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(54) **SCHEDULING REQUEST ENHANCEMENTS FOR 5G NETWORKS**

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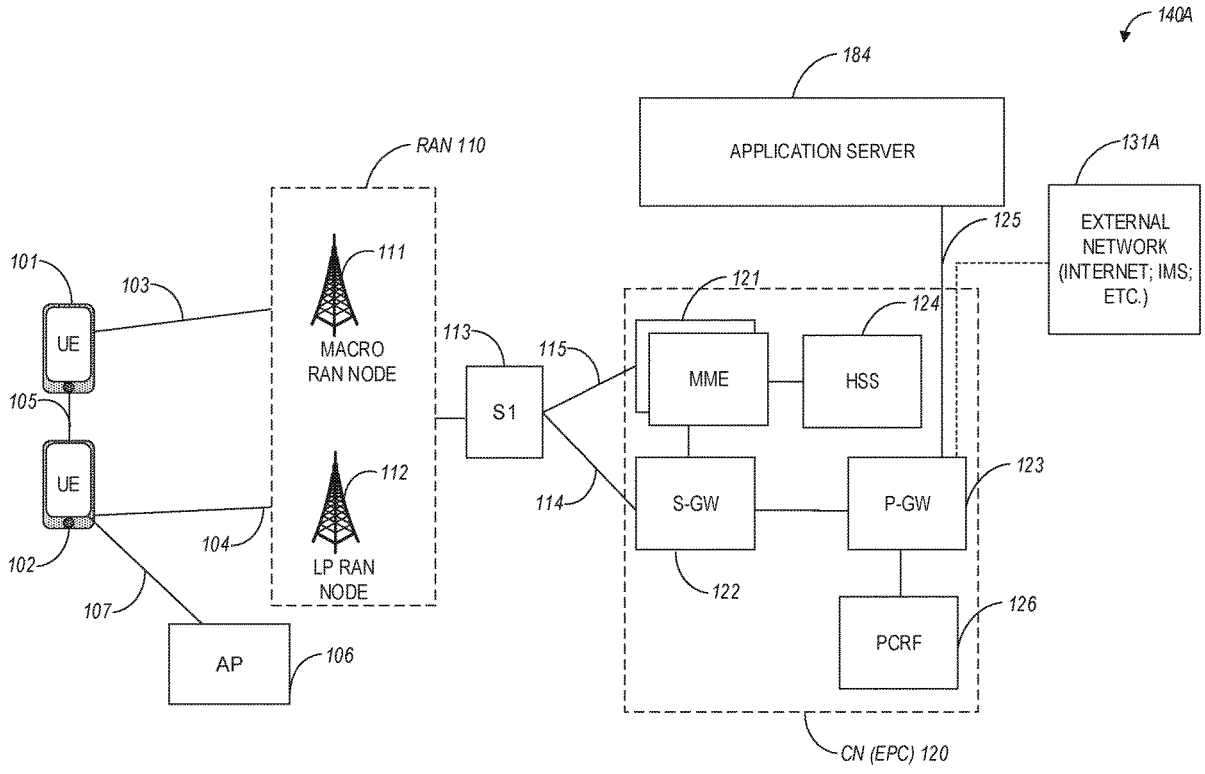
(57) **ABSTRACT**

An apparatus of user equipment (UE) includes processing circuitry coupled to memory, where to configure the UE for communication of data in a New Radio-Unlicensed (NR-U) spectrum, the processing circuitry is to decode RRC signaling from a base station. The RRC signaling includes configuration information to configure a listen-before-talk (LBT) timer and a scheduling request (SR) prohibit timer. An LBT procedure is performed while the LBT timer is activated. An SR is encoded for transmission to the base station, based on detecting an unoccupied transmission resource within the NR-U spectrum during the LBT procedure. The SR transmission activates the SR prohibit timer. An uplink grant from the base station is decoded in response to the SR, the uplink grant received while the SR prohibit timer is activated. A buffer status report (BSR) is encoded for transmission to the base station based on the uplink grant.



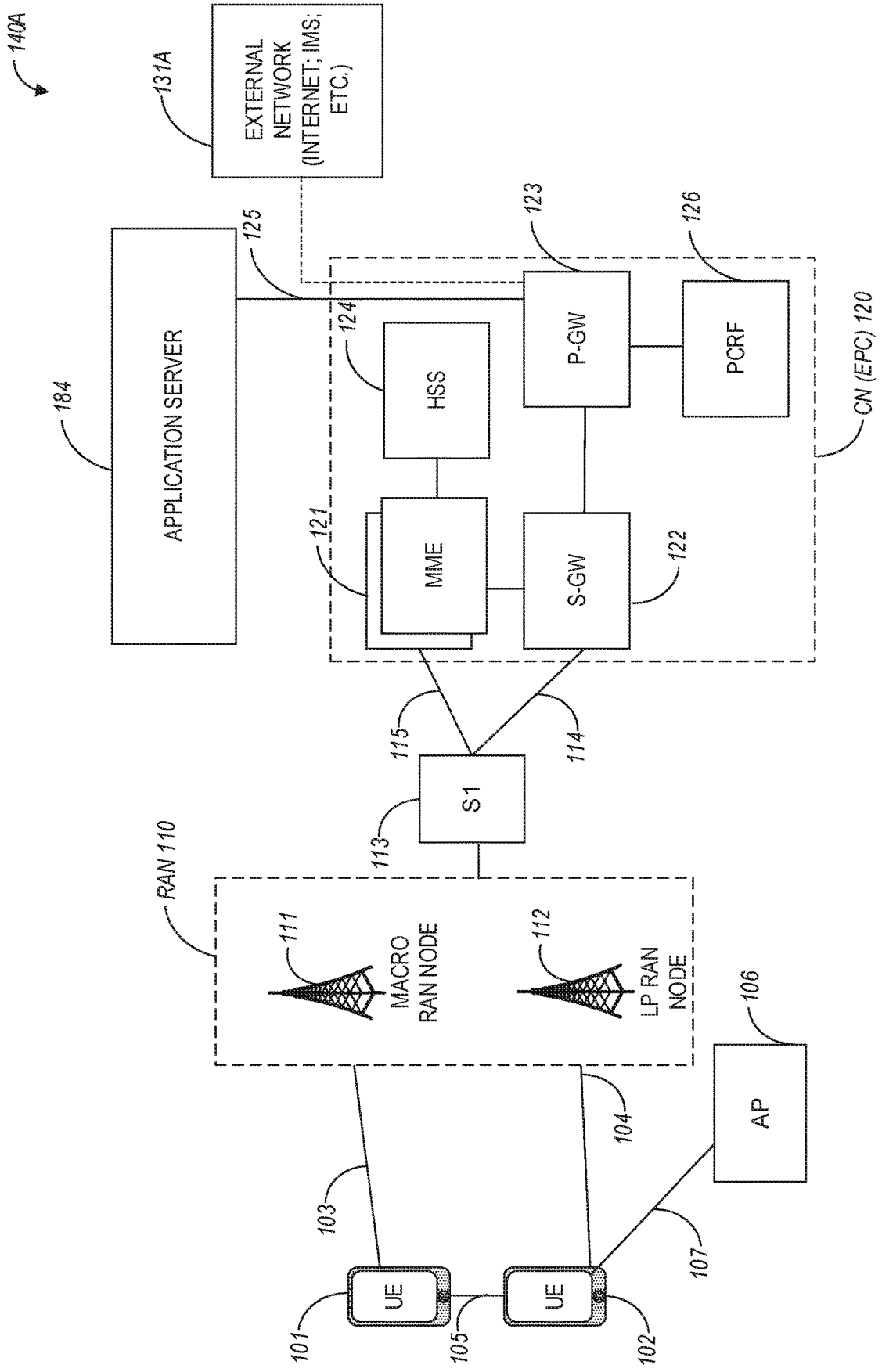

140A
131A
EXTERNAL NETWORK (INTERNET; IMS; ETC.)
125
123
126
APPLICATION SERVER
184
124
HSS
P-GW
PCRF
CN (EPC) 120
121
MME
S-GW
122
115
114
S1
113
RAN 110
111
MACRO RAN NODE
112
LP RAN NODE
106
AP
104
103
107
UE
UE
101
105
102

FIG. 1A

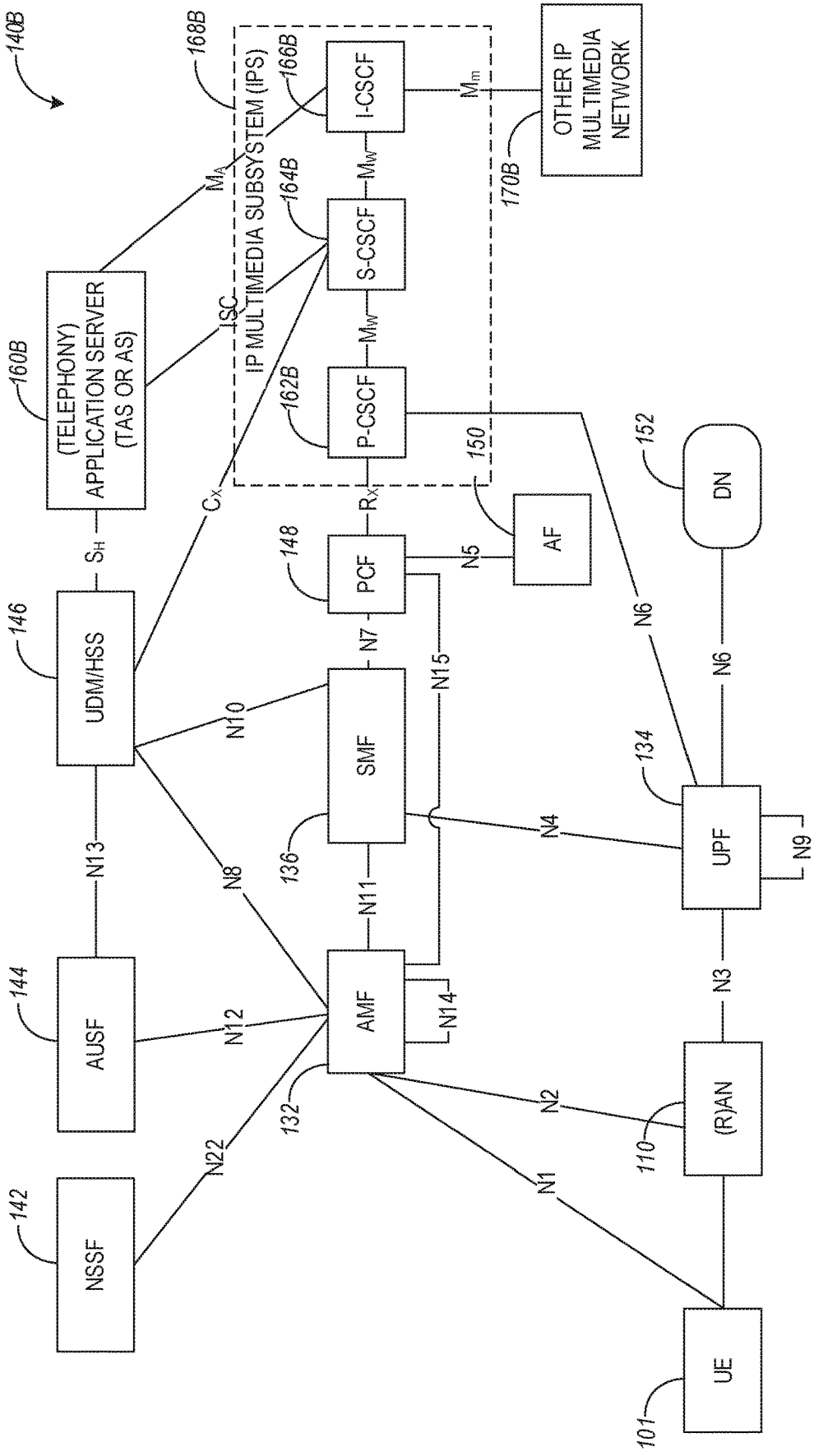

140B
168B
IP MULTIMEDIA SUBSYSTEM (IPS)
166B
I-CSCF
OTHER IP MULTIMEDIA NETWORK
170B
164B
S-CSCF
160B
(TELEPHONY) APPLICATION SERVER (TAS OR AS)
162B
P-CSCF
150
152
DN
AF
148
PCF
146
UDM/HSS
SMF
136
134
UPF
144
AUSF
AMF
132
(R)AN
110
142
NSSF
UE
101
M_A
M_W
M_m
ISC
C_X
S_H
R_X
N5
N6
N7
N8
N9
N10
N11
N12
N13
N14
N15
N22
N1
N2
N3
N4

FIG. 1B

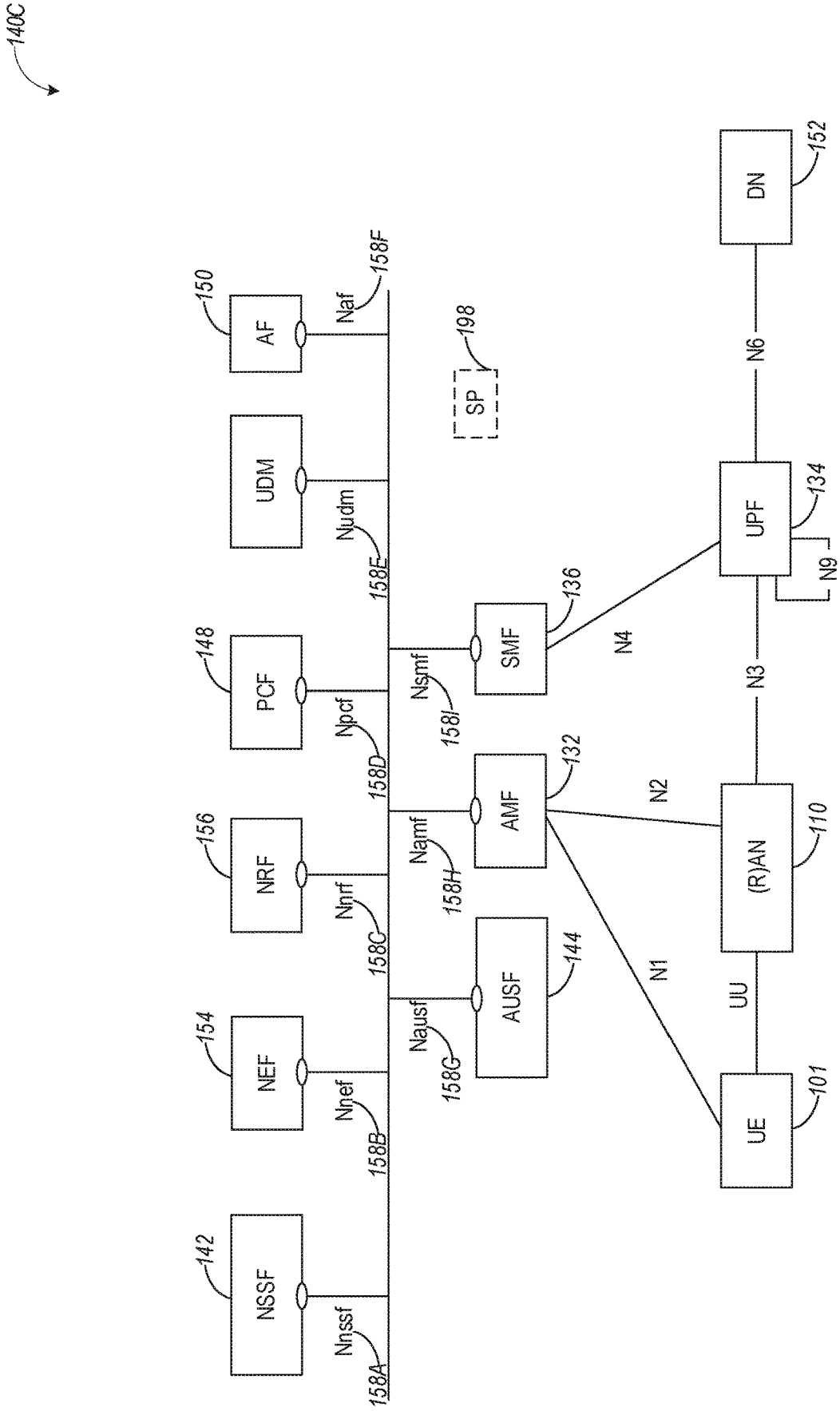

140C
NSSF
142
Nnssf
158A
NEF
154
Nnef
158B
NRF
156
Nnrf
158C
PCF
148
Npcf
158D
UDM
Nudm
158E
AF
150
Naf
158F
SP
198
Nausf
158G
AUSF
144
Namf
158H
AMF
132
Nsmf
158I
SMF
136
N1
N2
N3
N4
UE
101
UU
(R)AN
110
UPF
134
N9
N6
DN
152

FIG. 1C

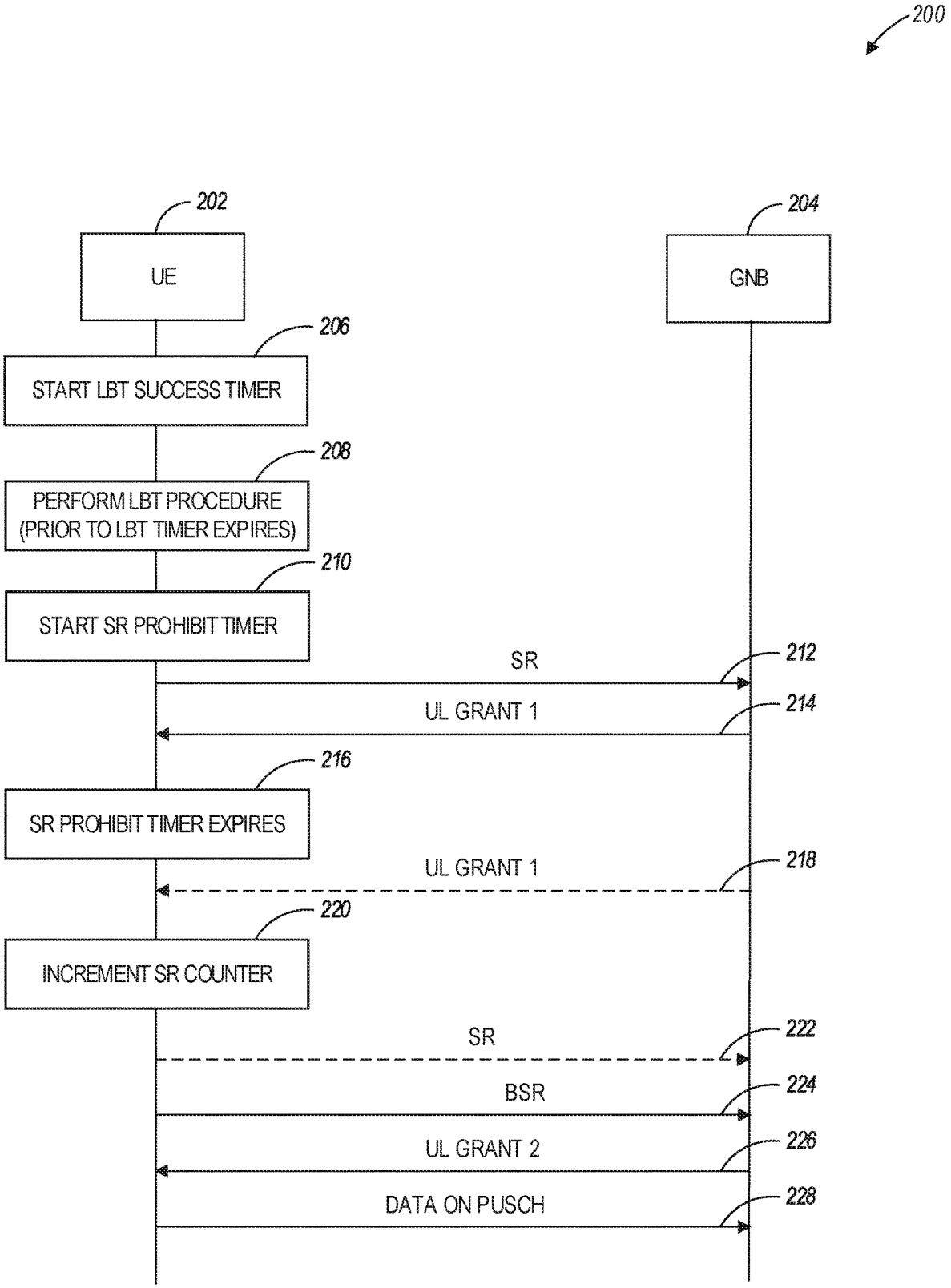

200
202
UE
204
GNB
206
START LBT SUCCESS TIMER
208
PERFORM LBT PROCEDURE (PRIOR TO LBT TIMER EXPIRES)
210
START SR PROHIBIT TIMER
SR
212
UL GRANT 1
214
216
SR PROHIBIT TIMER EXPIRES
UL GRANT 1
218
220
INCREMENT SR COUNTER
SR
222
BSR
224
UL GRANT 2
226
DATA ON PUSCH
228

FIG. 2

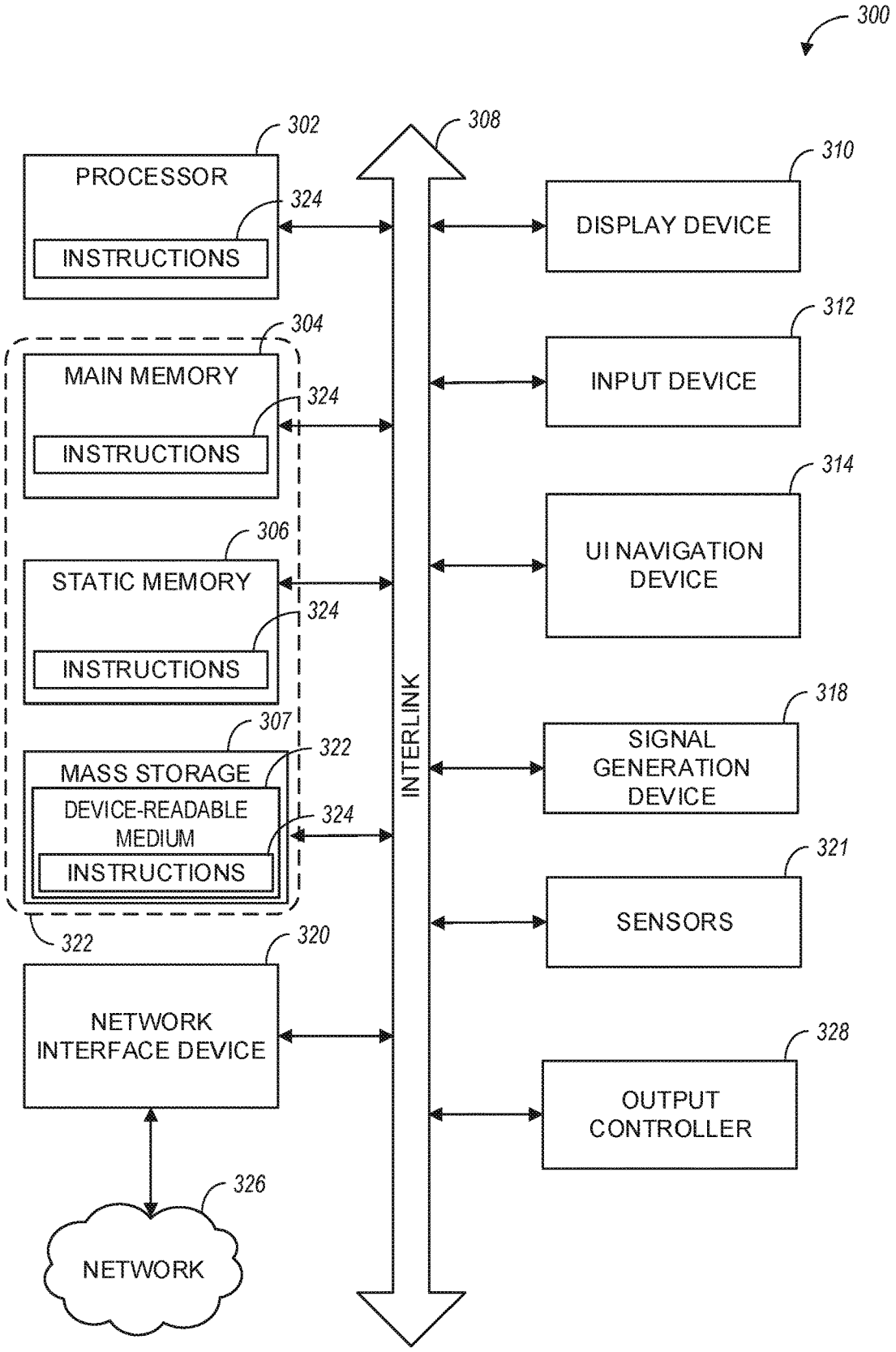

300
302
PROCESSOR
324
INSTRUCTIONS
304
MAIN MEMORY
324
INSTRUCTIONS
306
STATIC MEMORY
324
INSTRUCTIONS
307
322
MASS STORAGE
DEVICE-READABLE MEDIUM
INSTRUCTIONS
324
322
320
NETWORK INTERFACE DEVICE
326
NETWORK
308
INTERLINK
310
DISPLAY DEVICE
312
INPUT DEVICE
314
UI NAVIGATION DEVICE
318
SIGNAL GENERATION DEVICE
321
SENSORS
328
OUTPUT CONTROLLER

FIG. 3

SCHEDULING REQUEST ENHANCEMENTS FOR 5G NETWORKS

PRIORITY CLAIM

[0001] This application claims the benefit of priority to the U.S. Provisional Patent Application Ser. No. 62/753,830, filed Oct. 31, 2018, and entitled "SCHEDULING REQUEST ENHANCEMENT FOR NR UNLICENSED," which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Aspects pertain to wireless communications. Some aspects relate to wireless networks including 3GPP (Third Generation Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks, 3GPP LTE-A (LTE Advanced) networks, and fifth-generation (5G) networks including 5G new radio (NR) (or 5G-NR) networks, 5G-LTE networks, and 5G NR unlicensed spectrum (NR-U) networks. Other aspects are directed to systems and methods for scheduling request (SR) enhancements for 5G networks including NR-U networks.

BACKGROUND

[0003] Mobile communications have evolved significantly from early voice systems to today's highly sophisticated integrated communication platform. With the increase in different types of devices communicating with various network devices, usage of 3GPP LTE systems has increased. The penetration of mobile devices (user equipment or UEs) in modern society has continued to drive demand for a wide variety of networked devices in a number of disparate environments. Fifth-generation (5G) wireless systems are forthcoming and are expected to enable even greater speed, connectivity, and usability. Next generation 5G networks (or NR networks) are expected to increase throughput, coverage, and robustness and reduce latency and operational and capital expenditures. 5G-NR networks will continue to evolve based on 3GPP LTE-Advanced with additional potential new radio access technologies (RATS) to enrich people's lives with seamless wireless connectivity solutions delivering fast, rich content and services. As current cellular network frequency is saturated, higher frequencies, such as millimeter wave (mmWave) frequency, can be beneficial due to their high bandwidth.

[0004] Potential LTE operation in the unlicensed spectrum includes (and is not limited to) the LTE operation in the unlicensed spectrum via dual connectivity (DC), or DC-based LAA, and the standalone LTE system in the unlicensed spectrum, according to which LTE-based technology solely operates in unlicensed spectrum without requiring an "anchor" in the licensed spectrum, called MulteFire. MulteFire combines the performance benefits of LIE technology with the simplicity of Wi-Fi-like deployments.

[0005] Further enhanced operation of LTE systems in the licensed as well as unlicensed spectrum is expected in future releases and 5G systems. Such enhanced operations can include techniques for SR enhancements for 5G networks including NR-U networks.

BRIEF DESCRIPTION OF THE FIGURES

[0006] In the figures, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The figures illustrate generally, by way of example, but not by way of limitation, various aspects discussed in the present document.

[0007] FIG. **1**A illustrates an architecture of a network, in accordance with some aspects.

[0008] FIG. **1**B and FIG. **1**C illustrate a non-roaming 5G system architecture in accordance with some aspects.

[0009] FIG. **2** illustrates a swimlane diagram of a communication exchange between user equipment and a base station using scheduling request enhancement techniques, in accordance with some aspects.

[0010] FIG. **3** illustrates a block diagram of a communication device such as an evolved Node-B (eNB), a new generation Node-B (gNB), an access point (AP), a wireless station (STA), a mobile station (MS), or a user equipment (UE), in accordance with some aspects.

DETAILED DESCRIPTION

[0011] The following description and the drawings sufficiently illustrate aspects to enable those skilled in the art to practice them. Other aspects may incorporate structural, logical, electrical, process, and other changes. Portions and features of some aspects may be included in or substituted for, those of other aspects. Aspects set forth in the claims encompass all available equivalents of those claims.

[0012] FIG. **1**A illustrates an architecture of a network in accordance with some aspects. The network **140**A is shown to include user equipment (UE) **101** and UE **102**. The UEs **101** and **102** are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks) but may also include any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, drones, or any other computing device including a wired and/or wireless communications interface. The UEs **101** and **102** can be collectively referred to herein as UE **101**, and UE **101** can be used to perform one or more of the techniques disclosed herein.

[0013] Any of the radio links described herein (e.g., as used in the network **140**A or any other illustrated network) may operate according to any exemplary radio communication technology and/or standard.

[0014] LTE and LTE-Advanced are standards for wireless communications of high-speed data for UE such as mobile telephones. In LTE-Advanced and various wireless systems, carrier aggregation is a technology according to which multiple carrier signals operating on different frequencies may be used to carry communications for a single LT, thus increasing the bandwidth available to a single device. In some aspects, carrier aggregation may be used where one or more component carriers operate on unlicensed frequencies.

[0015] Aspects described herein can be used in the context of any spectrum management scheme including, for example, dedicated licensed spectrum, unlicensed spectrum, (licensed) shared spectrum (such as Licensed Shared Access (LSA) in 2.3-2.4 GHz, 3.4-3.6 GHz, 3.6-3.8 GHz, and further frequencies and Spectrum Access System (SAS) in 3.55-3.7 GHz and further frequencies).

[0016] Aspects described herein can also be applied to different Single Carrier or OFDM flavors (CP-OFDM, SC-FDMA, SC-OFDM, filter bank-based multicarrier (FBMC),

OFDMA, etc.) and in particular 3GPP NR (New Radio) by allocating the OFDM carrier data bit vectors to the corresponding symbol resources.

[0017] In some aspects, any of the UEs **101** and **102** can comprise an Internet-of-Things (IoT) UE or a Cellular IoT (CIoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. In some aspects, any of the UEs **101** and **102** can include a narrowband (NB) IoT UE (e.g., such as an enhanced NB-IoT (eNB-IoT) UE and Further Enhanced (FeNB-IoT) UE). An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network includes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0018] In some aspects, any of the UEs **101** and **102** can include enhanced MTC (eMTC) UEs or further enhanced MTC (FeMTC) UEs.

[0019] The UEs **101** and **102** may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) **110**. The RAN **110** may be, for example, an Evolved Universal Mobile Telecommunications System (UNITS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs **101** and **102** utilize connections **103** and **104**, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections **103** and **104** are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth-generation (5G) protocol, a New Radio (NR) protocol, and the like.

[0020] In an aspect, the UEs **101** and **102** may further directly exchange communication data via a ProSe interface **105**. The ProSe interface **105** may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0021] The UE **102** is shown to be configured to access an access point (AP) **106** via connection **107**. The connection **107** can comprise a local wireless connection, such as, for example, a connection consistent with any IEEE 802.11 protocol, according to which the AP **106** can comprise a wireless fidelity (WiFi®) router. In this example, the AP **106** is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0022] The RAN **110** can include one or more access nodes that enable the connections **103** and **104**. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), Next Generation NodeBs (gNBs), RAN nodes, and the like, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). In some aspects, the communication nodes **111** and **112** can be transmission/reception points (TRPs). In instances when the communication nodes **111** and **112** are NodeBs (e.g., eNBs or gNBs), one or more TRPs can function within the communication cell of the NodeBs. The RAN **110** may include one or more RAN nodes for providing macrocells, e.g., macro RAN node **111**, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node **112**.

[0023] Any of the RAN nodes **111** and **112** can terminate the air interface protocol and can be the first point of contact for the UEs **101** and **102**. In some aspects, any of the RAN nodes **111** and **112** can fulfill various logical functions for the RAN **110** including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In an example, any of the nodes **111** and/or **112** can be a new generation Node-B (gNB), an evolved node-B (eNB), or another type of RAN node.

[0024] The RAN **110** is shown to be communicatively coupled to a core network (CN) **120** via an S1 interface **113**. In aspects, the CN **120** may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN (e.g., as illustrated in reference to FIGS. 1B-1I). In this aspect, the S1 interface **113** is split into two parts: the S1-U interface **114**, which carries traffic data between the RAN nodes **111** and **112** and the serving gateway (S-GW) **122**, and the S1-mobility management entity (MMF) interface **115**, which is a signaling interface between the RAN nodes **111** and **112** and MMEs **121**.

[0025] In this aspect, the CN **120** comprises the MMEs **121**, the S-GW **122**, the Packet Data Network (PDN) Gateway (P-GW) **123**, and a home subscriber server (HSS) **124**. The MMEs **121** may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs **121** may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS **124** may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN **120** may comprise one or several HSSs **124**, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS **124** can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[0026] The S-GW **122** may terminate the S1 interface **113** towards the RAN **110**, and routes data packets between the RAN **110** and the CN **120**. In addition, the S-GW **122** may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP

mobility. Other responsibilities of the S-GW **122** may include a lawful intercept, charging, and some policy enforcement.

[0027] The P-GW **123** may terminate an SGi interface toward a PDN. The P-GW **123** may route data packets between the EPC network **120** and external networks such as a network including the application server **184** (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface **125**. The P-GW **123** can also communicate data to other external networks **131**A, which can include the Internet, IP multimedia subsystem (IPS) network, and other networks. Generally, the application server **184** may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this aspect, the P-GW **123** is shown to be communicatively coupled to an application server **184** via an IP interface **125**. The application server **184** can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs **101** and **102** via the CN **120**.

[0028] The P-GW **123** may further be a node for policy enforcement and charging data collection. Policy and Charging Rules Function (PCRF) **126** is the policy and charging control element of the CN **120**. In a non-roaming scenario, in some aspects, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with a local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within an HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF **126** may be communicatively coupled to the application server **184** via the P-GW **123**.

[0029] In some aspects, the communication network **140**A can be an IoT network or a 5G network, including 5G new radio network using communications in the licensed (5G NR) and the unlicensed (5G NR-U) spectrum. One of the current enablers of IoT is the narrowband-IoT (NB-IoT).

[0030] An NG system architecture can include the RAN **110** and a 5G network core (5GC) **120**. The NG-RAN **110** can include a plurality of nodes, such as gNBs and NG-eNBs. The core network **120** (e.g., a 5G core network or 5GC) can include an access and mobility function (ANTE) and/or a user plane function (UPF). The AMF and the UPF can be communicatively coupled to the gNBs and the NG-eNBs via NG interfaces. More specifically, in some aspects, the gNBs and the NG-eNBs can be connected to the AMF by NG-C interfaces, and to the UPF by NG-U interfaces. The gNBs and the NG-eNBs can be coupled to each other via Xn interfaces.

[0031] In some aspects, the NG system architecture can use reference points between various nodes as provided by 3GPP Technical Specification (TS) 23.501 (e.g., V15.4.0, 2018-12). In some aspects, each of the gNBs and the NG-eNBs can be implemented as a base station, a mobile edge server, a small cell, a home eNB, and so forth. In some aspects, a gNB can be a master node (MN) and NG-eNB can be a secondary node (SN) in a 5G architecture.

[0032] FIG. **1**B illustrates a non-roaming 5G system architecture in accordance with some aspects. Referring to FIG. **1**B, there is illustrated a 5G system architecture **140**B in a reference point representation. More specifically, UE **102** can be in communication with RAN **110** as well as one or more other 5G core (5GC) network entities. The 5G system architecture **140**B includes a plurality of network functions (NFs), such as access and mobility management function (ANTE) **132**, session management function (SMF) **136**, policy control function (PCF) **148**, application function (AF) **150**, user plane function (UPF) **134**, network slice selection function (NSSF) **142**, authentication server function (AUSF) **144**, and unified data management (UDM)/home subscriber server (HSS) **146**. The UPF **134** can provide a connection to a data network (DN) **152**, which can include, for example, operator services, Internet access, or third-party services. The AMF **132** can be used to manage access control and mobility and can also include network slice selection functionality. The SMF **136** can be configured to set up and manage various sessions according to network policy. The UPF **134** can be deployed in one or more configurations according to the desired service type. The PCF **148** can be configured to provide a policy framework using network slicing, mobility management, and roaming (similar to PCRF in a 4G communication system). The UDM can be configured to store subscriber profiles and data (similar to an HSS in a 4G communication system).

[0033] In some aspects, the 5G system architecture **140**B includes an IP multimedia subsystem (IMS) **168**B as well as a plurality of IP multimedia core network subsystem entities, such as call session control functions (CSCFs). More specifically, the IMS **168**B includes a CSCF, which can act as a proxy CSCF (P-CSCF) **162**BE, a serving CSCF (S-CSCF) **164**B, an emergency CSCF (E-CSCF) (not illustrated in FIG. B), or interrogating CSCF (I-CSCF) **166**B, The P-CSCF **162**B can be configured to be the first contact point for the UE **102** within the IM subsystem (IMS) **168**B. The S-CSCF **164**B can be configured to handle the session states in the network, and the E-CSCF can be configured to handle certain aspects of emergency sessions such as routing an emergency request to the correct emergency center or PSAP. The I-CSCF **166**B can be configured to function as the contact point within an operators network for all IMS connections destined to a subscriber of that network operator, or a roaming subscriber currently located within that network operator's service area. In some aspects, the I-CSCF **166**B can be connected to another IP multimedia network **170**E, e.g. an IMS operated by a different network operator.

[0034] In some aspects, the UDM/HSS **146** can be coupled to an application server **160**E, which can include a telephony application server (TAS) or another application server (AS). The AS **160**B can be coupled to the IMS **168**B via the S-CSCF **164**B or the I-CSCF **166**B.

[0035] A reference point representation shows that interaction can exist between corresponding NF services. For example, FIG. **19** illustrates the following reference points: N1 (between the UE **102** and the AMF **132**), N2 (between the RAN **110** and the AMF **132**), N3 (between the RAN **110** and the UPF **134**), N4 (between the SMF **136** and the UPF **134**), N5 (between the PCF **148** and the AF **150**, not shown), N6 (between the UPF **134** and the DN **152**), N7 (between the SWF **136** and the PCF **148**, not shown), N8 (between the UDM **146** and the AMF **132**, not shown), N9 (between two UPFs **134**, not shown), N10 (between the UDM **146** and the SMF **136**, not shown), N11 (between the AMF **132** and the SMF **136**, not shown), N12 (between the AUSF **144** and the

AMF **132**, not shown), N13 (between the AUSF **144** and the UDM **146**, not shown), N14 (between two AMFs **132**, not shown), N15 (between the PCF **148** and the AMF **132** in case of a non-roaming scenario, or between the PCF **148** and a visited network and AMF **132** in case of a roaming scenario, not shown), N16 (between two SMFs, not shown), and N22 (between AMF **132** and NSSF **142**, not shown). Other reference point representations not shown in FIG. **1**E can also be used.

[0036] FIG. **1**C illustrates a 5G system architecture **140**C and a service-based representation. In addition to the network entities illustrated in FIG. system architecture **140**C can also include a network exposure function (NEF) **154** and a network repository function (NRF) **156**. In some aspects, 5G system architectures can be service-based and interaction between network functions can be represented by corresponding point-to-point reference points Ni or as service-based interfaces.

[0037] In some aspects, as illustrated in FIG. **1**C, service-based representations can be used to represent network functions within the control plane that enable other authorized network functions to access their services. In this regard, 5G system architecture **140**C can include the following service-based interfaces: Namf **158**H (a service-based interface exhibited by the AMF **132**), Nsmf **1581** (a service-based interface exhibited by the SMF **136**), Nnef **158**B (a service-based interface exhibited by the NEF **154**), Npcf **158**D (a service-based interface exhibited by the PCF **148**), a Nudm **158**E (a service-based interface exhibited by the UDM **146**), Naf **158**F (a service-based interface exhibited by the AF **150**), Nnrf **158**C (a service-based interface exhibited by the NRF **156**), Nnssf **158**A (a service-based interface exhibited by the NSSF **142**), Nausf **158**G (a service-based interface exhibited by the AUSF **144**). Other service-based interfaces (e.g., Nudr, N5g-eir, and Nudsf) not shown in FIG. **1**C can also be used.

[0038] Techniques discussed herein can be performed by a UE or a base station (e.g., any of the UEs or base stations illustrated in connection with FIG. **1**A-FIG. **1**C).

[0039] Rel-15 NR systems are designed to operate on the licensed spectrum. The NR-U is a technology that enables the operation of NR systems on the unlicensed spectrum.

[0040] A scheduling request (SR) is needed for UEs in connected mode or in NR-U standalone mode, as well as in an LTE-NR-U deployment scenario. Transmitting an SR on a PUCCH may be subject to certain listen-before-talk (LBT) requirements in the unlicensed spectrum. Techniques discussed herein can be used to alleviate the impacts of LBT.

[0041] SR Counter and Timer.

[0042] In some aspects, RRC signaling can be used to configure an SR timer, an SR counter, and a threshold (e.g., sr-TransMax threshold) for the SR counter. Additionally, the RRC signaling can also configure a separate LBT timer (or LBT success timer) as well as in the LBT failure counter (and an associated LBT failure counter threshold). The LBT timer can be started after an LBT procedure is initiated. If the UE does not detect an available spectrum/channel before the LBT timer expires, the LBT failure counter is incremented. If the LBT failure counter threshold is reached, a connection reestablishment or another reconfiguration procedure can be initiated. Otherwise, a new LBT timer can be started after a new LBT procedure is initiated.

[0043] Upon successful detection of the available NR-U spectrum, the SR timer can be started upon the communication of an SR to the base station. If a response (e.g., a first uplink grant) is not received before the SR timer expires, the SR counter is incremented. If the SR counter threshold is reached, the UE can perform a connection reestablishment or another reconfiguration procedure. If the UE receives the first uplink grant before the SR timer expires, the UE can communicate a buffer status report (BSR) to the base station, and receive a second uplink grant in response to the BSR. The UE can then communicate the data reflected in the BSR to the base station using the second uplink grant.

[0044] In some aspects, when a separate LBT timer and a separate LBT counter are not configured, the UE can increase the timer duration for the SR timer as well as the SR counter threshold to account for a possible SR transmission delay due to LBT failures.

[0045] In some aspects, SR transmissions are subject to LBT (e.g., in NR-U communication networks). In this case, starting an SR timer (e.g., the sr-ProhibitTimer) may prevent the MAC entity of the UE from signaling the physical layer for an SR transmission if the SR transmission is not performed due to LBT during the SR transmission occasion configured for the pending SR. Hence, in some aspects, the physical layer may indicate the success of the LBT during the SR transmission occasion to initiate the start of the prohibit timer.

[0046] In aspects when a previous SR transmission is not successful due to LBT (i.e., absence of physical layer indication on the previous SR transmission occasion), the UE can determine whether to increment SR_COUNTER for the subsequent SR transmission occasion for the SR that is configured.

[0047] The purpose of the SR counter (e.g., SR_COUNTER) is to give a maximum attempts the UE can perform SR transmission to avoid the UE getting stuck in the requesting state due to poor RF conditions. LBT failure can be seen as another factor of poor RF condition (i.e., when the channel load is very high). In this regard, the SR_COUNTER may be incremented. To take into consideration of the LBT failure, the sr-TransMax counter threshold can be configured appropriately to provide the time domain solution to overcome LBT via RRC signaling/default configuration or set dynamically based on channel load (e.g. RSSI or channel occupancy, presence of DL transmission, etc.). For RSSI or channel occupancy, if such values are above a certain fixed or configurable threshold at the point the SR procedure started, the sr-TransMax threshold may be used for that RSSI or channel occupancy. In this regard, there is an sr-TransMax for different RSSIs or channel occupancy.

[0048] In aspects when the counter is not incremented, the MAC entity may get stuck in this state for a very long time if the channel continues to be busy during the SR transmission occasion. This processing may be acceptable when the channel is lightly loaded.

[0049] In some aspects, a separate LBT success timer and an LBT counter (per SR configuration) may be used to count the number of SR transmission failures due to LBT. In this case, the existing SR_COUNTER may continue to be associated with failure of SR transmission due to RF condition other than LBT failure, while the new separate LBT failure counter counts the number of LBT failures associated with the SR transmission. Once the separate LBT failure counter reaches a fix or configurable maximum value, it can either

report it to the network via RRC or MAC signaling message (for the DC or CA case) or perform RRC Connection Re-establishment.

[0050] FIG. **2** illustrates a swimlane diagram of a communication exchange **200** between a user equipment (UE) **202** and a base station **204** using scheduling request enhancement techniques, in accordance with some aspects. Referring to FIG. **2**, and an initial configuration stage, UE **202** may start the LBT success timer at operation **206**. While the tinier is running, at operation **208**, UE **202** may perform an LBT procedure and may detect an available NR-U spectrum prior to the expiration of the LBT success timer. Upon detecting the available spectrum, UE **202** may start the SR prohibit timer at operation **210**. While the SR prohibit timer is running, the UE **202** communicates an SR to the base station **204** at operation **212**. In response, at operation **214**, the base station **204** communicates a first uplink grant for communication of a BSR. At operation **216**, the SR prohibit timer expires.

[0051] Optionally, the first uplink grant may be received via operation **218**, subsequent to the expiration of the SR prohibit timer, and retransmits the SR at operation **222**.

[0052] The UE **202** communicates the BSR at operation **224**, based on the first uplink grant received from the base station **204**. At operation **226**, in response to the BSR, the base station **204** communicates a second uplink grant. At operation **228**, the UE **202** communicates data on a PUSCH based on the second uplink grant.

[0053] Increasing SR Transmission Opportunity.

[0054] In some aspects, an SR configuration may include a set of PUCCH resources for SR across different bandwidth parts (BWPs) and/or cells. The PUCCH resources associated with an SR configuration can be overlapping in time across different BWP and serving cells.

[0055] In some aspects, to increase the SR transmission opportunities, the MAC may pass on multiple SR PUCCH resources across the different serving cell associated with the SR configuration to the physical layer, thus allowing the physical layer to attempt SR transmission on the first PUCCH resource (across different serving cell) that passes LBT. If multiple active BWPs is possible for NR-U communications, the PUCCH resources across different active BWP can also be used to increase the SR transmission opportunities. Therefore, the UE MAC entity may provide the PUCCH resources across different serving cells of the SR configuration to the physical layer. If multiple active BWPs is possible for NR-U communications, it may also be beneficial for the UE MAC entity to provide the PUCCH resources across different active BWPs of the SR configuration to the physical layer.

[0056] Scheduling Request and Configured Grant.

[0057] In some aspects, a configured grant may be configured and active for the UE, and the BSR may be communicated via the configured grant, without communicating an SR first. In this case, there is a need to ensure the BSR that is triggered only by logical channels that are configured to use unlicensed serving cell with Configured Grant enhanced for unlicensed carrier will not trigger an SR (this is to reduce the possible collision between configured grant and scheduled grant from happening). If all the logical channels that triggered the BSR has logical channel restriction restricting to use unlicensed serving cell with Configured Grant enhanced for unlicensed carrier, then SR may not be triggered.

[0058] In some aspects, techniques disclosed herein can be used to manage counters and timers in scheduling request when the transmission is subjected to LBT. In some aspects, scheduling request transmission opportunities can be increased in light of LBT. In some aspects, scheduling requests may be bypassed when a configured grant is available. The start of the sr-ProhibitTimer may be subject to the successfully completed indication of LBT. The counter SR_COUNTER may be increment regardless of the outcome of LBT. In some aspects, the SR_COUNTER threshold is configurable based on network loading or RF condition. In some aspects, a separate counter is used to count the number of LBT failures. In some aspects, a separate LBT counter is configurable via signaling from the base station. In some aspects, when the LBT counter reaches a configurable threshold, the counter value is reported to the gNB. In some aspects, when the LBT counter reaches a configurable threshold, the UE will go through RRC Connection Reestablishment. In some aspects, the counter SR_COUNTER is incremented when LBT passes. In some aspects, multiple PUCCH resources can be configured for each SR. In some aspects, the PUCCH resources can be located in a different frequency domain. In some aspects, the different frequency domains can include different BWPs, subbands, or serving cells. In some aspects, the scheduling request can be skipped if the logical channel configuration allows it. In some aspects, a configuration field (e.g., in control signaling) for indicating a skipped SR may be used.

[0059] FIG. **3** illustrates a block diagram of a communication device such as an evolved. Node-B (eNB), a next generation Node-B (gNB), an access point (AP), a wireless station (STA), a mobile station (MS), or a user equipment (UE), in accordance with some aspects and to perform one or more of the techniques disclosed herein. In alternative aspects, the communication device **300** may operate as a standalone device or may be connected (e.g., networked) to other communication devices.

[0060] Circuitry (e.g., processing circuitry) is a collection of circuits implemented in tangible entities of the device **300** that include hardware (e.g., simple circuits, gates, logic, etc.). Circuitry membership may be flexible over time. Circuitries include members that may, alone or in combination, perform specified operations when operating. In an example, the hardware of the circuitry may be immutably designed to carry out a specific operation (e.g., hardwired). In an example, the hardware of the circuitry may include variably connected physical components (e.g., execution units, transistors, simple circuits, etc.) including a machine-readable medium physically modified (e.g., magnetically, electrically, moveable placement of invariant massed particles, etc.) to encode instructions of the specific operation.

[0061] In connecting the physical components, the underlying electrical properties of a hardware constituent are changed, for example, from an insulator to a conductor or vice versa. The instructions enable embedded hardware (e.g., the execution units or a loading mechanism) to create members of the circuitry in hardware via the variable connections to carry out portions of the specific operation when in operation. Accordingly, in an example, the machine-readable medium elements are part of the circuitry or are communicatively coupled to the other components of the circuitry when the device is operating. For example, any of the physical components may be used in more than one member of more than one circuitry. For example, under

operation, execution units may be used in a first circuit of a first circuitry at one point in time and reused by a second circuit in the first circuitry, or by a third circuit in a second circuitry at a different time. Additional examples of these components with respect to the device **300** follow.

[0062] In some aspects, the device **300** may operate as a standalone device or may be connected (e.g., networked) to other devices. In a networked deployment, the communication device **300** may operate in the capacity of a server communication device, a client communication device, or both in server-client network environments. In an example, the communication device **300** may act as a peer communication device in peer-to-peer (P2P) (or other distributed) network environment. The communication device **300** may be a UE, eNB, PC, a tablet PC, a STB, a PDA, a mobile telephone, a smartphone, a web appliance, a network router, switch or bridge, or any communication device capable of executing instructions (sequential or otherwise) that specify actions to be taken by that communication device. Further, while only a single communication device is illustrated, the term "communication device" shall also be taken to include any collection of communication devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), and other computer cluster configurations.

[0063] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. For example, the software may reside on a communication device-readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0064] Accordingly, the term "module" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using the software, the general-purpose hardware processor may be configured as respective different modules at different times. The software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0065] Communication device (e.g., UE) **300** may include a hardware processor **302** (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory **304**, a static memory **306**, and mass storage **307** (e.g., hard drive, tape drive, flash storage, or other block or storage devices), some or all of which may communicate with each other via an interlink (e.g., bus) **308**.

[0066] The communication device **300** may further include a display device **310**, an alphanumeric input device **312** (e.g., a keyboard), and a user interface (UI) navigation device **314** (e.g., a mouse). In an example, the display device **310**, input device **312** and UI navigation device **314** may be a touchscreen display. The communication device **300** may additionally include a signal generation device **318** (e.g., a speaker), a network interface device **320**, and one or more sensors **321**, such as a global positioning system (GPS) sensor, compass, accelerometer, or another sensor. The communication device **300** may include an output controller **328**, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.

[0067] The storage device **307** may include a communication device-readable medium **322**, on which is stored one or more sets of data structures or instructions **324** (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. In some aspects, registers of the processor **302**, the main memory **304**, the static memory **306**, and/or the mass storage **307** may be, or include (completely or at least partially), the device-readable medium **322**, on which is stored the one or more sets of data structures or instructions **324**, embodying or utilized by any one or more of the techniques or functions described herein. In an example, one or any combination of the hardware processor **302**, the main memory **304**, the static memory **306**, or the mass storage **316** may constitute the device-readable medium **322**.

[0068] As used herein, the term "device-readable medium" is interchangeable with "computer-readable medium" or "machine-readable medium". While the communication device-readable medium **322** is illustrated as a single medium, the term "communication device-readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database; and/or associated caches and servers) configured to store the one or more instructions **324**. The term "communication device-readable medium" is inclusive of the terms "machine-readable medium" or "computer-readable medium", and may include any medium that is capable of storing, encoding, or carrying instructions (e.g., instructions **324**) for execution by the communication device **300** and that cause the communication device **300** to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting communication device-readable medium examples may include solid-state memories and optical and magnetic media. Specific examples of communication device-readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, communication device-readable media may include non-transitory communication device-readable media. In some

examples, communication device-readable media may include communication device-readable media that is not a transitory propagating signal.

[0069] The instructions **324** may further be transmitted or received over a communications network **326** using a transmission medium via the network interface device **320** utilizing any one of a number of transfer protocols. In an example, the network interface device **320** may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network **326**. In an example, the network interface device **320** may include a plurality of antennas to wirelessly communicate using at least one of single-input-multiple-output (SIMO), MIMO, or multiple-input-single-output (MISO) techniques. In some examples, the network interface device **320** may wirelessly communicate using Multiple User MIMO techniques.

[0070] The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the communication device **300**, and includes digital or analog communications signals or another intangible medium to facilitate communication of such software. In this regard, a transmission medium in the context of this disclosure is a device-readable medium.

[0071] Although an aspect has been described with reference to specific exemplary aspects, it will be evident that various modifications and changes may be made to these aspects without departing from the broader scope of the present disclosure. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various aspects is defined only by the appended claims, along with the fill range of equivalents to which such claims are entitled.

1-20. (canceled)

21. An apparatus comprising:

at least one processor, wherein to configure a user equipment (UE) for communication of data in a New Radio-Unlicensed (NR-U) spectrum, the at least one processor is configured to cause the UE to:

instruct a physical layer to signal a scheduling request (SR) for transmission to the base station;

if the SR transmission is not successful due to a listen-before-talk (LBT) failure, increment an LBT failure counter without incrementing a SR counter and starting an SR prohibit timer;

if the LBT for the SR transmission is successful, increment the SR counter and start the SR prohibit timer.

22. The apparatus of claim **21**, wherein determination of the LBT failure is based on a physical layer indication.

23. The apparatus of claim **21**, wherein said instructing and incrementing is performed by a medium access control (MAC) layer.

24. The apparatus of claim **21**, wherein the at least one processor is further configured to:

perform RRC connection re-establishment when the LBT failure counter reaches an configured threshold.

25. The apparatus of claim **21**, wherein the at least one processor is further configured to:

report to a network via MAC or radio resource control (RRC) signaling when the LBT failure counter reaches a configured threshold.

26. The apparatus of claim **21**, wherein said instructing is response to triggering of an SR, and wherein the SR is triggering by a buffer status report (BSR).

27. The apparatus of claim **21**, wherein resources for the SR transmission are provided by an SR configuration, and wherein the SR configuration includes SR resources on corresponding physical uplink control channel (PUCCH) resources in a plurality of bandwidth parts.

28. The apparatus of claim **21**, wherein the at least one processor is further configured to:

increment the SR counter and start the SR prohibit timer when the LBT is successful and the SR transmission fails.

29. A user equipment (UE) comprising:

wireless communication circuitry; and

at least one processor coupled to the wireless communication circuitry, wherein to configure a user equipment (UE) for communication of data in a New Radio-Unlicensed (NR-U) spectrum, the at least one processor is configured to cause the UE to:

instruct a physical layer to signal a scheduling request (SR) for transmission to the base station;

if the SR transmission is not successful due to a listen-before-talk (LBT) failure, increment an LBT failure counter without incrementing a SR counter and starting an SR prohibit timer;

if the LBT for the SR transmission is successful, increment the SR counter and start the SR prohibit timer.

30. The UE of claim **29**, wherein determination of the LBT failure is based on a physical layer indication.

31. The UE of claim **29**, wherein said instructing and incrementing is performed by a medium access control (MAC) layer.

32. The UE of claim **29**, wherein the at least one processor is further configured to:

perform RRC connection re-establishment when the LBT failure counter reaches an configured threshold.

33. The UE of claim **29**, wherein the at least one processor is further configured to:

report to a network via MAC or radio resource control (RRC) signaling when the LBT failure counter reaches a configured threshold.

34. The UE of claim **29**, wherein said instructing is response to triggering of an SR, and wherein the SR is triggering by a buffer status report (BSR).

35. The UE of claim **29**, wherein resources for the SR transmission are provided by an SR configuration, and wherein the SR configuration includes SR resources on corresponding physical uplink control channel (PUCCH) resources in a plurality of bandwidth parts.

36. The UE of claim **29**, wherein the at least one processor is further configured to:

increment the SR counter and start the SR prohibit timer when the LBT is successful and the SR transmission fails.

37. A method for operating a user equipment (UE) comprising:

by the UE:

instructing a physical layer to signal a scheduling request (SR) for transmission to the base station;

if the SR transmission is not successful due to a listen-before-talk (LBT) failure, incrementing an LBT failure counter without incrementing a SR counter and starting an SR prohibit timer;

if the LBT for the SR transmission is successful, incrementing the SR counter and starting the SR prohibit timer.

38. The method of claim **37**, further comprising:

performing RRC connection re-establishment when the LBT failure counter reaches an configured threshold.

39. The method of claim **37**, wherein resources for the SR transmission are provided by an SR configuration, and wherein the SR configuration includes SR resources on corresponding physical uplink control channel (PUCCH) resources in a plurality of bandwidth parts.

40. The method of claim **37**, further comprising:

incrementing the SR counter and start the SR prohibit timer when the LBT is successful and the SR transmission fails.

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