADN service to the HLOS 612.

[0112] The application may send a setup request (Setup REQ) message to the modem 614 via the HLOS 612 based on the indication that the UE application is registered with the identified LADN service. The Setup REQ message may include a request to setup a PDU session with the LADN service, and may contain the DNN of the LADN service. Based on the Setup REQ message, the modem 614 sends a PDU Session Establishment Request message to the core network 620. The PDU Session Establishment Request message may include the DNN of the identified LADN service and a request to establish a PDU session between the UE 610 and the identified LADN service.

[0113] The core network 620 receives the PDU Session Establishment Request message, and may accept or deny the requested PDU Session based on a number of factors (such as whether the PDU Session Establishment Request is compliant with the user's subscriptions and local policies, and whether the UE 610 is located within the service area of the identified LADN). For the example of Figure 6, the core network 620 determines that the UE 610 is located within the service area of the identified LADN, and accepts the PDU Session Establishment Request. The core network 620 may indicate acceptance of the PDU session request by sending a PDU Session Establishment Accept message to the UE 610. The PDU Session Establishment Accept message may include the DNN of the identified LADN service and the TAI of the DNN.

[0114] The modem 614 receives the PDU Session Establishment Accept message, and sends a setup response (Setup RSP) message indicating "success" to the application via the HLOS 612. Once the connection is established with the DNN of the identified LADN service, the application may access the DNN of the identified LADN service using the established PDU session.

[0115] In some other implementations, the UE application may register with a LADN service and request setup of a PDU session with the LADN service, concurrently.

[0116] Figure 7 shows a sequence diagram depicting another example message exchange 700 for establishing a PDU session between a UE and a LADN service. The core network 720 may be associated with a radio access network (RAN) that includes a plurality of base stations such as base station 730. The UE 710 may be one example of the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, or the UE 504 of Figure 5. The base station 730 may be one example of the base station 102 of Figure 1, the base station 310 of Figure 3, or the base stations 502(1)–502(3) of Figure 5. The base station 730 may be any suitable base station or node including, for example, a gNB or an eNB. The RAN may be any suitable radio access network, and may include any suitable radio access technology. In some implementations, the RAN may be one example of the RAN 510 of Figure 5. The core network 720 may be any suitable core network including, for example, a 5G Core Network (5G CN) in communication with an EPC (not shown for simplicity). In some implementations, the core network 720 may be one example of the core network 520 of Figure 5.

[0117] The UE 710 is shown to include a HLOS 712, a modem 714, and an MCI (other components of the UE 710 are not shown for simplicity). The HLOS 712 may reside in an application processor of the UE 710, and is coupled to the modem 714 via the MCI. In some implementations, the HLOS 712 may be one example of the HLOS 418 of Figure 4, the modem 730 may be one example of the modem 430 of Figure 4, and the MCI may be one example of the MCI 420 of Figure 4.

[0118] An application executed by the HLOS 712 may select or otherwise identify a LADN service with which to establish a connection through the core network 720, and the UE 710 may register the application with the identified LADN service and request setup of a PDU session with the identified LADN service, concurrently. In some implementations, the application sends a LADN Request and Setup message to the modem 714 via the HLOS 712. The LADN Request and Setup message may include a request to register the application with the identified LADN service, a request to setup the PDU session with the identified LADN service when available to the UE 710, and the DNN of the identified LADN service.

[0119] The modem 714 receives the LADN Request and Setup message, and transmits a registration and setup request (REG & SETUP REQ) message to the core network 720. The REG & SETUP REQ message may include a DNN of the identified LADN service, a request to register the application with the identified LADN service, and a request to setup a PDU session with the DNN of the identified LADN service when available to the UE 710. The core network 720 accepts the registration and setup request, registers the application with the identified LADN service, and sends a Registration Accept (REG ACCEPT) message to the UE 710. The REG ACCEPT message may include the DNN of the LADN service, a TAI associated with the DNN, and an indication that the UE 710 is registered with the identified LADN service. The modem 714 receives the REG ACCEPT message, and may store the TAI of the DNN in a suitable memory within the UE 710.

[0120] The modem 714 receives, from the base station 730, a SIB containing a TAI list that includes one or more TAIs. As described with reference to Figure 6, the base station 730 may periodically or aperiodically broadcast SIBs containing TAIs or a TAI list, where each of the TAIs contained in the SIB may identify a corresponding tracking area. The tracking areas identified by the TAIs contained in the SIB may collectively indicate the service area of the base station 730.

[0121] In some implementations, the UE 710 may compare the TAIs contained in the SIB with the TAI of the DNN to determine whether the UE 710 is located within the LADN service area. As described with reference to Figure 6, a match between the TAI of the DNN and one of the TAIs contained in the broadcast TAI list may indicate that the UE 710 is within the service area of the DNN of the identified LADN, and a mismatch between the TAI of the DNN and the TAIs contained in the broadcast TAI list may indicate that the UE 710 is not located within the service area of the DNN of the identified LADN. For the example of Figure 7, the TAI of the DNN matches one of the TAIs contained in SIB received from the base station 730, and the UE 710 determines that it is located within the service area of the identified LADN.

[0122] Based on the determination that the UE 610 is located within the service area of the identified LADN, the modem 714 sends a PDU Session Establishment Request message to the core network 720. The PDU Session Establishment Request message may include the DNN of the identified LADN service and a request to establish a PDU session between the UE 710 and the identified LADN service.

[0123] The core network 720 receives the PDU Session Establishment Request message, and determines that the UE 710 is located within the service area of the identified LADN. The core network 720 accepts the PDU Session Establishment Request, and indicates acceptance of the PDU session request by sending a PDU Session Establishment Accept message to the UE 710. The PDU Session Establishment

Accept message may include the DNN of the identified LADN service, the TAI of the DNN, and an indication that the UE 710 is registered with the identified LADN service.

[0124] The modem 714 receives the PDU Session Establishment Accept message, and sends a setup response (Setup RSP) message indicating "success" to the application via the HLOS 712. Once the connection is established with the DNN of the identified LADN service, the application may access the DNN of the identified LADN service using the established PDU session.

[0125] Figure 8 shows a flowchart depicting an example operation 800 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 800 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. The operation 800 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some other implementations, the operation 800 may be performed by another suitable wireless communication device.

[0126] At block 802, the application sends a local area data network (LADN) Registration Request to the modem via the HLOS, the LADN Registration Request including at least a data network name (DNN) of the LADN service. At block 804, the UE transmits, to a core network associated with a radio access network (RAN), a registration request message including a request to register the application with the LADN service and indicating the DNN of the LADN service. At block 806, the UE receives, from the core network, a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN. At block 808, the modem sends a LADN indication message to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service. At block 810, the UE receives, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS. At block 812, the UE determines whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list. At block 814, the UE establishes a protocol data unit (PDU) session with the DNN of the LADN service based on the determination. In some instances, the broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH).

[0127] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, the LADN service area may be determined to be available to the UE based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a TAI or a cell identifier (ID). The TAI may be received from the base station on a physical downlink control channel (PDCCH).

[0128] Figure 9A shows a flowchart depicting an example operation 900 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 900 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. The operation 900 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 900 may be one example of establishing the PDU session in block 812 of the operation 800 of Figure 8. At block 902, the UE transmits, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service. At block 904, the UE receives, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0129] Figure 9B shows a flowchart depicting an example operation 910 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 910 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. The operation 910 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 910 may be performed after the modem sends the LADN indication in block 808 of the operation 800 of Figure 8. At block 912, the application sends a setup request to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to setup the PDU session with the DNN of the LADN service. At block 914, the modem sends a setup response to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

[0130] Figure 10 shows a flowchart depicting an example operation 1000 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1000 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. The operation 1000 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some other implementations, the operation 1000 may be performed by another suitable wireless communication device.

[0131] At block 1002, the application sends a Request and Setup message to the modem via the HLOS, the Request and Setup message including a request to register the application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with the LADN service when available to the UE, and a data network name (DNN) of the LADN service. At block 1004, the UE transmits a message to the core network, the message including a request to register the application with the LADN service, a request to setup the PDU session with the DNN of the LADN service when available to the UE, and the DNN of the LADN service. At block 1006, the UE receives, from the core network, an accept message including the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service. At block 1008, the UE determines that the LADN service is available to the UE. At block 1010, the UE establishes a PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session.

[0132] Figure 11A shows a flowchart depicting an example operation 1100 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1100 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. The operation 1100 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 1100 may be performed after establishing the PDU session in block 1010 of the operation 1000 of Figure 10. At block 1102, the modem sends a setup response message to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0133] Figure 11B shows a flowchart depicting an example operation 1110 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1110 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. The operation 1110 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 1110 may be performed before determining that the LADN service is available in block 1008 of the operation 1000 of Figure 10. At block 1112, the UE receives a system information block (SIB) broadcast from a base station (BS). In some implementations, the LADN service area may be determined to be available to the UE based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a TAI or a cell identifier (ID). The TAI may be received from the base station on a physical downlink control channel (PDCCH).

[0134] Figure 11C shows a flowchart depicting an example operation 1120 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1120 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. In some implementations, the operation 1120 may be one example of establishing the PDU session in block 1010 of the operation 1000 of Figure 10. At block 1102, the UE transmits, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service. At block 1104, the UE receives, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0135] Figure 12 shows a flowchart depicting an example operation 1200 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1200 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. At block 1202, the UE transmits a registration request message including a request to register the application with a local area data network (LADN) service and indicating at least a data network name (DNN) of the LADN service. At block 1204, the UE receives a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN. At block 1206, the UE receives, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS. At block 1208, the UE determines whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list. At block 1210, the UE establishes a protocol data unit (PDU) session with the DNN of the LADN service based on the determination indicating that the UE is within a service area of the LADN. In some instances, the broadcasted TAI list may be included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH).

[0136] In some implementations, the UE may be determined to be within the LADN service area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list, and the UE may be determined to be outside the LADN service area when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list. In some other implementations, the LADN service area may be determined to be available to the UE based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a TAI or a cell identifier (ID). The TAI may be received from the base station on a physical downlink control channel (PDCCH).

[0137] Figure 13A shows a flowchart a depicting an example operation 1300 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1300 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. In some implementations, the operation 1300 may be performed after determining whether the UE is within the service area of the LADN in block 1208 of the operation 1200 of Figure 12. At block 1302, the UE refrains from requesting or establishing the PDU session with the DNN of the LADN service based on the determination indicating that the UE is not within the service area of the LADN.

[0138] Figure 13B shows a flowchart a depicting an example operation 1310 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1310 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. In some implementations, the operation 1310 may be one example of establishing the PDU session in block 1210 of the operation 1200 of Figure 12. At block 1312, the UE transmits, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service. At block 1314, the UE receives, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0139] Figure 13C shows a flowchart a depicting an example operation 1320 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1320 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. The operation 1320 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a HLOS 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 1320 may be performed after determining whether the UE is within the service area of the LADN in block 1208 of the operation 1200 of Figure 12. At block 1322, the application sends a LADN Registration Request to the modem via the HLOS, the LADN Registration Request including at least the DNN of the LADN service. At block 1324, the modem sends a LADN indication message to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service.

[0140] Figure 13D shows a flowchart a depicting an example operation 1330 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1330 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 610 of Figure 6. The operation 1330 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a HLOS 418 configured to execute an application 416 on the UE 400. In some implementations, the operation 1330 may be performed after the modem sends the LADN indication message in block 1324 of the operation 1320 of Figure 13C. At block 1332, the application sends a setup request to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to setup the PDU session with the DNN of the LADN service. At block 1334, the modem sends a setup response to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

[0141] Figure 14 shows a flowchart depicting an example operation 1400 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1400 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. At block 1402, the UE transmits a message including a request to register the application with the LADN service, a request to setup the PDU session with the DNN of the LADN service when available to the UE, and the DNN of the LADN service. At block 1404, the UE receives an accept message including the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service. At block 1406, the UE determines that the LADN service is available to the UE. At block 1408, the UE establishes the PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session.

[0142] Figure 15A shows a flowchart depicting an example operation 1500 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1500 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. In some implementations, the operation 1500 may be performed before determining that the LADN service is available in block 1406 of the operation 1400 of Figure 14. At block 1502, the UE receives a system information block (SIB) broadcast from a base station (BS). In some implementations, the LADN service area may be determined to be available to the UE based on identity information included in the broadcasted SIB. In some instances, the identity information may include at least one of a TAI or a cell identifier (ID). The TAI may be received from the base station on a physical downlink control channel (PDCCH).

[0143] Figure 15B shows a flowchart depicting an example operation 1510 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1510 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. In some implementations, the operation 1510 may be one example of establishing the PDU session in block 1408 of the operation 1400 of Figure 14. At block 1512, the UE transmits, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service. At block 1514, the UE receives, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

[0144] Figure 15C shows a flowchart depicting an example operation 1520 for wireless communication that supports establishing a PDU session between a UE and a LADN service. The operation 1520 may be performed by a wireless communication device such as the UE 104 of Figure 1, the UE 350 of Figure 3, the UE 400 of Figure 4, the UE 504 of Figure 5, or the UE 710 of Figure 7. The operation 1520 is described with reference to the UE 400 of Figure 4, which includes at least a modem 430 and a high-level operating system (HLOS) 418 configured to execute an application 416 on the UE 400. In some other implementations, the operation 1520 may be performed by another suitable wireless communication device. At block 1522, the application sends a Request and Setup message to the modem via the HLOS, the Request and Setup message including the request to register the application, the request to setup the PDU session, and the DNN of the LADN service. At block 1524, the modem sends a setup response message to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the LADN service.

[0145] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a, b, c, a-b, a-c, b-c, and a-b-c.

[0146] The various illustrative logics, logical blocks, modules, circuits and algorithm processes described in connection with the implementations disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. The interchangeability of hardware and software has been described generally, in terms of functionality, and illustrated in the various illustrative components, blocks, modules, circuits and processes described above. Whether such functionality is implemented in hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0147] The hardware and data processing apparatus used to implement the various illustrative logics, logical blocks, modules and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices (such as a combination of a DSP and a microprocessor), a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some implementations, particular processes and methods may be performed by circuitry that is specific to a given function.

[0148] In one or more aspects, the functions described may be implemented in hardware, digital electronic circuitry, computer software, firmware, including the structures disclosed in this specification and their structural equivalents thereof, or in any combination thereof. Implementations of the subject matter described in this specification also can be implemented as one or more computer programs, i.e., one or more modules of computer program instructions, encoded on a computer storage media for execution by, or to control the operation of, data processing apparatus.

[0149] If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. The processes of a method or algorithm disclosed herein may be implemented in a processor-executable software module which may reside on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that can be enabled to transfer a computer program from one place to another. A storage media may be any available media that may be accessed by a computer. By way of example, and not limitation, such computer-readable media may include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Also, any connection can be properly termed a computer-readable medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and instructions on a machine readable medium and computer-readable medium, which may be incorporated into a computer program product.

[0150] Various modifications to the implementations described in this disclosure may be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations without departing from the spirit or scope of this disclosure. Thus, the claims are not intended to be limited to the implementations shown herein, but are to be accorded the widest scope consistent with this disclosure, the principles and the novel features disclosed herein.

CLAIMS

What is claimed is:

1. A method for wireless communication performed by an apparatus of a user equipment (UE), the UE including at least a modem and a high-level operating system (HLOS) configured to execute an application on the UE, the method comprising:

sending a local area data network (LADN) Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least a data network name (DNN) of the LADN service;

transmitting, to a core network associated with a radio access network (RAN), a registration request message including a request to register the application with the LADN service and indicating the DNN of the LADN service;

receiving, from the core network, a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN;

sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service;

receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS;

determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and

establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination indicating that the UE is within a service area of the LADN.

2. The method of claim 1, wherein the UE is determined to be within the service area of the LADN when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list.

3. The method of claim 1, wherein the UE is determined to be outside the service area of the LADN when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list.

4. The method of claim 1, further comprising:

refraining from requesting or establishing the PDU session with the DNN of the LADN service based on the determination indicating that the UE is not within the service area of the LADN.

5. The method of claim 1, wherein establishing the PDU session comprises:

transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and

receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

6. The method of claim 1, wherein the broadcasted TAI list is included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH).

7. The method of claim 6, wherein determining whether the UE is within the LADN service area is further based on a cell identity (ID) of the BS.

8. The method of claim 1, wherein the UE has a subscription to the DNN.

9. The method of claim 1, further comprising:

sending a setup request from the application to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to setup the PDU session with the DNN of the LADN service; and

sending a setup response from the modem to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

10. A user equipment (UE), comprising:

one or more processors; and

a memory coupled to the one or more processors and storing instructions that, when executed by the one or more processors, cause the UE to perform the operations of any one or more of claims 1–9.

11. A user equipment (UE) comprising means for performing the operations of any one or more of claims 1–9.

12. A non-transitory computer-readable memory comprising instructions that, when executed by one or more processors of a user equipment (UE), cause the UE to perform the operations of any one or more of claims 1–9.

13. A method for wireless communication performed by an apparatus of a user equipment (UE), the UE including at least a modem and a high-level operating system (HLOS) configured to execute an application on the UE, the method comprising:

sending a Request and Setup message from the application to the modem via the HLOS, the Request and Setup message including a request to register the application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with the LADN service when available to the UE, and a data network name (DNN) of the LADN service;

transmitting, to a core network associated with a radio access network (RAN), a message including:

a request to register the application with the LADN service,

a request to setup the PDU session with the DNN of the LADN service when available to the UE, and

the DNN of the LADN service;

receiving, from the core network, an accept message including:

the DNN of the LADN service,

a tracking area identity (TAI) associated with the DNN, and

an indication that the UE is registered with the LADN service;

determining that the LADN service is available to the UE; and establishing the PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session.

14. The method of claim 13, further comprising:

sending a setup response message from the modem to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the DNN of the LADN service.

15. The method of claim 13, further comprising:

receiving a system information block (SIB) broadcast from a base station (BS);

wherein determining that the LADN service area is available to the UE is based on identity information included in the broadcasted SIB.

16. The method of claim 14, wherein the identity information includes at least one of a TAI or a cell identifier (ID).

17. The method of claim 15, wherein the TAI is received from the BS on a physical downlink control channel (PDCCH).

18. The method of claim 13, wherein determining that the LADN service area is available to the UE includes receiving a UE Presence Indication from the core network.

19. The method of claim 13, wherein establishing the PDU session comprises:

transmitting, to the core network, a PDU Session Establishment request including at least the DNN of the LADN service; and

receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

20. The method of claim 13, wherein the UE has a subscription to the DNN.

21. A user equipment (UE), comprising:

one or more processors; and

a memory coupled to the one or more processors and storing instructions that, when executed by the one or more processors, cause the UE to perform the operations of any one or more of claims 13–20.

22. A user equipment (UE) comprising means for performing the operations of any one or more of claims 13–20.

23. A non-transitory computer-readable memory comprising instructions that, when executed by one or more processors of a user equipment (UE), cause the UE to perform the operations of any one or more of claims 13–20.

24. A method for wireless communication performed by an apparatus of a user equipment (UE), comprising:

transmitting a registration request message including a request to register a UE application with a local area data network (LADN) service and indicating at least a data network name (DNN) of the LADN service;

receiving a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN;

receiving, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS;

determining whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list; and

establishing a protocol data unit (PDU) session with the DNN of the LADN service based on the determination indicating that the UE is within a service area of the LADN.

25. The method of claim 24, wherein the UE is determined to be within the service area of the LADN area when the TAI associated with the DNN matches one TAI of the number of TAIs in the broadcasted TAI list.

26. The method of claim 24, wherein the UE is determined to be outside the service area of the LADN when the TAI associated with the DNN does not match any TAI of the number of TAIs in the broadcasted TAI list.

27. The method of claim 24, further comprising:

refraining from requesting or establishing the PDU session with the DNN of the LADN service based on the determination indicating that the UE is not within the service area of the LADN.

28. The method of claim 24, wherein establishing the PDU session comprises:

transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service; and

receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

29. The method of claim 24, wherein the registration request message is transmitted to a core network, and the registration accept message is received from the core network.

30. The method of claim 24, wherein the broadcasted TAI list is included in a system information block (SIB) received from the BS on a physical downlink control channel (PDCCH).

31. The method of claim 30, wherein determining whether the UE is within the service area of the LADN is further based on a cell identity (ID) of the BS.

32. The method of claim 24, wherein the UE has a subscription to the DNN.

33. The method of claim 24, wherein the UE includes at least a high-level operating system (HLOS) and a modem, the method further comprising:

sending a LADN Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least the DNN of the LADN service; and

sending a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service.

34. The method of claim 33, further comprising:

sending a setup request from the application to the modem via the HLOS, the setup request including the DNN of the LADN service and a request to register the UE application with the LADN service; and

sending a setup response from the modem to the application via the HLOS, the setup response indicating successful establishment of the PDU session with the DNN of the LADN service.

35. A user equipment (UE), comprising:

one or more processors; and

a memory coupled to the one or more processors and storing instructions that, when executed by the one or more processors, cause the UE to perform the operations of any one or more of claims 24–34.

36. A user equipment (UE) comprising means for performing the operations of any one or more of claims 24–34.

37. A non-transitory computer-readable memory comprising instructions that, when executed by one or more processors of a user equipment (UE), cause the UE to perform the operations of any one or more of claims 24–34.

38. A method for wireless communication performed by an apparatus of a user equipment (UE), comprising:

transmitting a message including:

a request to register a UE application with a local area data network (LADN) service,

a request to setup a protocol data unit (PDU) session with a data network name (DNN) of the LADN service when available to the UE, and

the DNN of the LADN service;

receiving an accept message including:

the DNN of the LADN service,

a tracking area identity (TAI) associated with the DNN, and

an indication that the UE is registered with the LADN service;

determining that the LADN service is available to the UE; and

establishing the PDU session with the DNN of the LADN based on the determination and the request to setup the PDU session.

39. The method of claim 38, further comprising:

receiving a system information block (SIB) broadcast from a base station (BS);

wherein determining that the LADN service is available to the UE is based on identity information included in the broadcasted SIB.

40. The method of claim 39, wherein the identity information includes at least one of a tracking area identity (TAI) or a cell identifier (ID).

41. The method of claim 40, wherein the TAI is received from the BS on a physical downlink control channel (PDCCH).

42. The method of claim 38, wherein determining that the LADN service is available to the UE includes receiving a UE Presence Indication from a core network.

43. The method of claim 38, wherein establishing the PDU session comprises:

transmitting, to a core network, a PDU Session Establishment request including at least the DNN of the LADN service; and receiving, from the core network, a PDU Session Establishment accept message indicating successful establishment of the PDU session with the DNN of the LADN service.

44. The method of claim 38, wherein the UE has a subscription to the DNN.

45. The method of claim 38, wherein the UE includes at least a high-level operating system (HLOS) and a modem, the method further comprising:

sending a Request and Setup message from the application to the modem via the HLOS, the Request and Setup message including the request to register the UE application, the request to setup the PDU session, and the DNN of the LADN service; and

sending a setup response message from the modem to the application via the HLOS, the setup response message indicating successful establishment of the PDU session with the LADN service.

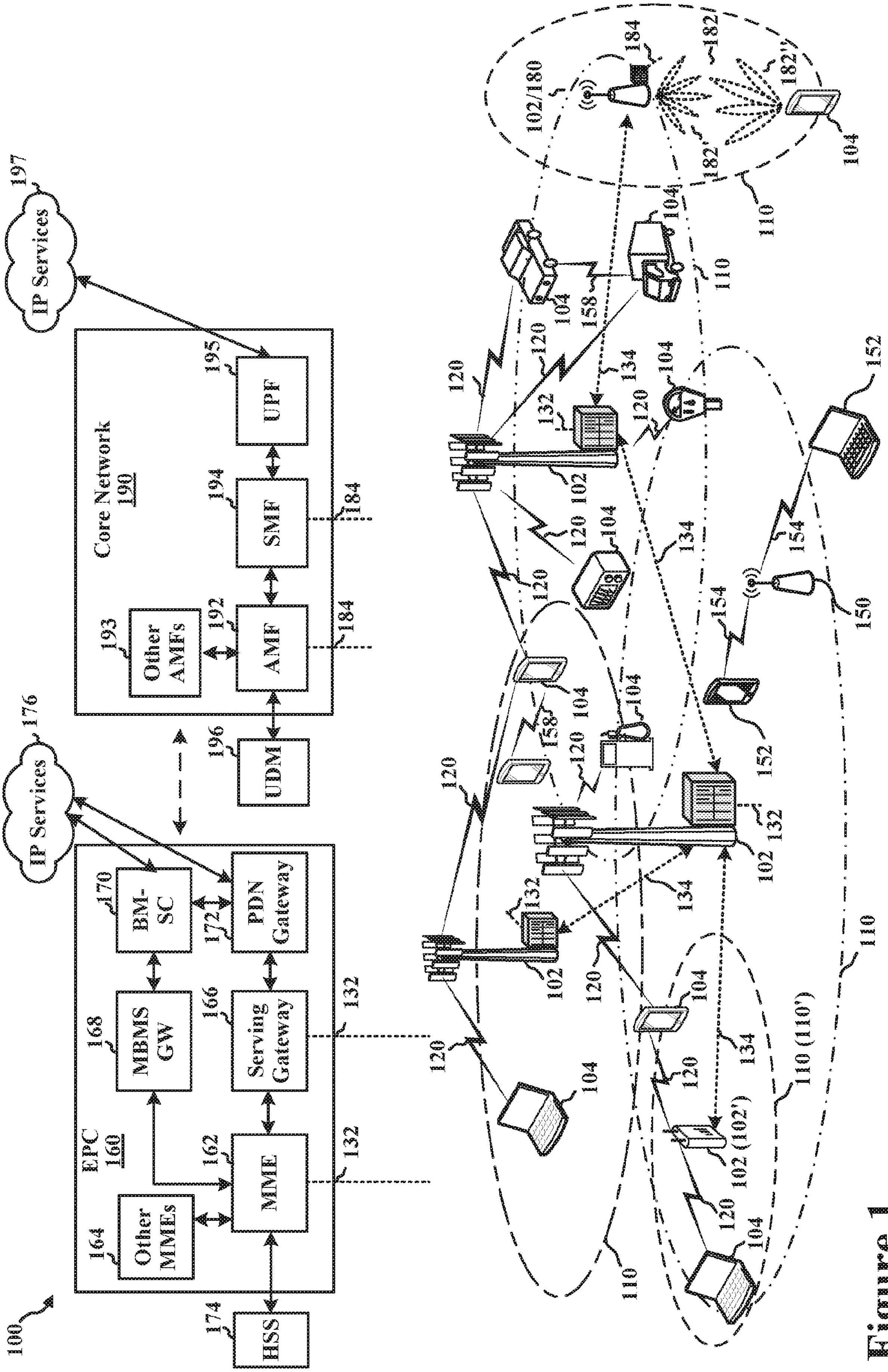
46. A user equipment (UE), comprising:

one or more processors; and

a memory coupled to the one or more processors and storing instructions that, when executed by the one or more processors, cause the UE to perform the operations of any one or more of claims 38–45.

47. A user equipment (UE) comprising means for performing the operations of any one or more of claims 38–45.

48. A non-transitory computer-readable memory comprising instructions that, when executed by one or more processors of a user equipment (UE), cause the UE to perform the operations of any one or more of claims 38–45.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EPC
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Other MMEs
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MME
162
MBMS GW
168
Serving Gateway
166
BM-SC
170
PDN Gateway
172
HSS
174
IP Services
176
Core Network
190
Other AMFs
193
AMF
192
SMF
194
UPF
195
UDM
196
IP Services
197
132
184
102
104
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182''
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Figure 1

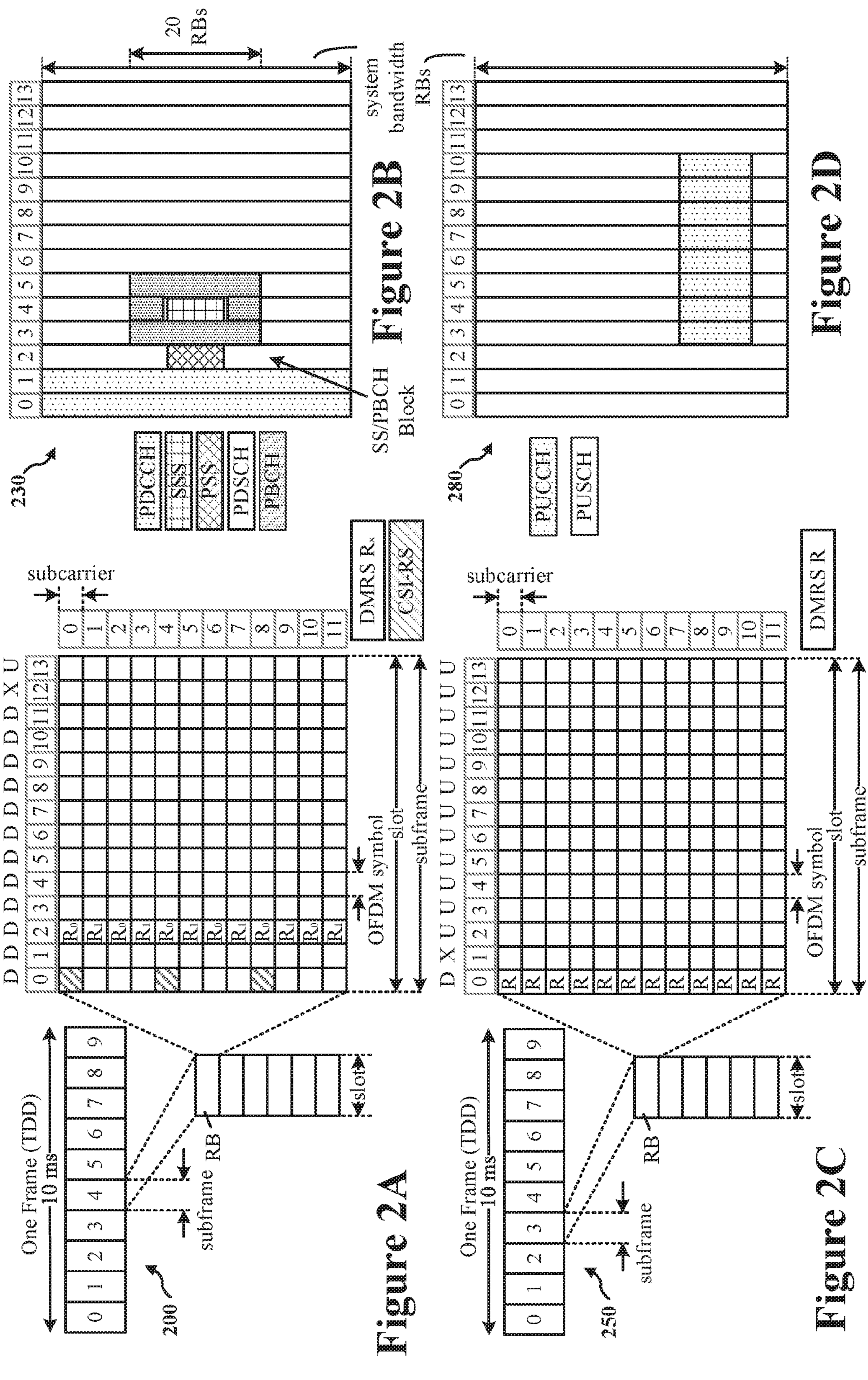
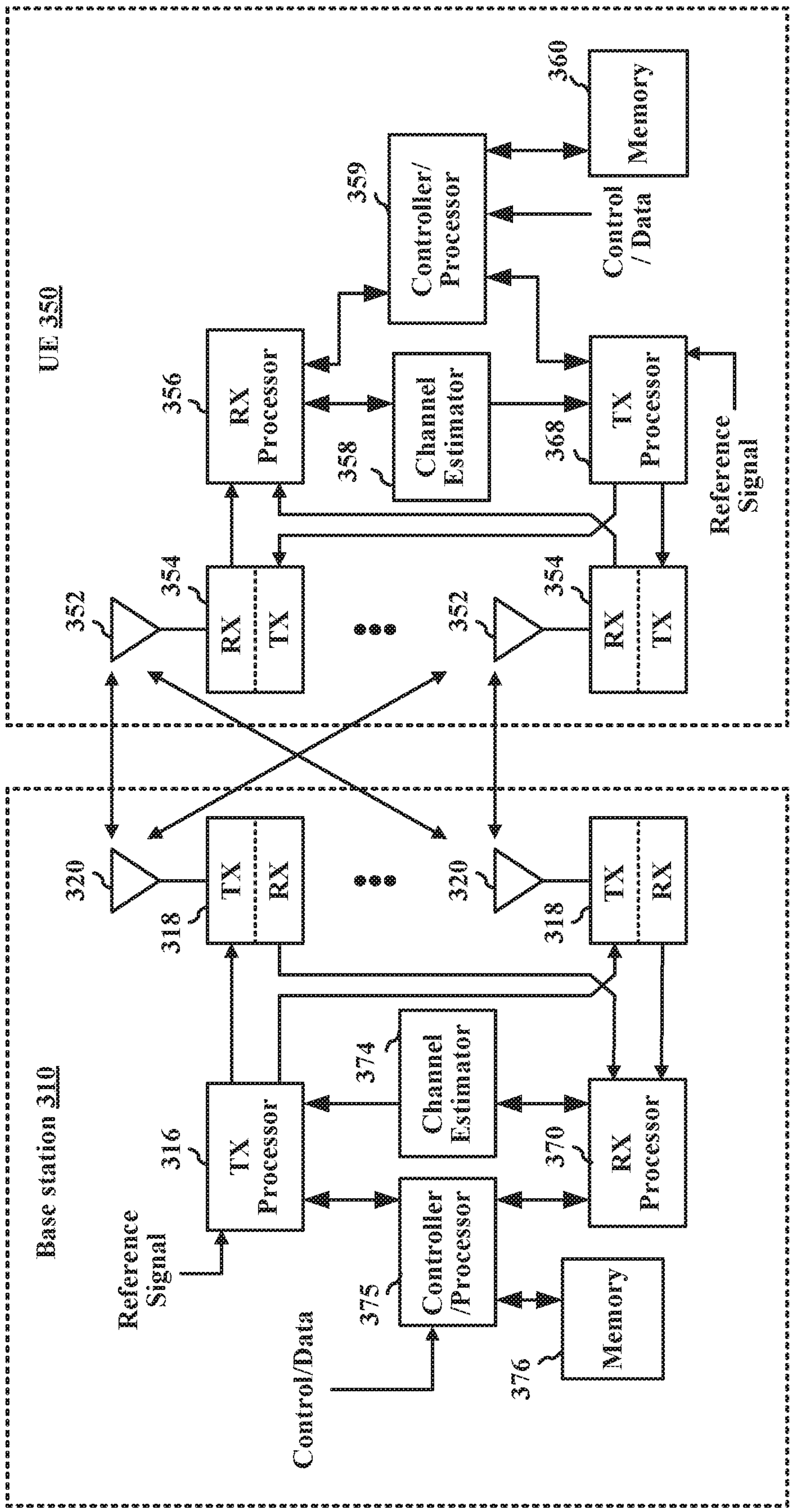


Figure 2A

Figure 2B

Figure 2C

Figure 2D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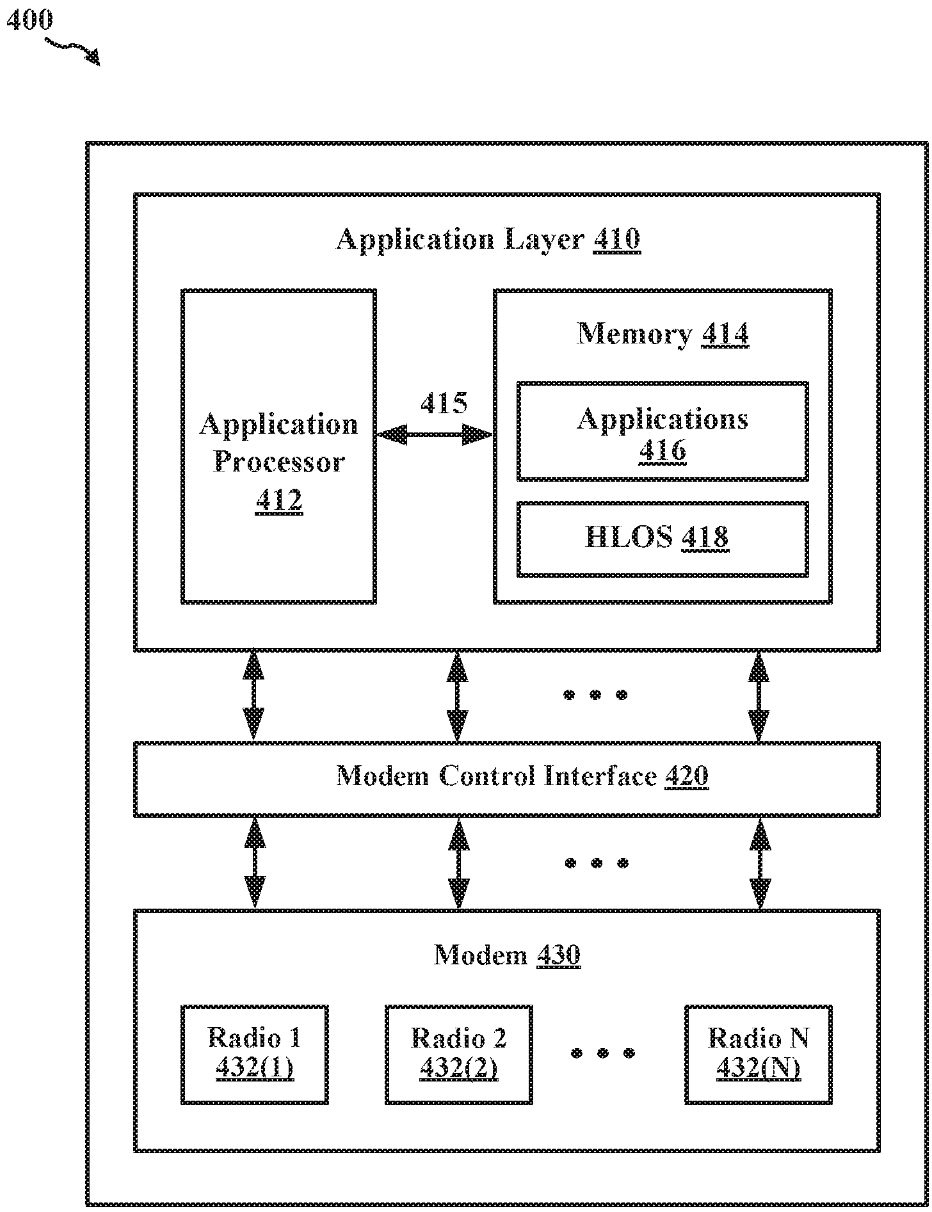
352
354
RX
TX
356
RX Processor
358
Channel Estimator
368
TX Processor
359
Controller/ Processor
360
Memory
Control / Data
Reference Signal
Base station 310
320
318
TX
RX
316
TX Processor
374
Channel Estimator
370
RX Processor
375
Controller /Processor
376
Memory
Reference Signal
Control/Data

Figure 3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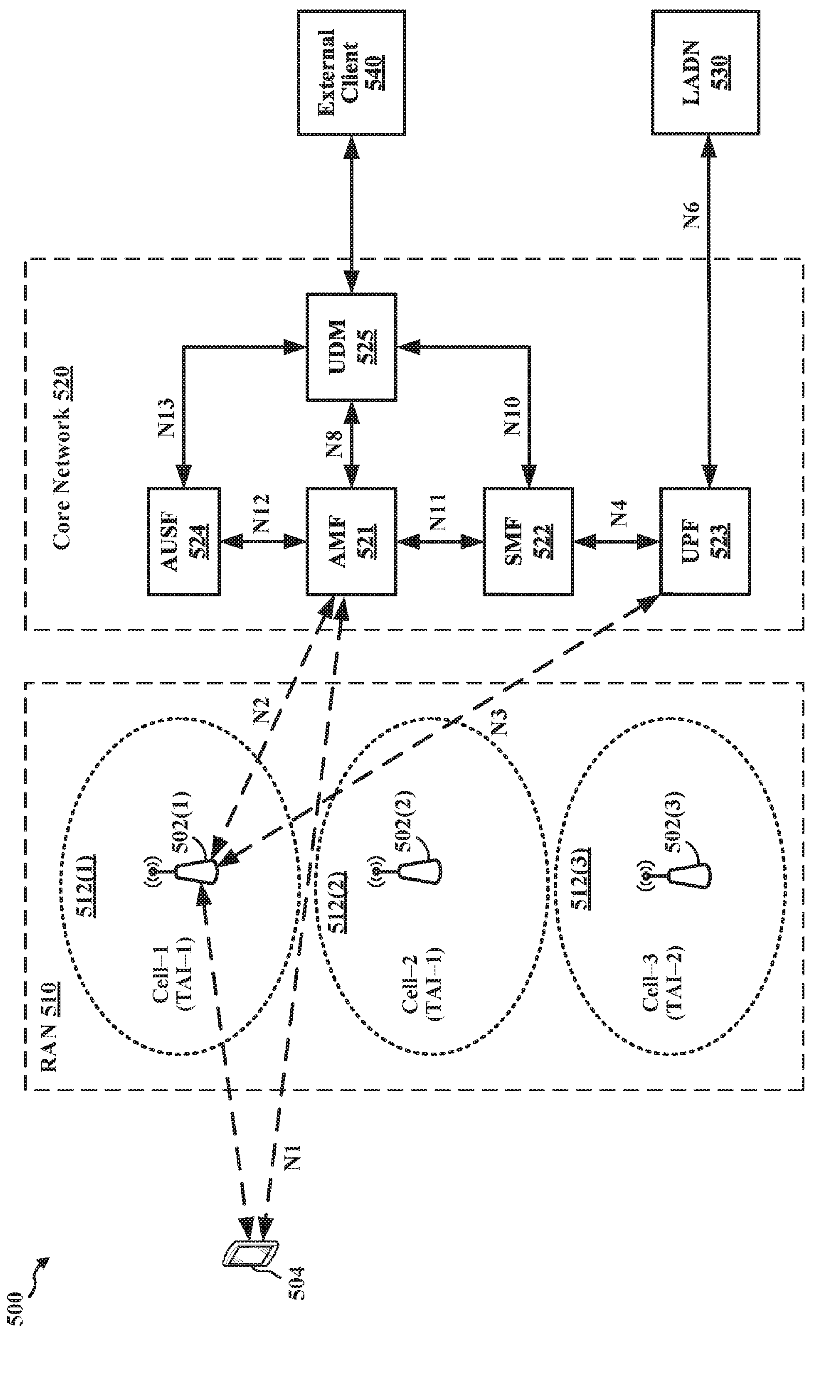
Application Layer 410
Application Processor 412
415
Memory 414
Applications 416
HLOS 418
Modem Control Interface 420
Modem 430
Radio 1 432(1)
Radio 2 432(2)
Radio N 432(N)

Figure 4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504
N1
RAN 510
Cell–1 (TAI–1)
512(1)
502(1)
Cell–2 (TAI–1)
512(2)
502(2)
Cell–3 (TAI–2)
512(3)
502(3)
N2
N3
Core Network 520
AUSF 524
AMF 521
SMF 522
UPF 523
UDM 525
N12
N11
N4
N13
N8
N10
N6
External Client 540
LADN 530

Figure 5

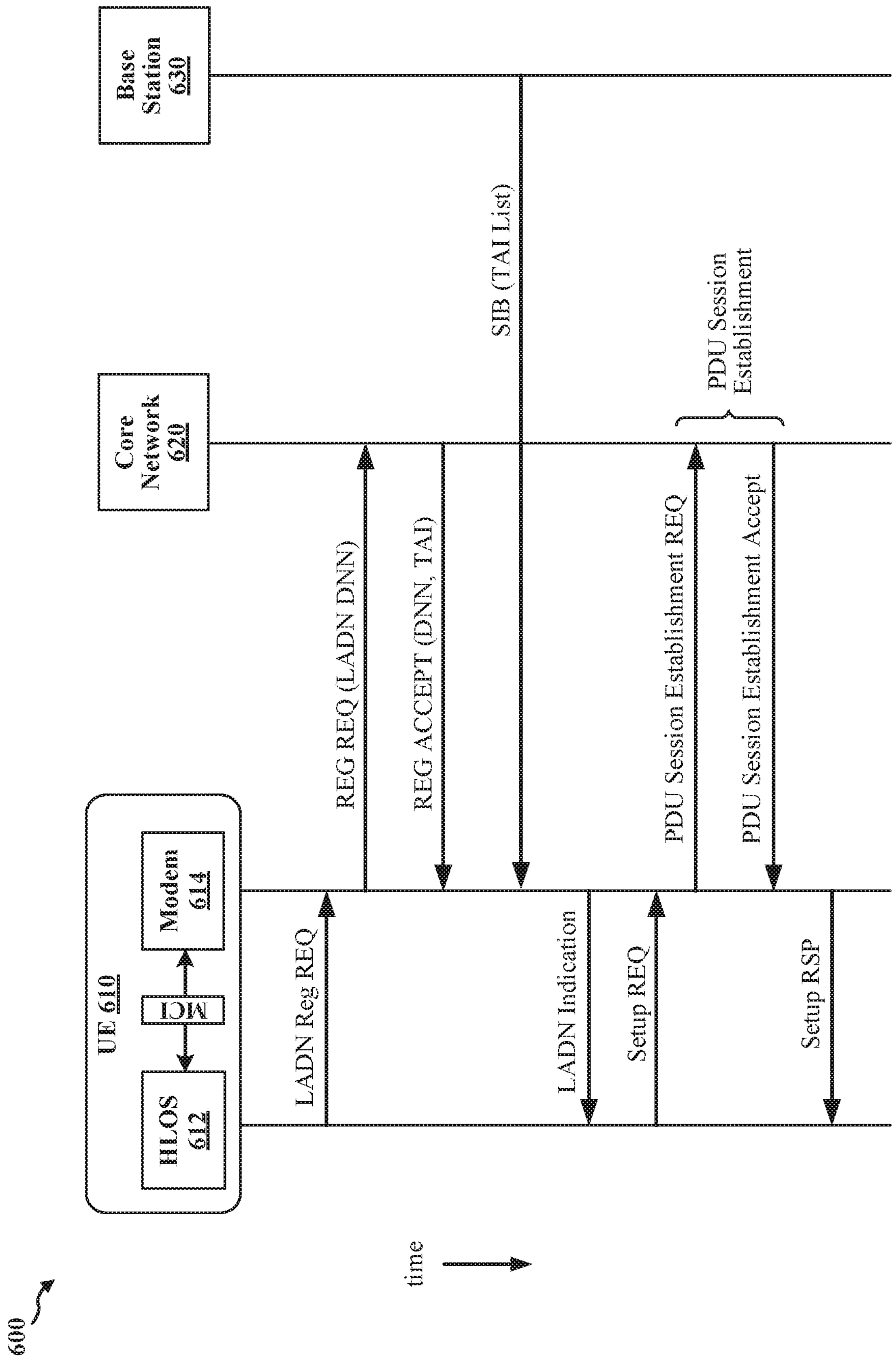
600
Base Station 630
Core Network 620
UE 610
HLOS 612
MCI
Modem 614
time
LADN Reg REQ
REG REQ (LADN DNN)
REG ACCEPT (DNN, TAI)
SIB (TAI List)
LADN Indication
Setup REQ
PDU Session Establishment REQ
PDU Session Establishment Accept
PDU Session Establishment
Setup RSP

Figure 6

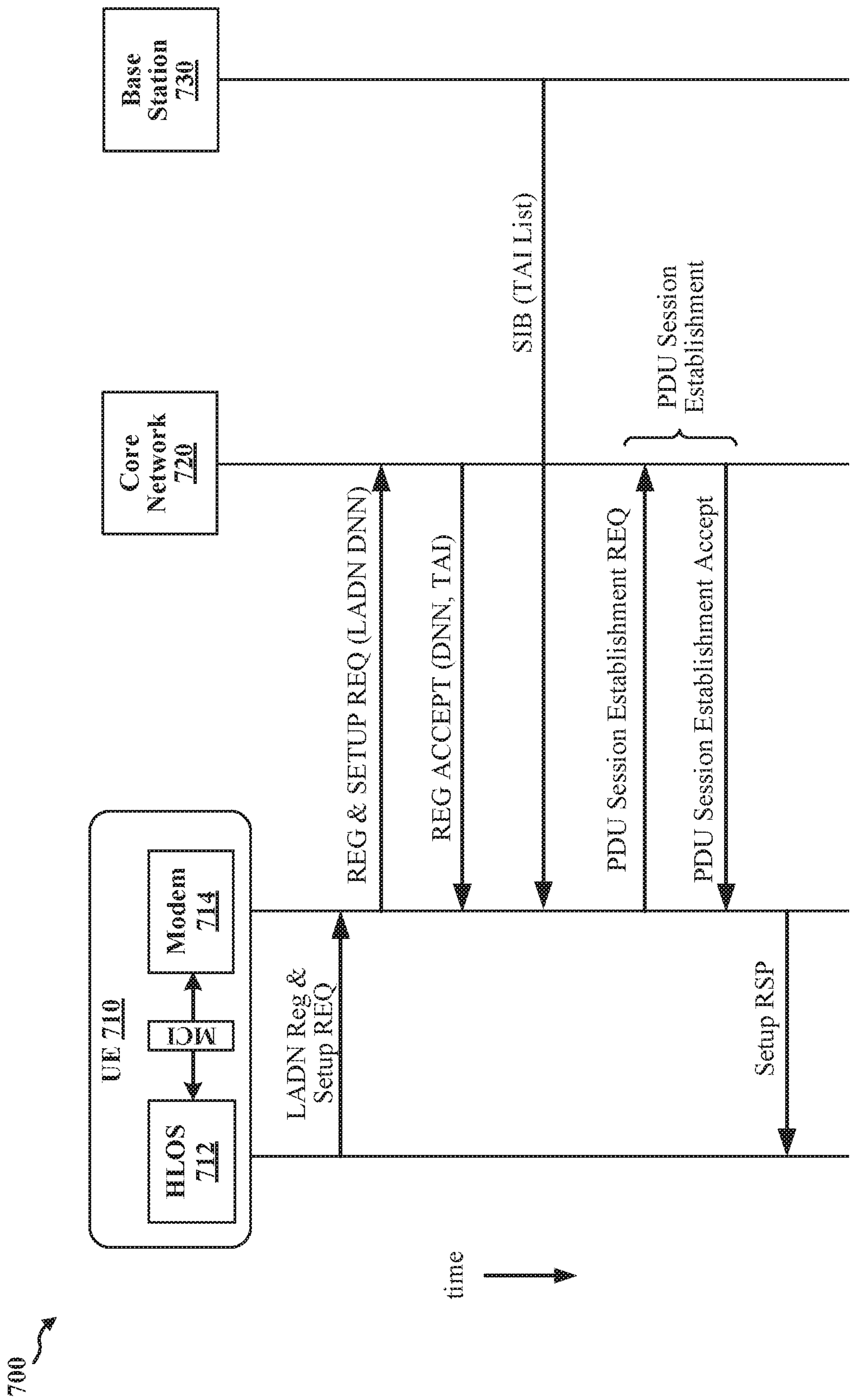
700
UE 710
HLOS 712
MCI
Modem 714
Core Network 720
Base Station 730
time
LADN Reg & Setup REQ
REG & SETUP REQ (LADN DNN)
REG ACCEPT (DNN, TAI)
SIB (TAI List)
PDU Session Establishment REQ
PDU Session Establishment Accept
PDU Session Establishment
Setup RSP

Figure 7

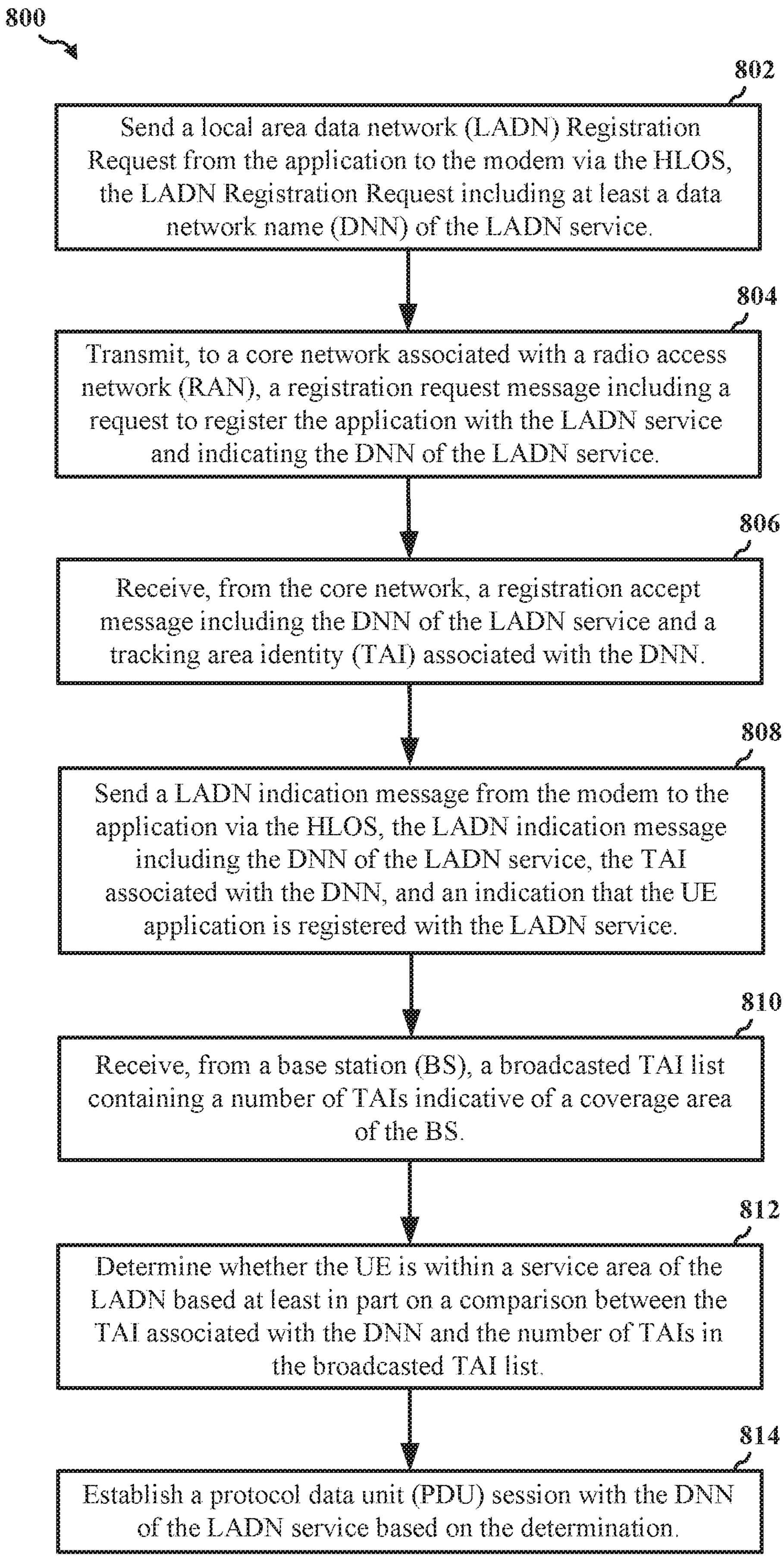
800
802
Send a local area data network (LADN) Registration Request from the application to the modem via the HLOS, the LADN Registration Request including at least a data network name (DNN) of the LADN service.
804
Transmit, to a core network associated with a radio access network (RAN), a registration request message including a request to register the application with the LADN service and indicating the DNN of the LADN service.
806
Receive, from the core network, a registration accept message including the DNN of the LADN service and a tracking area identity (TAI) associated with the DNN.
808
Send a LADN indication message from the modem to the application via the HLOS, the LADN indication message including the DNN of the LADN service, the TAI associated with the DNN, and an indication that the UE application is registered with the LADN service.
810
Receive, from a base station (BS), a broadcasted TAI list containing a number of TAIs indicative of a coverage area of the BS.
812
Determine whether the UE is within a service area of the LADN based at least in part on a comparison between the TAI associated with the DNN and the number of TAIs in the broadcasted TAI list.
814
Establish a protocol data unit (PDU) session with the DNN of the LADN service based on the determination.

Figure 8

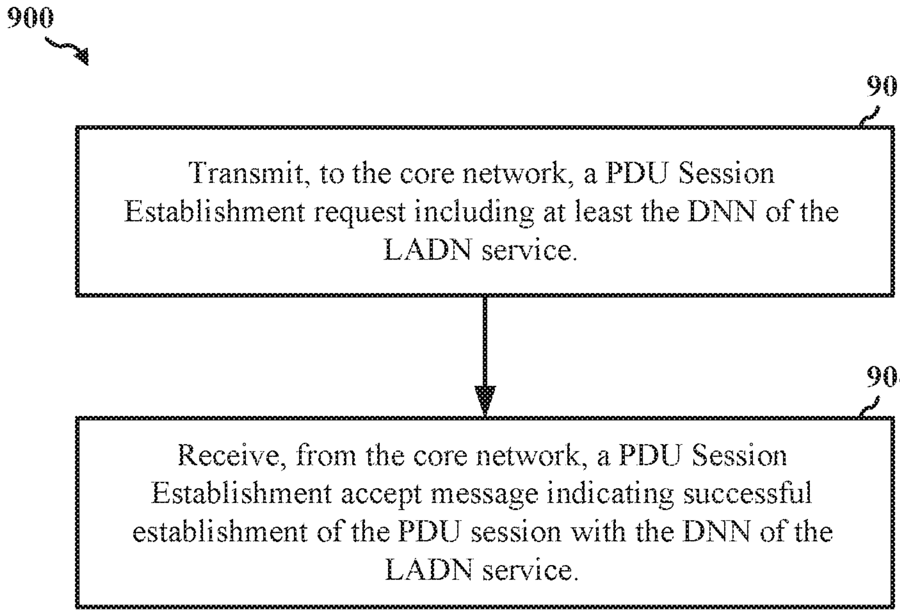

Figure 9A

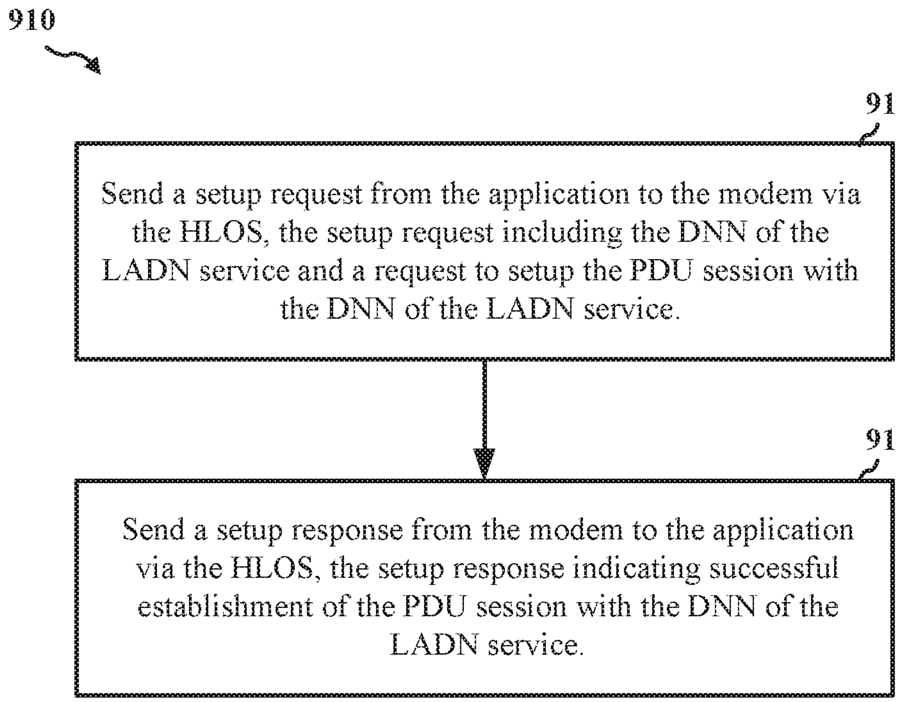

Figure 9B

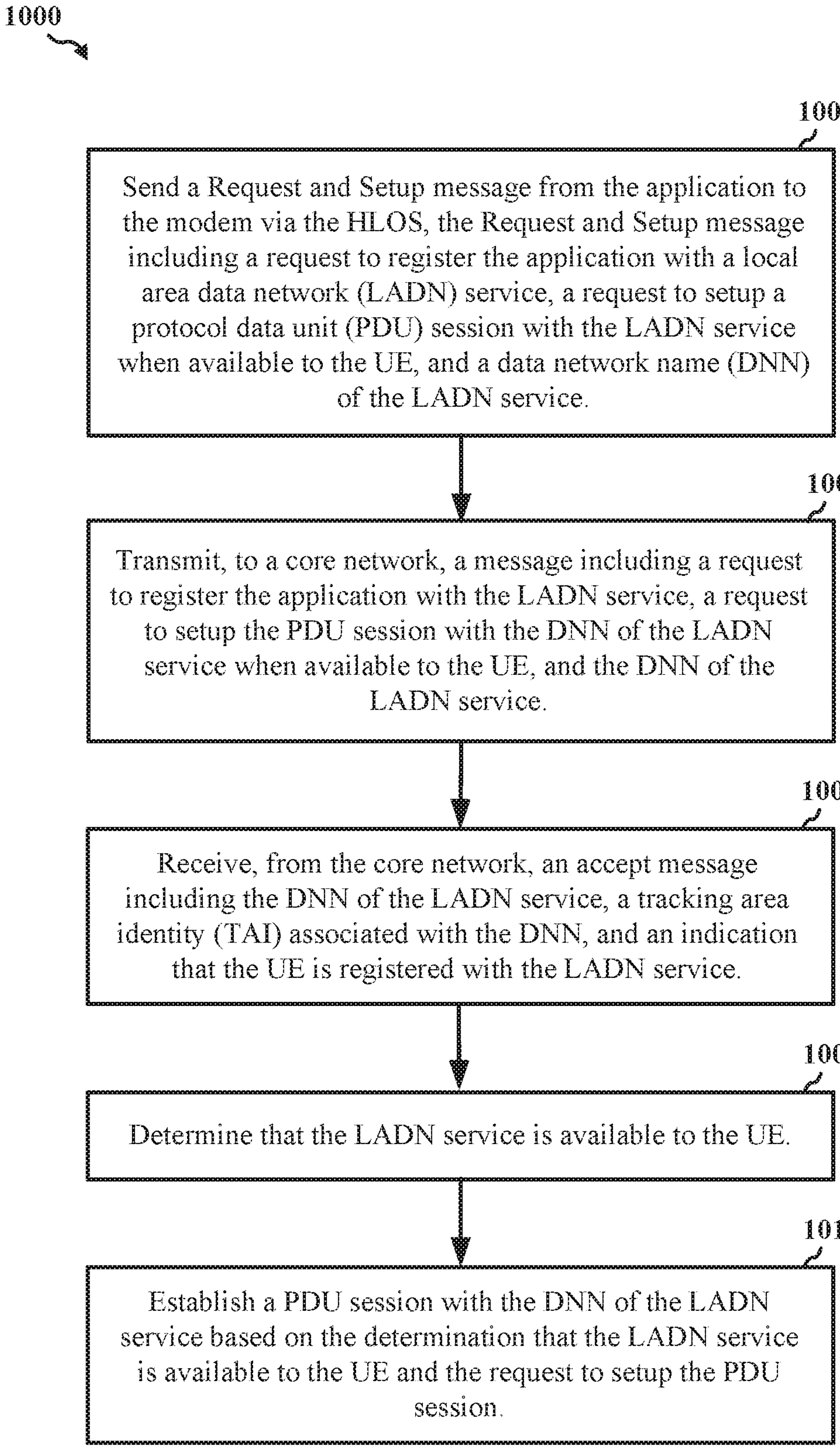
1000
1002
Send a Request and Setup message from the application to the modem via the HLOS, the Request and Setup message including a request to register the application with a local area data network (LADN) service, a request to setup a protocol data unit (PDU) session with the LADN service when available to the UE, and a data network name (DNN) of the LADN service.
1004
Transmit, to a core network, a message including a request to register the application with the LADN service, a request to setup the PDU session with the DNN of the LADN service when available to the UE, and the DNN of the LADN service.
1006
Receive, from the core network, an accept message including the DNN of the LADN service, a tracking area identity (TAI) associated with the DNN, and an indication that the UE is registered with the LADN service.
1008
Determine that the LADN service is available to the UE.
1010
Establish a PDU session with the DNN of the LADN service based on the determination that the LADN service is available to the UE and the request to setup the PDU session.

Figure 10

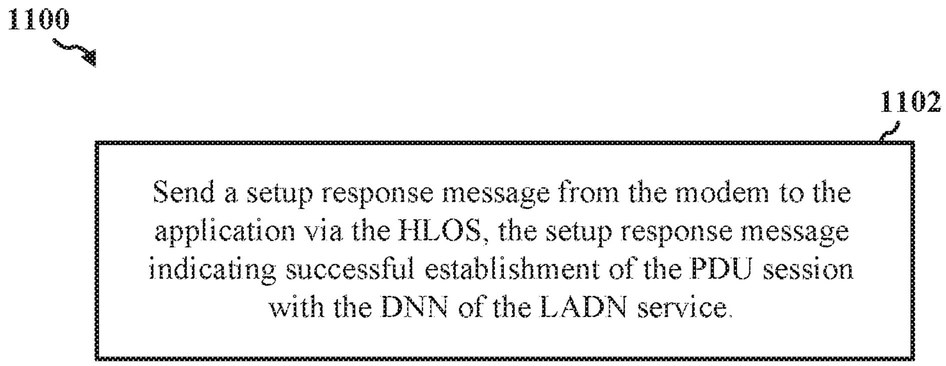

Figure 11A

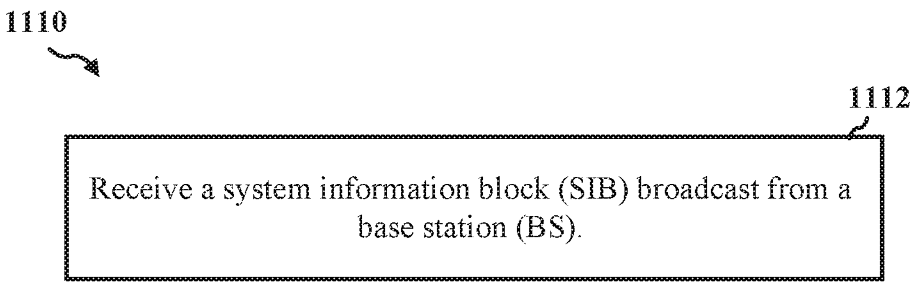

Figure 11B

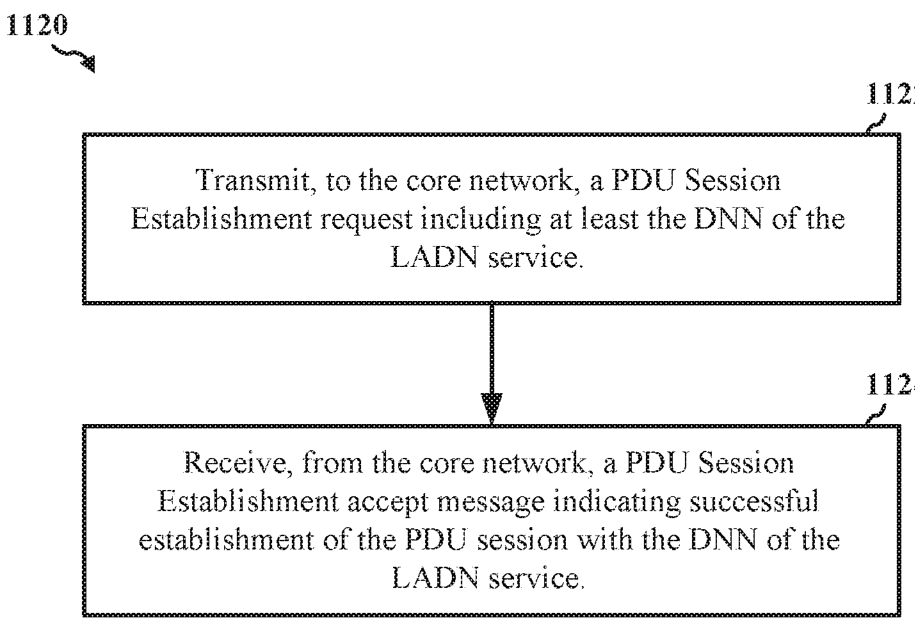

Figure 11C

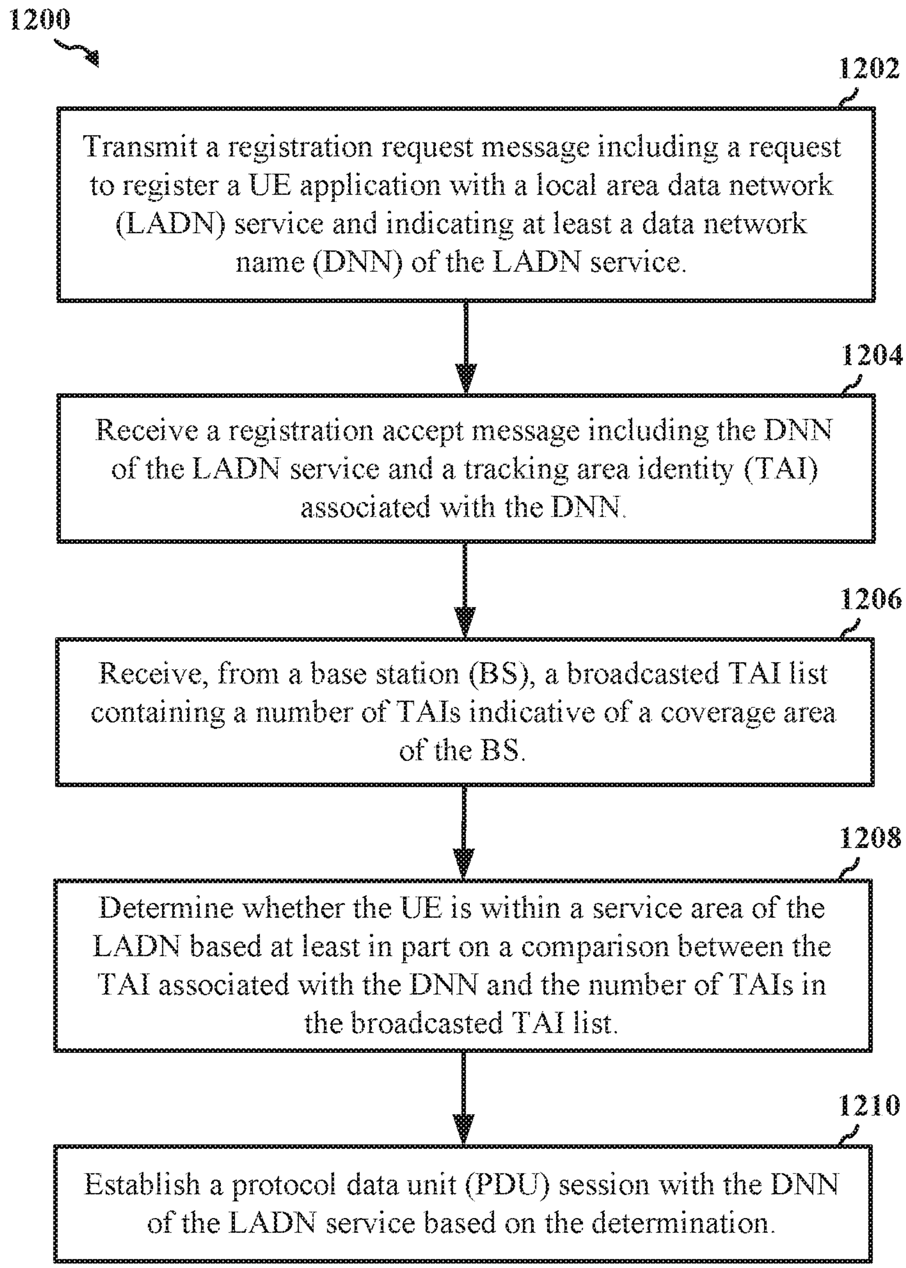

Figure 12

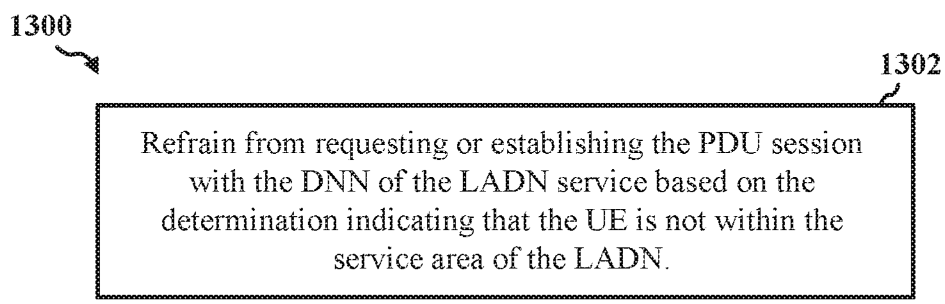

Figure 13A

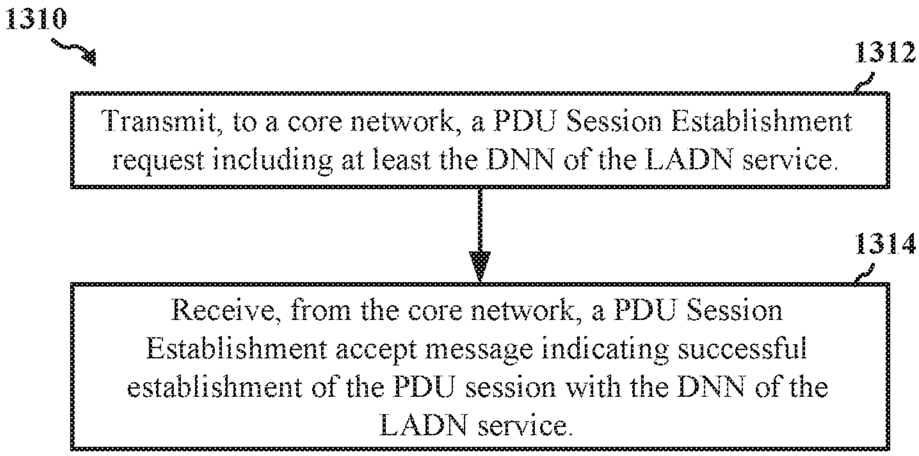

Figure 13B

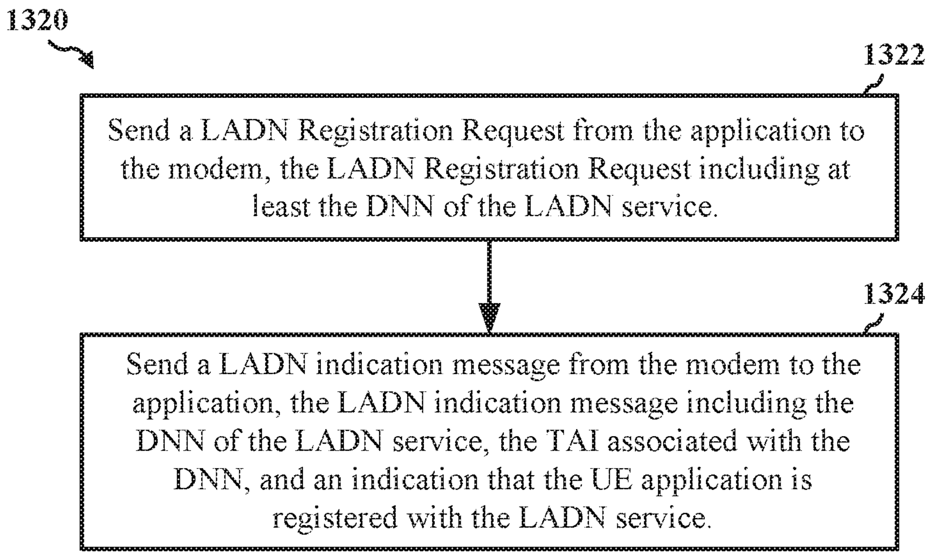

Figure 13C

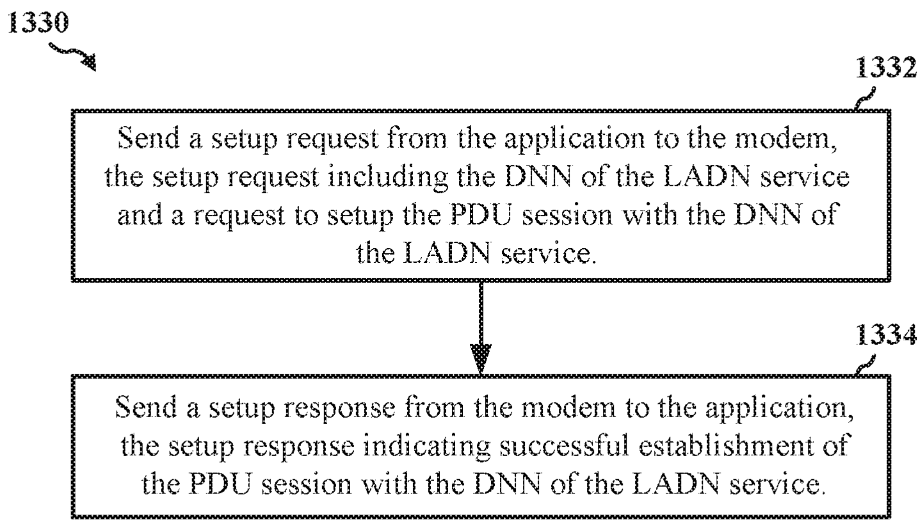

Figure 13D

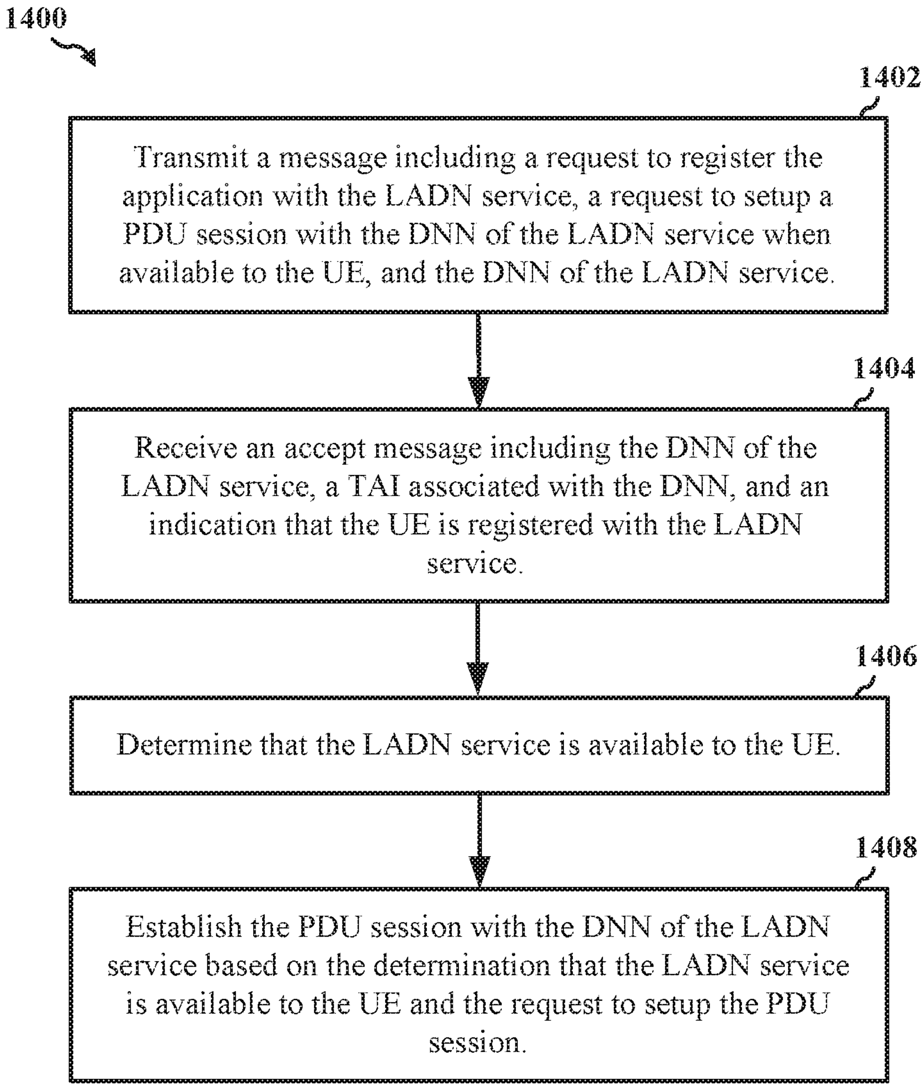

Figure 14

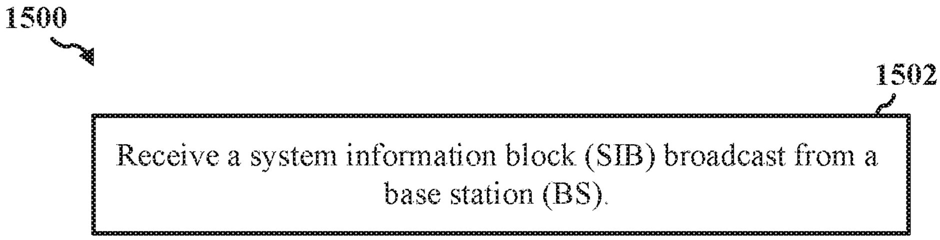

Figure 15A

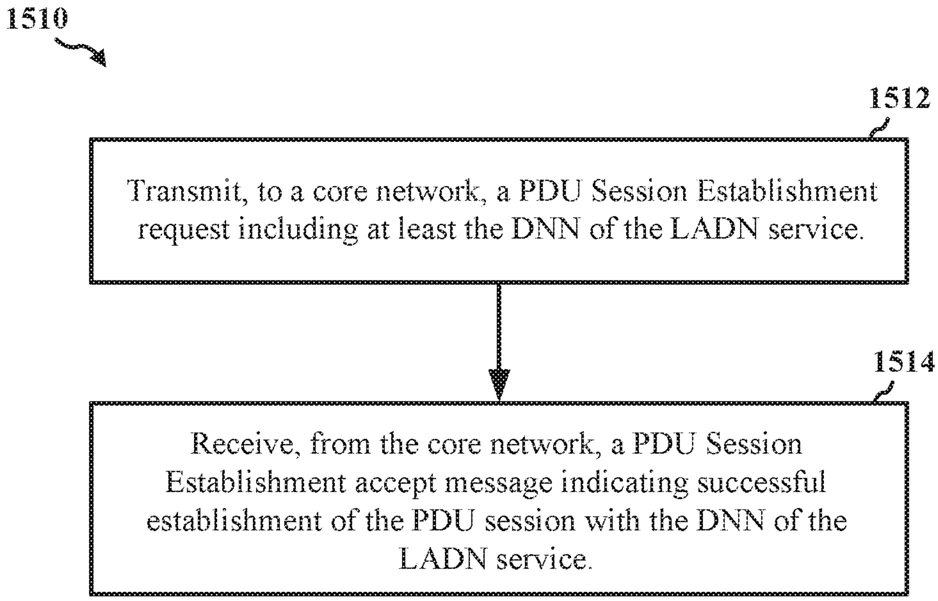

Figure 15B

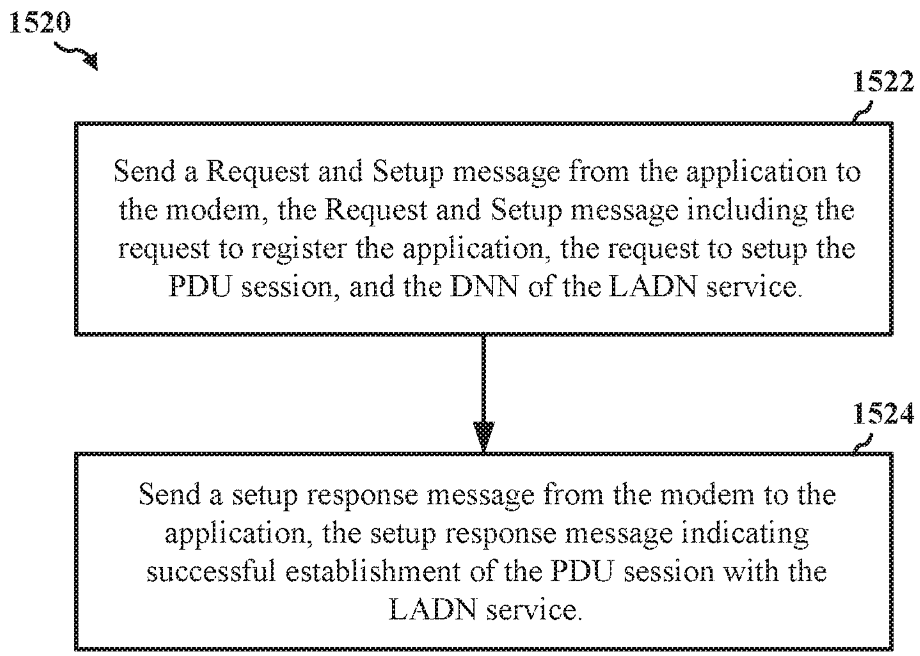

Figure 15C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/074470

A. CLASSIFICATION OF SUBJECT MATTER

H04W 4/02(2018.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, CNKI, WPI, EPODOC, 3GPP: LADN, TAI, DNN, PDU, register+, compar+, within, area, tracking area identity, broadcast+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP; Technical Specification Group Services and System Aspects. "System architecture for the 5G System (5GS); Stage 2 (Release 15)" *3GPP TS 23.501 v15.8.0 (2019-12),* 31 December 2019 (2019-12-31), section 5.3.2.3, 5.6.5	13-23,38-48
Y	3GPP; Technical Specification Group Services and System Aspects. "System architecture for the 5G System (5GS); Stage 2 (Release 15)" *3GPP TS 23.501 v15.8.0 (2019-12),* 31 December 2019 (2019-12-31), section 5.3.2.3, 5.6.5	1-12,24-37
Y	WO 2019157864 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 22 August 2019 (2019-08-22) description, page 7 line 10 to line 31	1-12,24-37
A	CN 109246853 A (HUAWEI TECHNOLOGIES CO., LTD.) 18 January 2019 (2019-01-18) the whole document	1-48
A	CN 110622572 A (SHARP KABUSHIKI KAISHA) 27 December 2019 (2019-12-27) the whole document	1-48
A	US 2019007500 A1 (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE) 03 January 2019 (2019-01-03) the whole document	1-48

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2020	**28 October 2020**

Name and mailing address of the ISA/CN

National Intellectual Property Administration, PRC
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088
China

Facsimile No. **(86-10)62019451**

Authorized officer

SU,Ning

Telephone No. **86-(10)-53961759**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/074470

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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CN	109246853	A	18 January 2019	US	2020120752	A1	16 April 2020
				KR	20190104602	A	10 September 2019
				EP	3634080	A1	08 April 2020
				JP	2020509634	A	26 March 2020
				BR	112019016891	A2	14 April 2020
CN	110622572	A	27 December 2019	US	2020120751	A1	16 April 2020
				EP	3637860	A1	15 April 2020
				WO	2018207837	A1	15 November 2018
				CA	3063020	A1	03 December 2019
				JP	2020113807	A	27 July 2020
US	2019007500	A1	03 January 2019		None		