US011956848B2

(12) **United States Patent**
Mecum et al.

(10) **Patent No.: US 11,956,848 B2**
(45) **Date of Patent: Apr. 9, 2024**

(54) **METHOD AND SYSTEM FOR DYNAMIC CONNECTED MODE DISCONTINUOUS RECEPTION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/326,514**

(22) Filed: **May 21, 2021**

(65) **Prior Publication Data**

US 2022/0377830 A1 Nov. 24, 2022

(51) **Int. Cl.**

H04W 76/28	(2018.01)
H04W 8/24	(2009.01)
H04W 48/16	(2009.01)
H04W 72/51	(2023.01)

(52) **U.S. Cl.**

CPC ***H04W 76/28*** (2018.02); ***H04W 8/24*** (2013.01); ***H04W 48/16*** (2013.01); ***H04W 72/51*** (2023.01)

(58) **Field of Classification Search**

CPC H04W 76/28; H04W 8/24; H04W 48/16; H04W 72/048

See application file for complete search history.

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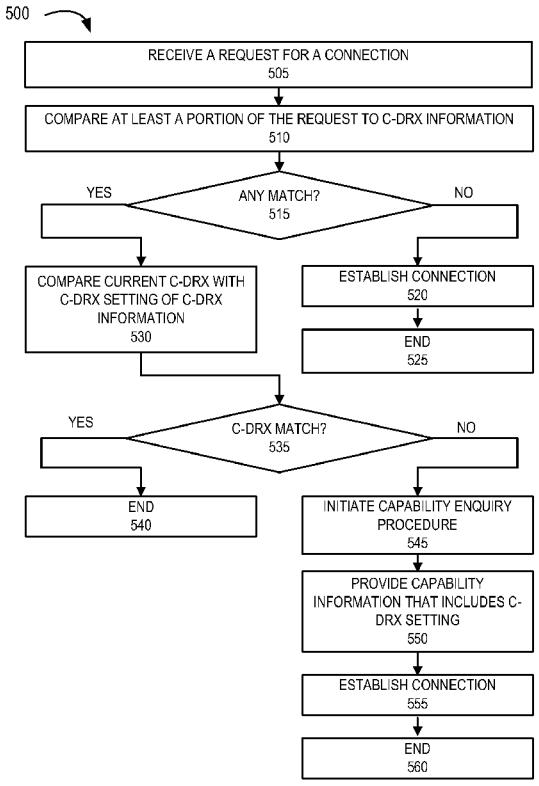
Primary Examiner — Diane D Mizrahi

(57) **ABSTRACT**

A method, a device, and a non-transitory storage medium are described in which a dynamic C-DRX provisioning service is provided. The service may disable or enable discontinuous reception on a per end device application or network slice basis. The service may invoke an end device capability procedure to modify a discontinuous reception configuration of a network. The service may store information that correlates an application or network slice to a discontinuous reception setting.

20 Claims, 12 Drawing Sheets



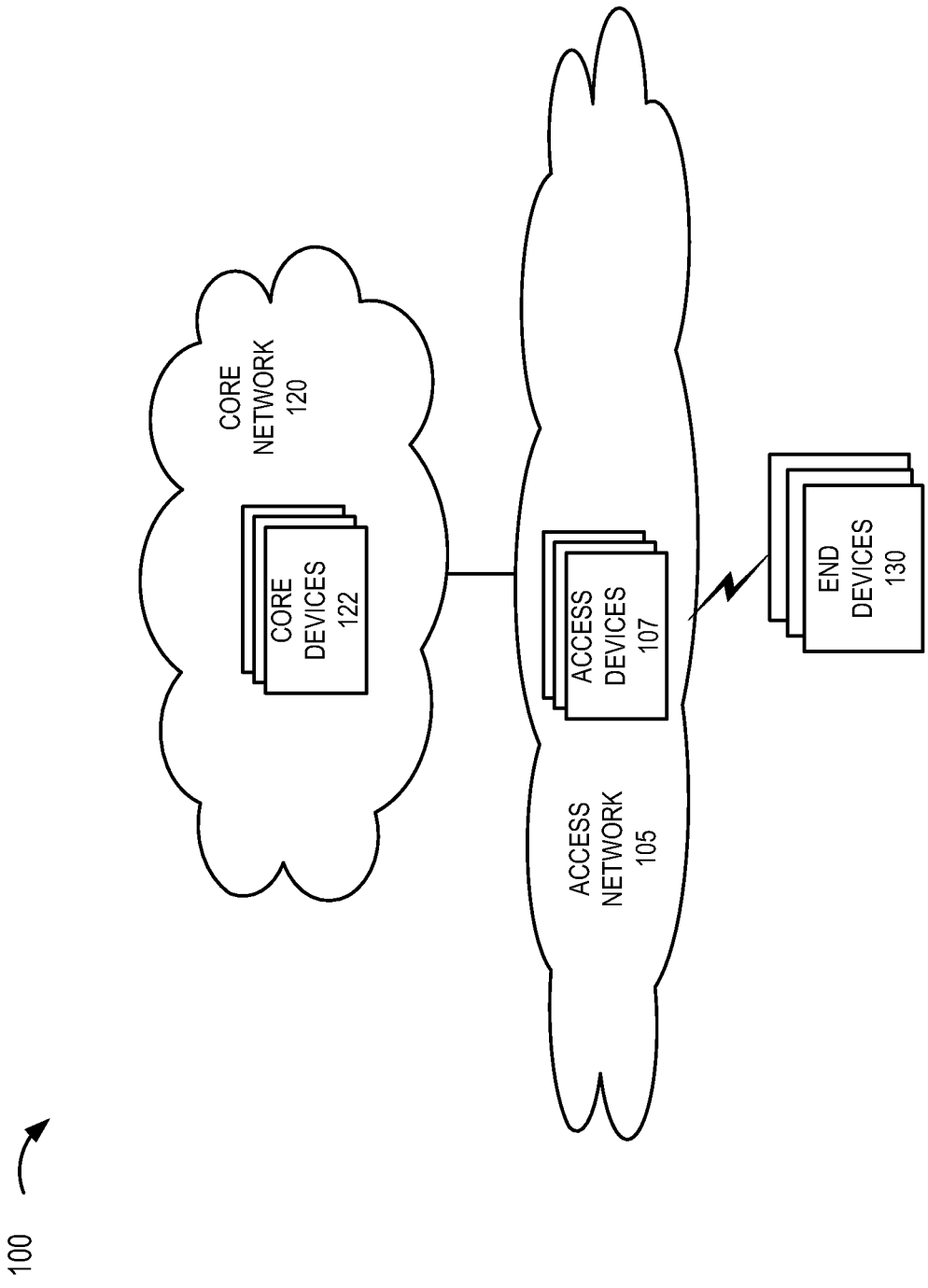

CORE NETWORK 120
CORE DEVICES 122
ACCESS DEVICES 107
ACCESS NETWORK 105
END DEVICES 130
100

Fig. 1

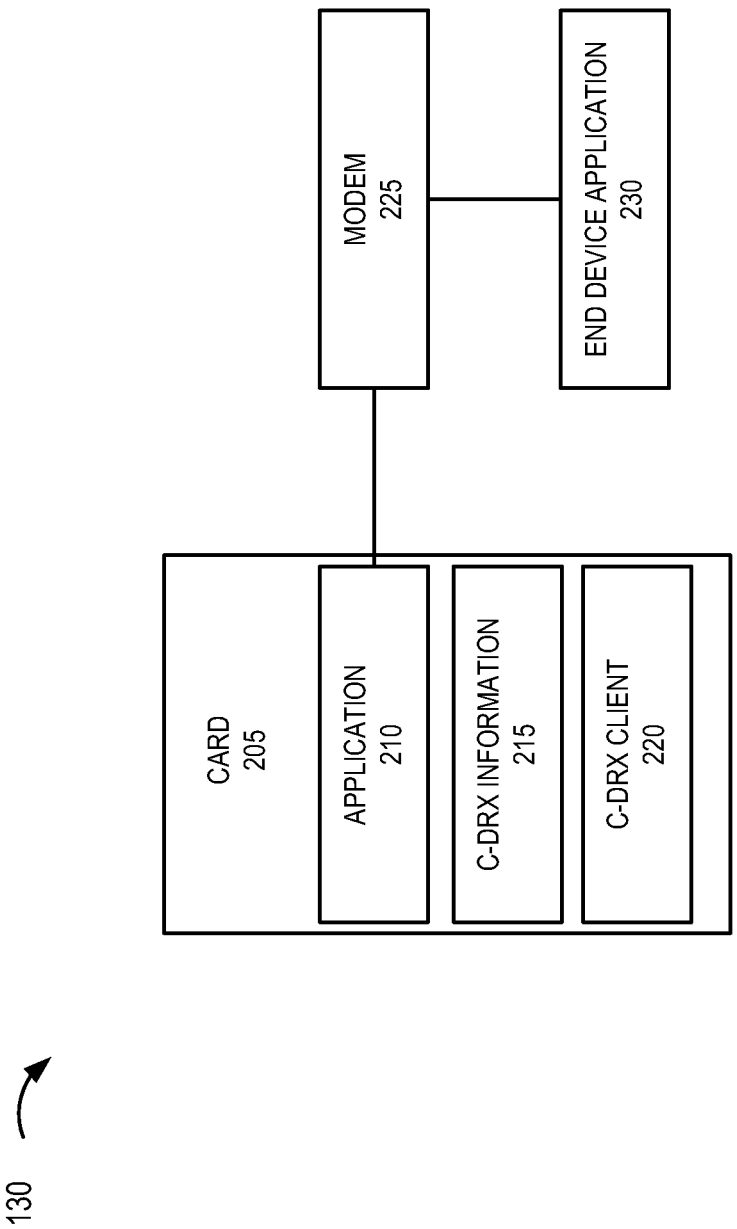

MODEM
225
END DEVICE APPLICATION
230
CARD
205
APPLICATION
210
C-DRX INFORMATION
215
C-DRX CLIENT
220
130

Fig. 2A

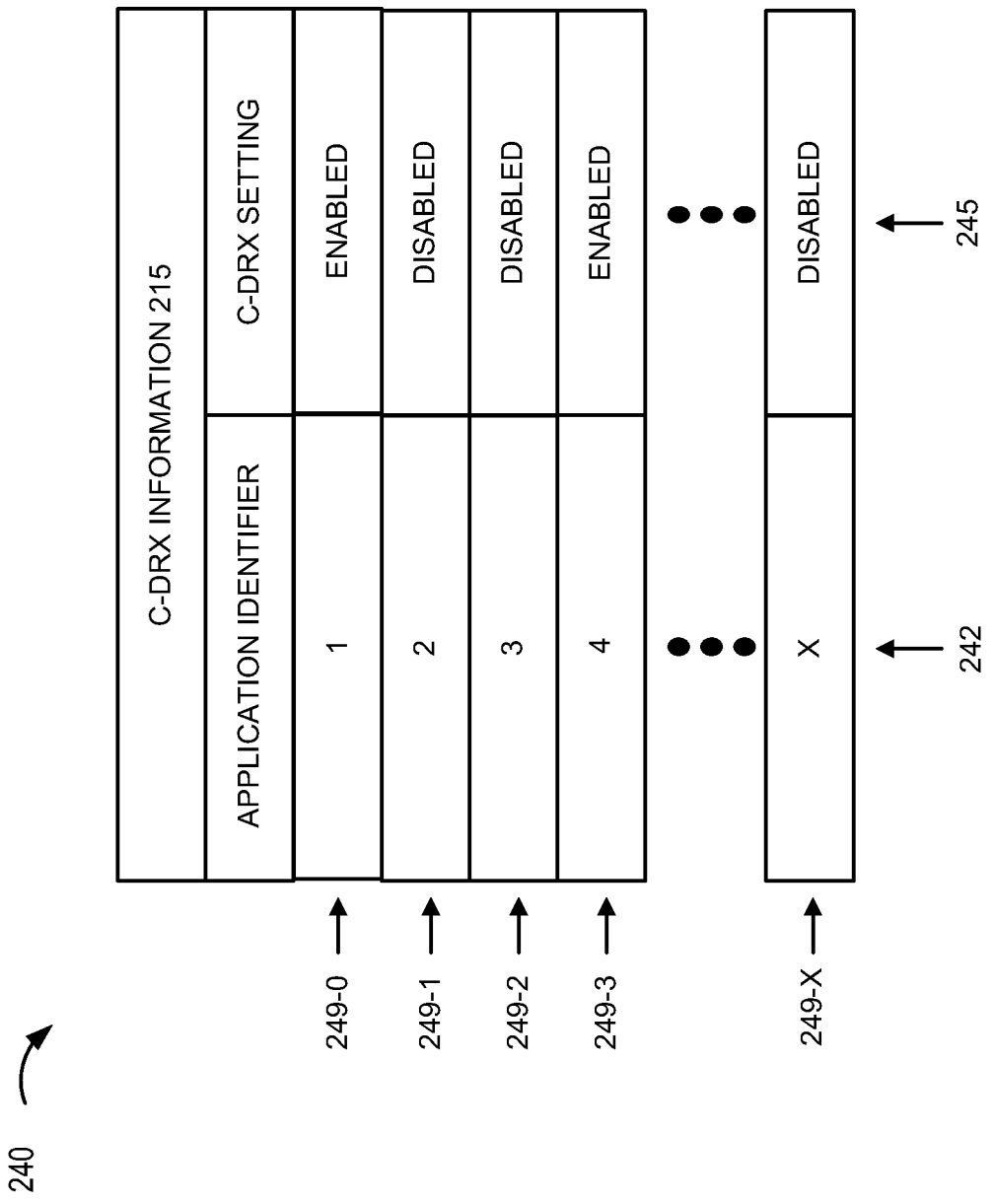
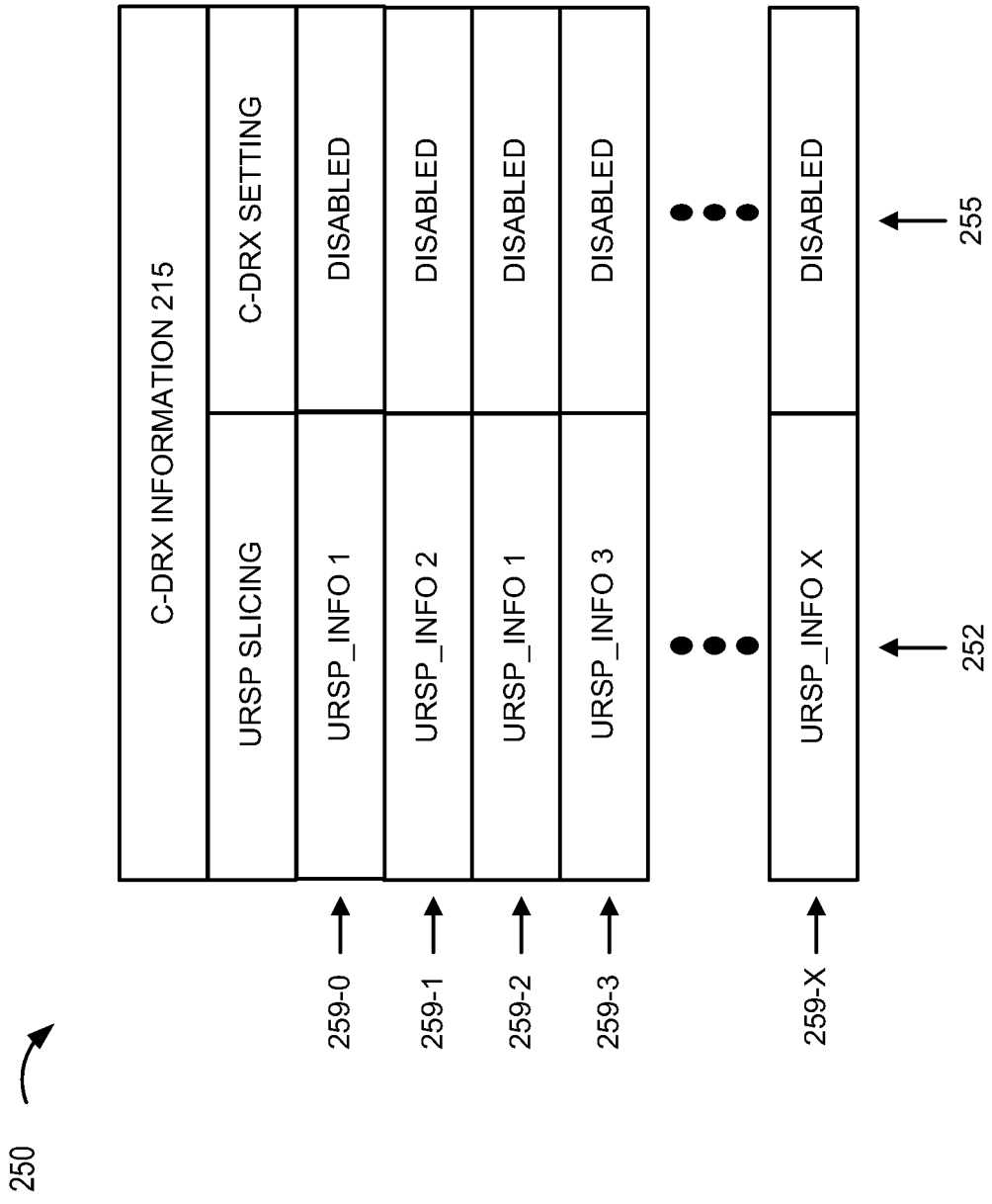

240
C-DRX INFORMATION 215
APPLICATION IDENTIFIER
C-DRX SETTING
1
ENABLED
2
DISABLED
3
DISABLED
4
ENABLED
X
DISABLED
249-0
249-1
249-2
249-3
249-X
242
245

Fig. 2B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C-DRX INFORMATION 215
URSP SLICING
C-DRX SETTING
URSP_INFO 1
DISABLED
URSP_INFO 2
DISABLED
URSP_INFO 1
DISABLED
URSP_INFO 3
DISABLED
URSP_INFO X
DISABLED
259-0
259-1
259-2
259-3
259-X
252
255

Fig. 2C

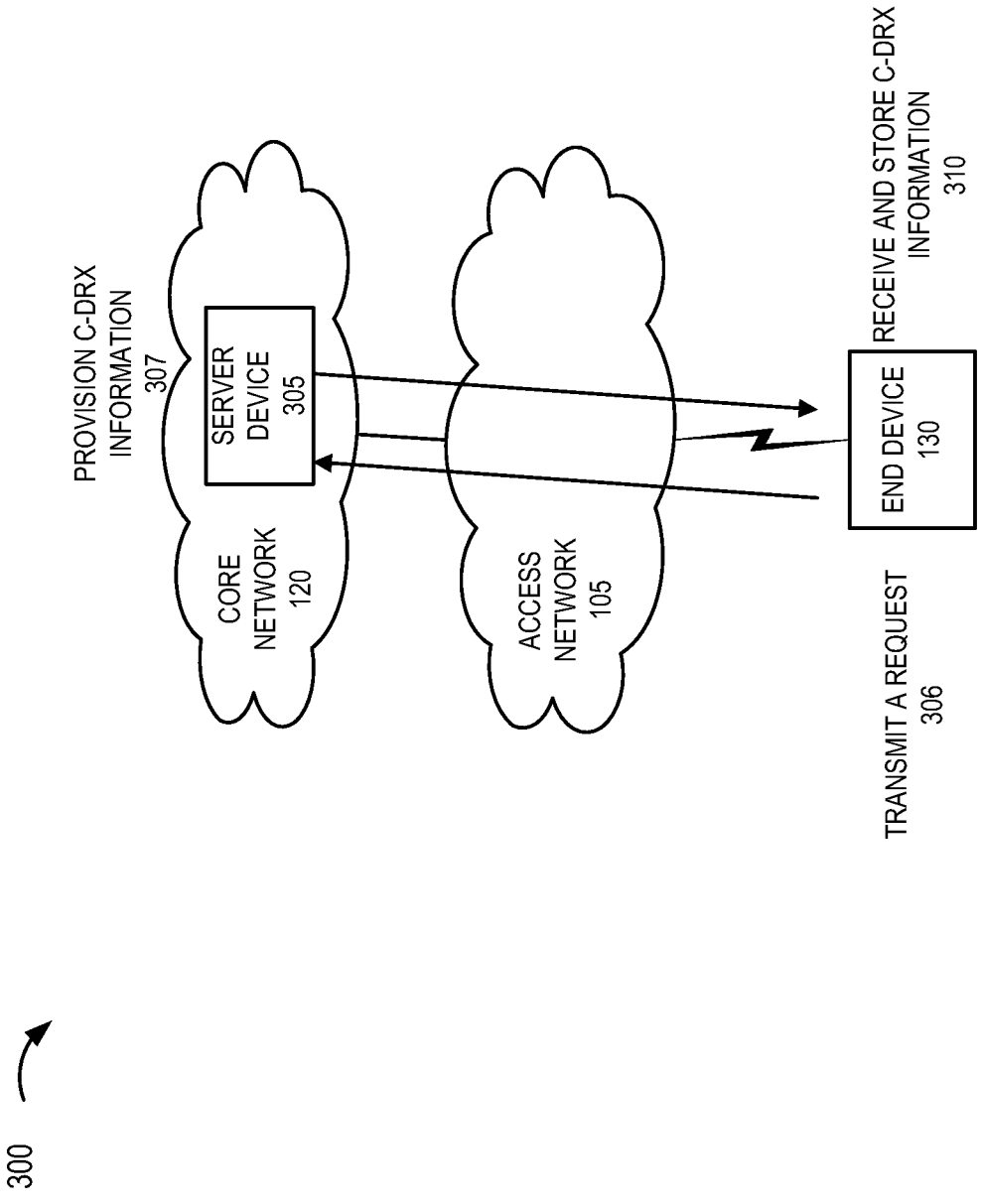

300
PROVISION C-DRX INFORMATION 307
SERVER DEVICE 305
CORE NETWORK 120
ACCESS NETWORK 105
END DEVICE 130
RECEIVE AND STORE C-DRX INFORMATION 310
TRANSMIT A REQUEST 306

Fig. 3A

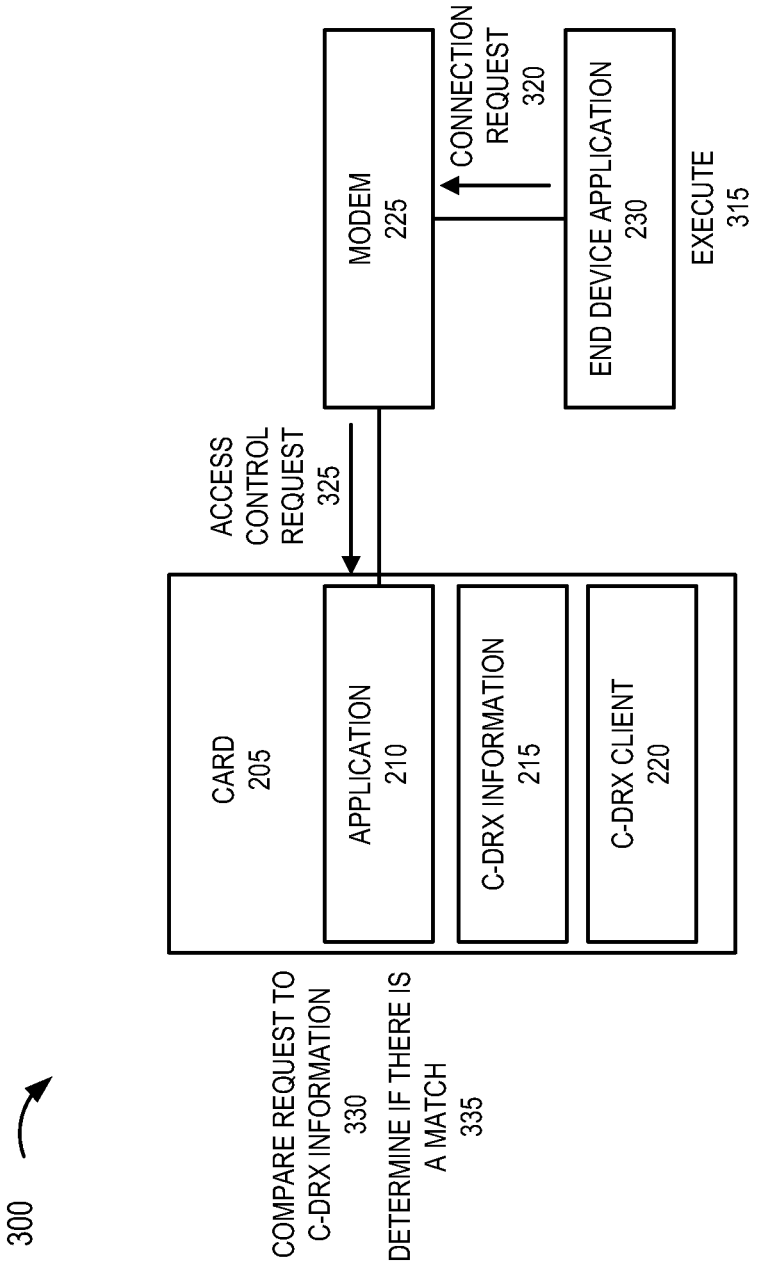
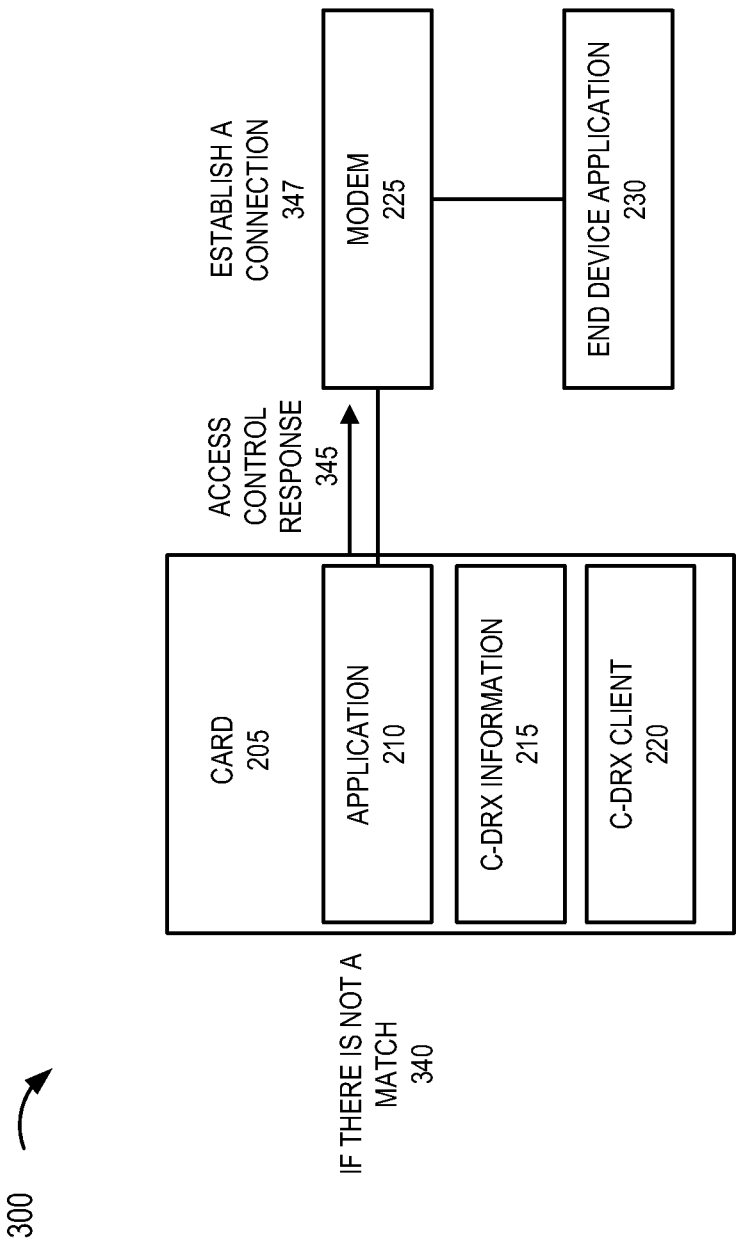

300
CARD
205
APPLICATION
210
C-DRX INFORMATION
215
C-DRX CLIENT
220
MODEM
225
END DEVICE APPLICATION
230
ACCESS CONTROL REQUEST
325
CONNECTION REQUEST
320
EXECUTE
315
COMPARE REQUEST TO C-DRX INFORMATION
330
DETERMINE IF THERE IS A MATCH
335

Fig. 3B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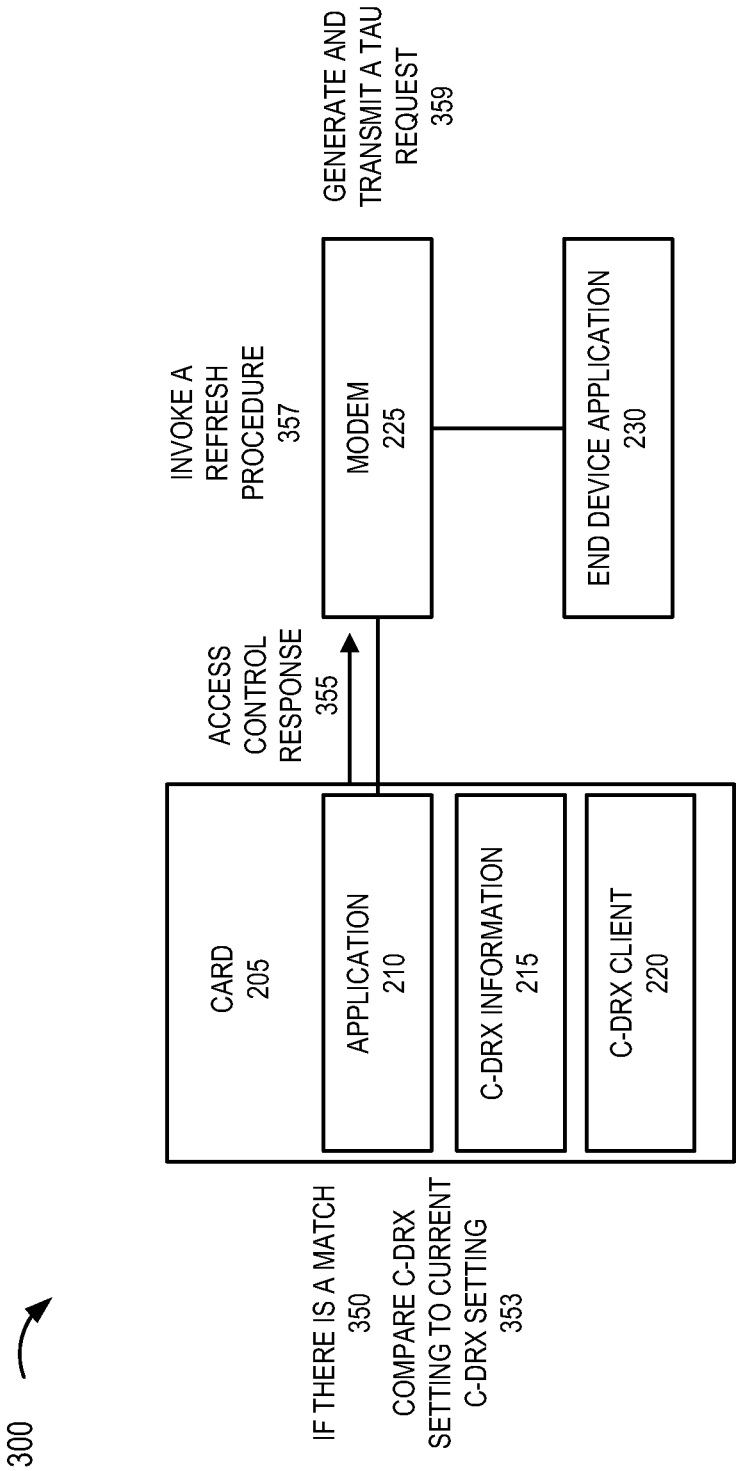
IF THERE IS NOT A MATCH 340
CARD 205
APPLICATION 210
C-DRX INFORMATION 215
C-DRX CLIENT 220
ACCESS CONTROL RESPONSE 345
ESTABLISH A CONNECTION 347
MODEM 225
END DEVICE APPLICATION 230

Fig. 3C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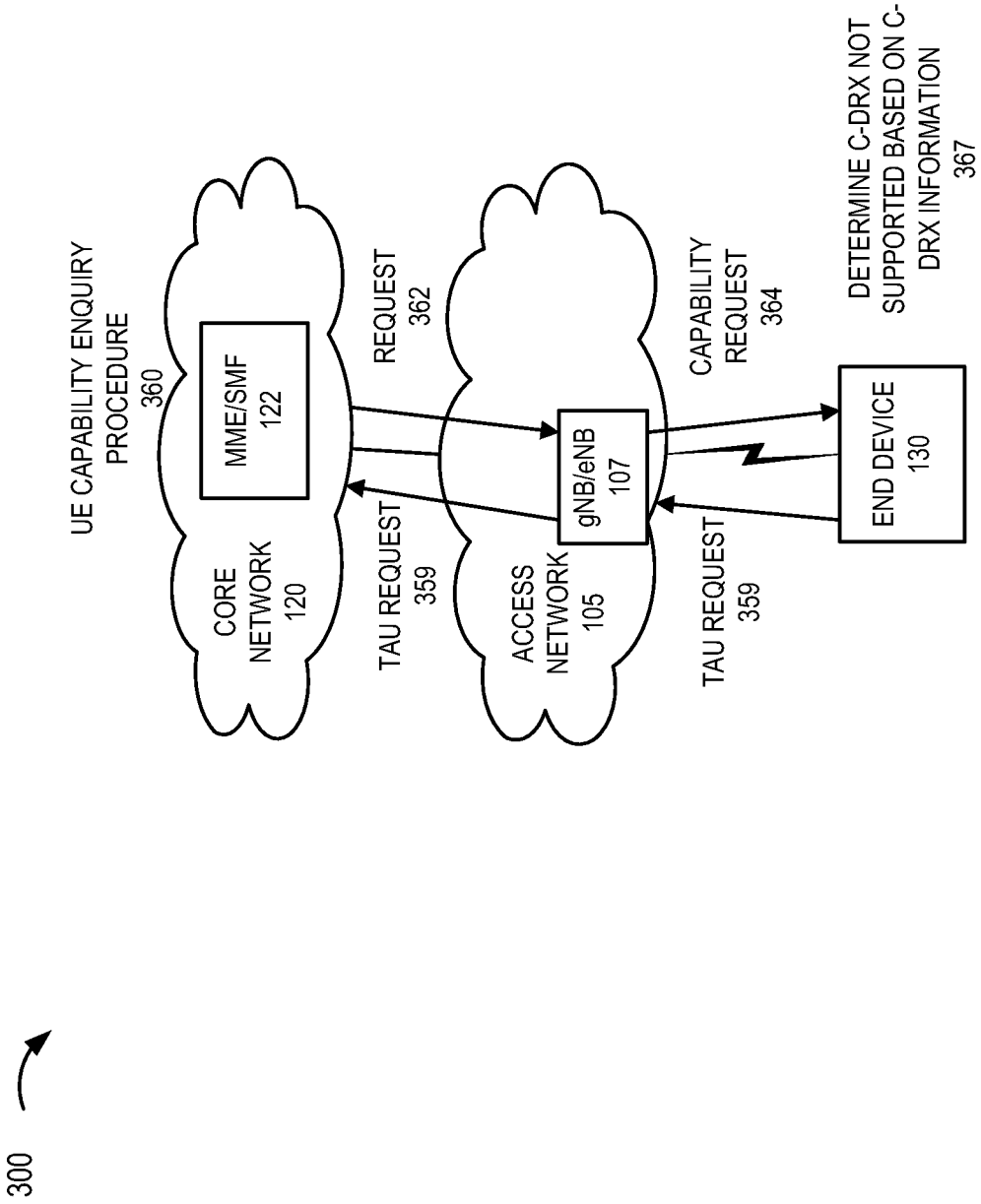
IF THERE IS A MATCH
350
COMPARE C-DRX
SETTING TO CURRENT
C-DRX SETTING
353
CARD
205
APPLICATION
210
C-DRX INFORMATION
215
C-DRX CLIENT
220
ACCESS
CONTROL
RESPONSE
355
INVOKE A
REFRESH
PROCEDURE
357
MODEM
225
END DEVICE APPLICATION
230
GENERATE AND
TRANSMIT A TAU
REQUEST
359

Fig. 3D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UE CAPABILITY ENQUIRY PROCEDURE 360
CORE NETWORK 120
MME/SMF 122
TAU REQUEST 359
REQUEST 362
ACCESS NETWORK 105
gNB/eNB 107
TAU REQUEST 359
CAPABILITY REQUEST 364
END DEVICE 130
DETERMINE C-DRX NOT SUPPORTED BASED ON C-DRX INFORMATION 367

Fig. 3E

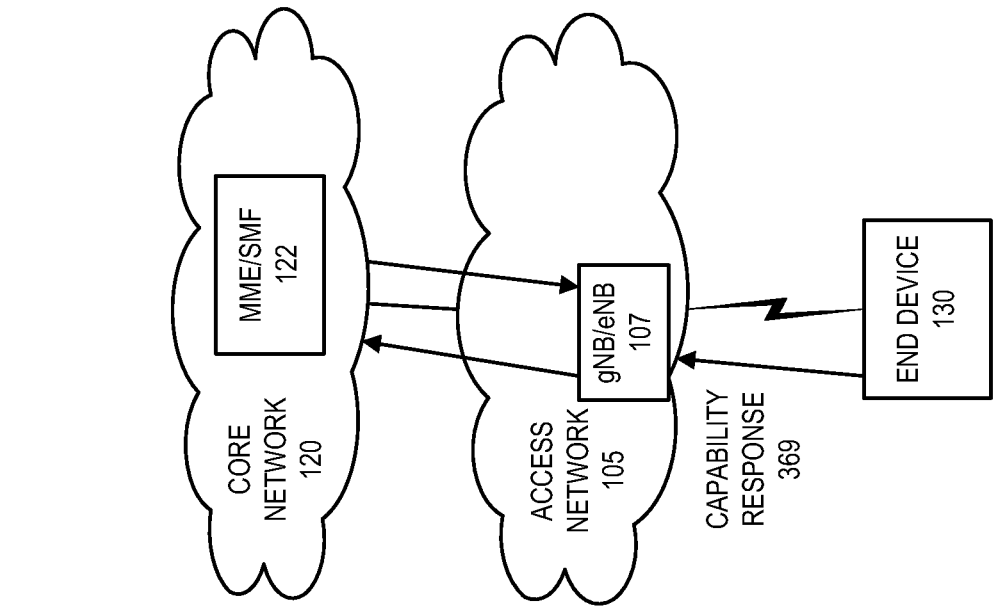
MME/SMF
122
CORE
NETWORK
120
gNB/eNB
107
ACCESS
NETWORK
105
CAPABILITY
RESPONSE
369
END DEVICE
130
300

Fig. 3F

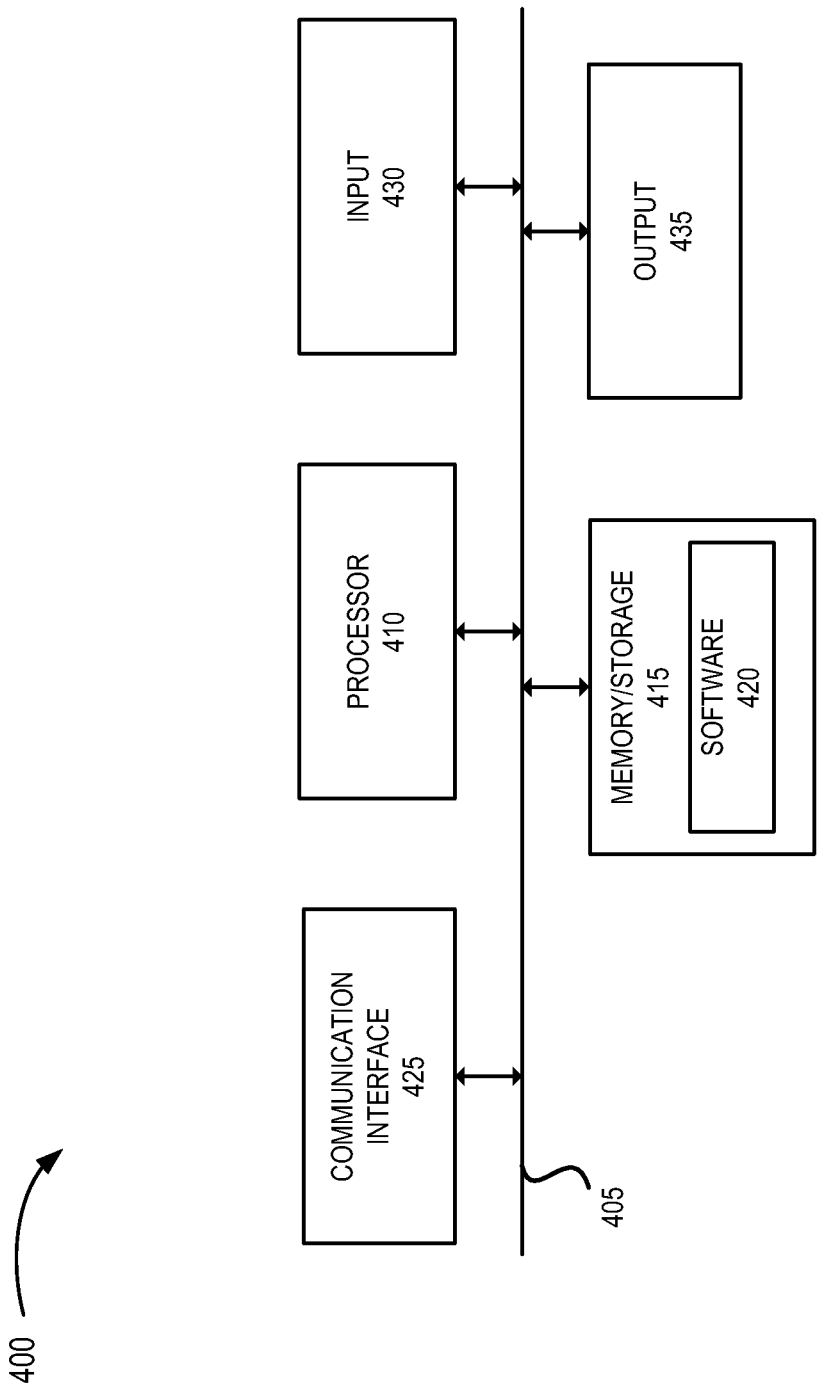
400
COMMUNICATION INTERFACE 425
PROCESSOR 410
INPUT 430
405
MEMORY/STORAGE 415
SOFTWARE 420
OUTPUT 435

Fig. 4

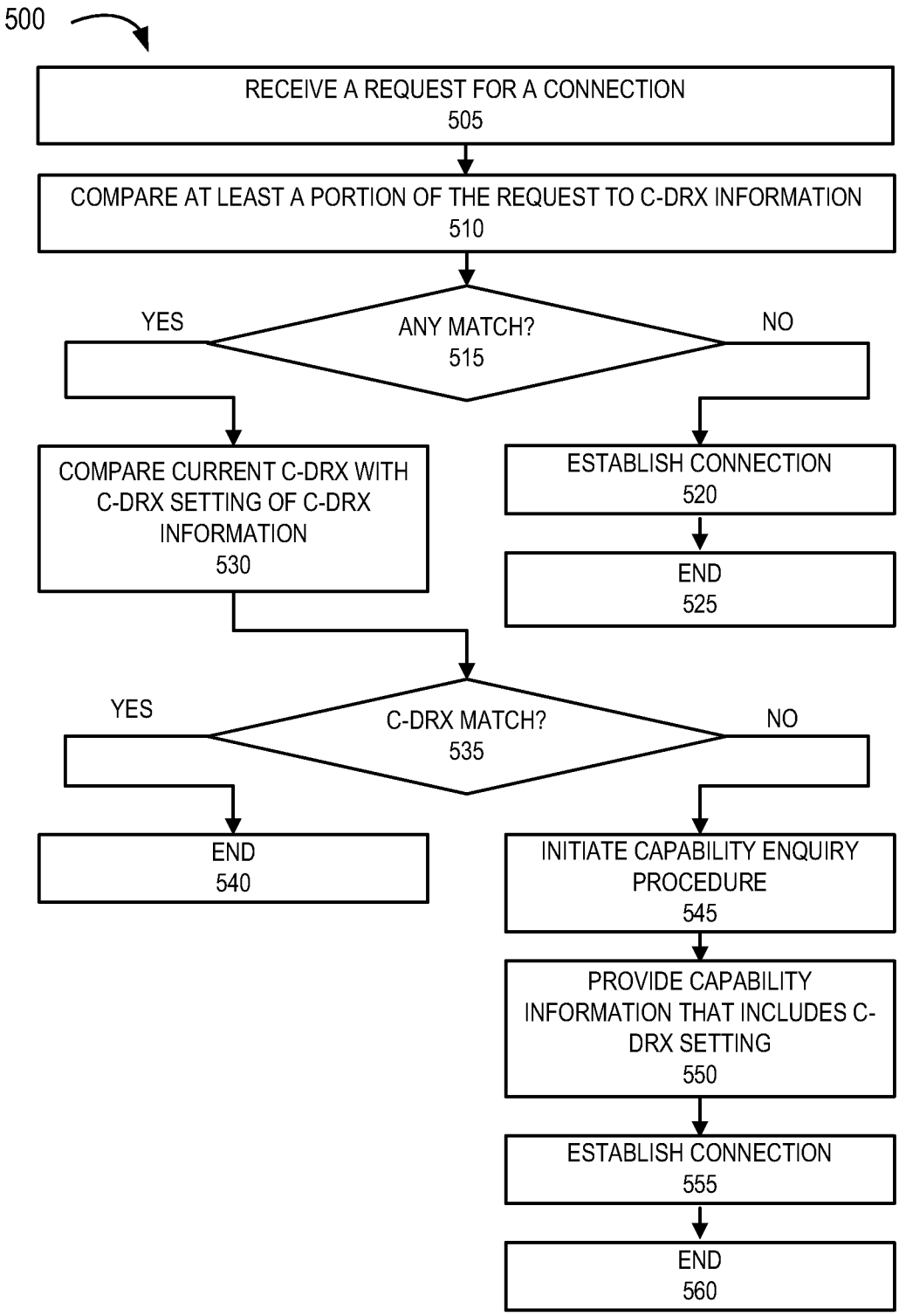
500
RECEIVE A REQUEST FOR A CONNECTION
505
COMPARE AT LEAST A PORTION OF THE REQUEST TO C-DRX INFORMATION
510
ANY MATCH?
515
YES
NO
COMPARE CURRENT C-DRX WITH C-DRX SETTING OF C-DRX INFORMATION
530
ESTABLISH CONNECTION
520
END
525
C-DRX MATCH?
535
YES
NO
END
540
INITIATE CAPABILITY ENQUIRY PROCEDURE
545
PROVIDE CAPABILITY INFORMATION THAT INCLUDES C-DRX SETTING
550
ESTABLISH CONNECTION
555
END
560

Fig. 5

METHOD AND SYSTEM FOR DYNAMIC CONNECTED MODE DISCONTINUOUS RECEPTION

BACKGROUND

Discontinuous reception (DRX) is a process of turning on and turning off a radio receiver according to a schedule that is coordinated between a wireless network and a wireless end device. In this way, the wireless device does not need to continuously monitor control channels for messages and can reduce power consumption and extend battery life. A wireless device may operate according to an Idle Mode DRX (I-DRX) and/or a Connected Mode DRX (C-DRX) that pertains to a corresponding Radio Resource Control (RRC) state (e.g., idle, connected, etc.).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an exemplary environment in which an exemplary embodiment of a dynamic C-DRX provisioning service may be implemented;

FIG. **2**A is a diagram illustrating exemplary components of an end device that provides an exemplary embodiment of the dynamic C-DRX provisioning service;

FIG. **2**B is a diagram illustrating exemplary C-DRX information according to an exemplary embodiment of the dynamic C-DRX provisioning service;

FIG. **2**C is a diagram illustrating another example of C-DRX information according to an exemplary embodiment of the dynamic C-DRX provisioning service;

FIGS. **3**A-**3**F are diagrams illustrating an exemplary process of an exemplary embodiment of the dynamic C-DRX provisioning service;

FIG. **4** is a diagram illustrating exemplary components of a device that may correspond to one or more of the devices illustrated and described herein; and

FIG. **5** is a flow diagram illustrating an exemplary process of an exemplary embodiment of a dynamic C-DRX provisioning service.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements. Also, the following detailed description does not limit the invention.

C-DRX may be provisioned in a wireless end device (e.g., user equipment (UE)) to extend battery life and to protect the wireless end device from overheating, for example. According to some standards (e.g., 3GPP, etc.), a per-UE based C-DRX configuration may be provisioned on the wireless end device by a wireless station of a radio access network (RAN), such as a next generation Node B (gNB), an evolved Node B (eNB), or another type of RAN device.

The wireless end device may include one or multiple applications. The application may include various characteristics, such as being active all the time, some of the time, periodically, aperiodically; being associated with minimum performance metrics and values (e.g., throughput, latency, error rate, bitrate, etc.); being associated with a category or type of application (e.g., mission critical, health-related, web browser, voice communication, Internet of Things (IoT), etc.); and/or another type of attribute of the application. In this regard, depending on one or more characteristics of the application, when the application is executing or running, it may be desirable to have the C-DRX disabled on the wireless end device because C-DRX will cause delay to the data transmission and/or reception of the application due to the discontinuous transmission and/or reception and associated time needed for enabling and disabling a transmitter/receiver at the end device. However, the wireless station of the RAN may not be aware of the characteristic of the application and/or is not configured to dynamically change the C-DRX configuration (e.g., OnDuration, DRX Cycle, Inactivity Timer, etc.) when the application is active or executing on a per wireless end device basis. In addition, it is complex for a base station of the RAN to maintain C-DRX state and manage the C-DRX configuration dynamically for each wireless end device service by it in a centralized manner in a mobile or non-mobile environment. In this regard, the performance of the application may be sub-optimal. It may be simpler and more straightforward for an end device to initiate any required change of C-DRX based on a need of an application, for example.

According to exemplary embodiments, a dynamic C-DRX provisioning service is described. According to an exemplary embodiment, an end device may include logic that provides the dynamic C-DRX provisioning service, as described herein. For example, the end device may store C-DRX information. The C-DRX information may include information that correlates an identifier of an application to a C-DRX configuration (e.g., enabled or disabled). The logic of the end device may include comparing the current C-DRX configuration of the end device to the C-DRX configuration of the C-DRX information and determine whether they match or not. When the C-DRX configurations do not match, according to an exemplary embodiment, the logic of the end device may initiate a procedure to modify the configuration, as described herein. For example, when the current C-DRX configuration is enabled and the C-DRX information indicates that the C-DRX configuration is to be disabled for the application, the procedure may cause a reconfiguration in which the C-DRX may be set to disabled.

According to an exemplary embodiment, a network device may include logic that provides the dynamic C-DRX provisioning service, as described herein. According to an exemplary embodiment, the dynamic C-DRX provisioning service may perform the procedure to reconfigure a C-DRX setting, as described herein. According to an exemplary embodiment, a network device may provision the C-DRX information onto the end device. For example, the network device may be implemented as an over-the-air (OTA) server or another type of server device.

In view of the foregoing, the dynamic C-DRX provisioning service may dynamically change C-DRX configurations on a per-end device and per-application basis to balance the optimization between battery life and latency and/or another performance metric requirement pertaining to an application of the end device. As a result, the C-DRX of the end device may be configured in a manner that may improve performance of an application of the end device relative to a different C-DRX configuration. Additionally, a device-centric dynamic C-DRX provisioning service may provide an improved versatility for configuring C-DRX on end devices for different device types. For example, not all end devices need to behave in the same manner based on their specific needs of battery optimization and/or another criterion.

FIG. **1** is a diagram illustrating an exemplary environment **100** in which an exemplary embodiment of dynamic C-DRX provisioning service may be implemented. As illustrated, environment **100** includes an access network **105** and a core network **120**. Access network **105** includes access devices

107 (also referred to individually or generally as access device 107). Core network 120 includes core devices 122 (also referred to individually or generally as core device 122). Environment 100 further includes end devices 130 (also referred to individually or generally as end device 130).

The number, type, and arrangement of networks illustrated in environment 100 are exemplary. For example, according to other exemplary embodiments, environment 100 may include fewer networks, additional networks, and/or different networks. For example, according to other exemplary embodiments, other networks not illustrated in FIG. 1 may be included, such as an X-haul network (e.g., backhaul, mid-haul, fronthaul, etc.), a transport network (e.g., Signaling System No. 7 (SS7), etc.), or another type of network that may support a wireless service and/or an application service, as described herein.

The number, the type, and the arrangement of network devices, and the number of end devices 130 are exemplary. A network device may be implemented according to one or multiple architectures, such as a client device, a server device, a peer device, a proxy device, a cloud device, and/or a virtualized network device. Additionally, the network device may be implemented according to various computing architectures, such as centralized, distributed, cloud (e.g., elastic, public, private, etc.), edge network, fog network, and/or another type of computing architecture, and may be incorporated into various types of network architectures (e.g., software defined network (SDN), virtual network, logical network, network slice, etc.).

Environment 100 includes communication links between the networks, between the network devices, and between end devices 130 and the network/network devices. Environment 100 may be implemented to include wired, optical, and/or wireless communication links. A communicative connection via a communication link may be direct or indirect. For example, an indirect communicative connection may involve an intermediary device and/or an intermediary network not illustrated in FIG. 1. A direct communicative connection may not involve an intermediary device and/or an intermediary network. The number, type, and arrangement of communication links illustrated in environment 100 are exemplary.

Environment 100 may include various planes of communication including, for example, a control plane, a user plane, a service plane, and/or a network management plane. Environment 100 may include other types of planes of communication. According to various exemplary implementations, the interface of the network device may be a service-based interface, a reference point-based interface, an Open Radio Access Network (O-RAN) interface, a 5G interface, another generation of interface (e.g., 5.5G interface, a sixth generation (6G) interface, a seventh generation (7G) interface, etc.), or some other type of interface.

Access network 105 may include one or multiple networks of one or multiple types and technologies. For example, access network 105 may be implemented to include a 5G RAN, a future generation RAN (e.g., a 6G RAN, a 7G RAN, or a subsequent generation RAN). Access network 105 may include a legacy RAN (e.g., a third generation (3G) RAN, a 4G or 4.5 RAN, etc.). Access network 105 may communicate with and/or include other types of access networks, such as, for example, a WiFi network, a Worldwide Interoperability for Microwave Access (WiMAX) network, a local area network (LAN), a Citizens Broadband Radio System (CBRS) network, a cloud RAN, an O-RAN network, a virtualized RAN (vRAN), a self-organizing network (SON), a wired network (e.g., optical, cable, etc.), or another type of network that provides access to or can be used as an on-ramp to access network 105 and/or core network 120.

Access network 105 may include different and multiple functional splitting, such as options 1, 2, 3, 4, 5, 6, 7, or 8 that relate to combinations of access network 105 and core network 120 including an evolved packet core (EPC) network and/or an NG core (NGC) network, or the splitting of the various layers (e.g., physical layer, medium access control (MAC) layer, radio link control (RLC) layer, and packet data convergence protocol (PDCP) layer, etc.), plane splitting (e.g., user plane, control plane, etc.), a centralized unit (CU) and distributed unit (DU), interface splitting (e.g., F1-U, F1-C, E1, Xn-C, Xn-U, X2-C, Common Public Radio Interface (CPRI), etc.) as well as other types of network services, such as dual connectivity (DC) or higher (e.g., a secondary cell group (SCG) split bearer service, a master cell group (MCG) split bearer, an SCG bearer service, NSA, SA, etc.), carrier aggregation (CA) (e.g., intra-band, inter-band, contiguous, non-contiguous, etc.), edge and core network slicing, coordinated multipoint (CoMP), various duplex schemes (e.g., frequency division duplex (FDD), time division duplex (TDD), half-duplex FDD (H-FDD), etc.), and/or another type of connectivity service (e.g., non-standalone (NSA) new radio (NR), stand-alone (SA) NR, etc.).

Depending on the implementation, access network 105 may include one or multiple types of network devices, such as access devices 107. For example, access device 107 may include a gNB, an evolved LTE (eLTE) eNB, an eNB, a radio network controller (RNC), a remote radio head (RRH), a baseband unit (BBU), an RU, a CU, a CU control plane (CU CP), a CU user plane (CU UP), a DU, a small cell node (e.g., a picocell device, a femtocell device, a microcell device, a home eNB, etc.), an open network device (e.g., O-RAN Centralized Unit (O-CU), O-RAN Distributed Unit (O-DU), O-RAN next generation Node B (O-gNB), O-RAN evolved Node B (O-eNB)), a 5G ultra-wide band (UWB) node, a future generation wireless access device (e.g., a 6G wireless station, a 7G wireless station, or another generation of wireless station), another type of wireless node (e.g., a WiFi device, a WiMax device, a hotspot device, etc.) that provides a wireless access service, or another type of network device that provides a transport service (e.g., routing and forwarding), such as a router, a switch, or another type of layer 3 (e.g., network layer of the Open Systems Interconnection (OSI) model) network device. Additionally, or alternatively, access device 107 may include a wired and/or optical device (e.g., modem, wired access point, optical access point, Ethernet device, etc.) that provides network access. According to some exemplary implementations, access device 107 may include a combined functionality of multiple RATs (e.g., 4G and 5G functionality, 5G and 5.5G functionality, 5G and 6G functionality, etc.) via soft and hard bonding based on demands and needs. According to some exemplary implementations, access device 107 may include an integrated functionality, such as a CU-CP and a CU-UP, or other integrations of split RAN nodes. Access device 107 may be an indoor device or an outdoor device. Access device 107 may include a controller device. For example, access device 107 may include a RAN Intelligent Controller (RIC).

According to various exemplary implementations, access device 107 may include one or multiple sectors or antennas. The antenna may be implemented according to various configurations, such as single input single output (SISO), single input multiple output (SIMO), multiple input single

output (MISO), multiple input multiple output (MIMO), massive MIMO, three dimensional (3D) and adaptive beamforming (also known as full-dimensional agile MIMO), two dimensional (2D) beamforming, antenna spacing, tilt (relative to the ground), radiation pattern, directivity, elevation, planar arrays, and so forth. Depending on the implementation, access device **107** may provide a wireless access service at a cell, a sector, a sub-sector, carrier, and/or other configurable level.

Core network **120** may include one or multiple networks of one or multiple network types and technologies. Core network **120** may include a complementary network of access network **105**. For example, core network **120** may be implemented to include an NGC network, an EPC of an LTE network, an LTE-Advanced (LTE-A) network, and/or an LTE-A Pro network, a future generation core network (e.g., a 5G, a 6G, a 7G, or beyond core network, etc.), and/or another type of core network.

Depending on the implementation of core network **120**, core network **120** may include various types of network devices that are illustrated in FIG. **1** as core devices **122**. For example, core devices **122** may include a user plane function (UPF), a Non-3GPP Interworking Function (N3IWF), an access and management mobility function (AMF), a session management function (SMF), a unified data management (UDM) device, a unified data repository (UDR) device, an authentication server function (AUSF), a network slice selection function (NSSF), a network repository function (NRF), a policy control function (PCF), a binding support function (BSF), a network data analytics function (NWDAF), a network exposure function (NEF), a lifecycle management (LCM) device, an application function (AF), a mobility management entity (MME), a packet gateway (PGW), an enhanced packet data gateway (ePDG), a serving gateway (SGW), a home agent (HA), a General Packet Radio Service (GPRS) support node (GGSN), a home subscriber server (HSS), an authentication, authorization, and accounting (AAA) server, a policy and charging rules function (PCRF), a policy and charging enforcement function (PCEF), and/or a charging system (CS). According to other exemplary implementations, core devices **122** may include additional, different, and/or fewer network devices than those described. For example, core devices **122** may include a non-standard or a proprietary network device, and/or another type of network device that may be well-known but not particularly mentioned herein. Core devices **122** may also include a network device that provides a multi-RAT functionality (e.g., 4G and 5G, 5G and 5.5G, 5G and 6G, etc.), such as an SMF with PGW control plane functionality (e.g., SMF+PGW-C), a UPF with PGW user plane functionality (e.g., UPF+PGW-U), a service capability exposure function (SCEF) with a NEF (SCEF+NEF), and/or other combined nodes (e.g., an HSS with a UDM and/or UDR, an MME with an AMF, etc.).

End device **130** include a device that may have computational and/or communication capabilities (e.g., wireless). End device **130** may also include wired and/or optical communication capabilities, for example. End device **130** may be implemented as a mobile device, a portable device, a stationary device (e.g., a non-mobile device and/or a non-portable device), a device operated by a user, or a device not operated by a user. For example, end device **130** may be implemented as a smartphone, a mobile phone, a personal digital assistant, a tablet, a netbook, a phablet, a wearable device (e.g., a watch, glasses, etc.), a computer, a gaming device, a music device, an IoT device, a drone, a smart device, or other type of wireless device (e.g., other type of UE). End device **130** may be configured to execute various types of software (e.g., applications, programs, etc.). The number and the types of software may vary among end devices **130**.

End device **130** may support one or multiple RATs (e.g., 4G, 5G, and/or future generation RAT) and various portions of the radio spectrum (e.g., multiple frequency bands, multiple carrier frequencies, licensed, unlicensed, mm wave, above mm wave, etc.), various levels and genres of network slicing, DC service, and/or other types of connectivity services. Additionally, end device **130** may include one or multiple communication interfaces that provide one or multiple (e.g., simultaneous, interleaved, etc.) connections via the same or different RATs, frequency bands, carriers, network slices, and/or other communication medium (e.g., wired, etc.). The multimode capabilities of end device **130** may vary among end devices **130**.

End device **130** may store one or multiple end device applications. For example, the end device applications may pertain to a communication application service (e.g., email, text (e.g., Short Messaging Service (SMS), Multimedia Messaging Service (MMS), etc.), voice, conferencing, instant messaging), video streaming, extreme real-time communications (e.g., tactile Internet, augmented reality (AR), virtual reality (VR), etc.), ultra-reliable communication (e.g., automated traffic control and driving, collaborative robots, a health-related service (e.g., monitoring, remote surgery, etc.), drone delivery, public safety, etc.), a web browser for browsing the Web, an IoT application service, and other types of end device applications.

According to an exemplary embodiment, end device **130** includes logic that provides the dynamic C-DRX provisioning service. According to some exemplary embodiments, end device **130** may include a Subscriber Identification Module (SIM) card, an embedded SIM (eSIM), a Universal SIM (USIM), a 5G USIM (or other generation SIM), a Universal Integrated Circuit Card (UICC), an embedded UICC (eUICC), or a similar type of component that may be configured to include logic of the dynamic C-DRX provisioning service (referred to as a "card"). According to other exemplary embodiments, end device **130** may not include a card and provide the dynamic C-DRX provisioning service.

FIG. **2**A is a diagram illustrating exemplary components in which an exemplary embodiment of the dynamic C-DRX provisioning service may be implemented. As illustrated, end device **130** may include a card **205**. Card **205** may include an application **210**, C-DRX information **215**, and a C-DRX client **220**. End device **130** may also include a modem **225** and an end device application **230**. Although not illustrated in FIG. **2**, end device **130** may include other components as illustrated and described in relation to FIG. **4**. Such components may be apart from or in addition to the exemplary components illustrated and described in FIG. **2**.

The arrangement of components and connections between components are exemplary. According to other exemplary embodiments, end device **130** may include additional, different, and/or fewer components, a different arrangement of components, and/or different connections between components than those illustrated and described herein. Additionally, a connection between components may include one or multiple intermediate components that are not illustrated and described. The number and arrangement of connections are exemplary.

Card **205** may be implemented as a SIM, a UICC, a USIM, etc., or a similar type of component, as previously described. According to various exemplary embodiments, although not illustrated, card **205** may include a memory, a

processor, a storage, an interface, input/output, and/or another type of hardware component. Card **205** may also include software. The software may include an application, firmware, middleware, microcode, an applet, an application programming interface (API), a module, an operating system (OS), and/or another type of entity. Card **205** may also include a file system (e.g., elementary file, directory, etc.), for example. Card **205** may be removable from end device **130** or permanently installed.

Application **210** may include logic that provides an exemplary embodiment of the dynamic C-DRX provisioning service. For example, application **210** may receive a request from an end device application via modem **225**, as described further herein. Application **210** may determine a C-DRX configuration for end device **130** based on the request and C-DRX information **215**, as described herein. For example, application **210** may compare a C-DRX configuration associated with the request (and end device application) to a current C-DRX configuration of end device **130**.

C-DRX information **215** may include information that correlates an end device application to a C-DRX configuration. FIG. **2**B is a diagram that illustrates exemplary C-DRX information **215**. For example, referring to a table **240** in FIG. **2**B, exemplary C-DRX information **215** is illustrated. Table **240** may include an application identifier field **242** and a C-DRX setting field **245**. As further illustrated, table **240** includes entries **249-0** through **249**-X (also referred as entries **249**, or individually or generally as entry **249**) that each includes a grouping of fields **242** and **245** that are correlated (e.g., a record, etc.). The C-DRX information **215** is illustrated in tabular form merely for the sake of description. In this regard, C-DRX information **215** may be implemented in a data structure different from a table (e.g., a list, a flat file, etc.), a database, or another type of structure. Additionally, values illustrated in field **242** and field **245** are exemplary. According to other embodiments, the values, strings, or instances of information stored in a field may be different. The number of entries **249** are exemplary for the sake of description purposes.

Application identifier field **242** may store data that identifies an end device application either directly or indirectly. For example, application identifier field **242** may store an application identifier, such as a string (e.g., numeric, alphabetic, alphanumeric, etc.), an access point name (APN), a Fully Qualified Domain Name (FQDN), a network address, an end device application name, or another suitable indicator of the end device application.

C-DRX setting field **245** may store one or multiple configuration settings for C-DRX. For example, C-DRX setting field **245** may store a setting that indicates whether C-DRX is enabled or disabled, on or off, supported or not supported, modified or not, extended or not, or the like. According to various exemplary embodiments, entries **249** may or may not include entries **249** in which C-DRX setting field **245** indicates "enabled" or "on," for example. For example, for some exemplary embodiments, only end device applications, which may be identified by application identifier field **242**, that are desired to have C-DRX setting "disabled" or "off" may be included in the C-DRX information **215**.

According to other exemplary embodiments, table **240** may store additional and/or different instances of C-DRX information in support of the dynamic C-DRX provisioning service, as described herein.

FIG. **2**C is a diagram that illustrates another example of C-DRX information **215**. For example, referring to a table **250** in FIG. **2**C, exemplary C-DRX information **215** is illustrated. Table **250** may include a UE Routing Selection Policy (URSP) slicing field **252** and a C-DRX setting field **255**. According to other exemplary embodiments, table **250** may also include an application identifier field, as previously described herein. As further illustrated, table **250** includes entries **259-0** through **259**-X (also referred to as entries **259**, or individually or generally as entry **259**) that each includes a grouping of fields **252** and **255** that are correlated (e.g., a record, etc.). The C-DRX information **215** is illustrated in tabular form merely for the sake of description. In this regard, C-DRX information **215** may be implemented in a data structure different from a table (e.g., a list, a flat file, etc.), a database, or another type of structure. Additionally, values illustrated in field **252** and field **255** are exemplary. According to other embodiments, the values, strings, or instances of information stored in a field may be different.

URSP slicing field **252** may store data pertaining to a network slice. For example, URSP information may include an application identifier, Internet Protocol (IP) descriptors, Single-Network Slice Selection Assistance Information (S-NSSAI), data network name (DNN), Session and Service Continuity (SSC) mode information for an application, network slice mapping, and/or similar types of information. C-DRX setting field **255** may store data similar to that described in relation to field **245** of table **240**.

According to other exemplary embodiments, table **250** may store additional and/or different instances of C-DRX information in support of the dynamic C-DRX provisioning service, as described herein.

Referring back to FIG. **2**A, C-DRX client **220** may include logic that communicates with a server device in support of the dynamic C-DRX provisioning service. For example, C-DRX client **220** may obtain C-DRX information **215** from an OTA server, a card server that may provision a card (e.g., card **205**), an over-the-top (OTT) server, a web server, or another type of server device that may be configured to provision end device **130** or card **205** with C-DRX information, as described herein.

Modem **225** may include logic with computational and communication capabilities. For example, modem **225** may include logic that modulates and demodulates signals. Modem **225** may include logic that encodes and decodes signals. Modem **225** may include an antenna. According to some exemplary embodiments, modem **225** may be implemented as a 4G, a 5G, or another generation modem. Modem **225** may also have a communication link with application **210** and end device application **230**, as illustrated in FIG. **2**A. As further described herein, modem **225** may receive and transmit messages between these other components.

End device application **230** may include one or multiple end device applications, as described herein. For example, end device application **230** may be a communication application, a video streaming application, an extreme real-time communication application, a web browser, an IoT application, or some other type of end device application. Each end device application **230** may have a set of characteristics, as previously described. For example, the characteristics may pertain to traffic behavior (e.g., continuous, bursty, periodic, aperiodic, amount of data, length of time pertaining to a transmission or a reception of data, etc.), execution behavior (e.g., background application, foreground application, runs intermittently, runs constantly, minimal end device resource usage, extensive end device resource usage, etc.), minimum performance metrics and values (e.g., SLA, QoS, etc.), a category or type of application, and/or another type of attribute.

FIGS. **3**A-**3**H are diagrams illustrating an exemplary process **300** of an exemplary embodiment of a dynamic C-DRX provisioning service. Referring to FIG. **3**A, end device **130** may be provisioned with C-DRX information. For example, end device **130** and/or card **205** may transmit a request **306** to server device **305**. In response to receiving request **306**, server device **305** may provision C-DRX information **307**. End device **130** and/or card **205** may receive and store the C-DRX information **310**. According to some exemplary embodiments, the provisioning may occur during an activation procedure for card **205**. According to other exemplary embodiments, the provisioning may occur during an attachment procedure or after attachment. Additionally, or alternatively, the provisioning may occur without request **305** being transmitted (e.g., a push communication). Although server device **305** is illustrated in core network **120**, according to other exemplary embodiments, server device **305** may reside elsewhere. After the C-DRX information is provisioning on end device **130** and/or card **205**, an exemplary embodiment of the dynamic C-DRX provisioning service may be executed, as described herein. The C-DRX information may be updated after initial provisioning.

Referring to FIG. **3**B, assume during execution **315**, end device application **230** wants to establish or use a network connection for an application session (e.g., to transmit packets). End device application **230** may transmit a connection request **320**, which is received by modem **225**. Modem **225** may pass the request to card **205** as an access control request **325**. For example, access control request **325** may be communicated to application **210** of card **205**. According to an exemplary embodiment, access control request **325** may include an application identifier that identifies end device application **230**. According to another exemplary embodiment, access control request **325** may include a network slice identifier that identifies a network slice to be used by end device application **230** for the application session. According to still other exemplary embodiments, access control request **325** may include additional and/or different information that may be used by application **210** for comparison with C-DRX information **215**, as described herein.

As further illustrated, after receiving access control request **325**, application **210** may read and/or extract information included in access control request **325** and compare the information to C-DRX information **330**. For example, application **210** may use information included in access control request **325** to perform a lookup in relation to C-DRX **215**. By way of further example, application **210** may compare an application identifier included access control request **325** to application identifier field **242** or URSP slicing field **252** of FIG. **2**B or **2**C, as previously explained. Based on a result of the lookup, application **210** may determine if there is a match **335**.

Referring to FIG. **3**C, if there is no match **340**, application **210** may communicate an access control response **345** to modem **225**. For example, application **210** may determine, based on the absence of a match, that the C-DRX state of end device **130** does not need to be modified for end device application **230**, the application session, and/or end device **130**. Access control response **345** may indicate that the connection is approved. In response to receiving access control response **345**, modem **225** may establish a connection **347**.

Referring to FIG. **3**D, if there is a match **350**, application **210** may compare the C-DRX setting included in C-DRX information **215** (e.g., C-DRX setting fields **245** or **255**) with the current C-DRX setting **353** of end device **130** (e.g., C-DRX setting associated with modem **225**). Based on a result of the comparison, application **210** may determine whether the C-DRX of end device **130** needs to be changed. For example, if the C-DRX setting included in C-DRX information **215** indicates that the C-DRX setting is to be disabled or off and the current C-DRX setting is enabled or on, application **210** may determine to modify the current C-DRX setting. On the other hand, if the C-DRX setting and the current C-DRX setting indicate as disabled or off, application **210** may determine to not modify the current C-DRX setting.

For purposes of description, assume that the C-DRX settings do not match, and application **210** determines to modify the current C-DRX setting. As illustrated, application **210** may communicate an access control response **355** to modem **225**. Access control response **355** may indicate that the connection is approved but with a modification. For example, the modification may be to disable the C-DRX of end device **130** and establish a connection for end device application **230**. As such, in response to receiving and reading access control response **355**, modem **225** may invoke a refresh procedure **357**. The refresh procedure may include modem generating and transmitting a tracking area update (TAU) request **359**. According to an exemplary implementation, the TAU request may include data indicating that the RRC capability of end device **130** needs to be updated. For example, the data may be implemented as a bit, an information element (IE), a flag, or another suitable data instance. In this way, the refresh procedure may initiate a (new) UE capabilities exchange in which end device **130** may provide capability information indicating that C-DRX is not supported, as described herein. As a consequence, C-DRX may be disabled.

Referring to FIG. **3**E, TAU request **359** may be received by a core device **122**, such as an MME **122**, an SMF **122**, or an integrated MME/SMF **122**. Based on receiving TAU request **359**, which includes the data indicating an RRC capability update request, MME/SMF **122** may initiate a new UE capability enquiry procedure **360**. For example, MME/SMF **122** may generate and transmit a request **362** to an access device **107**, such as a gNB **107** or an eNB **107**, to initiate a UE capability enquiry. Based on receiving request **362**, gNB/eNB **107** may generate and transmit a capability request **364** to end device **130**. End device **130** may receive request **364** and in response, end device **130** may generate capability information that includes data indicating that C-DRX is not supported. For example, end device **130** may indicate that C-DRX is not supported **367** based on C-DRX information **215**. Referring to FIG. **3**F, end device **130** may transmit a capability response **369** to gNB/eNB **107**. Capability response **369** may include data indicating that C-DRX is not supported. In this way, the network may identify end device **130** as a C-DRX-disabled device. End device **130** may establish a network connection that supports an application session for end device application **230** in which end device **130** is configured as DRX disabled or off, for example.

FIGS. **3**A-**3**F are diagrams illustrating an exemplary process **300**, according to other exemplary embodiments, process **300** may include additional, different, or fewer operations. For example, after the application session ends and/or end device application **130** goes into a sleep mode, end device **130** may enable C-DRX according to a similar process. Additionally, for example, when multiple end device applications **230** may request a network connection, application **210** may afford a precedence to an end device

application **230** for which C-DRX is to be disabled relative to another end device application **230** for which C-DRX may be enabled.

FIG. **4** is a diagram illustrating exemplary components of a device **400** that may be included in one or more of the devices described herein. For example, device **400** may correspond to access device **107**, core device **122**, end device **130**, MME/SMF **122**, gNB/eNB **107**, and/or another type of network device, as described herein. As illustrated in FIG. **4**, device **400** includes a bus **405**, a processor **410**, a memory/storage **415** that stores software **420**, a communication interface **425**, an input **430**, and an output **435**. According to other embodiments, device **400** may include fewer components, additional components, different components, and/or a different arrangement of components than those illustrated in FIG. **4** and described herein.

Bus **405** includes a path that permits communication among the components of device **400**. For example, bus **405** may include a system bus, an address bus, a data bus, and/or a control bus. Bus **405** may also include bus drivers, bus arbiters, bus interfaces, clocks, and so forth.

Processor **410** includes one or multiple processors, microprocessors, data processors, co-processors, graphics processing units (GPUs), application specific integrated circuits (ASICs), controllers, programmable logic devices, chipsets, field-programmable gate arrays (FPGAs), application specific instruction-set processors (ASIPs), system-on-chips (SoCs), central processing units (CPUs) (e.g., one or multiple cores), microcontrollers, neural processing unit (NPUs), and/or some other type of component that interprets and/or executes instructions and/or data. Processor **410** may be implemented as hardware (e.g., a microprocessor, etc.), a combination of hardware and software (e.g., a SoC, an ASIC, etc.), may include one or multiple memories (e.g., cache, etc.), etc.

Processor **410** may control the overall operation, or a portion of operation(s) performed by device **400**. Processor **410** may perform one or multiple operations based on an operating system and/or various applications or computer programs (e.g., software **420**). Processor **410** may access instructions from memory/storage **415**, from other components of device **400**, and/or from a source external to device **400** (e.g., a network, another device, etc.). Processor **410** may perform an operation and/or a process based on various techniques including, for example, multithreading, parallel processing, pipelining, interleaving, learning, model-based, etc.

Memory/storage **415** includes one or multiple memories and/or one or multiple other types of storage mediums. For example, memory/storage **415** may include one or multiple types of memories, such as, a random access memory (RAM), a dynamic random access memory (DRAM), a static random access memory (SRAM), a cache, a read only memory (ROM), a programmable read only memory (PROM), an erasable PROM (EPROM), an electrically EPROM (EEPROM), a single in-line memory module (SIMM), a dual in-line memory module (DIMM), a flash memory (e.g., 2D, 3D, NOR, NAND, etc.), a solid state memory, and/or some other type of memory. Memory/storage **415** may include a hard disk (e.g., a magnetic disk, an optical disk, a magneto-optic disk, a solid-state disk, etc.), a Micro-Electromechanical System (MEMS)-based storage medium, and/or a nanotechnology-based storage medium. Memory/storage **415** may include drives for reading from and writing to the storage medium.

Memory/storage **415** may be external to and/or removable from device **400**, such as, for example, a Universal Serial Bus (USB) memory stick, a dongle, a hard disk, mass storage, off-line storage, or some other type of storing medium (e.g., a compact disk (CD), a digital versatile disk (DVD), a Blu-Ray disk (BD), etc.). Memory/storage **415** may store data, software, and/or instructions related to the operation of device **400**.

Software **420** includes an application or a program that provides a function and/or a process. As an example, with reference to application service manager **119**, software **420** may include an application that, when executed by processor **410**, provides a function and/or a process of dynamic C-DRX provisioning service, as described herein. Software **420** may also include firmware, middleware, microcode, hardware description language (HDL), and/or other form of instruction. Software **420** may also be virtualized. Software **420** may further include an operating system (OS) (e.g., Windows, Linux, Android, proprietary, etc.).

Communication interface **425** permits device **400** to communicate with other devices, networks, systems, and/or the like. Communication interface **425** includes one or multiple wireless interfaces and/or wired interfaces. For example, communication interface **425** may include one or multiple transmitters and receivers, or transceivers. Communication interface **425** may operate according to a protocol stack and a communication standard. Communication interface **425** may include an antenna. Communication interface **425** may include various processing logic or circuitry (e.g., multiplexing/de-multiplexing, filtering, amplifying, converting, error correction, application programming interface (API), etc.). Communication interface **425** may be implemented as a point-to-point interface, a service-based interface, or a reference interface, for example.

Input **430** permits an input into device **400**. For example, input **430** may include a keyboard, a mouse, a display, a touchscreen, a touchless screen, a button, a switch, an input port, a joystick, speech recognition logic, and/or some other type of visual, auditory, tactile, affective, olfactory, etc., input component. Output **435** permits an output from device **400**. For example, output **435** may include a speaker, a display, a touchscreen, a touchless screen, a light, an output port, and/or some other type of visual, auditory, tactile, etc., output component.

As previously described, a network device may be implemented according to various computing architectures (e.g., in a cloud, etc.) and according to various network architectures (e.g., a virtualized function, etc.). Device **400** may be implemented in the same manner. For example, device **400** may be instantiated, created, deleted, or some other operational state during its life-cycle (e.g., refreshed, paused, suspended, rebooting, or another type of state or status), using well-known virtualization technologies (e.g., hypervisor, container engine, virtual container, virtual machine, etc.) in an application layer network (e.g., external network **115**) and/or another type of network (e.g., access network **105**, core network **120**, etc.). Thus, network devices described herein may be implemented as device **400**.

Device **400** may perform a process and/or a function, as described herein, in response to processor **410** executing software **420** stored by memory/storage **415**. By way of example, instructions may be read into memory/storage **415** from another memory/storage **415** (not shown) or read from another device (not shown) via communication interface **425**. The instructions stored by memory/storage **415** cause processor **410** to perform a function or a process described herein. Alternatively, for example, according to other imple-

mentations, device **400** performs a function or a process described herein based on the execution of hardware (processor **410**, etc.).

FIG. **5** is a flow diagram illustrating an exemplary process **500** of an exemplary embodiment of dynamic C-DRX provisioning service. According to an exemplary embodiment, end device **130** may perform a step of process **500**. According to an exemplary implementation, processor **410** executes software **420** to perform the step of process **500**, as described herein. Alternatively, the step may be performed by execution of only hardware.

In block **505**, end device **130** may receive a request for a connection. For example, end device application **230**, modem **225**, and/or application **210** of card **205** may receive a request for a network connection, as described herein.

In block **510**, end device **130** may compare at least a portion of the request to C-DRX information. For example, application **210** may compare information included in the request to C-DRX information **215**, as described herein.

In block **515**, a determination may be made whether there is a match. For example, based on a lookup procedure, application **210** may determine if there is a match based on the comparison, as described herein.

When it is determined that there is not a match (block **515**-NO), end device may establish a connection (block **520**). For example, application **210** may communicate approval for the network connection to modem **225**. Modem **225** may establish the network connection. Process **500** may end (block **525**).

When it is determined that there is a match (block **515**—YES), end device **130** may compare the current C-DRX with the C-DRX setting of the C-DRX information (block **530**). For example, application **210** may compare the correlated C-DRX setting information with the current C-DRX of end device **130**, as described herein. In block **535**, end device **130** may determine whether there is a match.

When there is a match (block **535**—YES), process **500** may end (block **540**). For example, application **210** may communicate approval for the network connection to modem **225**. Modem **225** may establish the network connection. When there is not a match (block **535**-NO), end device **130** may initiate a capability enquiry procedure (block **545**). For example, application **210** may communicate approval with modification for the network connection to modem **225**. Modem **225** may transmit a request (e.g., a TAU request) that includes an RRC capability update request, as described herein.

In block **550**, end device **130** may provide capability information that includes information indicating whether or not C-DRX is supported on the end device. For example, end device **130** may receive a capability inquiry from a RAN device **107**. End device **130** may generate and transmit capability information that indicates C-DRX is not supported based on C-DRX information **215**, as described herein. For example, this may be indicated in Feature-Groupindicator IE (4 and 5). In block **555**, end device **130** may establish a connection. In block **560**, process **500** may end.

FIG. **5** illustrates an exemplary embodiment of a process of dynamic C-DRX provisioning service, according to other exemplary embodiments, the dynamic C-DRX provisioning service may perform additional operations, fewer operations, and/or different operations than those illustrated and described.

As set forth in this description and illustrated by the drawings, reference is made to "an exemplary embodiment," "exemplary embodiments," "an embodiment," "embodiments," etc., which may include a particular feature, structure, or characteristic in connection with an embodiment(s). However, the use of the phrase or term "an embodiment," "embodiments," etc., in various places in the description does not necessarily refer to all embodiments described, nor does it necessarily refer to the same embodiment, nor are separate or alternative embodiments necessarily mutually exclusive of other embodiment(s). The same applies to the term "implementation," "implementations," etc.

The foregoing description of embodiments provides illustration but is not intended to be exhaustive or to limit the embodiments to the precise form disclosed. Accordingly, modifications to the embodiments described herein may be possible. For example, various modifications and changes may be made thereto, and additional embodiments may be implemented, without departing from the broader scope of the invention as set forth in the claims that follow. The description and drawings are accordingly to be regarded as illustrative rather than restrictive.

The terms "a," "an," and "the" are intended to be interpreted to include one or more items. Further, the phrase "based on" is intended to be interpreted as "based, at least in part, on," unless explicitly stated otherwise. The term "and/or" is intended to be interpreted to include any and all combinations of one or more of the associated items. The word "exemplary" is used herein to mean "serving as an example." Any embodiment or implementation described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or implementations.

In addition, while a series of blocks has been described regarding the process illustrated in FIG. **5**, the order of the blocks may be modified according to other embodiments. Further, non-dependent blocks may be performed in parallel. Additionally, other processes described in this description may be modified and/or non-dependent operations may be performed in parallel.

Embodiments described herein may be implemented in many different forms of software executed by hardware. For example, a process or a function may be implemented as "logic," a "component," or an "element." The logic, the component, or the element, may include, for example, hardware (e.g., processor **410**, etc.), or a combination of hardware and software (e.g., software **420**).

Embodiments have been described without reference to the specific software code because the software code can be designed to implement the embodiments based on the description herein and commercially available software design environments and/or languages. For example, various types of programming languages including, for example, a compiled language, an interpreted language, a declarative language, or a procedural language may be implemented.

Use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another, the temporal order in which acts of a method are performed, the temporal order in which instructions executed by a device are performed, etc., but are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements.

Additionally, embodiments described herein may be implemented as a non-transitory computer-readable storage medium that stores data and/or information, such as instructions, program code, a data structure, a program module, an application, a script, or other known or conventional form suitable for use in a computing environment. The program

code, instructions, application, etc., is readable and executable by a processor (e.g., processor **410**) of a device. A non-transitory storage medium includes one or more of the storage mediums described in relation to memory/storage **415**. The non-transitory computer-readable storage medium may be implemented in a centralized, distributed, or logical division that may include a single physical memory device or multiple physical memory devices spread across one or multiple network devices.

To the extent the aforementioned embodiments collect, store, or employ personal information of individuals, it should be understood that such information shall be collected, stored, and used in accordance with all applicable laws concerning protection of personal information. Additionally, the collection, storage and use of such information can be subject to consent of the individual to such activity, for example, through well known "opt-in" or "opt-out" processes as can be appropriate for the situation and type of information. Collection, storage and use of personal information can be in an appropriately secure manner reflective of the type of information, for example, through various encryption and anonymization techniques for particularly sensitive information.

No element, act, or instruction set forth in this description should be construed as critical or essential to the embodiments described herein unless explicitly indicated as such.

All structural and functional equivalents to the elements of the various aspects set forth in this disclosure that are known or later come to be known are expressly incorporated herein by reference and are intended to be encompassed by the claims.

What is claimed is:

1. A method comprising:

receiving, by a device, a first request for a network connection pertaining to an application;

determining, by the device based on the first request, that a discontinuous reception (DRX) configuration of the device is to be changed;

transmitting, by the device based on the determining to a network, a second request that includes a radio resource control (RRC) capability update request;

receiving, by the device from the network, a capability enquiry request; and

transmitting, by the device to the network, a response to the capability enquiry request that includes data indicating that DRX is not supported by the device.

2. The method of claim **1**, further comprising:

storing, by the device, information that includes a DRX setting correlated to at least one of an application identifier that identifies the application or a network slice identifier that identifies a network slice.

3. The method of claim **2**, wherein the determining further comprises:

comparing, by the device, at least a portion of the first request to the information; and

determining, by the device, whether there is a match.

4. The method of claim **1**, wherein the second request includes a tracking area update (TAU) request.

5. The method of claim **1**, wherein when the device receives the first request for the network connection, the device is DRX enabled.

6. The method of claim **1**, wherein the device includes a card that includes a Subscriber Identification Module (SIM) card, an embedded SIM (eSIM), a Universal SIM (USIM), a Universal Integrated Circuit Card (UICC), or an embedded UICC (eUICC), and the card performs the determining.

7. The method of claim **1**, further comprising:

establishing, by the device with the network after the transmitting of the response, the network connection that supports an application session of the application, wherein the device is DRX disabled.

8. The method of claim **1**, wherein the application is resident on the device.

9. A device comprising:

a processor configured to:

receive a first request for a network connection pertaining to an application;

determine, based on the first request, that a discontinuous reception (DRX) configuration of the device is to be changed;

transmit, to a network based on the determination, a second request that includes a radio resource control (RRC) capability update request;

receive, from the network, a capability enquiry request; and

transmit, to the network, a response to the capability enquiry request that includes data indicating that DRX is not supported by the device.

10. The device of claim **9**, wherein the processor is further configured to:

store information that includes a DRX setting correlated to at least one of an application identifier that identifies the application or a network slice identifier that identifies a network slice.

11. The device of claim **10**, wherein when determining, the processor is further configured to:

compare at least a portion of the first request to the information; and

determine whether there is a match.

12. The device of claim **9**, wherein the second request includes a tracking area update (TAU) request.

13. The device of claim **9**, wherein when the device receives the first request for the network connection, the device is DRX enabled.

14. The device of claim **9**, wherein the device includes a card that includes a Subscriber Identification Module (SIM) card, an embedded SIM (eSIM), a Universal SIM (USIM), a Universal Integrated Circuit Card (UICC), or an embedded UICC (eUICC), and the card performs the determining.

15. The device of claim **9**, wherein the processor is further configured to:

establish with the network, after transmission of the response, the network connection that supports an application session of the application, wherein the device is DRX disabled.

16. The device of claim **9**, wherein the application is resident on the device.

17. A non-transitory computer-readable storage medium storing instructions executable by a processor of a device, which when executed cause the processor to:

receive a first request for a network connection pertaining to an application;

determine, based on the first request, that a discontinuous reception (DRX) configuration of the device is to be changed;

transmit, to a network based on the determination, a second request that includes a radio resource control (RRC) capability update request;

receive, from the network, a capability enquiry request; and

transmit, to the network, a response to the capability enquiry request that includes data indicating that DRX is not supported by the device.

18. The non-transitory computer-readable storage medium of claim 17, wherein the instructions comprise further instructions, which when executed, cause the processor to:

store information that includes a DRX setting correlated to at least one of an application identifier that identifies the application or a network slice identifier that identifies a network slice.

19. The non-transitory computer-readable storage medium of claim 18, wherein the instructions to determine comprise further instructions, which when executed, cause the processor to:

compare at least a portion of the first request to the information; and

determine whether there is a match.

20. The non-transitory computer-readable storage medium of claim 17, wherein when the device receives the first request for the network connection, the device is DRX enabled.

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