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(54) **RESOURCE CONFIGURATION FOR JOINT COMMUNICATION AND SENSING**

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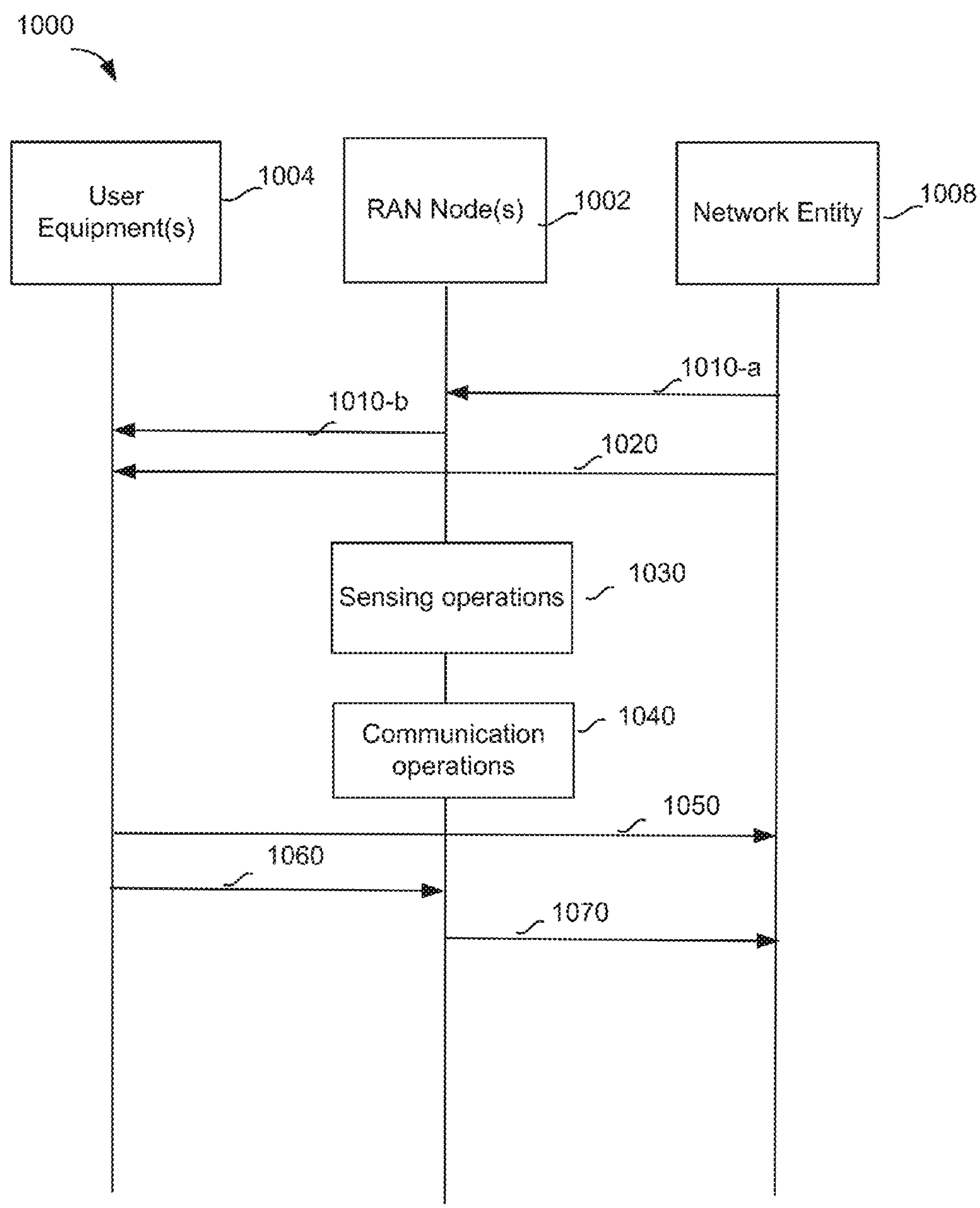
(57) **ABSTRACT**

Disclosed are techniques for wireless communication. In an aspect, a user equipment may receive a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations. The user equipment may perform one or more sensing operations during the sensing time resources.



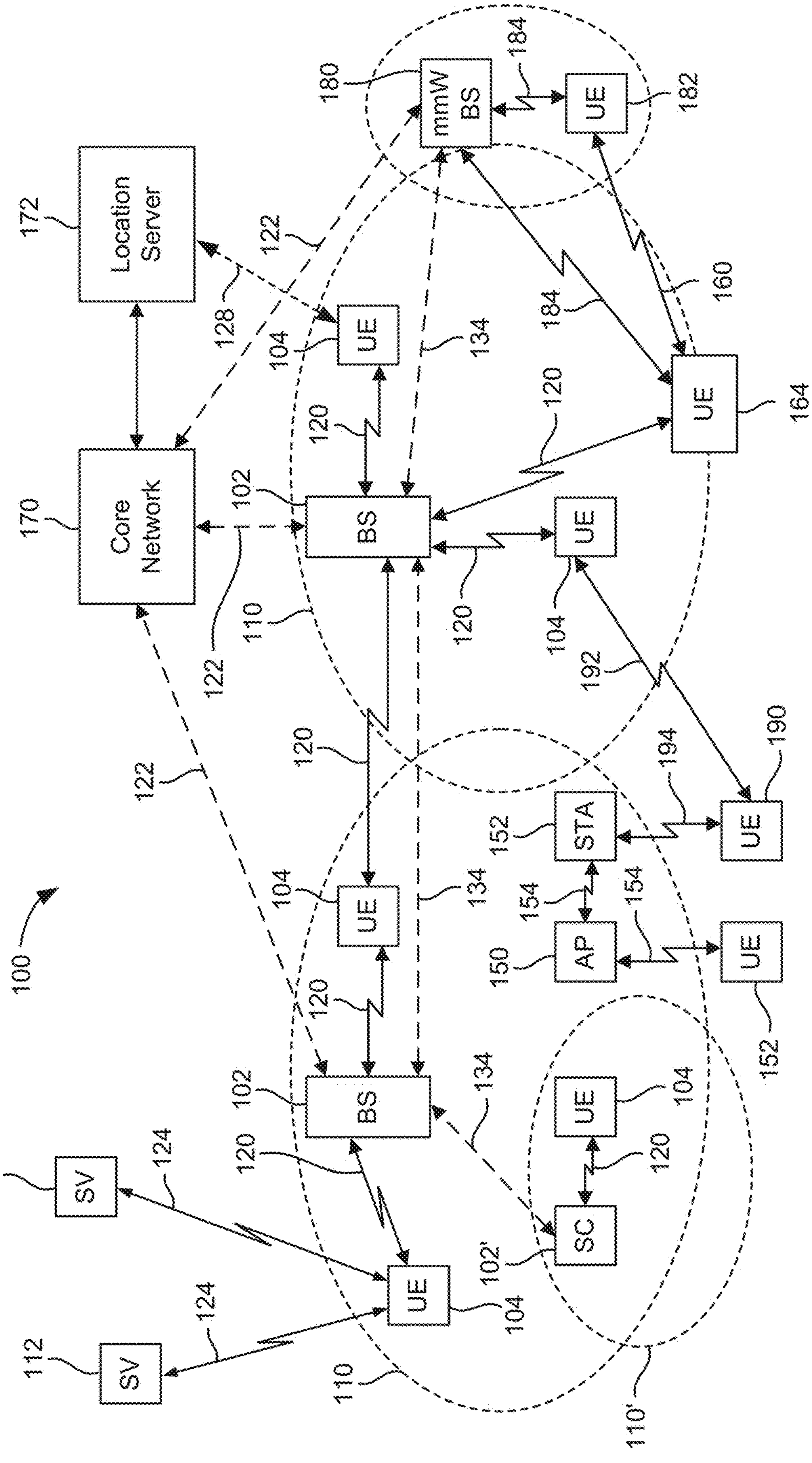

100
Core Network
170
Location Server
172
mmW BS
180
UE
182
184
128
122
UE
104
134
184
160
120
UE
164
102
BS
110
120
192
190
194
STA
152
154
AP
150
UE
152
SC
102'
110'
SV
112
124

FIG. 1

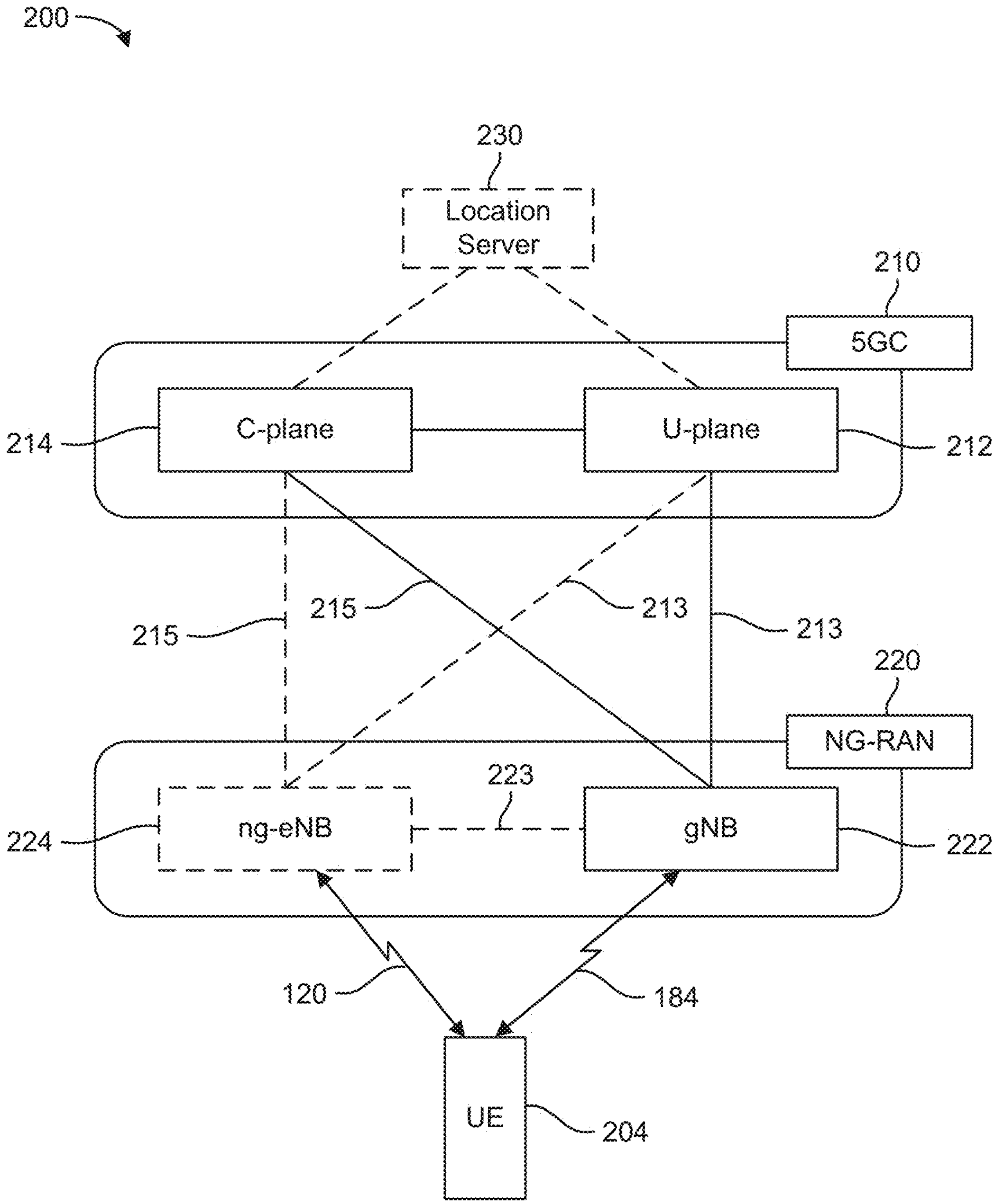

200
230
Location Server
210
5GC
C-plane
U-plane
214
212
215
215
213
213
220
NG-RAN
223
ng-eNB
gNB
224
222
120
184
UE
204

FIG. 2A

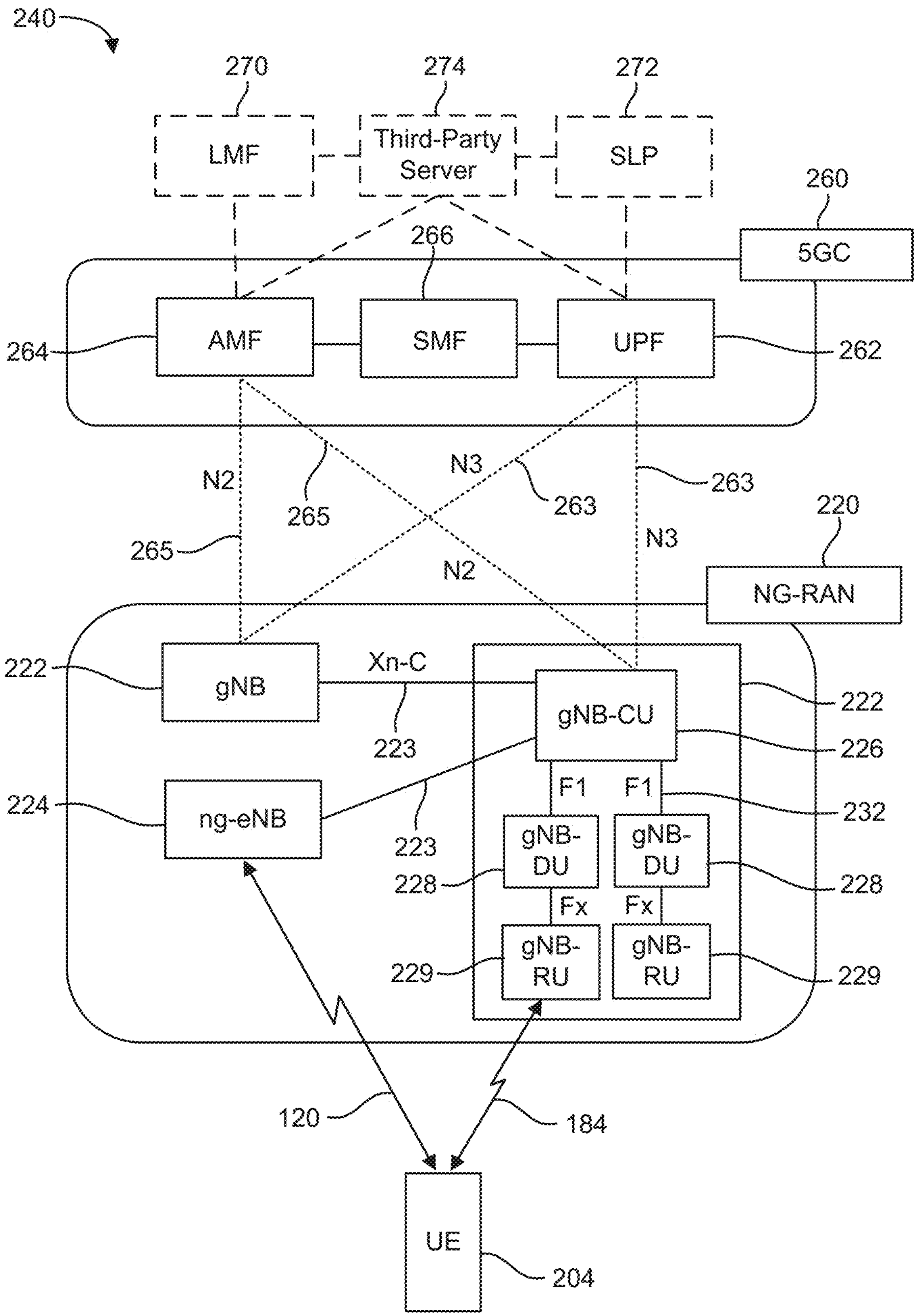

240
270
274
272
LMF
Third-Party Server
SLP
260
5GC
266
264
AMF
SMF
UPF
262
N2
265
N3
263
263
265
N3
N2
220
NG-RAN
222
gNB
Xn-C
223
gNB-CU
222
226
224
ng-eNB
223
F1
F1
232
gNB-DU
gNB-DU
228
228
Fx
Fx
gNB-RU
gNB-RU
229
229
120
184
UE
204

FIG. 2B

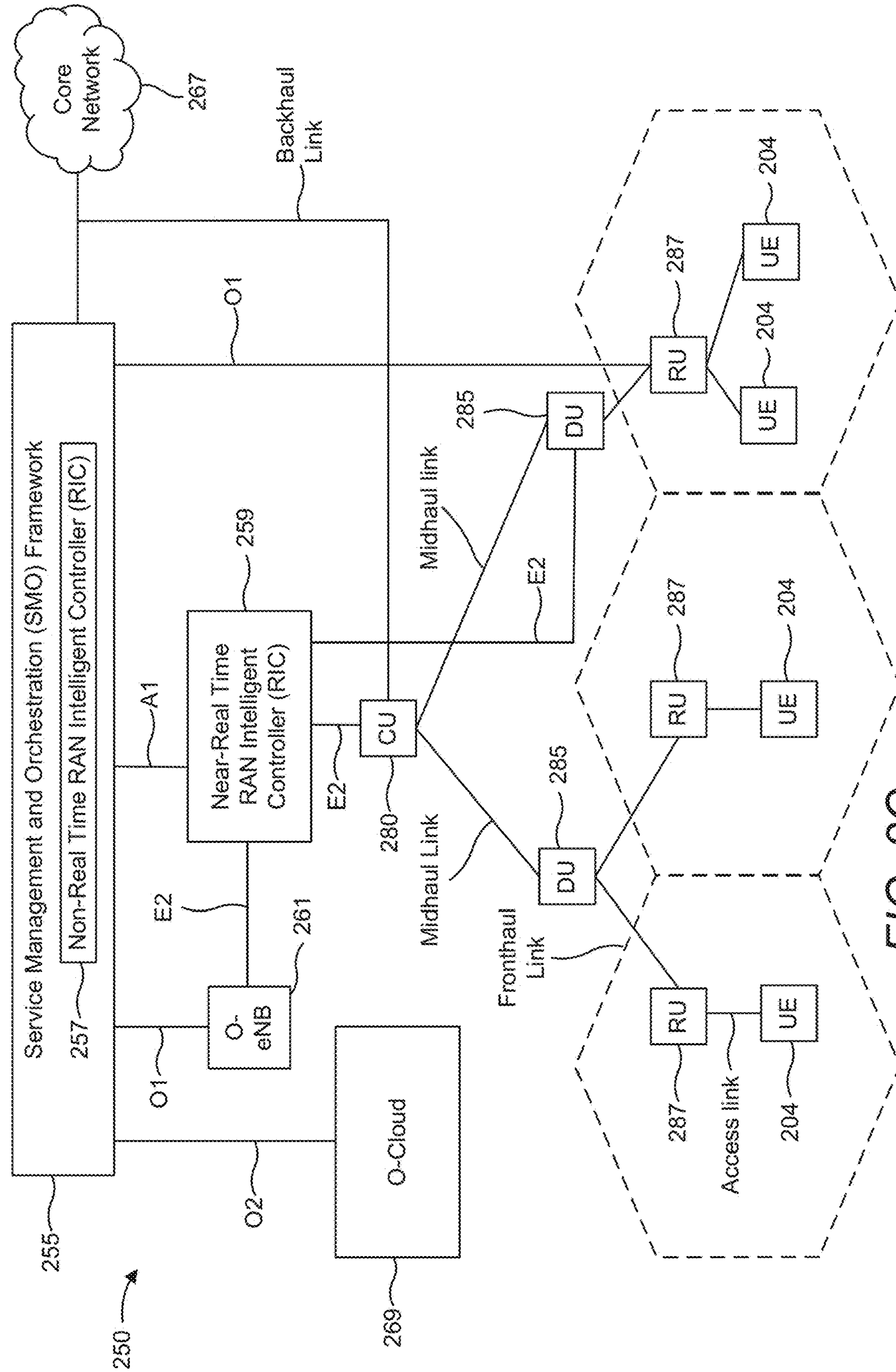

Core Network
267
Backhaul Link
Service Management and Orchestration (SMO) Framework
Non-Real Time RAN Intelligent Controller (RIC)
257
255
250
O1
O1
O2
A1
E2
E2
E2
Near-Real Time RAN Intelligent Controller (RIC)
259
O-eNB
261
O-Cloud
269
CU
280
DU
DU
285
285
Midhaul link
Midhaul Link
Fronthaul Link
RU
RU
RU
287
287
287
UE
UE
UE
UE
204
204
204
204
Access link

FIG. 2C

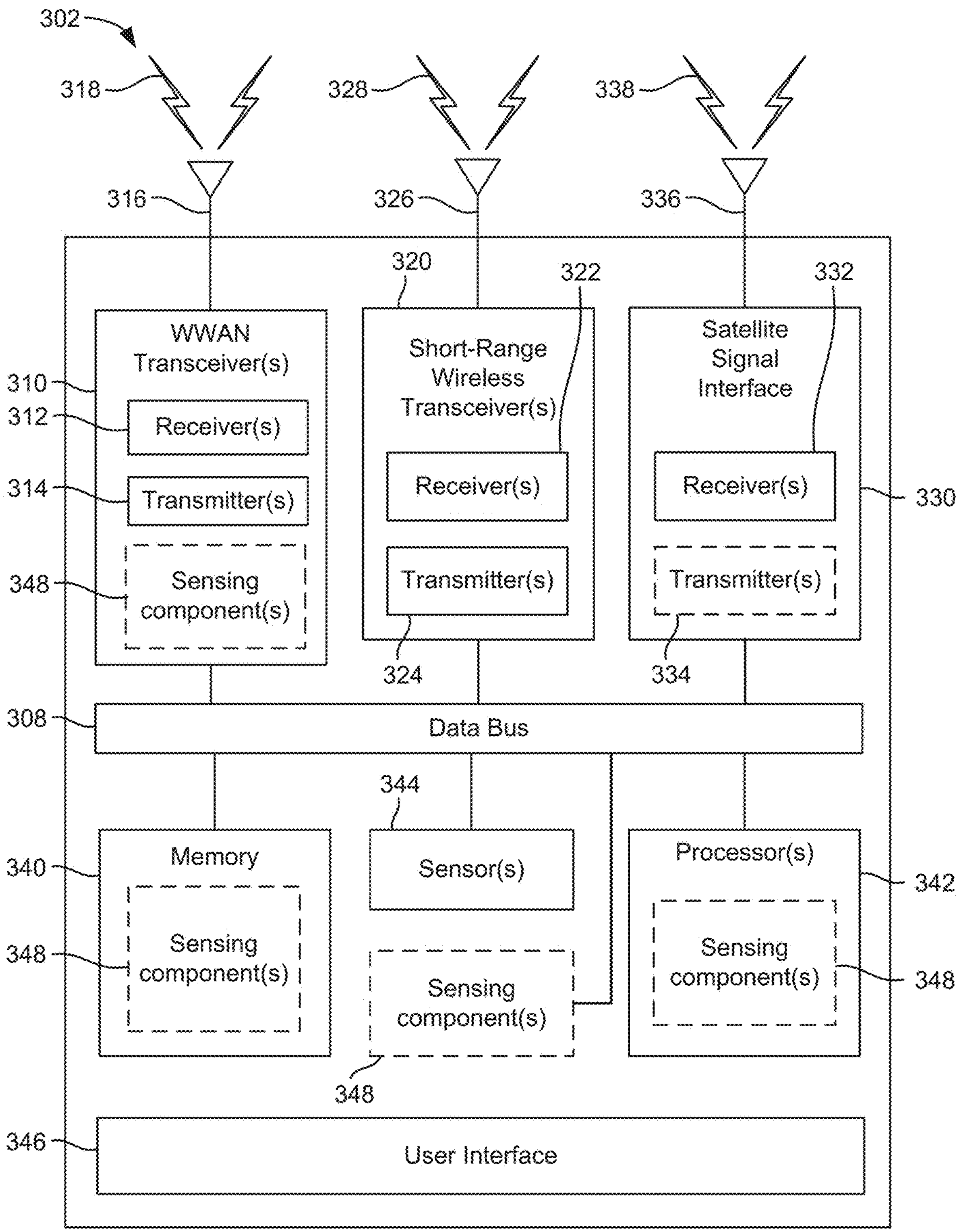

302
318
328
338
316
326
336
320
322
332
WWAN Transceiver(s)
Short-Range Wireless Transceiver(s)
Satellite Signal Interface
310
312
Receiver(s)
314
Transmitter(s)
348
Sensing component(s)
Receiver(s)
Transmitter(s)
Receiver(s)
Transmitter(s)
330
324
334
308
Data Bus
344
340
Memory
Sensor(s)
Processor(s)
342
348
Sensing component(s)
Sensing component(s)
Sensing component(s)
348
348
346
User Interface

FIG. 3A

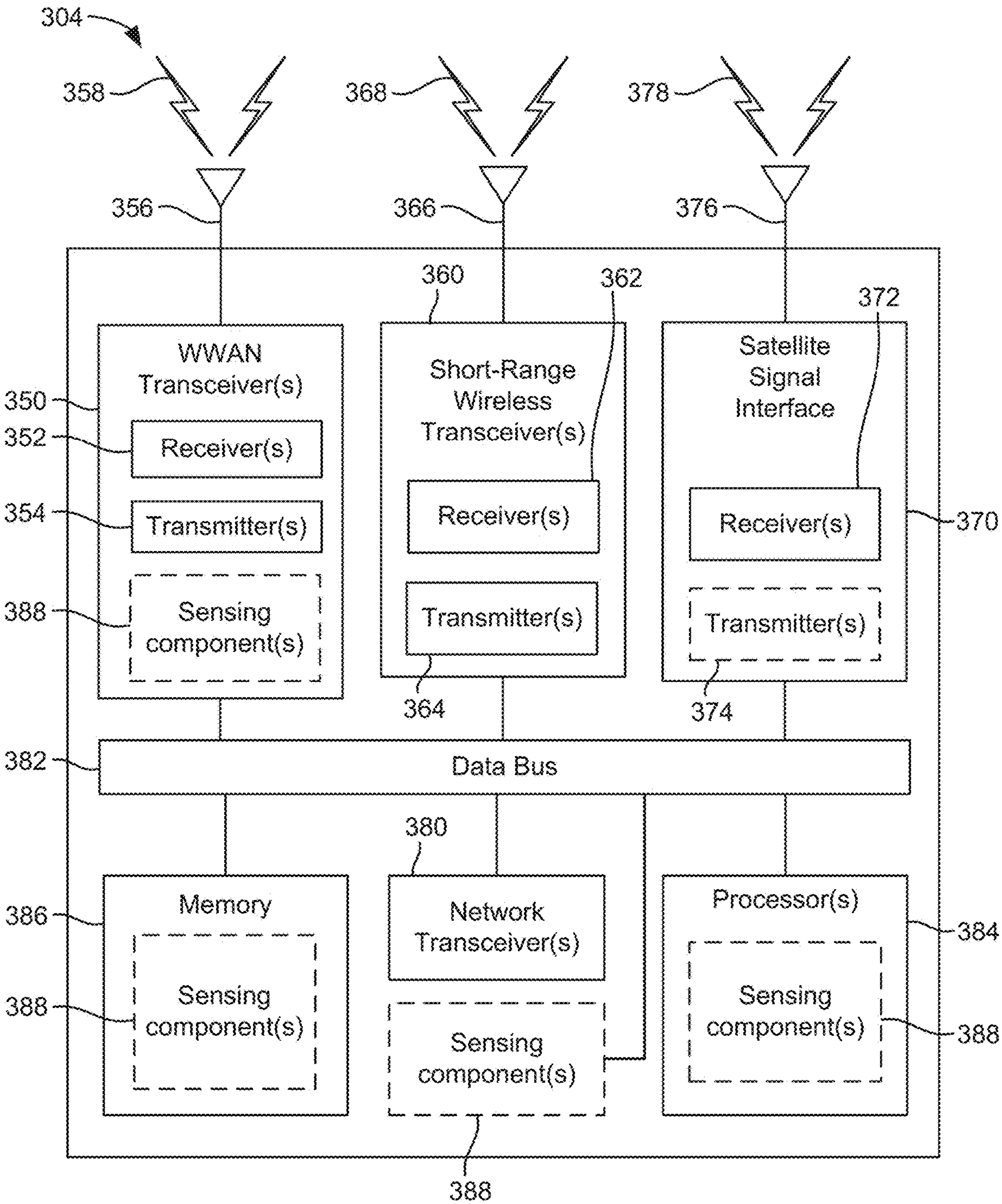

304
358
368
378
356
366
376
360
362
372
WWAN Transceiver(s)
350
352
Receiver(s)
354
Transmitter(s)
388
Sensing component(s)
Short-Range Wireless Transceiver(s)
Receiver(s)
Transmitter(s)
364
Satellite Signal Interface
Receiver(s)
370
Transmitter(s)
374
382
Data Bus
380
386
Memory
Sensing component(s)
388
Network Transceiver(s)
Sensing component(s)
388
Processor(s)
384
Sensing component(s)
388

FIG. 3B

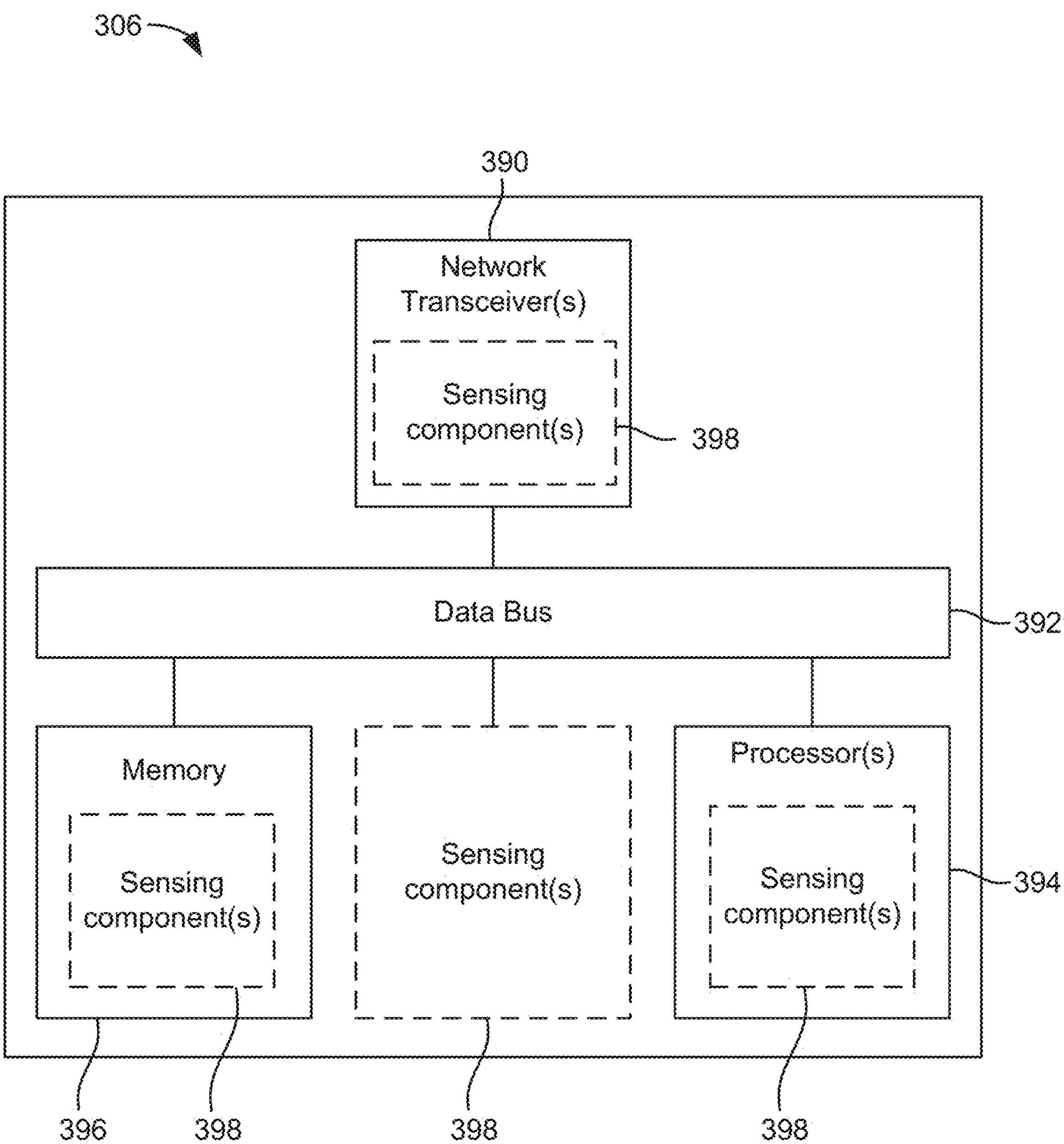

306
390
Network Transceiver(s)
Sensing component(s)
398
Data Bus
392
Memory
Sensing component(s)
Sensing component(s)
Processor(s)
Sensing component(s)
394
396
398
398
398

FIG. 3C

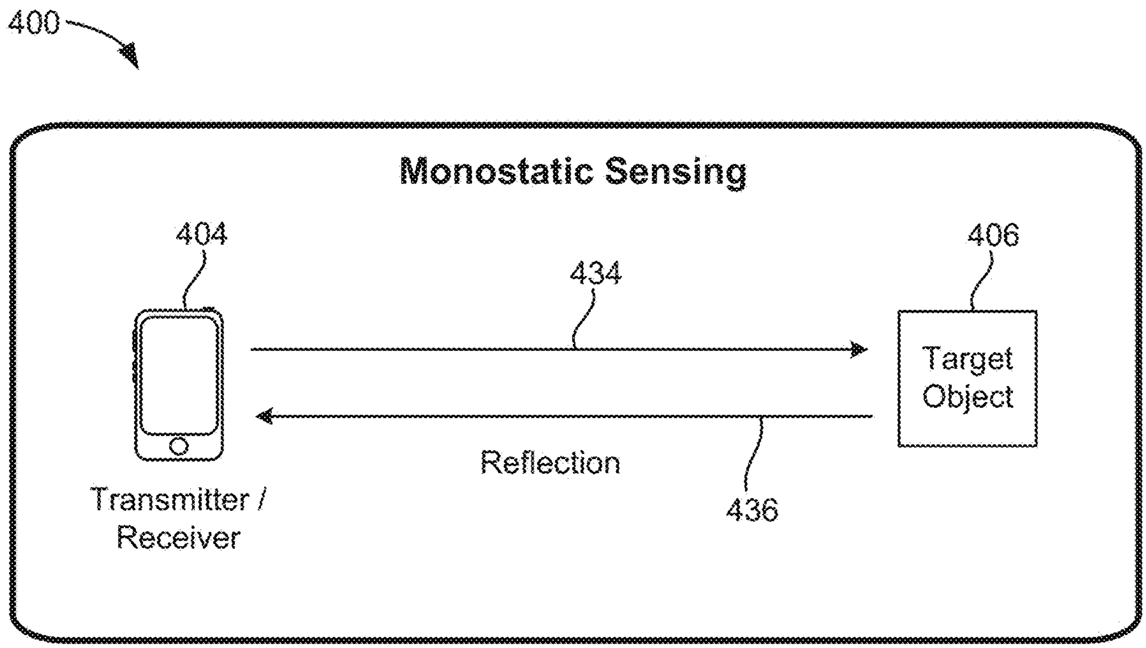

400
Monostatic Sensing
404
434
406
Target Object
Reflection
436
Transmitter / Receiver

FIG. 4A

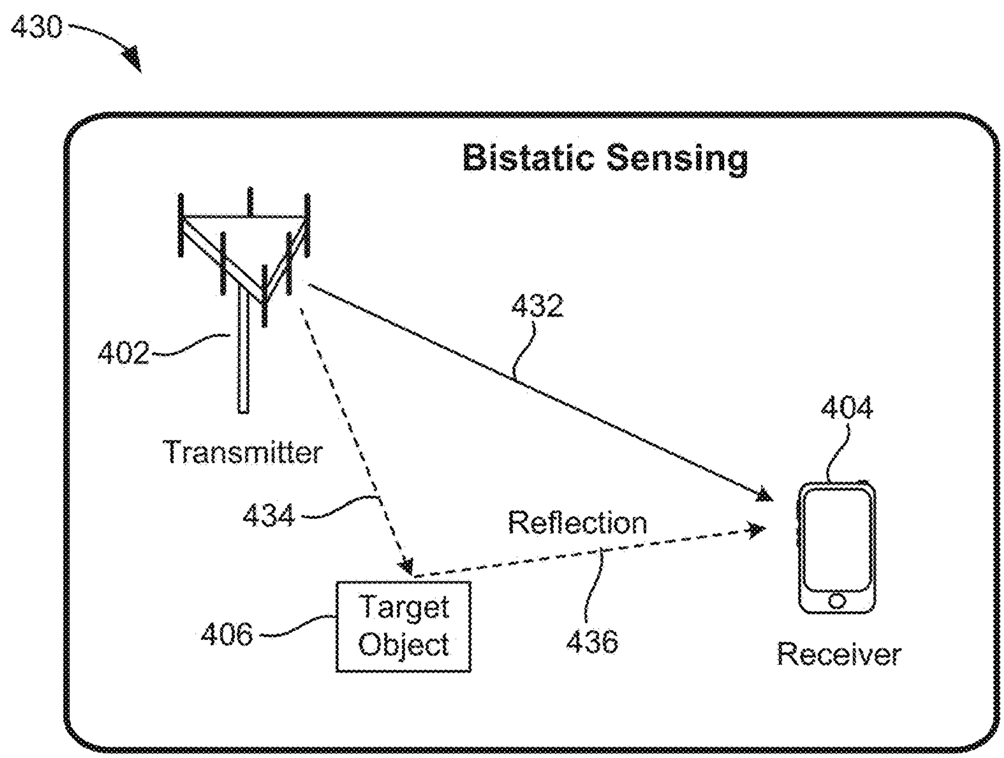

430
Bistatic Sensing
402
Transmitter
432
404
434
Reflection
406
Target Object
436
Receiver

FIG. 4B

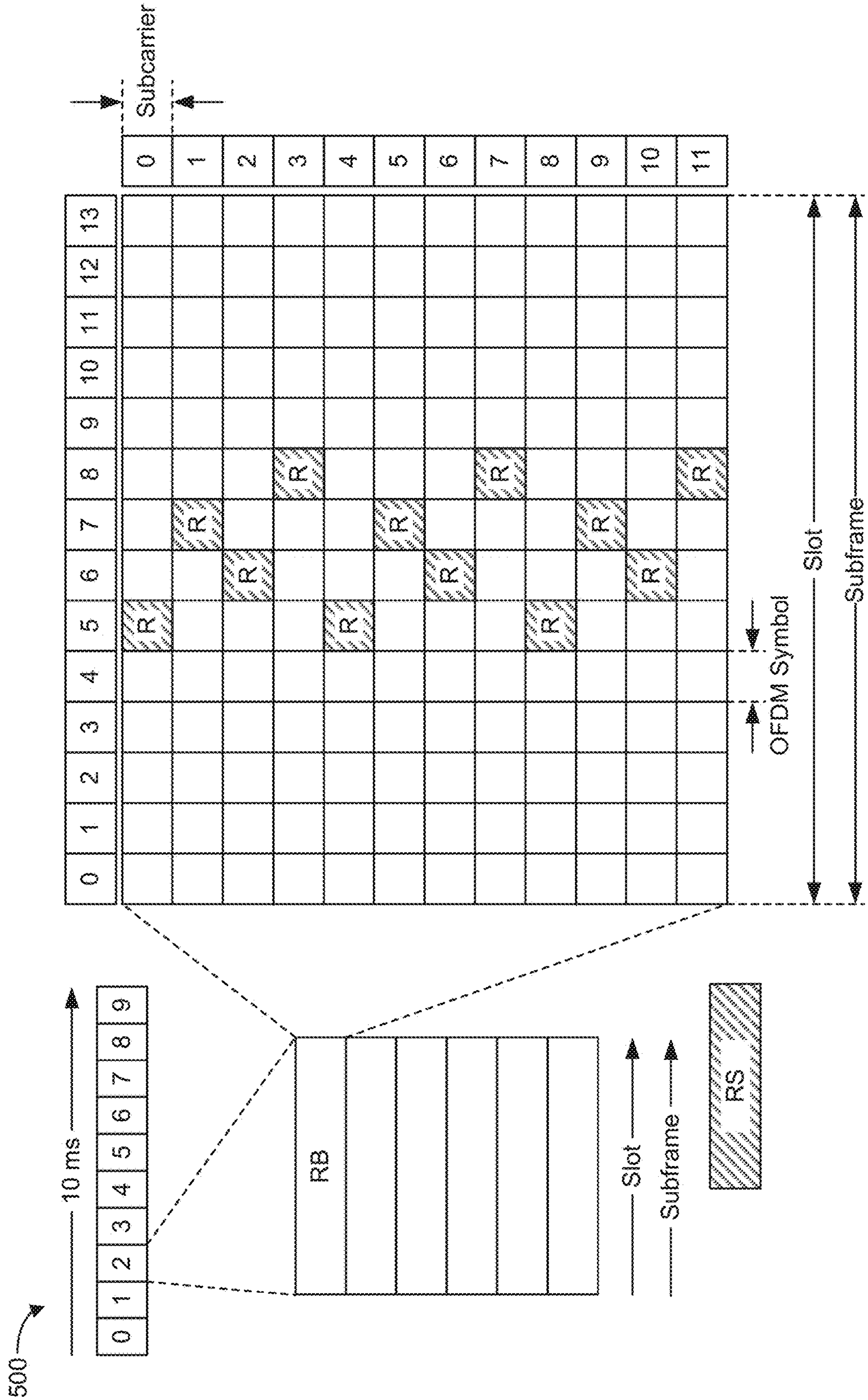

500
10 ms
0 1 2 3 4 5 6 7 8 9
RB
Slot
Subframe
RS
Subcarrier
0 1 2 3 4 5 6 7 8 9 10 11
0 1 2 3 4 5 6 7 8 9 10 11 12 13
R
OFDM Symbol
Slot
Subframe

FIG. 5

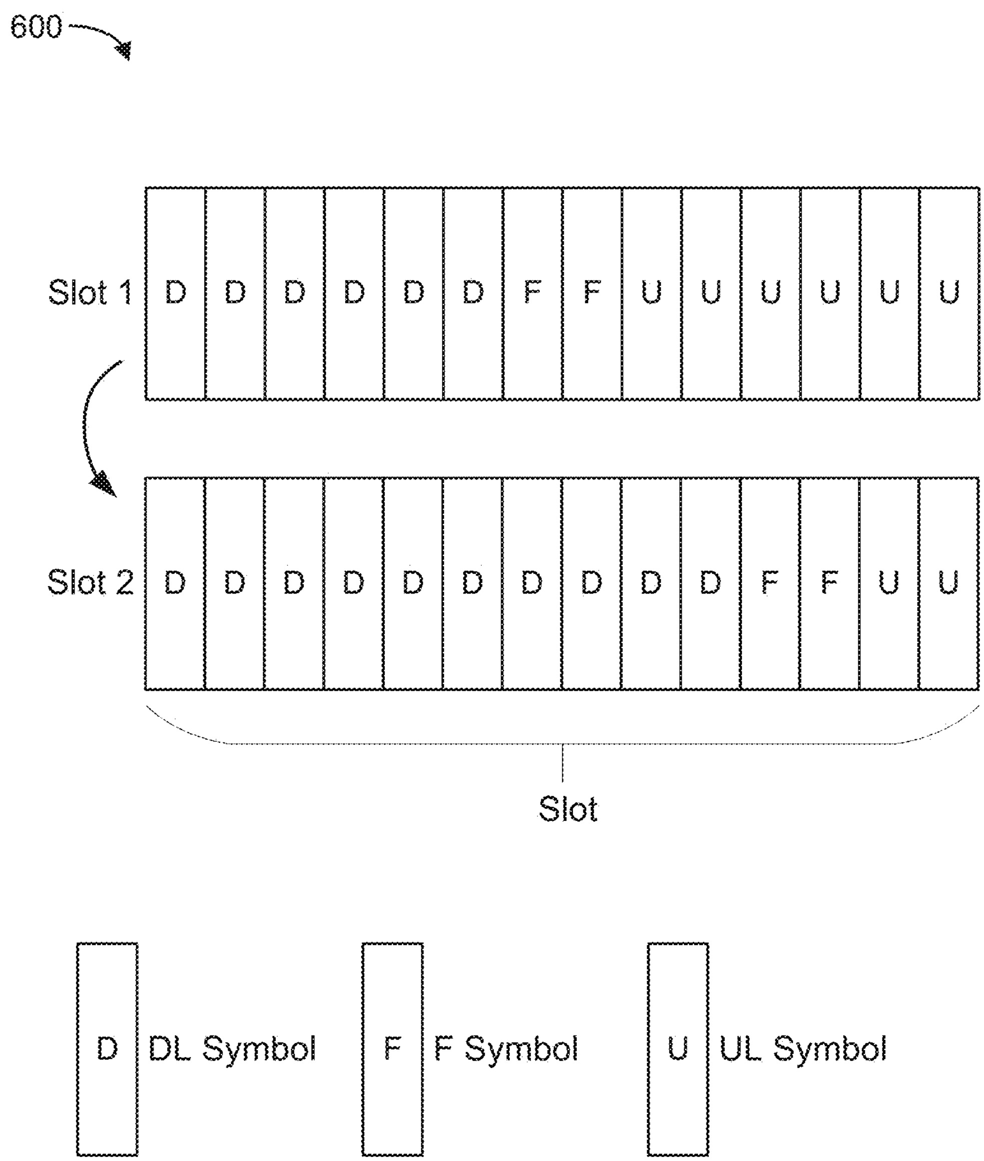

600
Slot 1
D
D
D
D
D
D
F
F
U
U
U
U
U
U
Slot 2
D
D
D
D
D
D
D
D
D
D
F
F
U
U
Slot
D
DL Symbol
F
F Symbol
U
UL Symbol

FIG. 6

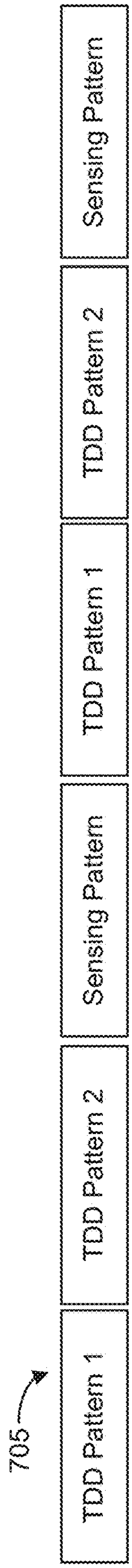


FIG. 7A

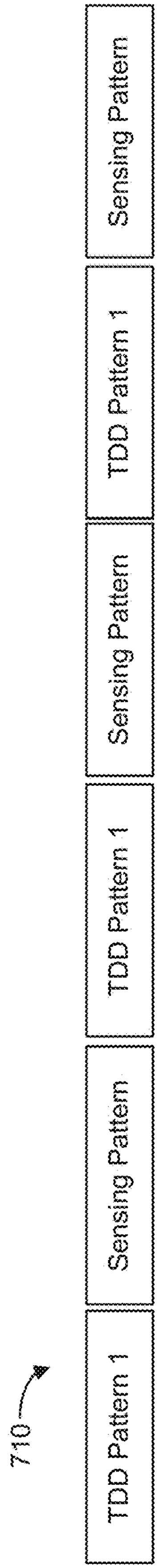


FIG. 7B

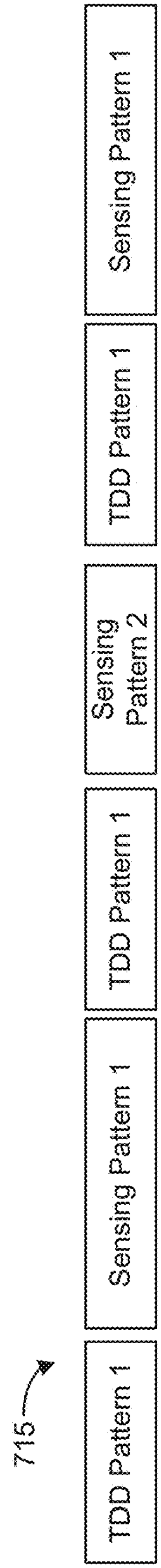


FIG. 7C

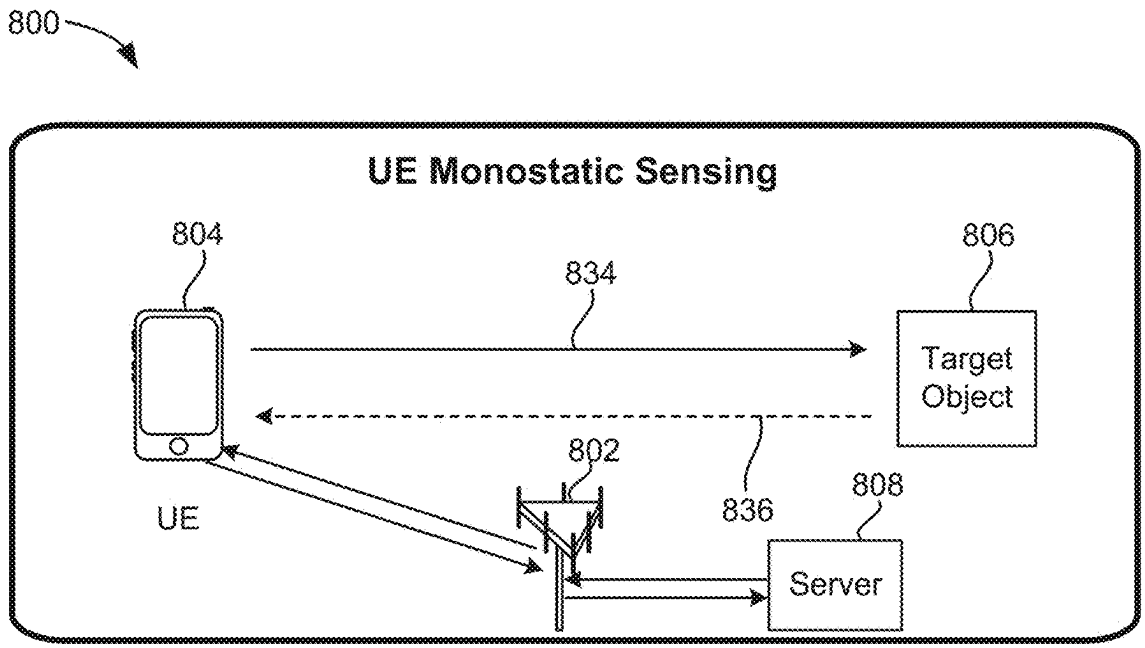

800
UE Monostatic Sensing
804
834
806
Target Object
802
836
808
UE
Server

FIG. 8A

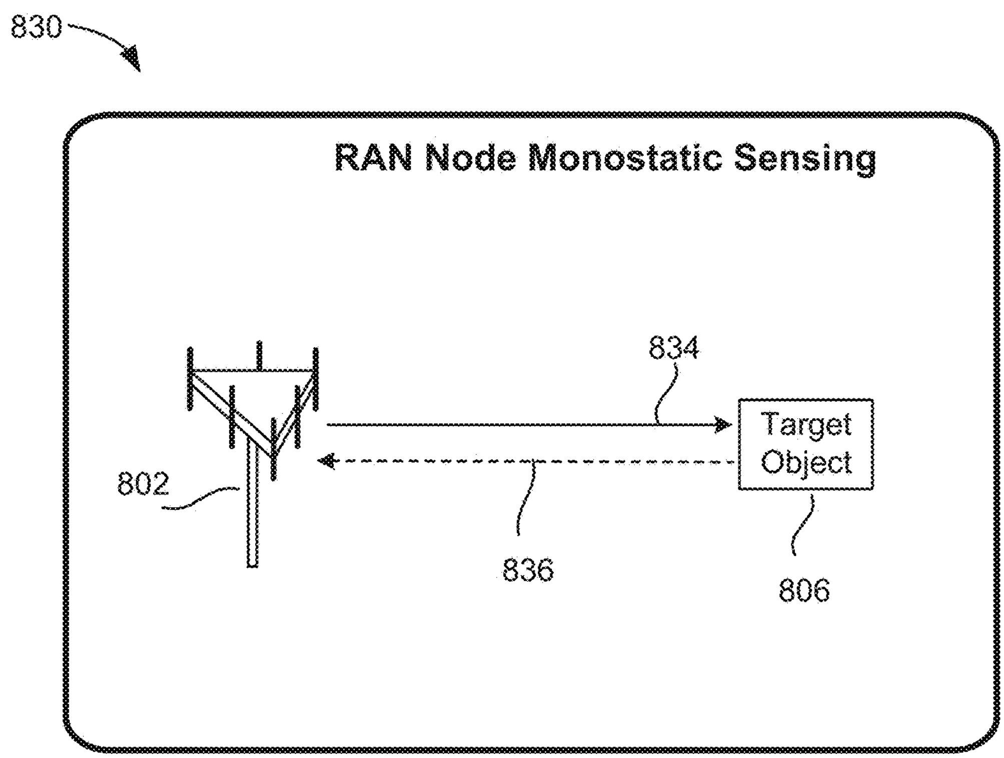

830
RAN Node Monostatic Sensing
834
Target Object
802
836
806

FIG. 8B

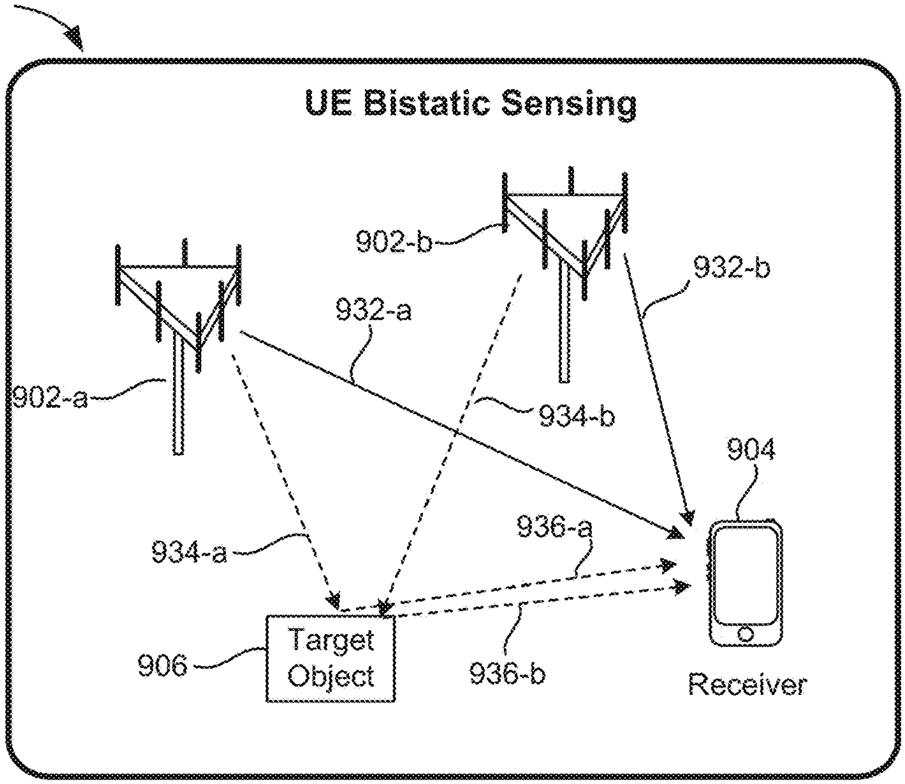

UE Bistatic Sensing
902-b
932-b
932-a
902-a
934-b
904
936-a
934-a
Target Object
906
936-b
Receiver

FIG. 9A

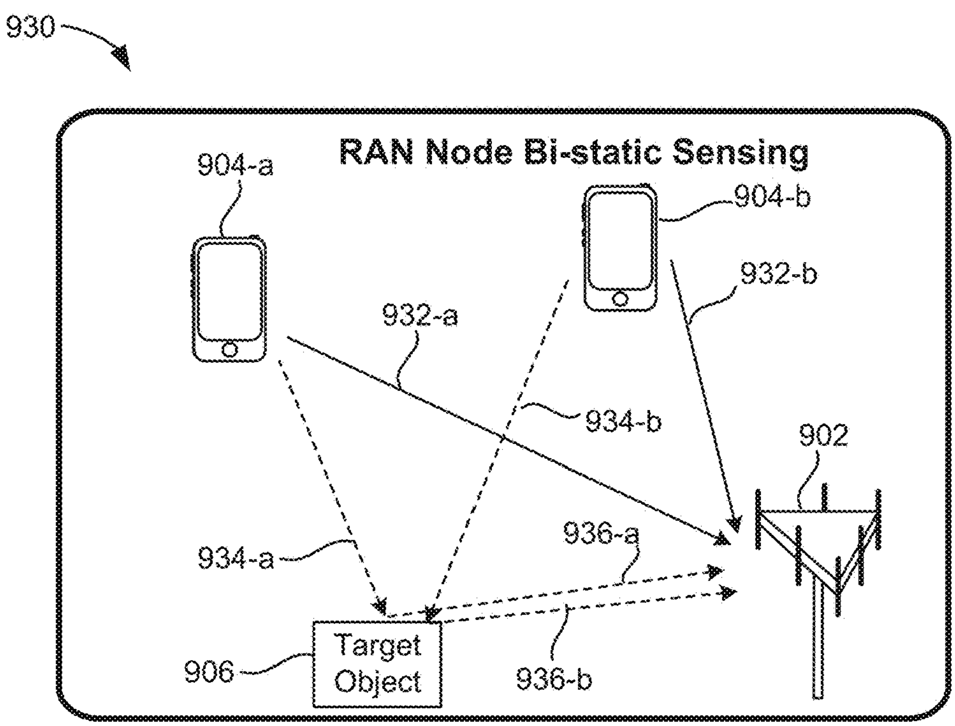

930
RAN Node Bi-static Sensing
904-a
904-b
932-b
932-a
934-b
902
936-a
934-a
Target Object
906
936-b

FIG. 9B

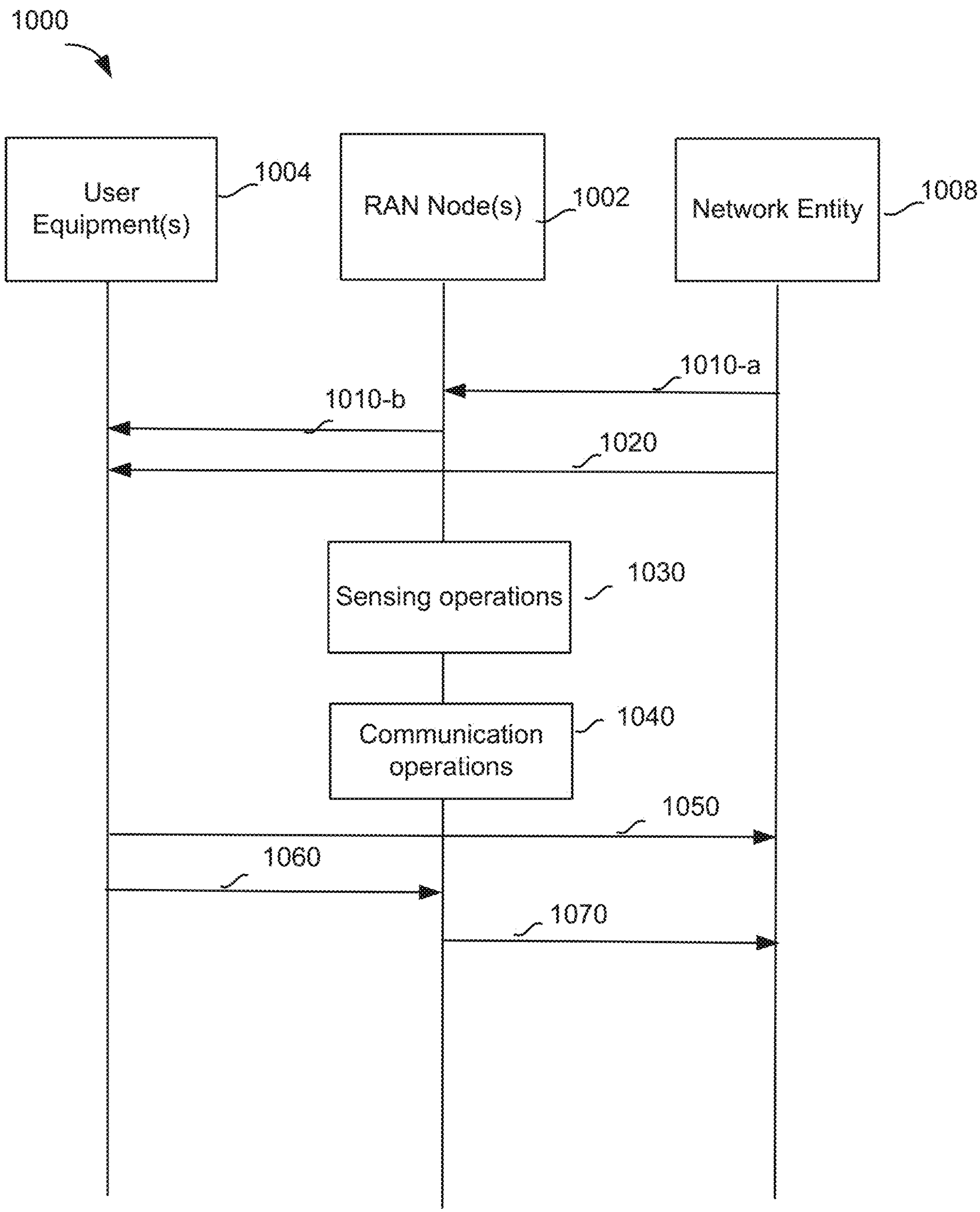

1000
User Equipment(s)
1004
RAN Node(s)
1002
Network Entity
1008
1010-a
1010-b
1020
Sensing operations
1030
Communication operations
1040
1050
1060
1070

FIG. 10

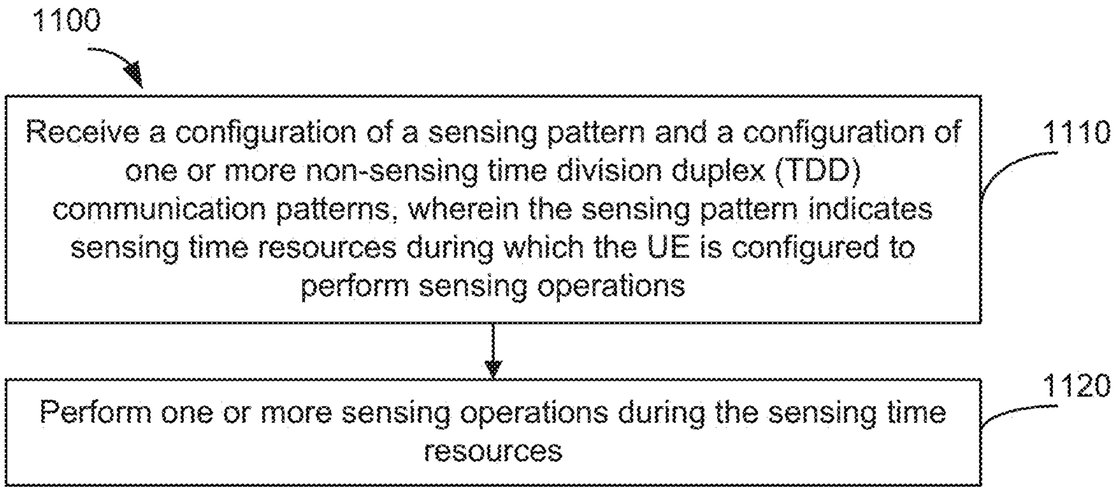

1100
Receive a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations
1110
Perform one or more sensing operations during the sensing time resources
1120

FIG. 11

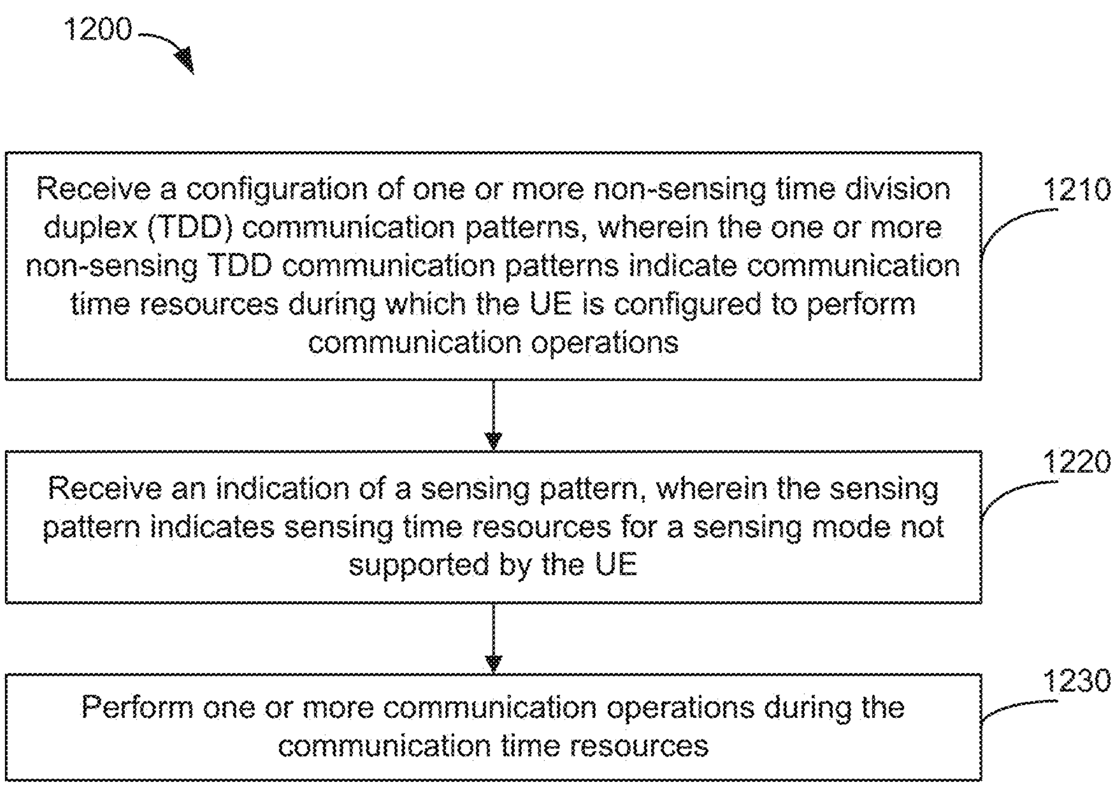

1200
Receive a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations
1210
Receive an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for a sensing mode not supported by the UE
1220
Perform one or more communication operations during the communication time resources
1230

FIG. 12

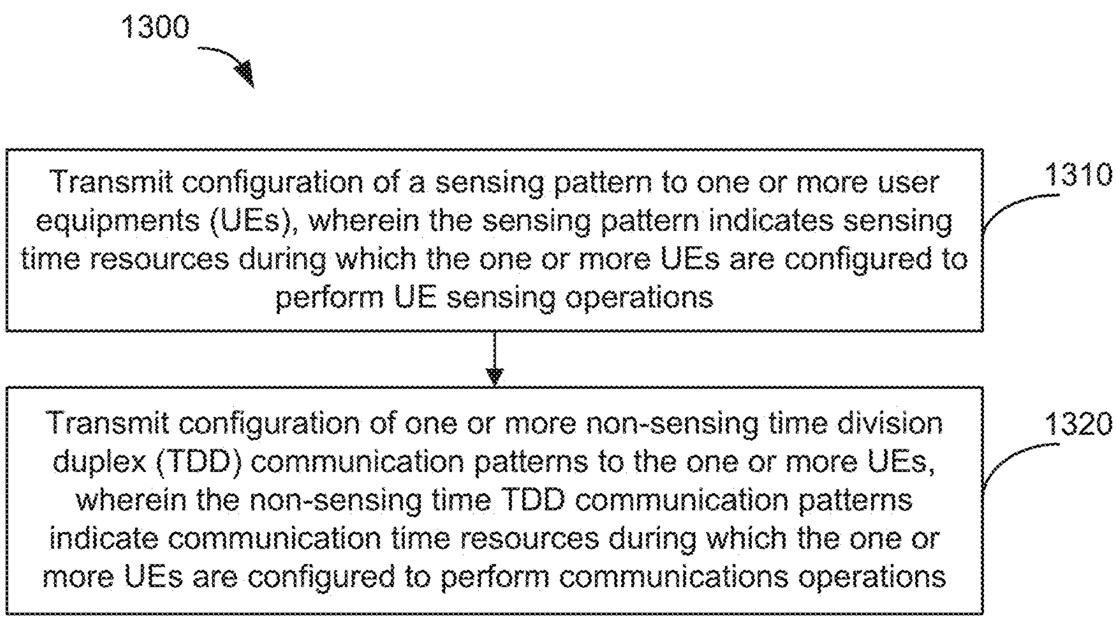

1300
Transmit configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations
1310
Transmit configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing time TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations
1320

FIG. 13

RESOURCE CONFIGURATION FOR JOINT COMMUNICATION AND SENSING

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

[0001] Aspects of the disclosure relate generally to wireless technologies.

2. Description of the Related Art

[0002] Wireless communication systems have developed through various generations, including a first-generation analog wireless phone service (1G), a second-generation (2G) digital wireless phone service (including interim 2.5G and 2.75G networks), a third-generation (3G) high speed data, Internet-capable wireless service and a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax). There are presently many different types of wireless communication systems in use, including cellular and personal communications service (PCS) systems. Examples of known cellular systems include the cellular analog advanced mobile phone system (AMPS), and digital cellular systems based on code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), the Global System for Mobile communications (GSM), etc.

[0003] A fifth generation (5G) wireless standard, referred to as New Radio (NR), enables higher data transfer speeds, greater numbers of connections, and better coverage, among other improvements. The 5G standard, according to the Next Generation Mobile Networks Alliance, is designed to provide higher data rates as compared to previous standards, more accurate positioning (e.g., based on reference signals for positioning (RS-P), such as downlink, uplink, or sidelink positioning reference signals (PRS)), and other technical enhancements. These enhancements, as well as the use of higher frequency bands, advances in PRS processes and technology, and high-density deployments for 5G, enable highly accurate 5G-based positioning.

SUMMARY

[0004] The following presents a simplified summary relating to one or more aspects disclosed herein. Thus, the following summary should not be considered an extensive overview relating to all contemplated aspects, nor should the following summary be considered to identify key or critical elements relating to all contemplated aspects or to delineate the scope associated with any particular aspect. Accordingly, the following summary has the sole purpose to present certain concepts relating to one or more aspects relating to the mechanisms disclosed herein in a simplified form to precede the detailed description presented below.

[0005] In an aspect, a method of wireless transmission at a user equipment (UE) includes receiving a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and performing one or more sensing operations during the sensing time resources.

[0006] In an aspect, a method of wireless transmission at a user equipment (UE) includes receiving a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receiving an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and performing one or more communication operations during the communication time resources.

[0007] In an aspect, a method of communication at a network entity includes transmitting configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmitting configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0008] In an aspect, a user equipment (UE) includes one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: receive, via the one or more transceivers, a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and perform one or more sensing operations during the sensing time resources.

[0009] In an aspect, a user equipment (UE) includes one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: receive, via the one or more transceivers, a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receive, via the one or more transceivers, an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and perform one or more communication operations during the communication time resources.

[0010] In an aspect, a network entity includes one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: transmit, via the one or more transceivers, configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmit, via the one or more transceivers, configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0011] In an aspect, a user equipment (UE) includes means for receiving a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and means for performing one or more sensing operations during the sensing time resources.

[0012] In an aspect, a user equipment (UE) includes means for receiving a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; means for receiving an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and means for performing one or more communication operations during the communication time resources.

[0013] In an aspect, a network entity includes means for transmitting configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and means for transmitting configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0014] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a user equipment (UE), cause the user equipment to: receive a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and perform one or more sensing operations during the sensing time resources.

[0015] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a user equipment (UE), cause the user equipment to: receive a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receive an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and perform one or more communication operations during the communication time resources.

[0016] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a network entity, cause the network entity to: transmit configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmit configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0017] Other objects and advantages associated with the aspects disclosed herein will be apparent to those skilled in the art based on the accompanying drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings are presented to aid in the description of various aspects of the disclosure and are provided solely for illustration of the aspects and not limitation thereof.

[0019] FIG. **1** illustrates an example wireless communications system, according to aspects of the disclosure.

[0020] FIGS. **2**A, **2**B, and **2**C illustrate example wireless network structures, according to aspects of the disclosure.

[0021] FIGS. **3**A, **3**B, and **3**C are simplified block diagrams of several sample aspects of components that may be employed in a user equipment (UE), a base station, and a network entity, respectively, and configured to support communications as taught herein.

[0022] FIGS. **4**A and **4**B illustrate different types of wireless sensing, according to aspects of the disclosure.

[0023] FIG. **5** is a diagram illustrating an example frame structure, according to aspects of the disclosure.

[0024] FIG. **6** is a diagram illustrating example Time Division Duplex (TDD) slots, according to aspects of the disclosure.

[0025] FIGS. **7**A, **7**B, and **7**C illustrate example time resource allocations for TDD communication pattern(s) time multiplexed with sensing pattern(s), according to some aspects of the disclosure.

[0026] FIG. **8**A illustrates an example of UE monostatic sensing, according to some aspects of the disclosure.

[0027] FIG. **8**B illustrates an example of Radio Access Network (RAN) node monostatic sensing, according to some aspects of the disclosure.

[0028] FIG. **9**A illustrates an example of UE bistatic sensing, according to some aspects of the disclosure.

[0029] FIG. **9**B illustrates an example of RAN node bistatic sensing, according to some aspects of the disclosure.

[0030] FIG. **10** illustrates an example method **1000** for sensing pattern configuration and measurement, according to some aspects.

[0031] FIGS. **11** to **13** illustrate example methods of communication, according to aspects of the disclosure.

DETAILED DESCRIPTION

[0032] Aspects of the disclosure are provided in the following description and related drawings directed to various examples provided for illustration purposes. Alternate aspects may be devised without departing from the scope of the disclosure. Additionally, well-known elements of the disclosure will not be described in detail or will be omitted so as not to obscure the relevant details of the disclosure.

[0033] Various aspects relate generally to joint communication and sensing systems. Some aspects more specifically relate to configuring one or more sensing patterns and one or more communication patterns, which are multiplexed using (for example) time division multiplexing (TDM). In some aspects, the current techniques provide for resource configuration that accommodates time division duplexing (TDD) of communication resources, which is commonly used at mmW frequencies. Additionally, aspects of the current disclosure support a number of different sensing modes, including monostatic, bistatic, and multistatic modes for user equipments (UEs) and other devices such as Radion Access Network (RAN) nodes.

[0034] Particular aspects of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. In some aspects, the current techniques can provide accurate range and speed/velocity sensing, by enabling configuration of sensing patterns time division multiplexed with TDD communication patterns (commonly used for higher frequency communication, which improves sensing accuracy). This can be a particular advantage in challenging situations; for example, for long-range sensing, high speed/velocity sensing, and/or sensing at or near a cell edge. Further, by enabling a number of sensing modes, the techniques can allow high quality sensing in different sensing environments incorporating devices with a range of sensing capabilities.

[0035] The words "exemplary" and/or "example" are used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" and/or "example" is not necessarily to be construed as preferred or advantageous over other aspects. Likewise, the term "aspects of the disclosure" does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation.

[0036] Those of skill in the art will appreciate that the information and signals described below may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description below may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof, depending in part on the particular application, in part on the desired design, in part on the corresponding technology, etc.

[0037] Further, many aspects are described in terms of sequences of actions to be performed by, for example, elements of a computing device. It will be recognized that various actions described herein can be performed by specific circuits (e.g., application specific integrated circuits (ASICs)), by program instructions being executed by one or more processors, or by a combination of both. Additionally, the sequence(s) of actions described herein can be considered to be embodied entirely within any form of non-transitory computer-readable storage medium having stored therein a corresponding set of computer instructions that, upon execution, would cause or instruct an associated processor of a device to perform the functionality described herein. Thus, the various aspects of the disclosure may be embodied in a number of different forms, all of which have been contemplated to be within the scope of the claimed subject matter. In addition, for each of the aspects described herein, the corresponding form of any such aspects may be described herein as, for example, "logic configured to" perform the described action.

[0038] As used herein, the terms "user equipment" (UE) and "base station" are not intended to be specific or otherwise limited to any particular radio access technology (RAT), unless otherwise noted. In general, a UE may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop computer, consumer asset locating device, wearable (e.g., smartwatch, glasses, augmented reality (AR)/virtual reality (VR) headset, etc.), vehicle (e.g., automobile, motorcycle, bicycle, etc.), Internet of Things (IoT) device, etc.) used by a user to communicate over a wireless communications network. A UE may be mobile or may (e.g., at certain times) be stationary, and may communicate with a radio access network (RAN). As used herein, the term "UE" may be referred to interchangeably as an "access terminal" or "AT," a "client device," a "wireless device," a "subscriber device," a "subscriber terminal," a "subscriber station," a "user terminal" or "UT," a "mobile device," a "mobile terminal," a "mobile station," or variations thereof. Generally, UEs can communicate with a core network via a RAN, and through the core network the UEs can be connected with external networks such as the Internet and with other UEs. Of course, other mechanisms of connecting to the core network and/or the Internet are also possible for the UEs, such as over wired access networks, wireless local area network (WLAN) networks (e.g., based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 specification, etc.) and so on.

[0039] A base station may operate according to one of several RATs in communication with UEs depending on the network in which it is deployed, and may be alternatively referred to as an access point (AP), a network node, a NodeB, an evolved NodeB (CNB), a next generation cNB (ng-eNB), a New Radio (NR) Node B (also referred to as a gNB or gNodeB), etc. A base station may be used primarily to support wireless access by UEs, including supporting data, voice, and/or signaling connections for the supported UEs. In some systems a base station may provide purely edge node signaling functions while in other systems it may provide additional control and/or network management functions. A communication link through which UEs can send signals to a base station is called an uplink (UL) channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the base station can send signals to UEs is called a downlink (DL) or forward link channel (e.g., a paging channel, a control channel, a broadcast channel, a forward traffic channel, etc.). As used herein the term traffic channel (TCH) can refer to either an uplink/reverse or downlink/forward traffic channel.

[0040] The term "base station" may refer to a single physical transmission-reception point (TRP) or to multiple physical TRPs that may or may not be co-located. For example, where the term "base station" refers to a single physical TRP, the physical TRP may be an antenna of the base station corresponding to a cell (or several cell sectors) of the base station. Where the term "base station" refers to multiple co-located physical TRPs, the physical TRPs may be an array of antennas (e.g., as in a multiple-input multiple-output (MIMO) system or where the base station employs beamforming) of the base station. Where the term "base station" refers to multiple non-co-located physical TRPs, the physical TRPs may be a distributed antenna system (DAS) (a network of spatially separated antennas connected to a common source via a transport medium) or a remote radio head (RRH) (a remote base station connected to a serving base station). Alternatively, the non-co-located physical TRPs may be the serving base station receiving the measurement report from the UE and a neighbor base station whose reference radio frequency (RF) signals the UE is measuring. Because a TRP is the point from which a base station transmits and receives wireless signals, as used herein, references to transmission from or reception at a base station are to be understood as referring to a particular TRP of the base station.

[0041] In some implementations that support positioning of UEs, a base station may not support wireless access by UEs (e.g., may not support data, voice, and/or signaling connections for UEs), but may instead transmit reference signals to UEs to be measured by the UEs, and/or may receive and measure signals transmitted by the UEs. Such a base station may be referred to as a positioning beacon (e.g., when transmitting signals to UEs) and/or as a location measurement unit (e.g., when receiving and measuring signals from UEs).

[0042] An "RF signal" comprises an electromagnetic wave of a given frequency that transports information through the space between a transmitter and a receiver. As used herein, a transmitter may transmit a single "RF signal" or multiple "RF signals" to a receiver. However, the receiver may receive multiple "RF signals" corresponding to each transmitted RF signal due to the propagation characteristics of RF signals through multipath channels. The same transmitted RF signal on different paths between the transmitter and receiver may be referred to as a "multipath" RF signal. As used herein, an RF signal may also be referred to as a "wireless signal" or simply a "signal" where it is clear from the context that the term "signal" refers to a wireless signal or an RF signal.

[0043] FIG. **1** illustrates an example wireless communications system **100**, according to aspects of the disclosure. The wireless communications system **100** (which may also be referred to as a wireless wide area network (WWAN)) may include various base stations **102** (labeled "BS") and various UEs **104**. The base stations **102** may include macro cell base stations (high power cellular base stations) and/or small cell base stations (low power cellular base stations). In an aspect, the macro cell base stations may include eNBs and/or ng-eNBs where the wireless communications system **100** corresponds to an LTE network, or gNBs where the wireless communications system **100** corresponds to a NR network, or a combination of both, and the small cell base stations may include femtocells, picocells, microcells, etc.

[0044] The base stations **102** may collectively form a RAN and interface with a core network **170** (e.g., an evolved packet core (EPC) or a 5G core (5GC)) through backhaul links **122**, and through the core network **170** to one or more location servers **172** (e.g., a location management function (LMF) or a secure user plane location (SUPL) location platform (SLP)). The location server(s) **172** may be part of core network **170** or may be external to core network **170**. A location server **172** may be integrated with a base station **102**. A UE **104** may communicate with a location server **172** directly or indirectly. For example, a UE **104** may communicate with a location server **172** via the base station **102** that is currently serving that UE **104**. A UE **104** may also communicate with a location server **172** through another path, such as via an application server (not shown), via another network, such as via a wireless local area network (WLAN) access point (AP) (e.g., AP **150** described below), and so on. For signaling purposes, communication between a UE **104** and a location server **172** may be represented as an indirect connection (e.g., through the core network **170**, etc.) or a direct connection (e.g., as shown via direct connection **128**), with the intervening nodes (if any) omitted from a signaling diagram for clarity.

[0045] In addition to other functions, the base stations **102** may perform functions that relate to one or more of transferring user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, RAN sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations **102** may communicate with each other directly or indirectly (e.g., through the EPC/5GC) over backhaul links **134**, which may be wired or wireless.

[0046] The base stations **102** may wirelessly communicate with the UEs **104**. Each of the base stations **102** may provide communication coverage for a respective geographic coverage area **110**. In an aspect, one or more cells may be supported by a base station **102** in each geographic coverage area **110**. A "cell" is a logical communication entity used for communication with a base station (e.g., over some frequency resource, referred to as a carrier frequency, component carrier, carrier, band, or the like), and may be associated with an identifier (e.g., a physical cell identifier (PCI), an enhanced cell identifier (ECI), a virtual cell identifier (VCI), a cell global identifier (CGI), etc.) for distinguishing cells operating via the same or a different carrier frequency. In some cases, different cells may be configured according to different protocol types (e.g., machine-type communication (MTC), narrowband IoT (NB-IoT), enhanced mobile broadband (cMBB), or others) that may provide access for different types of UEs. Because a cell is supported by a specific base station, the term "cell" may refer to either or both of the logical communication entity and the base station that supports it, depending on the context. In addition, because a TRP is typically the physical transmission point of a cell, the terms "cell" and "TRP" may be used interchangeably. In some cases, the term "cell" may also refer to a geographic coverage area of a base station (e.g., a sector), insofar as a carrier frequency can be detected and used for communication within some portion of geographic coverage areas **110**.

[0047] While neighboring macro cell base station **102** geographic coverage areas **110** may partially overlap (e.g., in a handover region), some of the geographic coverage areas **110** may be substantially overlapped by a larger geographic coverage area **110**. For example, a small cell base station **102'** (labeled "SC" for "small cell") may have a geographic coverage area **110'** that substantially overlaps with the geographic coverage area **110** of one or more macro cell base stations **102**. A network that includes both small cell and macro cell base stations may be known as a heterogeneous network. A heterogeneous network may also include home eNBs (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG).

[0048] The communication links **120** between the base stations **102** and the UEs **104** may include uplink (also referred to as reverse link) transmissions from a UE **104** to a base station **102** and/or downlink (DL) (also referred to as forward link) transmissions from a base station **102** to a UE **104**. The communication links **120** may use MIMO antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links **120** may be through one or more carrier frequencies. Allocation of carriers may be asymmetric with respect to downlink and uplink (e.g., more or less carriers may be allocated for downlink than for uplink).

[0049] The wireless communications system **100** may further include a wireless local area network (WLAN) access point (AP) **150** in communication with WLAN stations (STAs) **152** via communication links **154** in an unlicensed frequency spectrum (e.g., 5 GHz). When communicating in an unlicensed frequency spectrum, the WLAN STAs **152** and/or the WLAN AP **150** may perform a clear channel assessment (CCA) or listen before talk (LBT) procedure prior to communicating in order to determine whether the channel is available.

[0050] The small cell base station **102'** may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell base station **102'** may employ LTE or NR technology and use the same 5 GHz unlicensed frequency spectrum as used by the WLAN AP **150**. The small cell base station **102'**, employing LTE/5G in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network. NR in unlicensed spectrum may be referred to as NR-U. LTE in an unlicensed spectrum may be referred to as LTE-U, licensed assisted access (LAA), or MULTEFIRE®.

[0051] The wireless communications system **100** may further include a millimeter wave (mmW) base station **180** that may operate in mmW frequencies and/or near mmW frequencies in communication with a UE **182**. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in this band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHZ with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW/near mmW radio frequency band have high path loss and a relatively short range. The mmW base station **180** and the UE **182** may utilize beamforming (transmit and/or receive) over a mmW communication link **184** to compensate for the extremely high path loss and short range. Further, it will be appreciated that in alternative configurations, one or more base stations **102** may also transmit using mmW or near mmW and beamforming. Accordingly, it will be appreciated that the foregoing illustrations are merely examples and should not be construed to limit the various aspects disclosed herein.

[0052] Transmit beamforming is a technique for focusing an RF signal in a specific direction. Traditionally, when a network node (e.g., a base station) broadcasts an RF signal, it broadcasts the signal in all directions (omni-directionally). With transmit beamforming, the network node determines where a given target device (e.g., a UE) is located (relative to the transmitting network node) and projects a stronger downlink RF signal in that specific direction, thereby providing a faster (in terms of data rate) and stronger RF signal for the receiving device(s). To change the directionality of the RF signal when transmitting, a network node can control the phase and relative amplitude of the RF signal at each of the one or more transmitters that are broadcasting the RF signal. For example, a network node may use an array of antennas (referred to as a "phased array" or an "antenna array") that creates a beam of RF waves that can be "steered" to point in different directions, without actually moving the antennas. Specifically, the RF current from the transmitter is fed to the individual antennas with the correct phase relationship so that the radio waves from the separate antennas add together to increase the radiation in a desired direction, while cancelling to suppress radiation in undesired directions.

[0053] Transmit beams may be quasi-co-located, meaning that they appear to the receiver (e.g., a UE) as having the same parameters, regardless of whether or not the transmitting antennas of the network node themselves are physically co-located. In NR, there are four types of quasi-co-location (QCL) relations. Specifically, a QCL relation of a given type means that certain parameters about a second reference RF signal on a second beam can be derived from information about a source reference RF signal on a source beam. Thus, if the source reference RF signal is QCL Type A, the receiver can use the source reference RF signal to estimate the Doppler shift, Doppler spread, average delay, and delay spread of a second reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type B, the receiver can use the source reference RF signal to estimate the Doppler shift and Doppler spread of a second reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type C, the receiver can use the source reference RF signal to estimate the Doppler shift and average delay of a second reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type D, the receiver can use the source reference RF signal to estimate the spatial receive parameter of a second reference RF signal transmitted on the same channel.

[0054] In receive beamforming, the receiver uses a receive beam to amplify RF signals detected on a given channel. For example, the receiver can increase the gain setting and/or adjust the phase setting of an array of antennas in a particular direction to amplify (e.g., to increase the gain level of) the RF signals received from that direction. Thus, when a receiver is said to beamform in a certain direction, it means the beam gain in that direction is high relative to the beam gain along other directions, or the beam gain in that direction is the highest compared to the beam gain in that direction of all other receive beams available to the receiver. This results in a stronger received signal strength (e.g., reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-interference-plus-noise ratio (SINR), etc.) of the RF signals received from that direction.

[0055] Transmit and receive beams may be spatially related. A spatial relation means that parameters for a second beam (e.g., a transmit or receive beam) for a second reference signal can be derived from information about a first beam (e.g., a receive beam or a transmit beam) for a first reference signal. For example, a UE may use a particular receive beam to receive a reference downlink reference signal (e.g., synchronization signal block (SSB)) from a base station. The UE can then form a transmit beam for sending an uplink reference signal (e.g., sounding reference signal (SRS)) to that base station based on the parameters of the receive beam.

[0056] Note that a "downlink" beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the downlink beam to transmit a reference signal to a UE, the downlink beam is a transmit beam. If the UE is forming the downlink beam, however, it is a receive beam to receive the downlink reference signal. Similarly, an "uplink" beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the uplink beam, it is an uplink receive beam, and if a UE is forming the uplink beam, it is an uplink transmit beam.

[0057] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR two initial operating bands have been identified as frequency range designations FR1 (410 MHZ-7.125 GHZ) and FR2 (24.25 GHz-52.6 GHZ). It should be understood that although a portion of FR1 is greater than 6 GHZ, FR1 is often referred to (interchangeably) as a "Sub-6 GHz" band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a "millimeter wave" band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHZ-300 GHz) which is identified by the INTERNATIONAL TELECOMMUNICATION UNION® as a "millimeter wave" band.

[0058] The frequencies between FR1 and FR2 are often referred to as mid-band frequencies. Recent 5G NR studies have identified an operating band for these mid-band frequencies as frequency range designation FR3 (7.125 GHz-24.25 GHZ). Frequency bands falling within FR3 may inherit FR1 characteristics and/or FR2 characteristics, and thus may effectively extend features of FR1 and/or FR2 into mid-band frequencies. In addition, higher frequency bands are currently being explored to extend 5G NR operation beyond 52.6 GHz. For example, three higher operating bands have been identified as frequency range designations FR4a or FR4-1 (52.6 GHZ-71 GHZ), FR4 (52.6 GHz-114.25 GHZ), and FR5 (114.25 GHZ-300 GHz). Each of these higher frequency bands falls within the EHF band.

[0059] With the above aspects in mind, unless specifically stated otherwise, it should be understood that the term "sub-6 GHz" or the like if used herein may broadly represent frequencies that may be less than 6 GHZ, may be within FR1, or may include mid-band frequencies. Further, unless specifically stated otherwise, it should be understood that the term "millimeter wave" or the like if used herein may broadly represent frequencies that may include mid-band frequencies, may be within FR2, FR4, FR4-a or FR4-1, and/or FR5, or may be within the EHF band.

[0060] In a multi-carrier system, such as 5G, one of the carrier frequencies is referred to as the "primary carrier" or "anchor carrier" or "primary serving cell" or "PCell," and the remaining carrier frequencies are referred to as "secondary carriers" or "secondary serving cells" or "SCells." In carrier aggregation, the anchor carrier is the carrier operating on the primary frequency (e.g., FR1) utilized by a UE **104/182** and the cell in which the UE **104/182** either performs the initial radio resource control (RRC) connection establishment procedure or initiates the RRC connection re-establishment procedure. The primary carrier carries all common and UE-specific control channels, and may be a carrier in a licensed frequency (however, this is not always the case). A secondary carrier is a carrier operating on a second frequency (e.g., FR2) that may be configured once the RRC connection is established between the UE **104** and the anchor carrier and that may be used to provide additional radio resources. In some cases, the secondary carrier may be a carrier in an unlicensed frequency. The secondary carrier may contain only necessary signaling information and signals, for example, those that are UE-specific may not be present in the secondary carrier, since both primary uplink and downlink carriers are typically UE-specific. This means that different UEs **104/182** in a cell may have different downlink primary carriers. The same is true for the uplink primary carriers. The network is able to change the primary carrier of any UE **104/182** at any time. This is done, for example, to balance the load on different carriers. Because a "serving cell" (whether a PCell or an SCell) corresponds to a carrier frequency/component carrier over which some base station is communicating, the term "cell," "serving cell," "component carrier," "carrier frequency," and the like can be used interchangeably.

[0061] For example, still referring to FIG. **1**, one of the frequencies utilized by the macro cell base stations **102** may be an anchor carrier (or "PCell") and other frequencies utilized by the macro cell base stations **102** and/or the mmW base station **180** may be secondary carriers ("SCells"). The simultaneous transmission and/or reception of multiple carriers enables the UE **104/182** to significantly increase its data transmission and/or reception rates. For example, two 20 MHz aggregated carriers in a multi-carrier system would theoretically lead to a two-fold increase in data rate (i.e., 40 MHZ), compared to that attained by a single 20 MHz carrier.

[0062] The wireless communications system **100** may further include a UE **164** that may communicate with a macro cell base station **102** over a communication link **120** and/or the mmW base station **180** over a mmW communication link **184**. For example, the macro cell base station **102** may support a PCell and one or more SCells for the UE **164** and the mmW base station **180** may support one or more SCells for the UE **164**.

[0063] In some cases, the UE **164** and the UE **182** may be capable of sidelink communication. Sidelink-capable UEs (SL-UEs) may communicate with base stations **102** over communication links **120** using the Uu interface (i.e., the air interface between a UE and a base station). SL-UEs (e.g., UE **164**, UE **182**) may also communicate directly with each other over a wireless sidelink **160** using the PC5 interface (i.e., the air interface between sidelink-capable UEs). A wireless sidelink (or just "sidelink") is an adaptation of the core cellular (e.g., LTE, NR) standard that allows direct communication between two or more UEs without the communication needing to go through a base station. Sidelink communication may be unicast or multicast, and may be used for device-to-device (D2D) media-sharing, vehicle-to-vehicle (V2V) communication, vehicle-to-everything (V2X) communication (e.g., cellular V2X (cV2X) communication, enhanced V2X (cV2X) communication, etc.), emergency rescue applications, etc. One or more of a group of SL-UEs utilizing sidelink communications may be within the geographic coverage area **110** of a base station **102**. Other SL-UEs in such a group may be outside the geographic coverage area **110** of a base station **102** or be otherwise unable to receive transmissions from a base station **102**. In some cases, groups of SL-UEs communicating via sidelink communications may utilize a one-to-many (**1**: M) system in which each SL-UE transmits to every other SL-UE in the group. In some cases, a base station **102** facilitates the scheduling of resources for sidelink communications. In other cases, sidelink communications are carried out between SL-UEs without the involvement of a base station **102**.

[0064] In an aspect, the sidelink **160** may operate over a wireless communication medium of interest, which may be shared with other wireless communications between other vehicles and/or infrastructure access points, as well as other RATs. A "medium" may be composed of one or more time, frequency, and/or space communication resources (e.g., encompassing one or more channels across one or more carriers) associated with wireless communication between one or more transmitter/receiver pairs. In an aspect, the medium of interest may correspond to at least a portion of an unlicensed frequency band shared among various RATs. Although different licensed frequency bands have been reserved for certain communication systems (e.g., by a government entity such as the Federal Communications Commission (FCC) in the United States), these systems, in particular those employing small cell access points, have recently extended operation into unlicensed frequency bands such as the Unlicensed National Information Infrastructure (U-NII) band used by wireless local area network (WLAN) technologies, most notably IEEE 802.11x WLAN technologies generally referred to as "Wi-Fi." Example systems of this type include different variants of CDMA systems, TDMA systems, FDMA systems, orthogonal FDMA (OFDMA) systems, single-carrier FDMA (SC-FDMA) systems, and so on.

[0065] Note that although FIG. **1** only illustrates two of the UEs as SL-UEs (i.e., UEs **164** and **182**), any of the illustrated UEs may be SL-UEs. Further, although only UE **182** was described as being capable of beamforming, any of the illustrated UEs, including UE **164**, may be capable of beamforming. Where SL-UEs are capable of beamforming, they may beamform towards each other (i.e., towards other SL-UEs), towards other UEs (e.g., UEs **104**), towards base stations (e.g., base stations **102**, **180**, small cell **102'**, access point **150**), etc. Thus, in some cases, UEs **164** and **182** may utilize beamforming over sidelink **160**.

[0066] In the example of FIG. **1**, any of the illustrated UEs (shown in FIG. **1** as a single UE **104** for simplicity) may receive signals **124** from one or more Earth orbiting space vehicles (SVs) **112** (e.g., satellites). In an aspect, the SVs **112** may be part of a satellite positioning system that a UE **104** can use as an independent source of location information. A satellite positioning system typically includes a system of transmitters (e.g., SVs **112**) positioned to enable receivers (e.g., UEs **104**) to determine their location on or above the Earth based, at least in part, on positioning signals (e.g., signals **124**) received from the transmitters. Such a transmitter typically transmits a signal marked with a repeating pseudo-random noise (PN) code of a set number of chips. While typically located in SVs **112**, transmitters may sometimes be located on ground-based control stations, base stations **102**, and/or other UEs **104**. A UE **104** may include one or more dedicated receivers specifically designed to receive signals **124** for deriving geo location information from the SVs **112**.

[0067] In a satellite positioning system, the use of signals **124** can be augmented by various satellite-based augmentation systems (SBAS) that may be associated with or otherwise enabled for use with one or more global and/or regional navigation satellite systems. For example an SBAS may include an augmentation system(s) that provides integrity information, differential corrections, etc., such as the Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay Service (EGNOS), the Multi-functional Satellite Augmentation System (MSAS), the Global Positioning System (GPS) Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system (GAGAN), and/or the like. Thus, as used herein, a satellite positioning system may include any combination of one or more global and/or regional navigation satellites associated with such one or more satellite positioning systems.

[0068] In an aspect, SVs **112** may additionally or alternatively be part of one or more non-terrestrial networks (NTNs). In an NTN, an SV **112** is connected to an earth station (also referred to as a ground station, NTN gateway, or gateway), which in turn is connected to an element in a 5G network, such as a modified base station **102** (without a terrestrial antenna) or a network node in a 5GC. This element would in turn provide access to other elements in the 5G network and ultimately to entities external to the 5G network, such as Internet web servers and other user devices. In that way, a UE **104** may receive communication signals (e.g., signals **124**) from an SV **112** instead of, or in addition to, communication signals from a terrestrial base station **102**.

[0069] The wireless communications system **100** may further include one or more UEs, such as UE **190**, that connects indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links (referred to as "sidelinks"). In the example of FIG. **1**, UE **190** has a D2D P2P link **192** with one of the UEs **104** connected to one of the base stations **102** (e.g., through which UE **190** may indirectly obtain cellular connectivity) and a D2D P2P link **194** with WLAN STA **152** connected to the WLAN AP **150** (through which UE **190** may indirectly obtain WLAN-based Internet connectivity). In an example, the D2D P2P links **192** and **194** may be supported with any well-known D2D RAT, such as LTE Direct (LTE-D), WI-FI DIRECT®, BLUETOOTH®, and so on.

[0070] FIG. **2**A illustrates an example wireless network structure **200**. For example, a 5GC **210** (also referred to as a Next Generation Core (NGC)) can be viewed functionally as control plane (C-plane) functions **214** (e.g., UE registration, authentication, network access, gateway selection, etc.) and user plane (U-plane) functions **212**, (e.g., UE gateway function, access to data networks, IP routing, etc.) which operate cooperatively to form the core network. User plane interface (NG-U) **213** and control plane interface (NG-C) **215** connect the gNB **222** to the 5GC **210** and specifically to the user plane functions **212** and control plane functions **214**, respectively. In an additional configuration, an ng-eNB **224** may also be connected to the 5GC **210** via NG-C **215** to the control plane functions **214** and NG-U **213** to user plane functions **212**. Further, ng-eNB **224** may directly communicate with gNB **222** via a backhaul connection **223**. In some configurations, a Next Generation RAN (NG-RAN) **220** may have one or more gNBs **222**, while other configurations include one or more of both ng-eNBs **224** and gNBs **222**. Either (or both) gNB **222** or ng-eNB **224** may communicate with one or more UEs **204** (e.g., any of the UEs described herein).

[0071] Another optional aspect may include a location server **230**, which may be in communication with the 5GC **210** to provide location assistance for UE(s) **204**. The location server **230** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The location server **230** can be configured to support one or more location services for UEs **204** that can connect to the location server **230** via the core network, 5GC **210**, and/or via the Internet (not illustrated). Further, the location server **230** may be integrated into a component of the core network, or alternatively may be external to the core network (e.g., a third party server, such as an original equipment manufacturer (OEM) server or service server).

[0072] FIG. 2B illustrates another example wireless network structure **240**. A 5GC **260** (which may correspond to 5GC **210** in FIG. 2A) can be viewed functionally as control plane functions, provided by an access and mobility management function (AMF) **264**, and user plane functions, provided by a user plane function (UPF) **262**, which operate cooperatively to form the core network (i.e., 5GC **260**). The functions of the AMF **264** include registration management, connection management, reachability management, mobility management, lawful interception, transport for session management (SM) messages between one or more UEs **204** (e.g., any of the UEs described herein) and a session management function (SMF) **266**, transparent proxy services for routing SM messages, access authentication and access authorization, transport for short message service (SMS) messages between the UE **204** and the short message service function (SMSF) (not shown), and security anchor functionality (SEAF). The AMF **264** also interacts with an authentication server function (AUSF) (not shown) and the UE **204**, and receives the intermediate key that was established as a result of the UE **204** authentication process. In the case of authentication based on a UMTS (universal mobile telecommunications system) subscriber identity module (USIM), the AMF **264** retrieves the security material from the AUSF. The functions of the AMF **264** also include security context management (SCM). The SCM receives a key from the SEAF that it uses to derive access-network specific keys. The functionality of the AMF **264** also includes location services management for regulatory services, transport for location services messages between the UE **204** and a location management function (LMF) **270** (which acts as a location server **230**), transport for location services messages between the NG-RAN **220** and the LMF **270**, evolved packet system (EPS) bearer identifier allocation for interworking with the EPS, and UE **204** mobility event notification. In addition, the AMF **264** also supports functionalities for non-3GPP® (Third Generation Partnership Project) access networks.

[0073] Functions of the UPF **262** include acting as an anchor point for intra/inter-RAT mobility (when applicable), acting as an external protocol data unit (PDU) session point of interconnect to a data network (not shown), providing packet routing and forwarding, packet inspection, user plane policy rule enforcement (e.g., gating, redirection, traffic steering), lawful interception (user plane collection), traffic usage reporting, quality of service (QOS) handling for the user plane (e.g., uplink/downlink rate enforcement, reflective QoS marking in the downlink), uplink traffic verification (service data flow (SDF) to QoS flow mapping), transport level packet marking in the uplink and downlink, downlink packet buffering and downlink data notification triggering, and sending and forwarding of one or more "end markers" to the source RAN node. The UPF **262** may also support transfer of location services messages over a user plane between the UE **204** and a location server, such as an SLP **272**.

[0074] The functions of the SMF **266** include session management, UE Internet protocol (IP) address allocation and management, selection and control of user plane functions, configuration of traffic steering at the UPF **262** to route traffic to the proper destination, control of part of policy enforcement and QoS, and downlink data notification. The interface over which the SMF **266** communicates with the AMF **264** is referred to as the N11 interface.

[0075] Another optional aspect may include an LMF **270**, which may be in communication with the 5GC **260** to provide location assistance for UEs **204**. The LMF **270** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The LMF **270** can be configured to support one or more location services for UEs **204** that can connect to the LMF **270** via the core network, 5GC **260**, and/or via the Internet (not illustrated). The SLP **272** may support similar functions to the LMF **270**, but whereas the LMF **270** may communicate with the AMF **264**, NG-RAN **220**, and UEs **204** over a control plane (e.g., using interfaces and protocols intended to convey signaling messages and not voice or data), the SLP **272** may communicate with UEs **204** and external clients (e.g., third-party server **274**) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).

[0076] Yet another optional aspect may include a third-party server **274**, which may be in communication with the LMF **270**, the SLP **272**, the 5GC **260** (e.g., via the AMF **264** and/or the UPF **262**), the NG-RAN **220**, and/or the UE **204** to obtain location information (e.g., a location estimate) for the UE **204**. As such, in some cases, the third-party server **274** may be referred to as a location services (LCS) client or an external client. The third-party server **274** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server.

[0077] User plane interface **263** and control plane interface **265** connect the 5GC **260**, and specifically the UPF **262** and AMF **264**, respectively, to one or more gNBs **222** and/or ng-cNBs **224** in the NG-RAN **220**. The interface between gNB(s) **222** and/or ng-eNB(s) **224** and the AMF **264** is referred to as the "N2" interface, and the interface between gNB(s) **222** and/or ng-eNB(s) **224** and the UPF **262** is referred to as the "N3" interface. The gNB(s) **222** and/or ng-cNB(s) **224** of the NG-RAN **220** may communicate directly with each other via backhaul connections **223**, referred to as the "Xn-C" interface. One or more of gNBs **222** and/or ng-eNBs **224** may communicate with one or more UEs **204** over a wireless interface, referred to as the "Uu" interface.

[0078] The functionality of a gNB **222** may be divided between a gNB central unit (gNB-CU) **226**, one or more gNB distributed units (gNB-DUs) **228**, and one or more gNB radio units (gNB-RUs) **229**. A gNB-CU **226** is a logical node that includes the base station functions of transferring user data, mobility control, radio access network sharing, positioning, session management, and the like, except for those functions allocated exclusively to the gNB-DU(s) **228**. More specifically, the gNB-CU **226** generally host the radio resource control (RRC), service data adaptation protocol (SDAP), and packet data convergence protocol (PDCP) protocols of the gNB **222**. A gNB-DU **228** is a logical node that generally hosts the radio link control (RLC) and medium access control (MAC) layer of the gNB **222**. Its operation is controlled by the gNB-CU **226**. One gNB-DU **228** can support one or more cells, and one cell is supported by only one gNB-DU **228**. The interface **232** between the gNB-CU **226** and the one or more gNB-DUs **228** is referred to as the "F1" interface. The physical (PHY) layer functionality of a gNB **222** is generally hosted by one or more standalone gNB-RUs **229** that perform functions such as power amplification and signal transmission/reception. The interface between a gNB-DU **228** and a gNB-RU **229** is referred to as the "Fx" interface. Thus, a UE **204** communicates with the gNB-CU **226** via the RRC, SDAP, and PDCP layers, with a gNB-DU **228** via the RLC and MAC layers, and with a gNB-RU **229** via the PHY layer.

[0079] Deployment of communication systems, such as 5G NR systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a network, a RAN node, a core network node, a network element, or a network equipment, such as a base station, or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a base station (such as a Node B (NB), evolved NB (eNB), NR base station, 5G NB, AP, TRP, cell, etc.) may be implemented as an aggregated base station (also known as a standalone base station or a monolithic base station) or a disaggregated base station.

[0080] An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUS)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CU, DU and RU also can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).

[0081] Base station-type operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN ALLIANCE®)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be configured for wired or wireless communication with at least one other unit.

[0082] FIG. 2C illustrates an example disaggregated base station architecture **250**, according to aspects of the disclosure. The disaggregated base station architecture **250** may include one or more central units (CUs) **280** (e.g., gNB-CU **226**) that can communicate directly with a core network **267** (e.g., 5GC **210**, 5GC **260**) via a backhaul link, or indirectly with the core network **267** through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) **259** via an E2 link, or a Non-Real Time (Non-RT) RIC **257** associated with a Service Management and Orchestration (SMO) Framework **255**, or both). A CU **280** may communicate with one or more DUs **285** (e.g., gNB-DUs **228**) via respective midhaul links, such as an F1 interface. The DUs **285** may communicate with one or more radio units (RUs) **287** (e.g., gNB-RUs **229**) via respective fronthaul links. The RUs **287** may communicate with respective UEs **204** via one or more radio frequency (RF) access links. In some implementations, the UE **204** may be simultaneously served by multiple RUs **287**.

[0083] Each of the units, i.e., the CUS **280**, the DUs **285**, the RUs **287**, as well as the Near-RT RICs **259**, the Non-RT RICs **257** and the SMO Framework **255**, may include one or more interfaces or be coupled to one or more interfaces configured to receive or transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or transmit signals over a wired transmission medium to one or more of the other units. Additionally, the units can include a wireless interface, which may include a receiver, a transmitter or transceiver (such as a RF transceiver), configured to receive or transmit signals, or both, over a wireless transmission medium to one or more of the other units.

[0084] In some aspects, the CU **280** may host one or more higher layer control functions. Such control functions can include RRC, PDCP, service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU **280**. The CU **280** may be configured to handle user plane functionality (i.e., Central Unit-User Plane (CU-UP)), control plane functionality (i.e., Central Unit-Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU **280** can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as the E1 interface when implemented in an O-RAN configuration. The CU **280** can be implemented to communicate with the DU **285**, as necessary, for network control and signaling.

[0085] The DU **285** may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs **287**. In some aspects, the DU **285** may host one or more of a RLC layer, a MAC layer, and one or more high PHY layers (such as modules for forward error correction (FEC) encoding and decoding, scrambling, modulation and demodulation, or the like) depending, at least in part, on a functional split, such as those defined by the 3rd Generation Partnership Project (3GPP®). In some aspects, the DU **285** may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU **285**, or with the control functions hosted by the CU **280**.

[0086] Lower-layer functionality can be implemented by one or more RUs **287**. In some deployments, an RU **287**, controlled by a DU **285**, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (IFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) **287** can be implemented to handle over the air (OTA) communication with one or more UEs **204**. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) **287** can be controlled by the corresponding DU **285**. In some scenarios, this configuration can enable the DU(s) **285** and the CU **280** to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.

[0087] The SMO Framework **255** may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework **255** may be configured to support the deployment of dedicated physical resources for RAN coverage requirements which may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework **255** may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) **269**) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs **280**, DUs **285**, RUs **287** and Near-RT RICs **259**. In some implementations, the SMO Framework **255** can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) **261**, via an O1 interface. Additionally, in some implementations, the SMO Framework **255** can communicate directly with one or more RUs **287** via an O1 interface. The SMO Framework **255** also may include a Non-RT RIC **257** configured to support functionality of the SMO Framework **255**.

[0088] The Non-RT RIC **257** may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, artificial intelligence/machine learning (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC **259**. The Non-RT RIC **257** may be coupled to or communicate with (such as via an A1 interface) the Near-RT RIC **259**. The Near-RT RIC **259** may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs **280**, one or more DUs **285**, or both, as well as an O-eNB, with the Near-RT RIC **259**.

[0089] In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC **259**, the Non-RT RIC **257** may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC **259** and may be received at the SMO Framework **255** or the Non-RT RIC **257** from non-network data sources or from network functions. In some examples, the Non-RT RIC **257** or the Near-RT RIC **259** may be configured to tune RAN behavior or performance. For example, the Non-RT RIC **257** may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO Framework **255** (such as reconfiguration via O1) or via creation of RAN management policies (such as A1 policies).

[0090] FIGS. **3**A, **3**B, and **3**C illustrate several example components (represented by corresponding blocks) that may be incorporated into a UE **302** (which may correspond to any of the UEs described herein), a base station **304** (which may correspond to any of the base stations described herein), and a network entity **306** (which may correspond to or embody any of the network functions described herein, including the location server **230** and the LMF **270**, a sensing server/sensing function, or alternatively may be independent from the NG-RAN **220** and/or 5GC **210**/**260** infrastructure depicted in FIGS. **2**A and **2**B, such as a private network) to support the operations described herein. It will be appreciated that these components may be implemented in different types of apparatuses in different implementations (e.g., in an ASIC, in a system-on-chip (SoC), etc.). The illustrated components may also be incorporated into other apparatuses in a communication system. For example, other apparatuses in a system may include components similar to those described to provide similar functionality. Also, a given apparatus may contain one or more of the components. For example, an apparatus may include multiple transceiver components that enable the apparatus to operate on multiple carriers and/or communicate via different technologies.

[0091] The UE **302** and the base station **304** each include one or more wireless wide area network (WWAN) transceivers **310** and **350**, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) via one or more wireless communication networks (not shown), such as an NR network, an LTE network, a GSM network, and/or the like. The WWAN transceivers **310** and **350** may each be connected to one or more antennas **316** and **356**, respectively, for communicating with other network nodes, such as other UEs, access points, base stations (e.g., eNBs, gNBs), etc., via at least one designated RAT (e.g., NR, LTE, GSM, etc.) over a wireless communication medium of interest (e.g., some set of time/frequency resources in a particular frequency spectrum). The WWAN transceivers **310** and **350** may be variously configured for transmitting and encoding signals **318** and **358** (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals **318** and **358** (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the WWAN transceivers **310** and **350** include one or more transmitters **314** and **354**, respectively, for transmitting and encoding signals **318** and **358**, respectively, and one or more receivers **312** and **352**, respectively, for receiving and decoding signals **318** and **358**, respectively.

[0092] The UE **302** and the base station **304** each also include, at least in some cases, one or more short-range wireless transceivers **320** and **360**, respectively. The short-range wireless transceivers **320** and **360** may be connected to one or more antennas **326** and **366**, respectively, and provide means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) with other network nodes, such as other UEs, access points, base stations, etc., via at least one designated RAT (e.g., Wi-Fi, LTE Direct, BLUETOOTH®, ZIGBEE®, Z-WAVE®, PC5, dedicated short-range communications (DSRC), wireless access for vehicular environments (WAVE), near-field communication (NFC), ultra-wideband (UWB), etc.) over a wireless communication medium of interest. The short-range wireless transceivers **320** and **360** may be variously configured for transmitting and encoding signals **328** and **368** (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals **328** and **368** (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the short-range wireless transceivers **320** and **360** include one or more transmitters **324** and **364**, respectively, for transmitting and encoding signals **328** and **368**, respectively, and one or more receivers **322** and **362**, respectively, for receiving and decoding signals **328** and **368**, respectively. As specific examples, the short-range wireless transceivers **320** and **360** may be Wi-Fi transceivers, BLUETOOTH® transceivers, ZIGBEE® and/or Z-WAVE® transceivers, NFC transceivers, UWB transceivers, or vehicle-to-vehicle (V2V) and/or vehicle-to-everything (V2X) transceivers.

[0093] The UE **302** and the base station **304** also include, at least in some cases, satellite signal interfaces **330** and **370**, which each include one or more satellite signal receivers **332** and **372**, respectively, and may optionally include one or more satellite signal transmitters **334** and **374**, respectively. In some cases, the base station **304** may be a terrestrial base station that may communicate with space vehicles (e.g., space vehicles **112**) via the satellite signal interface **370**. In other cases, the base station **304** may be a space vehicle (or other non-terrestrial entity) that uses the satellite signal interface **370** to communicate with terrestrial networks and/or other space vehicles.

[0094] The satellite signal receivers **332** and **372** may be connected to one or more antennas **336** and **376**, respectively, and may provide means for receiving and/or measuring satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal receiver(s) **332** and **372** are satellite positioning system receivers, the satellite positioning/communication signals **338** and **378** may be global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC), Quasi-Zenith Satellite System (QZSS) signals, etc. Where the satellite signal receiver(s) **332** and **372** are non-terrestrial network (NTN) receivers, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal receiver (s) **332** and **372** may comprise any suitable hardware and/or software for receiving and processing satellite positioning/communication signals **338** and **378**, respectively. The satellite signal receiver(s) **332** and **372** may request information and operations as appropriate from the other systems, and, at least in some cases, perform calculations to determine locations of the UE **302** and the base station **304**, respectively, using measurements obtained by any suitable satellite positioning system algorithm.

[0095] The optional satellite signal transmitter(s) **334** and **374**, when present, may be connected to the one or more antennas **336** and **376**, respectively, and may provide means for transmitting satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal transmitter(s) **374** are satellite positioning system transmitters, the satellite positioning/communication signals **378** may be GPS signals, GLONASS® signals, Galileo signals, Beidou signals, NAVIC, QZSS signals, etc. Where the satellite signal transmitter(s) **334** and **374** are NTN transmitters, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal transmitter(s) **334** and **374** may comprise any suitable hardware and/or software for transmitting satellite positioning/communication signals **338** and **378**, respectively. The satellite signal transmitter(s) **334** and **374** may request information and operations as appropriate from the other systems.

[0096] The base station **304** and the network entity **306** each include one or more network transceivers **380** and **390**, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, etc.) with other network entities (e.g., other base stations **304**, other network entities **306**). For example, the base station **304** may employ the one or more network transceivers **380** to communicate with other base stations **304** or network entities **306** over one or more wired or wireless backhaul links. As another example, the network entity **306** may employ the one or more network transceivers **390** to communicate with one or more base station **304** over one or more wired or wireless backhaul links, or with other network entities **306** over one or more wired or wireless core network interfaces.

[0097] A transceiver may be configured to communicate over a wired or wireless link. A transceiver (whether a wired transceiver or a wireless transceiver) includes transmitter circuitry (e.g., transmitters **314**, **324**, **354**, **364**) and receiver circuitry (e.g., receivers **312**, **322**, **352**, **362**). A transceiver may be an integrated device (e.g., embodying transmitter circuitry and receiver circuitry in a single device) in some implementations, may comprise separate transmitter circuitry and separate receiver circuitry in some implementations, or may be embodied in other ways in other implementations. The transmitter circuitry and receiver circuitry of a wired transceiver (e.g., network transceivers **380** and **390** in some implementations) may be coupled to one or more wired network interface ports. Wireless transmitter circuitry (e.g., transmitters **314**, **324**, **354**, **364**) may include or be coupled to a plurality of antennas (e.g., antennas **316**, **326**, **356**, **366**), such as an antenna array, that permits the respective apparatus (e.g., UE **302**, base station **304**) to perform transmit "beamforming," as described herein. Similarly, wireless receiver circuitry (e.g., receivers **312**, **322**, **352**, **362**) may include or be coupled to a plurality of antennas (e.g., antennas **316**, **326**, **356**, **366**), such as an antenna array, that permits the respective apparatus (e.g., UE **302**, base station **304**) to perform receive beamforming, as described herein. In an aspect, the transmitter circuitry and receiver circuitry may share the same plurality of antennas (e.g., antennas **316**, **326**, **356**, **366**), such that the respective apparatus can only receive or transmit at a given time, not both at the same time. A wireless transceiver (e.g., WWAN transceivers **310** and **350**, short-range wireless transceivers **320** and **360**) may also include a network listen module (NLM) or the like for performing various measurements.

[0098] As used herein, the various wireless transceivers (e.g., transceivers **310**, **320**, **350**, and **360**, and network transceivers **380** and **390** in some implementations) and wired transceivers (e.g., network transceivers **380** and **390** in some implementations) may generally be characterized as "a transceiver," "at least one transceiver," or "one or more transceivers." As such, whether a particular transceiver is a wired or wireless transceiver may be inferred from the type of communication performed. For example, backhaul communication between network devices or servers will generally relate to signaling via a wired transceiver, whereas wireless communication between a UE (e.g., UE **302**) and a base station (e.g., base station **304**) will generally relate to signaling via a wireless transceiver.

[0099] The UE **302**, the base station **304**, and the network entity **306** also include other components that may be used in conjunction with the operations as disclosed herein. The UE **302**, the base station **304**, and the network entity **306** include one or more processors **342**, **384**, and **394**, respectively, for providing functionality relating to, for example, wireless communication, and for providing other processing functionality. The processors **342**, **384**, and **394** may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processors **342**, **384**, and **394** may include, for example, one or more general purpose processors, multi-core processors, central processing units (CPUs), ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGAs), other programmable logic devices or processing circuitry, or various combinations thereof.

[0100] The UE **302**, the base station **304**, and the network entity **306** include memory circuitry implementing memories **340**, **386**, and **396** (e.g., each including a memory device), respectively, for maintaining information (e.g., information indicative of reserved resources, thresholds, parameters, and so on). The memories **340**, **386**, and **396** may therefore provide means for storing, means for retrieving, means for maintaining, etc. In some cases, the UE **302**, the base station **304**, and the network entity **306** may include sensing component(s) **348**, **388**, and **398**, respectively. The sensing component(s) **348**, **388**, and **398** may be hardware circuits that are part of or coupled to the processors **342**, **384**, and **394**, respectively, that, when executed, cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. In other aspects, the sensing component(s) **348**, **388**, and **398** may be external to the processors **342**, **384**, and **394** (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the sensing component(s) **348**, **388**, and **398** may be memory modules stored in the memories **340**, **386**, and **396**, respectively, that, when executed by the processors **342**, **384**, and **394** (or a modem processing system, another processing system, etc.), cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. FIG. **3**A illustrates possible locations of the sensing component(s) **348**, which may be, for example, part of the one or more WWAN transceivers **310**, the memory **340**, the one or more processors **342**, or any combination thereof, or may be a standalone component. FIG. **3**B illustrates possible locations of the sensing component(s) **388**, which may be, for example, part of the one or more WWAN transceivers **350**, the memory **386**, the one or more processors **384**, or any combination thereof, or may be a standalone component. FIG. **3**C illustrates possible locations of the sensing component(s) **398**, which may be, for example, part of the one or more network transceivers **390**, the memory **396**, the one or more processors **394**, or any combination thereof, or may be a standalone component.

[0101] The UE **302** may include one or more sensors **344** coupled to the one or more processors **342** to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the one or more WWAN transceivers **310**, the one or more short-range wireless transceivers **320**, and/or the satellite signal interface **330**. By way of example, the sensor(s) **344** may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor. Moreover, the sensor(s) **344** may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s) **344** may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in two-dimensional (2D) and/or three-dimensional (3D) coordinate systems.

[0102] In addition, the UE **302** includes a user interface **346** providing means for providing indications (e.g., audible and/or visual indications) to a user and/or for receiving user input (e.g., upon user actuation of a sensing device such a keypad, a touch screen, a microphone, and so on). Although not shown, the base station **304** and the network entity **306** may also include user interfaces.

[0103] Referring to the one or more processors **384** in more detail, in the downlink, IP packets from the network entity **306** may be provided to the processor **384**. The one or more processors **384** may implement functionality for an RRC layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The one or more processors **384** may provide RRC layer functionality associated with broadcasting of system information (e.g., master information block (MIB), system information blocks (SIBs)), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter-RAT mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression/decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer PDUs, error correction through automatic repeat request (ARQ), concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, scheduling information reporting, error correction, priority handling, and logical channel prioritization.

[0104] The transmitter **354** and the receiver **352** may implement Layer-1 (L1) functionality associated with various signal processing functions. Layer-1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The transmitter **354** handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an orthogonal frequency division multiplexing (OFDM) subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an inverse fast Fourier transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM symbol stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE **302**. Each spatial stream may then be provided to one or more different antennas **356**. The transmitter **354** may modulate an RF carrier with a respective spatial stream for transmission.

[0105] At the UE **302**, the receiver **312** receives a signal through its respective antenna(s) **316**. The receiver **312** recovers information modulated onto an RF carrier and provides the information to the one or more processors **342**. The transmitter **314** and the receiver **312** implement Layer-1 functionality associated with various signal processing functions. The receiver **312** may perform spatial processing on the information to recover any spatial streams destined for the UE **302**. If multiple spatial streams are destined for the UE **302**, they may be combined by the receiver **312** into a single OFDM symbol stream. The receiver **312** then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **304**. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to recover the data and control signals that were originally transmitted by the base station **304** on the physical channel. The data and control signals are then provided to the one or more processors **342**, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

[0106] In the downlink, the one or more processors **342** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The one or more processors **342** are also responsible for error detection.

[0107] Similar to the functionality described in connection with the downlink transmission by the base station **304**, the one or more processors **342** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.

[0108] Channel estimates derived by the channel estimator from a reference signal or feedback transmitted by the base station **304** may be used by the transmitter **314** to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the transmitter **314** may be provided to different antenna(s) **316**. The transmitter **314** may modulate an RF carrier with a respective spatial stream for transmission.

[0109] The uplink transmission is processed at the base station **304** in a manner similar to that described in connection with the receiver function at the UE **302**. The receiver **352** receives a signal through its respective antenna(s) **356**. The receiver **352** recovers information modulated onto an RF carrier and provides the information to the one or more processors **384**.

[0110] In the uplink, the one or more processors **384** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE **302**. IP packets from the one or more processors **384** may be provided to the core network. The one or more processors **384** are also responsible for error detection.

[0111] For convenience, the UE **302**, the base station **304**, and/or the network entity **306** are shown in FIGS. **3**A, **3**B, and **3**C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated components may have different functionality in different designs. In particular, various components in FIGS. **3**A to **3**C are optional in alternative configurations and the various aspects include configurations that may vary due to design choice, costs, use of the device, or other considerations. For example, in case of FIG. **3**A, a particular implementation of UE **302** may omit the WWAN transceiver(s) **310** (e.g., a wearable device or tablet computer or personal computer (PC) or laptop may have Wi-Fi and/or BLUETOOTH® capability without cellular capability), or may omit the short-range wireless transceiver(s) **320** (e.g., cellular-only, etc.), or may omit the satellite signal interface **330**, or may omit the sensor(s) **344**, and so on. In another example, in case of FIG. **3**B, a particular implementation of the base station **304** may omit the WWAN transceiver(s) **350** (e.g., a Wi-Fi “hotspot” access point without cellular capability), or may omit the short-range wireless transceiver(s) **360** (e.g., cellular-only, etc.), or may omit the satellite signal interface **370**, and so on. For brevity, illustration of the various alternative configurations is not provided herein, but would be readily understandable to one skilled in the art.

[0112] The various components of the UE **302**, the base station **304**, and the network entity **306** may be communicatively coupled to each other over data buses **308**, **382**, and **392**, respectively. In an aspect, the data buses **308**, **382**, and

392 may form, or be part of, a communication interface of the UE 302, the base station 304, and the network entity 306, respectively. For example, where different logical entities are embodied in the same device (e.g., gNB and location server, sensing server, etc. functionality incorporated into the same base station 304), the data buses 308, 382, and 392 may provide communication between them.

[0113] The components of FIGS. 3A, 3B, and 3C may be implemented in various ways. In some implementations, the components of FIGS. 3A, 3B, and 3C may be implemented in one or more circuits such as, for example, one or more processors and/or one or more ASICs (which may include one or more processors). Here, each circuit may use and/or incorporate at least one memory component for storing information or executable code used by the circuit to provide this functionality. For example, some or all of the functionality represented by blocks 310 to 346 may be implemented by processor and memory component(s) of the UE 302 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Similarly, some or all of the functionality represented by blocks 350 to 388 may be implemented by processor and memory component(s) of the base station 304 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Also, some or all of the functionality represented by blocks 390 to 398 may be implemented by processor and memory component(s) of the network entity 306 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). For simplicity, various operations, acts, and/or functions are described herein as being performed "by a UE," "by a base station," "by a network entity," etc. However, as will be appreciated, such operations, acts, and/or functions may actually be performed by specific components or combinations of components of the UE 302, base station 304, network entity 306, etc., such as the processors 342, 384, 394, the transceivers 310, 320, 350, and 360, the memories 340, 386, and 396, the sensing component(s) 348, 388, and 398, etc.

[0114] In some designs, the network entity 306 may be implemented as a core network component. In other designs, the network entity 306 may be distinct from a network operator or operation of the cellular network infrastructure (e.g., NG RAN 220 and/or 5GC 210/260). For example, the network entity 306 may be a component of a private network that may be configured to communicate with the UE 302 via the base station 304 or independently from the base station 304 (e.g., over a non-cellular communication link, such as Wi-Fi).

[0115] Wireless communication signals (e.g., radio frequency (RF) signals configured to carry orthogonal frequency division multiplexing (OFDM) symbols in accordance with a wireless communications standard, such as LTE, NR, etc.) transmitted between a UE and a base station can be used for environment sensing (also referred to as "RF sensing" or "radar"). Using wireless communication signals for environment sensing can be regarded as consumer-level radar with advanced detection capabilities that enable, among other things, touchless/device-free interaction with a device/system. The wireless communication signals may be cellular communication signals, such as LTE or NR signals, WLAN signals, such as Wi-Fi signals, etc. As a particular example, the wireless communication signals may be an OFDM waveform as utilized in LTE and NR. High-frequency communication signals, such as millimeter wave (mmW) RF signals, are especially beneficial to use as sensing signals because the higher frequency provides, at least, more accurate range (distance) detection.

[0116] Possible use cases of RF sensing include health monitoring use cases, such as heartbeat detection, respiration rate monitoring, and the like, gesture recognition use cases, such as human activity recognition, keystroke detection, sign language recognition, and the like, contextual information acquisition use cases, such as location detection/tracking, direction finding, range estimation, and the like, and automotive sensing use cases, such as smart cruise control, collision avoidance, and the like.

[0117] There are different types of sensing, including monostatic sensing (also referred to as "active sensing") and bistatic sensing (also referred to as "passive sensing"). FIGS. 4A and 4B illustrate these different types of sensing. Specifically, FIG. 4A is a diagram 400 illustrating a monostatic sensing scenario and FIG. 4B is a diagram 430 illustrating a bistatic sensing scenario. In FIG. 4A, the transmitter (Tx) and receiver (Rx) are co-located in the same sensing device 404 (e.g., a UE). The sensing device 404 transmits one or more RF sensing signals 434 (e.g., uplink or sidelink positioning reference signals (PRS) where the sensing device 404 is a UE), and some of the RF sensing signals 434 reflect off a target object 406. The sensing device 404 can measure various properties (e.g., times of arrival (ToAs), angles of arrival (AoAs), phase shift, etc.) of the reflections 436 of the RF sensing signals 434 to determine characteristics of the target object 406 (e.g., size, shape, speed, motion state, etc.).

[0118] In FIG. 4B, the transmitter (Tx) and receiver (Rx) are not co-located, that is, they are separate devices (e.g., a UE and a base station). Note that while FIG. 4B illustrates using a downlink RF signal as the RF sensing signal 432, uplink RF signals or sidelink RF signals can also be used as RF sensing signals 432. In a downlink scenario, as shown, the transmitter is a base station and the receiver is a UE or another base station, whereas in an uplink scenario, the transmitter is a UE and the receiver is a base station.

[0119] Referring to FIG. 4B in greater detail, the transmitter device 402 transmits RF sensing signals 432 and 434 (e.g., positioning reference signals (PRS)) to the sensing device 404, but some of the RF sensing signals 434 reflect off a target object 406. The sensing device 404 (also referred to as the "sensing device") can measure the times of arrival (ToAs) of the RF sensing signals 432 received directly from the transmitter device and the ToAs of the reflections 436 of the RF sensing signals 434 reflected from the target object 406.

[0120] More specifically, as described above, a transmitter device (e.g., a base station) may transmit a single RF signal or multiple RF signals to a sensing device (e.g., a UE). However, the receiver may receive multiple RF signals corresponding to each transmitted RF signal due to the propagation characteristics of RF signals through multipath channels. Each path may be associated with a cluster of one or more channel taps. Generally, the time at which the receiver detects the first cluster of channel taps is considered the ToA of the RF signal on the line-of-site (LOS) path (i.e., the shortest path between the transmitter and the receiver). Later clusters of channel taps are considered to have reflected off objects between the transmitter and the receiver and therefore to have followed non-LOS (NLOS) paths between the transmitter and the receiver.

[0121] Thus, referring back to FIG. **4**B, the RF sensing signals **432** followed the LOS path between the transmitter device **402** and the sensing device **404**, and the RF sensing signals **434** followed an NLOS path between the transmitter device **402** and the sensing device **404** due to reflecting off the target object **406**. The transmitter device **402** may have transmitted multiple RF sensing signals **432**, **434**, some of which followed the LOS path and others of which followed the NLOS path. Alternatively, the transmitter device **402** may have transmitted a single RF sensing signal in a broad enough beam that a portion of the RF sensing signal followed the LOS path (RF sensing signal **432**) and a portion of the RF sensing signal followed the NLOS path (RF sensing signal **434**).

[0122] Based on the ToA of the LOS path, the ToA of the NLOS path, and the speed of light, the sensing device **404** can determine the distance to the target object(s). For example, the sensing device **404** can calculate the distance to the target object as the difference between the ToA of the LOS path and the ToA of the NLOS path multiplied by the speed of light. In addition, if the sensing device **404** is capable of receive beamforming, the sensing device **404** may be able to determine the general direction to a target object as the direction (angle) of the receive beam on which the RF sensing signal following the NLOS path was received. That is, the sensing device **404** may determine the direction to the target object as the angle of arrival (AoA) of the RF sensing signal, which is the angle of the receive beam used to receive the RF sensing signal. The sensing device **404** may then optionally report this information to the transmitter device **402**, its serving base station, an application server associated with the core network, an external client, a third-party application, or some other sensing entity. Alternatively, the sensing device **404** may report the ToA measurements to the transmitter device **402**, or other sensing entity (e.g., if the sensing device **404** does not have the processing capability to perform the calculations itself), and the transmitter device **402** may determine the distance and, optionally, the direction to the target object **406**.

[0123] Note that if the RF sensing signals are uplink RF signals transmitted by a UE to a base station, the base station would perform object detection based on the uplink RF signals just like the UE does based on the downlink RF signals.

[0124] Like conventional radar, wireless communication-based sensing signals can be used to estimate the range (distance), velocity (Doppler), and angle (AoA) of a target object. However, the performance (e.g., resolution and maximum values of range, velocity, and angle) may depend on the design of the reference signal.

[0125] Various frame structures may be used to support downlink and uplink transmissions between network nodes (e.g., base stations and UEs). FIG. **5** is a diagram **500** illustrating an example frame structure, according to aspects of the disclosure. The frame structure may be a downlink or uplink frame structure. Other wireless communications technologies may have different frame structures and/or different channels.

[0126] LTE, and in some cases NR, utilizes orthogonal frequency-division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. Unlike LTE, however, NR has an option to use OFDM on the uplink as well. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kilohertz (kHz) and the minimum resource allocation (resource block) may be 12 subcarriers (or 180 kHz). Consequently, the nominal fast Fourier transform (FFT) size may be equal to 128, 256, 512, 1024, or 2048 for system bandwidth of 1.25, 2.5, 5, 10, or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., **6** resource blocks), and there may be 1, 2, 4, 8, or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10, or 20 MHZ, respectively.

[0127] LTE supports a single numerology (subcarrier spacing (SCS), symbol length, etc.). In contrast, NR may support multiple numerologies (u), for example, subcarrier spacings of 15 kHz (μ=0), 30 kHz (μ=1), 60 kHz (μ=2), 120 kHz (μ=3), and 240 kHz (μ=4) or greater may be available. In each subcarrier spacing, there are 14 symbols per slot. For 15 KHz SCS (μ=0), there is one slot per subframe, 10 slots per frame, the slot duration is 1 millisecond (ms), the symbol duration is 66.7 microseconds (us), and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 50. For 30 kHz SCS (μ=1), there are two slots per subframe, 20 slots per frame, the slot duration is 0.5 ms, the symbol duration is 33.3 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 100. For 60 kHz SCS (μ=2), there are four slots per subframe, 40 slots per frame, the slot duration is 0.25 ms, the symbol duration is 16.7 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 200. For 120 kHz SCS (μ=3), there are eight slots per subframe, 80 slots per frame, the slot duration is 0.125 ms, the symbol duration is 8.33 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 400. For 240 kHz SCS (μ=4), there are 16 slots per subframe, 160 slots per frame, the slot duration is 0.0625 ms, the symbol duration is 4.17 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 800.

[0128] In the example of FIG. **5**, a numerology of 15 kHz is used. Thus, in the time domain, a 10 ms frame is divided into 10 equally sized subframes of 1 ms each, and each subframe includes one time slot. In FIG. **5**, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top.

[0129] A resource grid may be used to represent time slots, each time slot including one or more time-concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)) in the frequency domain. The resource grid is further divided into multiple resource elements (REs). An RE may correspond to one symbol length in the time domain and one subcarrier in the frequency domain. In the numerology of FIG. **5**, for a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and seven consecutive symbols in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and six consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

[0130] Some of the REs may carry reference (pilot) signals (RS). The reference signals may include positioning reference signals (PRS), tracking reference signals (TRS), phase tracking reference signals (PTRS), cell-specific reference signals (CRS), channel state information reference signals (CSI-RS), demodulation reference signals (DMRS), primary synchronization signals (PSS), secondary synchronization signals (SSS), synchronization signal blocks (SSBs), sounding reference signals (SRS), etc., depending on whether the illustrated frame structure is used for uplink or downlink communication. FIG. **5** illustrates example locations of REs carrying a reference signal (labeled "R").

[0131] There is emerging interest in devices with both communication and sensing capabilities. For example, sensing technologies may be a fundamental feature of the next generation of communication technology (sometimes referred to as sixth generation). In some aspects of the current disclosure, a device can transmit signals for sensing, and transmit signals for communication. One example of a sensing technique is radar, where probing signals are sent to uncooperative targets, where an uncooperative target is one that is not in communication with the sending device. Information can be inferred from the target echoes; for example, distance from the sensing device and relative speed/velocity of the target with respect to the sensing device. By contrast, communication techniques include information exchange between two or more cooperative transceivers.

[0132] Systems that incorporate both techniques can be referred to as Joint Communication and Sensing (JCS) systems or Integrated Communication and Sensing (ICAS) systems. An example of a JCS system is an integrated system that can perform both wireless communication and remote radar sensing over the same time period. JCS systems may provide a cost-efficient deployment for dual radar and communication systems.

[0133] For an integrated approach, time resources, frequency resources, and/or spatial resources can be allocated between communication and sensing. Communication and sensing resources can be allocated using multiplexing techniques; for example, using Time Division Multiplexing (TDM) techniques.

[0134] Incorporating both sensing and communication may present a number of challenges. For example, sensing techniques may require a large bandwidth to accurately estimate the target range and/or a long signal duration to estimate the target speed/velocity. Additionally, the link budget for sensing may be more limited than the link budget for communications, due to long sensing signal propagation distances or other factors. For example, the signal propagation distance is about twice the distance to the target in monostatic sensing, which can pose difficulties with sensing link budgets. In another example, a longer signal duration may be needed to meet signal to noise ratio (SNR) requirements for uplink sensing, which can also pose difficulties with sensing link budgets. In some challenging scenarios, like cell edge sensing or long-range sensing may require repeating sensing transmissions across multiple slots. For example, a few milliseconds of coherent sensing signal transmission may be needed to achieve a desired speed resolution.

[0135] Efficient resource allocation for long duration and/or large bandwidth sensing may be difficult in the context of current 4G and 5G communication techniques. For example, to enable a few milliseconds of coherent sensing signal transmission on the uplink, time and/or frequency resources may need to be fragmented (allocated among non-continuous resources).

[0136] In some aspects, frequencies in the mmW range or higher may be more suitable for sensing techniques. In current 5G communication techniques, communications using Frequency Range 2 (FR2, including mmW frequencies) are designated as Time Division Duplex (TDD), in order to enable better channel estimation for beamforming. Aspects of the current disclosure provide resource allocation for integrated communication and sensing systems that accommodate TDD configuration for communication.

[0137] Resource allocation for joint communication and sensing systems may also need to consider different modalities for sensing systems. For example, the resource allocation may need to accommodate monostatic sensing (where the same entity transmits sensing signals and detects reflections) and multistatic sensing (where one or more entities transmit sensing signals and one or more different entities detect the signals and signals reflected by the target object). Examples of monostatic sensing include RAN node monostatic sensing (where the RAN node transmits sensing signals and detects associated echoes) and UE monostatic sensing (where the UE transmits sensing signals and detects associated echoes). Examples of multistatic sensing include RAN node bistatic sensing (where a RAN node detects sensing signals transmitted by a UE or a different RAN node) and UE bistatic sensing (where a UE detects sensing signals transmitted by a RAN node or a different UE). Note that a "RAN node" refers generally to access nodes, and not to any particular radio access technology; for example, a RAN node can be an access point (AP), a network node, a NodeB, an evolved NodeB (eNB), a next generation eNB (ng-eNB), a New Radio (NR) Node B (also referred to as a gNB or gNodeB), a Node B for a future generation, etc. In some current uses, sensing modes can also be designated with respect to Transmission Reception Points (TRPs) of the RAN nodes. For example, sensing modes can be designated as TRP-TRP bistatic sensing, TRP monostatic sensing, TRP-UE bistatic sensing (where the TRP is the transmitting entity and UE is the receiving entity), UE-TRP bistatic sensing (where the UE is the transmitting entity and the TRP is the receiving entity), UE-UE bistatic sensing, and UE monostatic sensing.

[0138] For 5G communication systems, slot format indicators (SFIs) designate symbol periods of the slot as either downlink (D), uplink (U), or flexible (F). Slots can be configured as all downlink, all uplink, or mixed. A UE in communication with a network device such as a gNB can communicate information to the gNB on symbol periods designated as uplink and can receive information from the gNB on symbol periods designated as downlink. Symbol periods designated as flexible can be configured for uplink transmission, downlink transmission, or guard periods. FIG. **6** shows an illustration **600** of two fourteen-symbol Time Division Duplex (TDD) slots **605**-A and **605**-B. Slot **605**-A and slot **605**-B have different numbers of downlink symbol periods, followed by two flexible symbol periods, followed in turn by uplink symbol periods. The flexible symbol periods may be configured as a guard period to allow transceiver switching and allow timing advance in the uplink.

[0139] For some current 5G TDD communications, the information element (IE) TDD-UL-DL-ConfigurationCommon determines the cell-specific Uplink/Downlink TDD configuration, common to UEs in the cell. Either one or two patterns can be configured, with each configured pattern specified by transmission periodicity, number of downlink slots, number of downlink symbols, number of uplink slots, and number of uplink symbols. The IE also contains a referenceSubcarrierSpacing field. The IE TDD-UL-DL-ConfigurationDedicated provides UE-specific Uplink/Downlink TDD configuration.

[0140] The current disclosure provides techniques to allocate resources for effective sensing, while maintaining the ability of communication systems to perform TDD communications. In some aspects, a dedicated sensing pattern can be configured to reserve or configure system-wide resources for sensing. During configured sensing time resources of the sensing pattern, a UE can transmit and receive sensing signals according to the configuration, but not perform communications operations. A non-sensing UE (e.g., without sensing capability or without capability for a particular sensing mode) does not perform uplink transmission to a RAN node or receive downlink transmissions from a RAN node on communication data channels during resources configured for sensing and included in a sensing pattern. Instead, the sensing time resources are treated as a gap in the resource grid and the non-sensing UE ignores the sensing time resources. In some cases, the UE may rate-match around the sensing time resources. During time resources configured for TDD communication, sensing and non-sensing UEs perform communication operations; for example, transmit uplink signals on designated uplink slots/symbols, receive downlink signals on designated downlink slots/symbols, and uses flexible symbol periods as configured (uplink, downlink, or guard). Note that in some circumstances, resources in the sensing pattern can be configured for communication, as explained below.

[0141] FIGS. **7**A, **7**B, and **7**C show example time resource allocations for TDD communication pattern(s) time multiplexed with sensing pattern(s), according to some aspects of the disclosure. FIG. **7**A shows a time resource allocation **705**, where two TDD patterns are configured for communication, and a sensing pattern configured in time resources between instances of the TDD patterns. In FIG. **7**A, the sensing pattern is time multiplexed after TDD Pattern 2 and before the next instance of TDD Pattern 1. In other examples, the order of the TDD Patterns may differ, and in some cases time resources included in the sensing pattern may be configured after TDD Pattern 1 and after TDD Pattern 2 (i.e., a sensing pattern alternates with each of TDD Patterns 1 and 2 in turn). Note that the patterns need not be of equal numbers of symbols/slots (or span different amounts of time for sensing signals using a sensing specific waveform), depending on the implementation. FIG. **7**B shows a time resource allocation **710** where a single TDD communication pattern is configured, and a sensing pattern configured between instances of TDD Pattern 1. FIG. **7**C shows a time resource allocation **715**, where one TDD pattern and two sensing patterns are configured. Further, FIG. **7**C illustrates an example allocation where Sensing Pattern 1 is longer than Sensing Pattern 2 and TDD Pattern 1.

[0142] A number of sensing operations can be performed by sensing-capable UEs during sensing time resources included in the sensing pattern. For example, the sensing operations can be performed according to different sensing modes, such as the monostatic and bistatic sensing modes illustrated in FIGS. **4**A and **4**B and discussed in the associated description. Sensing modality may be indicated by the type (monostatic, bistatic, or other multistatic sensing), and for bistatic/multistatic sensing, with an indication of whether the UE (or RAN node) is configured to transmit sensing signals or detect sensing signals. Example sensing operations include transmitting sensing signals, receiving/detecting sensing signals (including sensing signals reflected from a target object and/or sensing signals on a shortest/LOS path or other path). Example sensing modes are described below and with reference to FIGS. **8**A, **8**B, **9**A, **9**B, **10**A, and **10**B.

[0143] FIG. **8**A illustrates an example of a UE monostatic sensing scenario **800**, according to some aspects of the disclosure. A UE **804** can receive configuration of a sensing pattern from a RAN node **802**, where the configuration of the sensing pattern may be determined by RAN node **802** and/or a server **808**, in an example implementation in which server **808** provides at least some sensing management. UE **804** can also receive configuration of one or more non-sensing TDD communication patterns from RAN node **802**. The configuration of the sensing pattern(s) and the configuration of the communication pattern(s) may use the same or different configuration messaging/protocols. For example, configuration of the sensing pattern(s) and/or communication pattern(s) may be accomplished using Radio Resource Control (RRC) configuration, Downlink Control Information (DCI) configuration, Media Access Control (MAC) Control Element (CE) configuration, or a combination thereof, and may vary according to circumstances.

[0144] The configuration of the sensing pattern can include an indication of a monostatic UE sensing mode, and provide resources and other information to perform the monostatic UE sensing. During configured sensing time resources, UE **804** performs sensing operations; for example, UE **804** transmits sensing signals **834** and detects signals **836** reflected from a target object **806**; for example, as shown in FIG. **4**A and described in the associated description. In some implementations, UE **804** can determine a range, speed/velocity, and/or other parameters of target object **806** based on the transmitted and detected signals, and can transmit the determined parameter(s) to RAN node **802** and/or server **808**. In some implementations, UE **804** can transmit detected sensing signal information to a network device such as RAN node **802** and/or a network entity such as a server **808** for processing. Note that sensing signal information can be transmitted to server **808** via one or more RAN nodes using one or more appropriate protocols.

[0145] FIG. **8**B shows an example of RAN node monostatic sensing scenario **830**, according to some aspects of the disclosure. For a RAN node/TRP monostatic sensing mode, a RAN node **802** transmits sensing signals **834**, and also receives signals **836** reflected from target object **806** according to sensing time resources included in a sensing pattern; for example, as illustrated in FIG. **4**A and discussed in the associated description. In an implementation in which a network entity such as a sensing server manages at least some sensing, RAN node sensing may be performed in response to a sensing request from the network entity. In some implementations, RAN node **802** can determine a range, speed/velocity, and/or other parameters of target object **806** based on the transmitted and detected signals and can transmit the determined parameter(s) to a network entity. In some implementations, RAN node **802** can transmit at least some detected sensing signal information to a network entity such as a server for processing.

[0146] FIG. **9**A shows an example of UE bistatic sensing, according to some aspects. A sensing pattern may be configured for UE bistatic sensing, where the sensing pattern includes sensing time resources to transmit and receive sensing signals. As with the above examples, the configuration may be managed by a network entity such as a server, or managed by one or more RAN nodes **902**. For the TRP-UE bistatic sensing mode example shown in FIG. **9**A, RAN nodes **902**-*a* and **902**-*b* may transmit sensing signals according to the sensing time resources. Signals **932**-*a* and **932**-*b* are line-of-sight signals and are detected at UE **904** while signals **934**-*a* and **934**-*b* are incident on target object **906**, and reflected signals **936**-*a* and **936**-*b* are detected by UE **904**; for example, as illustrated in FIG. **4**B and discussed in the associated description. In some implementations, UE **904** can determine a range, speed/velocity, and/or other parameters of target object **906** based on the transmitted and detected signals, and can transmit the determined parameter (s) to a RAN node **902** and/or a network entity such as a server. In some implementations, UE **904** can transmit detected sensing signal information to a RAN node **902** and/or server for processing. Although FIG. **9**A shows RAN nodes **902** as the transmitters, in some implementations other UEs **904** can be configured to transmit signals for UE bistatic sensing (a UE-UE bistatic sensing mode). Additionally, additional transmitters may be incorporated for multistatic UE sensing.

[0147] FIG. **9**B shows an example of RAN node bistatic sensing, according to some aspects of the disclosure. A sensing pattern may be configured for RAN node bistatic sensing, where the sensing pattern includes sensing time resources to transmit and receive sensing signals. As with the above examples, the configuration may be managed by a network entity such as a server, or managed by one or more RAN nodes **902**. UEs **904**-*a* and **904**-*b* may transmit sensing signals according to the sensing time resources. Signals **932**-*a* and **932**-*b* are line-of-sight signals and are detected at RAN node **902**, while signals **934**-*a* and **934**-*b* are incident on target object **906**, and reflected signals **936**-*a* and **936**-*b* are detected by RAN node **902**; for example, as illustrated in FIG. **4**B and described in the associated description. In some implementations, RAN node **902** can determine a range, speed/velocity, and/or other parameters of target object **906** based on the transmitted and detected signals, and can transmit the determined parameter(s) to a network entity such as a server. In some implementations, RAN node **902** can transmit detected sensing signal information to a server for processing. Although FIG. **9**B shows UEs **904** as the transmitters (a UE-TRP bistatic sensing mode), in some implementations other RAN nodes **902** can be configured to transmit signals for RAN node bistatic sensing (for a TRP-TRP bistatic sensing mode). Additionally, additional transmitters may be incorporated for multistatic RAN node sensing.

[0148] The sensing pattern can be configured in a number of ways. For example, sensing time resources included in the sensing pattern can be configured explicitly as another TDD pattern but used for sensing. In another example, time resources included in the sensing pattern can be configured particularly for sensing.

[0149] In a first example, a sensing pattern can be configured as a TDD pattern with slots/symbols designated as uplink (U), downlink (D), or flexible (F). Slots/symbols designated as uplink in the sensing pattern may be allocated to UE monostatic sensing, UE bistatic sensing (based on another UE transmission, UE-UE bistatic sensing), or RAN node bistatic sensing (based on UE transmission, UE-TRP bistatic sensing). Slots/symbols designated as downlink in the sensing pattern may be allocated for RAN node monostatic sensing, RAN node bistatic sensing (based on another RAN node transmission, TRP-TRP bistatic sensing), or UE bistatic sensing (based on RAN node transmission, TRP-UE bistatic sensing). In some aspects, the mapping of sensing pattern to symbol designation may be selected differently.

[0150] Configuration of sensing patterns may include some messages, information elements, fields, etc., similar to those used for communication. For the example where the sensing pattern is configured as a TDD pattern described above, an information element for configuration of a sensing pattern may include one or more fields indicating the sensing modality, transmission periodicity, number of downlink slots, number of downlink symbols, number of uplink slots, number of uplink symbols, and/or other fields.

[0151] In another example, a sensing pattern can be configured as a full duplex slot format. The full duplex slot format may be used for monostatic sensing (e.g., RAN node or UE single-frequency full duplex operation for monostatic sensing). Configuration of a sensing pattern incorporating a full duplex slot format may include an indication that a sensing type is full duplex, a number of symbols/slots, etc.

[0152] In another example, a sensing pattern can be configured based on indicating one or more sensing modes. Sensing modes may be indicated in a number of ways. For example, the sensing mode can indicate monostatic sensing or bistatic/multistatic sensing. In another example, the sensing modes may be indicated as UE sensing modes (monostatic and/or bistatic), or RAN node sensing (monostatic and/or bistatic). In another example, more than two formats may be used; for example, the sensing mode can be indicated as monostatic, bistatic, UE sensing, or RAN node sensing (that is, a combination of the first two examples). For example, a sensing mode can be indicated as UE monostatic, TRP monostatic, UE-UE bistatic, UE-TRP bistatic, TRP-TRP bistatic, or TRP-UE bistatic. A UE may participate in sensing based on slot format configuration in the sensing pattern, and in general does not perform a different mode of sensing in a slot than the mode that has been configured/associated with the slot.

[0153] In another example, the sensing pattern could be frequency division duplex (FDD) or a hybrid version of FDD and TDD. For example, some symbols/slots within the sensing pattern may be configured as TDD, while others can be configured as FDD/full duplex.

[0154] Further, although in general no resources for communication are included in the sensing pattern, in some aspects a limited number of symbols within the sensing pattern can be reused for communication based on explicit indication from the network. For example, resources in the sensing pattern can be allocated to low latency communications to provide expected performance, or when the traffic load for sensing is light. The network can configure sensing resources for communication using Radio Resource Control (RRC), Downlink Control Information (DCI), or Media Access Control (MAC) Control Element (CE) indication.

[0155] In some aspects, the waveform used for sensing may be the same as a communication waveform, or may be different. For example, an OFDM waveform (or similar) can be used for sensing signals, or a radar waveform like Frequency Modulated Continuous Waveform (FMCW) can be used. Further, resources may be allocated differently; for example, slot or symbol duration may differ from communication allocations. For example, for FMCW waveform, the resource may be formatted based on FMCW chirp design, so there is no concept of OFDM symbol in the sensing pattern. In general, the time boundary for the sensing pattern(s) should be aligned with slot boundary for communications.

[0156] In some aspects, for a system with multiple carriers, sensing pattern across carriers may be the same (partially or fully overlapping) to facilitate large bandwidth operation of sensing (sensing carrier aggregation).

[0157] In some aspects, configuration of a sensing pattern may incorporate a network entity such as one or more sensing servers, which may be included in a core network or other network. This may be particularly beneficial for high-speed target sensing, especially for high band cells with small cell radius. Because the high-speed target may quickly cross multiple small cells, incorporating a sensing server can enable coordinated sensing across large numbers of cells. Additionally, in some aspects it may be beneficial for at least some sensing signal processing to be performed at a network entity such as a RAN node and/or sensing server.

[0158] In some aspects, at least some sensing pattern configuration may be determined by a network entity for sensing management, in addition to/instead of a RAN node such as a gNB. FIG. **10** shows an example method **1000** for sensing pattern configuration and measurement, according to some aspects.

[0159] In some implementations, a network entity for sensing management **1008**, such as a sensing server, coordinates at least some sensing among one or more UEs **1004** and one or more RAN nodes **1002**. For example, at **1010**-*a*, network entity **1008** transmits sensing request information including information indicative of one or more target objects to a RAN node **1002**. The sensing request information may be configuration of a sensing pattern, or may be information that RAN node **1002** uses to generate the configuration of the sensing pattern to transmit to one or more UEs **1004** at **1010**-*b*. RAN node **1002** additionally transmits configuration of one or more non-sensing TDD communication patterns to UEs **1004**. The configuration of a sensing pattern may include any or all of the types of configuration described above. The sensing pattern configuration sent to RAN nodes **1002** may provide configuration for the RAN node **1002** to perform sensing operations, and may enable configuration of some communication resources in a sensing pattern. In some implementations, network entity **1008** may transmit configuration of a sensing pattern to one or more UE(s) at **1020**; for example as part of a sensing session with UE(s) **1004**, initiated by network entity **1008** or UE(s) **1004**.

[0160] At **1030**, UEs **1004** and/or RAN nodes **1002** may perform sensing operations according to the sensing pattern configuration, while at **1040**, UEs **1004** and/or RAN nodes **1002** may perform communication operations for configured TDD time resources and, if configured, communication operations during communication time resources included in the sensing pattern time resources.

[0161] In some implementations, UE **1004** and/or RAN nodes **1002** may report sensing measurement information to network entity **1008**. For example, sensing measurements can be transmitted to network entity **1008** to determine parameter(s) of the target object, such as a target position, range, a speed/velocity, etc. In other implementations, the sensing measurement information may be parameter(s) determined at UE **1004** and/or RAN nodes **1002** based on measurements, which can then be transmitted to network entity **1008**. UE **1004** may transmit the sensing measurements/parameter(s) to network entity **1008** as part of a sensing session at **1050**, or to RAN node **1002** at **1060** to transmit to network entity **1008** at **1070** (optionally along with sensing measurements made my RAN node **1002**).

[0162] FIG. **11** illustrates an example method **1100** of communication, according to aspects of the disclosure. In an aspect, method **1100** can be performed by a UE (e.g., UE **302** of FIG. **3**A or any of the user equipments described herein).

[0163] At **1110**, a user equipment may receive a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations. In some aspects, operation **1110** may be performed, for example, using WWAN transceiver(s) **310**, short-range wireless transceiver(s) **320**, processor(s) **342**, memory **340**, and/or sensing component(s) **348** of UE **302**, which may be considered means (structure) for performing operation **1110**.

[0164] At **1120**, the user equipment may perform one or more sensing operations during the sensing time resources. In some aspects, operation **1120** may be performed, for example, using WWAN transceiver(s) **310**, short range transceiver(s) **320**, processor(s) **342**, memory **340**, and/or sensing component(s) **348** of UE **302**, which may be considered means (structure) for performing operation **1120**.

[0165] As will be appreciated, a technical advantage of the method **1100** is enabling accurate range and speed/velocity sensing, by configuration of sensing patterns multiplexed with TDD communication patterns (commonly used for higher frequency communication, which improves sensing accuracy). Aspects of the disclosed techniques may facilitate coexistence of sensing and communication and provide efficient radio resource management in an integrated sensing and communication system.

[0166] FIG. **12** illustrates an example method **1200** of communication, according to aspects of the disclosure. In an aspect, method **1200** can be performed by a UE (e.g., UE **302** of FIG. **3**A or any of the user equipments described herein).

[0167] At **1210**, a user equipment may receive a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations. In some aspects, operation **1210** may be performed, for example, using WWAN transceiver(s) **310**, short range transceiver(s) **320**, processor

(s) **342**, and/or memory **340** of UE **302**, which may be considered means (structure) for performing operation **1210**.

[0168] At **1220**, the user equipment may receive an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for a sensing mode not supported by the UE. In some aspects, operation **1220** may be performed, for example, using WWAN transceiver(s) **310**, short range transceiver(s) **320**, processor(s) **342**, and/or memory **340** of UE **302**, which may be considered means (structure) for performing operation **1220**.

[0169] At **1230**, the user equipment can perform one or more communication operations during the communication time resources. In some aspects, operation **1230** may be performed, for example, using WWAN transceiver(s) **310**, short range transceiver(s) **320**, processor(s) **342**, and/or memory **340** of UE **302**, which may be considered means (structure) for performing operation **1230**.

[0170] As will be appreciated, a technical advantage of the method **1200** is enabling user equipments that do not support at least a configured sensing mode to perform communications during time resources configured for communication.

[0171] FIG. **13** illustrates an example method **1300** of communication, according to aspects of the disclosure. In an aspect, method **1300** can be performed by a network entity such as a RAN node, sensing server, or other network entity, for example, base station **304** of FIG. **3**B, network entity **306** of FIG. **3**C or any of the RAN nodes described herein).

[0172] At **1310**, a network entity can transmit configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations. In an aspect, where the network entity is a RAN node, operation **1310** may be performed by the one or more WWAN transceivers **350**, the one or more short-range wireless transceivers **360**, the one or more network transceivers **380**, the one or more processors **384**, memory **386**, and/or sensing component(s) **388**, any or all of which may be considered means (structure) for performing this operation. In an aspect, where the network entity is a sensing server, operation **1310** may be performed by the one or more network transceivers **390**, the one or more processors **394**, memory **396**, and/or sensing component **398**, any or all of which may be considered means (structure) for performing this operation.

[0173] At **1320**, a network entity can transmit configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing time TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations. In an aspect, where the network entity is a RAN node, operation **1320** may be performed by the one or more WWAN transceivers **350**, the one or more short-range wireless transceivers **360**, the one or more network transceivers **380**, the one or more processors **384**, memory **386**, and/or sensing component **388**, any or all of which may be considered means (structure) for performing this operation. In an aspect, where the network entity is a sensing server, operation **1310** may be performed by the one or more network transceivers **390**, the one or more processors **394**, memory **396**, and/or sensing component **398**, any or all of which may be considered means (structure) for performing this operation.

[0174] In some aspects, the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and wherein the method further comprises performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations. In some aspects, the sensing time resources during which the RAN node is configured to perform sensing operations may comprise sensing time resources configured for full duplex sensing operations, and wherein performing the one or more RAN node sensing operations comprises performing RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations. In some aspects, the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

[0175] In some aspects, the network entity is a RAN node, and the method can further comprise receiving sensing request information from a different network entity, the sensing request information including information indicative of a target object, and wherein transmitting the configuration of a sensing pattern to the one or more UEs comprises transmitting the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information. In some aspects, the method further comprises transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources. In some aspects, the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and further comprising: performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations, and transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations. In some aspects, the different network entity may be a sensing server.

[0176] As will be appreciated, a technical advantage of method **1300** is enabling accurate range and speed/velocity sensing, by configuration of sensing patterns time division multiplexed with TDD communication patterns. Additionally, a different network entity such as a sensing server can provide sensing management. This may be particularly beneficial for high-speed target sensing, especially for high band cells with small cell radius. Sensing management may facilitate coexistence of sensing and communication and provide efficient radio resource management in an integrated sensing and communication system.

[0177] In the detailed description above it can be seen that different features are grouped together in examples. This manner of disclosure should not be understood as an intention that the example clauses have more features than are explicitly mentioned in each clause. Rather, the various aspects of the disclosure may include fewer than all features of an individual example clause disclosed. Therefore, the following clauses should hereby be deemed to be incorporated in the description, wherein each clause by itself can stand as a separate example. Although each dependent clause can refer in the clauses to a specific combination with one of the other clauses, the aspect(s) of that dependent clause are not limited to the specific combination. It will be appreciated that other example clauses can also include a combination of the dependent clause aspect(s) with the subject matter of any other dependent clause or independent clause or a combination of any feature with other dependent and independent clauses. The various aspects disclosed herein expressly include these combinations, unless it is explicitly expressed or can be readily inferred that a specific combination is not intended (e.g., contradictory aspects, such as defining an element as both an electrical insulator and an electrical conductor). Furthermore, it is also intended that aspects of a clause can be included in any other independent clause, even if the clause is not directly dependent on the independent clause.

[0178] Implementation examples are described in the following numbered clauses:

[0179] Clause 1. A method of wireless transmission at a user equipment (UE) comprising: receiving a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and performing one or more sensing operations during the sensing time resources.

[0180] Clause 2. The method of clause 1, wherein performing the one or more sensing operations comprises transmitting sensing signals, detecting sensing signals, or both for monostatic sensing, bistatic sensing, or multistatic sensing for more than two entities.

[0181] Clause 3. The method of any of clauses 1 to 2, wherein the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

[0182] Clause 4. The method of clause 3, wherein performing the one or more sensing operations during the sensing time resources comprises performing UE monostatic sensing operations during at least some sensing time resources configured as uplink.

[0183] Clause 5. The method of any of clauses 3 to 4, wherein performing the one or more sensing operations during the sensing time resources comprises performing UE bistatic sensing operations during at least some sensing time resources configured as uplink.

[0184] Clause 6. The method of any of clauses 3 to 5, wherein performing the one or more sensing operations during the sensing time resources comprises performing UE bistatic sensing operations during at least some sensing time resources configured as downlink.

[0185] Clause 7. The method of any of clauses 1 to 6, wherein the configuration of the sensing pattern includes configuration of at least some of the sensing time resources as full duplex, and wherein performing the one or more sensing operations during the sensing time resources comprises performing UE monostatic sensing operations during at least some of the sensing time resources configured as full duplex.

[0186] Clause 8. The method of any of clauses 1 to 7, wherein the configuration of the sensing pattern includes an indication of a sensing mode.

[0187] Clause 9. The method of clause 8, wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

[0188] Clause 10. The method of any of clauses 1 to 9, wherein the configuration of the sensing pattern further includes configuration of sensing frequency resources, and wherein the configuration of the sensing pattern includes configuration of at least some of the sensing pattern as frequency division duplex (FDD).

[0189] Clause 11. The method of clause 10, wherein the configuration of the sensing pattern includes configuration of some of the sensing pattern as frequency division duplex and some of the sensing pattern as time division duplex.

[0190] Clause 12. The method of any of clauses 1 to 11, wherein receiving the configuration of the sensing pattern comprises receiving configuration of communication resources included in the sensing pattern.

[0191] Clause 13. The method of clause 12, wherein receiving the configuration of the communication resources included in the sensing pattern comprises receiving Radio Resource Control (RRC) configuration of the communication resources included in the sensing pattern, receiving Downlink Control Information (DCI) configuration of the communication resources included in the sensing pattern, receiving Media Access Control (MAC) Control Element (CE) configuration of the communication resources included in the sensing pattern, or a combination thereof.

[0192] Clause 14. The method of any of clauses 1 to 13, wherein receiving the configuration of the sensing pattern comprises receiving configuration of sensing time resources for an Orthogonal Frequency Division Multiplex (OFDM) sensing waveform.

[0193] Clause 15. The method of any of clauses 1 to 13, wherein receiving the configuration of the sensing pattern comprises receiving configuration of sensing time resources for a Frequency Modulated Continuous Waveform (FMCW) sensing waveform.

[0194] Clause 16. The method of any of clauses 1 to 15, wherein receiving the configuration of the sensing pattern comprises receiving configuration of the sensing pattern for a plurality of carriers, wherein the sensing time resources include sensing time resources for each of the plurality of carriers, and wherein the sensing time resources for a first carrier of the plurality of carriers overlap the sensing time resources for a second carrier of the plurality of carriers.

[0195] Clause 17. The method of any of clauses 1 to 16, further comprising: receiving configuration of a second sensing pattern, wherein the second sensing pattern indicates second sensing time resources during which the UE is configured to perform sensing operations.

[0196] Clause 18. A method of wireless transmission at a user equipment (UE) comprising: receiving a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receiving an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and performing one or more communication operations during the communication time resources.

[0197] Clause 19. The method of clause 18, wherein performing the one or more communication operations during the communication time resources comprises performing rate matching around the sensing time resources.

[0198] Clause 20. The method of any of clauses 18 to 19, wherein the sensing pattern further indicates communication time resources during which the UE is configured to perform communication operations; and performing communication operations during the communication time resources included in the sensing pattern.

[0199] Clause 21. A method of communication at a network entity comprising: transmitting configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmitting configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0200] Clause 22. The method of clause 21, wherein the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and further comprising: performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0201] Clause 23. The method of clause 22, wherein the sensing time resources during which the RAN node is configured to perform sensing operations comprise sensing time resources configured for full duplex sensing operations, and wherein performing the one or more RAN node sensing operations comprises performing RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations.

[0202] Clause 24. The method of any of clauses 21 to 23, wherein the configuration of the sensing pattern includes configuration of one or more sensing modes for at least one UE of the one or more UEs, at least one Transmission Reception Point (TRP) of one or more Radio Access Network (RAN) nodes, or a combination thereof, and wherein the one or more sensing modes include: a UE monostatic sensing mode; a TRP monostatic sensing mode; a TRP-TRP bistatic sensing mode; a UE-TRP bistatic sensing mode; a TRP-UE bistatic sensing mode; a UE-UE bistatic sensing mode; or a combination thereof.

[0203] Clause 25. The method of any of clauses 21 to 24, wherein the configuration of the sensing pattern further includes configuration of at least some communication time resources.

[0204] Clause 26. The method of any of clauses 21 to 25, further comprising: receiving sensing request information from a different network entity, the sensing request information including information indicative of a target object; and wherein transmitting the configuration of a sensing pattern to the one or more UEs comprises transmitting the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information.

[0205] Clause 27. The method of clause 26, further comprising: transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources.

[0206] Clause 28. The method of any of clauses 26 to 27, wherein the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and further comprising: performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations; and transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0207] Clause 29. A user equipment (UE), comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: receive, via the one or more transceivers, a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and perform one or more sensing operations during the sensing time resources.

[0208] Clause 30. The user equipment of clause 29, wherein, to perform the one or more sensing operations, the one or more processors, either alone or in combination, are configured to transmit sensing signals, detect sensing signals, or both for monostatic sensing, bistatic sensing, or multistatic sensing for more than two entities.

[0209] Clause 31. The user equipment of any of clauses 29 to 30, wherein the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

[0210] Clause 32. The user equipment of clause 31, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE monostatic sensing operations during at least some sensing time resources configured as uplink.

[0211] Clause 33. The user equipment of any of clauses 31 to 32, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE bistatic sensing operations during at least some sensing time resources configured as uplink.

[0212] Clause 34. The user equipment of any of clauses 31 to 33, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE bistatic sensing operations during at least some sensing time resources configured as downlink.

[0213] Clause 35. The user equipment of any of clauses 29 to 34, wherein the configuration of the sensing pattern includes configuration of at least some of the sensing time resources as full duplex, and wherein performing the one or more sensing operations during the sensing time resources comprises performing UE monostatic sensing operations during at least some of the sensing time resources configured as full duplex.

[0214] Clause 36. The user equipment of any of clauses 29 to 35, wherein the configuration of the sensing pattern includes an indication of a sensing mode.

[0215] Clause 37. The user equipment of clause 36, wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

[0216] Clause 38. The user equipment of any of clauses 29 to 37, wherein the configuration of the sensing pattern further includes configuration of sensing frequency resources, and wherein the configuration of the sensing pattern includes configuration of at least some of the sensing pattern as frequency division duplex (FDD).

[0217] Clause 39. The user equipment of clause 38, wherein the configuration of the sensing pattern includes configuration of some of the sensing pattern as frequency division duplex and some of the sensing pattern as time division duplex.

[0218] Clause 40. The user equipment of any of clauses 29 to 39, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of communication resources included in the sensing pattern.

[0219] Clause 41. The user equipment of clause 40, wherein, to receive the configuration of the communication resources included in the sensing pattern, the one or more processors, either alone or in combination, are configured to receive Radio Resource Control (RRC) configuration of the communication resources included in the sensing pattern, to receive Downlink Control Information (DCI) configuration of the communication resources included in the sensing pattern, to receive Media Access Control (MAC) Control Element (CE) configuration of the communication resources included in the sensing pattern, or a combination thereof.

[0220] Clause 42. The user equipment of any of clauses 29 to 41, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of sensing time resources for an Orthogonal Frequency Division Multiplex (OFDM) sensing waveform.

[0221] Clause 43. The user equipment of any of clauses 29 to 41, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of sensing time resources for a Frequency Modulated Continuous Waveform (FMCW) sensing waveform.

[0222] Clause 44. The user equipment of any of clauses 29 to 43, wherein receiving the configuration of the sensing pattern comprises receiving configuration of the sensing pattern for a plurality of carriers, wherein the sensing time resources include sensing time resources for each of the plurality of carriers, and wherein the sensing time resources for a first carrier of the plurality of carriers overlap the sensing time resources for a second carrier of the plurality of carriers.

[0223] Clause 45. The user equipment of any of clauses 29 to 44, wherein the one or more processors, either alone or in combination, are further configured to: receive, via the one or more transceivers, configuration of a second sensing pattern, wherein the second sensing pattern indicates second sensing time resources during which the UE is configured to perform sensing operations.

[0224] Clause 46. A user equipment (UE), comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: receive, via the one or more transceivers, a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receive, via the one or more transceivers, an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and perform one or more communication operations during the communication time resources.

[0225] Clause 47. The user equipment of clause 46, wherein, to perform the one or more communication operations during the communication time resources, the one or more processors, either alone or in combination, are configured to perform rate matching around the sensing time resources.

[0226] Clause 48. The user equipment of any of clauses 46 to 47, wherein the sensing pattern further indicates communication time resources during which the UE is configured to perform communication operations, and wherein the one or more processors, either alone or in combination, are further configured to: perform communication operations during the communication time resources included in the sensing pattern.

[0227] Clause 49. A network entity, comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: transmit, via the one or more transceivers, configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmit, via the one or more transceivers, configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0228] Clause 50. The network entity of clause 49, wherein the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and wherein the one or more processors, either alone or in combination, are further configured to: perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0229] Clause 51. The network entity of clause 50, wherein the sensing time resources during which the RAN node is configured to perform sensing operations comprise sensing time resources configured for full duplex sensing operations, and wherein, to perform the one or more RAN node sensing operations, the one or more processors, either alone or in combination, are configured to perform RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations.

[0230] Clause 52. The network entity of any of clauses 49 to 51, wherein the configuration of the sensing pattern includes configuration of one or more sensing modes for at least one UE of the one or more UEs, at least one Transmission Reception Point (TRP) of one or more Radio Access Network (RAN) nodes, or a combination thereof, and wherein the one or more sensing modes include: a UE monostatic sensing mode; a TRP monostatic sensing mode; a TRP-TRP bistatic sensing mode; a UE-TRP bistatic sensing mode; a TRP-UE bistatic sensing mode; a UE-UE bistatic sensing mode; or a combination thereof.

[0231] Clause 53. The network entity of any of clauses 49 to 52, wherein the configuration of the sensing pattern further includes configuration of at least some communication time resources.

[0232] Clause 54. The network entity of any of clauses 49 to 53, wherein the one or more processors, either alone or in combination, are further configured to: receive, via the one or more transceivers, sensing request information from a different network entity, the sensing request information including information indicative of a target object; and wherein, to transmit the configuration of a sensing pattern to the one or more UEs, the one or more processors, either alone or in combination, are configured to transmit the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information.

[0233] Clause 55. The network entity of clause 54, wherein the one or more processors, either alone or in combination, are further configured to: transmit, via the one or more transceivers, sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources.

[0234] Clause 56. The network entity of any of clauses 54 to 55, wherein the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and wherein the one or more processors, either alone or in combination, are further configured to: perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations; and transmit, via the one or more transceivers, sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0235] Clause 57. A user equipment (UE), comprising: means for receiving a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and means for performing one or more sensing operations during the sensing time resources.

[0236] Clause 58. The user equipment of clause 57, wherein the means for performing the one or more sensing operations comprises means for transmitting sensing signals, detecting sensing signals, or both for monostatic sensing, bistatic sensing, or multistatic sensing for more than two entities.

[0237] Clause 59. The user equipment of any of clauses 57 to 58, wherein the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

[0238] Clause 60. The user equipment of clause 59, wherein the means for performing the one or more sensing operations during the sensing time resources comprises means for performing UE monostatic sensing operations during at least some sensing time resources configured as uplink.

[0239] Clause 61. The user equipment of any of clauses 59 to 60, wherein the means for performing the one or more sensing operations during the sensing time resources comprises means for performing UE bistatic sensing operations during at least some sensing time resources configured as uplink.

[0240] Clause 62. The user equipment of any of clauses 59 to 61, wherein the means for performing the one or more sensing operations during the sensing time resources comprises means for performing UE bistatic sensing operations during at least some sensing time resources configured as downlink.

[0241] Clause 63. The user equipment of any of clauses 57 to 62, wherein the configuration of the sensing pattern includes configuration of at least some of the sensing time resources as full duplex, and wherein the means for performing the one or more sensing operations during the sensing time resources comprises means for performing UE monostatic sensing operations during at least some of the sensing time resources configured as full duplex.

[0242] Clause 64. The user equipment of any of clauses 57 to 63, wherein the configuration of the sensing pattern includes an indication of a sensing mode.

[0243] Clause 65. The user equipment of clause 64, wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

[0244] Clause 66. The user equipment of any of clauses 57 to 65, wherein the configuration of the sensing pattern further includes configuration of sensing frequency resources, and wherein the configuration of the sensing pattern includes configuration of at least some of the sensing pattern as frequency division duplex (FDD).

[0245] Clause 67. The user equipment of clause 66, wherein the configuration of the sensing pattern includes configuration of some of the sensing pattern as frequency division duplex and some of the sensing pattern as time division duplex.

[0246] Clause 68. The user equipment of any of clauses 57 to 67, wherein the means for receiving the configuration of the sensing pattern comprises means for receiving configuration of communication resources included in the sensing pattern.

[0247] Clause 69. The user equipment of clause 68, wherein the means for receiving the configuration of the communication resources included in the sensing pattern comprises means for receiving Radio Resource Control (RRC) configuration of the communication resources included in the sensing pattern, means for receiving Downlink Control Information (DCI) configuration of the communication resources included in the sensing pattern, means for receiving Media Access Control (MAC) Control Element (CE) configuration of the communication resources included in the sensing pattern, or a combination thereof.

[0248] Clause 70. The user equipment of any of clauses 57 to 69, wherein the means for receiving the configuration of the sensing pattern comprises means for receiving configuration of sensing time resources for an Orthogonal Frequency Division Multiplex (OFDM) sensing waveform.

[0249] Clause 71. The user equipment of any of clauses 57 to 69, wherein the means for receiving the configuration of the sensing pattern comprises means for receiving configuration of sensing time resources for a Frequency Modulated Continuous Waveform (FMCW) sensing waveform.

[0250] Clause 72. The user equipment of any of clauses 57 to 71, wherein the means for receiving the configuration of the sensing pattern comprises means for receiving configuration of the sensing pattern for a plurality of carriers, wherein the sensing time resources include sensing time resources for each of the plurality of carriers, and wherein the sensing time resources for a first carrier of the plurality of carriers overlap the sensing time resources for a second carrier of the plurality of carriers.

[0251] Clause 73. The user equipment of any of clauses 57 to 72, further comprising: means for receiving configuration of a second sensing pattern, wherein the second sensing pattern indicates second sensing time resources during which the UE is configured to perform sensing operations.

[0252] Clause 74. A user equipment (UE), comprising: means for receiving a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; means for receiving an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and means for performing one or more communication operations during the communication time resources.

[0253] Clause 75. The user equipment of clause 74, wherein the means for performing the one or more communication operations during the communication time resources comprises means for performing rate matching around the sensing time resources.

[0254] Clause 76. The user equipment of any of clauses 74 to 75, wherein the sensing pattern further indicates communication time resources during which the UE is configured to perform communication operations; and means for performing communication operations during the communication time resources included in the sensing pattern.

[0255] Clause 77. A network entity, comprising: means for transmitting configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and means for transmitting configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0256] Clause 78. The network entity of clause 77, wherein the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and further comprising: means for performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0257] Clause 79. The network entity of clause 78, wherein the sensing time resources during which the RAN node is configured to perform sensing operations comprise sensing time resources configured for full duplex sensing operations, and wherein the means for performing the one or more RAN node sensing operations comprises means for performing RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations.

[0258] Clause 80. The network entity of any of clauses 77 to 79, wherein the configuration of the sensing pattern includes configuration of one or more sensing modes for at least one UE of the one or more UEs, at least one Transmission Reception Point (TRP) of one or more Radio Access Network (RAN) nodes, or a combination thereof, and wherein the one or more sensing modes include: a UE monostatic sensing mode; a TRP monostatic sensing mode; a TRP-TRP bistatic sensing mode; a UE-TRP bistatic sensing mode; a TRP-UE bistatic sensing mode; a UE-UE bistatic sensing mode; or a combination thereof.

[0259] Clause 81. The network entity of any of clauses 77 to 80, wherein the configuration of the sensing pattern further includes configuration of at least some communication time resources.

[0260] Clause 82. The network entity of any of clauses 77 to 81, further comprising: means for receiving sensing request information from a different network entity, the sensing request information including information indicative of a target object; and wherein the means for transmitting the configuration of a sensing pattern to the one or more UEs comprises means for transmitting the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information.

[0261] Clause 83. The network entity of clause 82, further comprising: means for transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources.

[0262] Clause 84. The network entity of any of clauses 82 to 83, wherein the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and further comprising: means for performing one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations; and means for transmitting sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0263] Clause 85. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the user equipment to: receive a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and perform one or more sensing operations during the sensing time resources.

[0264] Clause 86. The non-transitory computer-readable medium of clause 85, wherein the computer-executable instructions cause the user equipment to transmit sensing signals, detecting sensing signals, or both for monostatic sensing, bistatic sensing, or multistatic sensing for more than two entities.

[0265] Clause 87. The non-transitory computer-readable medium of any of clauses 85 to 86, wherein the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

[0266] Clause 88. The non-transitory computer-readable medium of clause 87, wherein the computer-executable instructions comprise computer-executable instructions that, when executed by the user equipment, cause the user equipment to perform UE monostatic sensing operations during at least some sensing time resources configured as uplink.

[0267] Clause 89. The non-transitory computer-readable medium of any of clauses 87 to 88, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to perform the one or more sensing operations during the sensing time resources comprise instruction to perform UE bistatic sensing operations during at least some sensing time resources configured as uplink.

[0268] Clause 90. The non-transitory computer-readable medium of any of clauses 87 to 89, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to perform the one or more sensing operations during the sensing time resources comprise instructions to perform UE bistatic sensing operations during at least some sensing time resources configured as downlink.

[0269] Clause 91. The non-transitory computer-readable medium of any of clauses 85 to 90, wherein the configuration of the sensing pattern includes configuration of at least some of the sensing time resources as full duplex, and wherein the instructions to perform the one or more sensing operations during the sensing time resources comprise instructions to perform UE monostatic sensing operations during at least some of the sensing time resources configured as full duplex.

[0270] Clause 92. The non-transitory computer-readable medium of any of clauses 85 to 91, wherein the configuration of the sensing pattern includes an indication of a sensing mode.

[0271] Clause 93. The non-transitory computer-readable medium of clause 92, wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

[0272] Clause 94. The non-transitory computer-readable medium of any of clauses 85 to 93, wherein the configuration of the sensing pattern further includes configuration of sensing frequency resources, and wherein the configuration of the sensing pattern includes configuration of at least some of the sensing pattern as frequency division duplex (FDD).

[0273] Clause 95. The non-transitory computer-readable medium of clause 94, wherein the configuration of the sensing pattern includes configuration of some of the sensing pattern as frequency division duplex and some of the sensing pattern as time division duplex.

[0274] Clause 96. The non-transitory computer-readable medium of any of clauses 85 to 95, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to receive the configuration of the sensing pattern comprise instructions to receive configuration of communication resources included in the sensing pattern.

[0275] Clause 97. The non-transitory computer-readable medium of clause 96, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to receive the configuration of the communication resources included in the sensing pattern comprise instructions to receive Radio Resource Control (RRC) configuration of the communication resources included in the sensing pattern, instructions to receive Downlink Control Information (DCI) configuration of the communication resources included in the sensing pattern, instructions to receive Media Access Control (MAC) Control Element (CE) configuration of the communication resources included in the sensing pattern, or a combination thereof.

[0276] Clause 98. The non-transitory computer-readable medium of any of clauses 85 to 97, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to receive the configuration of the sensing pattern comprise instructions to receive configuration of sensing time resources for an Orthogonal Frequency Division Multiplex (OFDM) sensing waveform.

[0277] Clause 99. The non-transitory computer-readable medium of any of clauses 85 to 97, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to receive the configuration of the sensing pattern comprise instructions to receive configuration of sensing time resources for a Frequency Modulated Continuous Waveform (FMCW) sensing waveform.

[0278] Clause 100. The non-transitory computer-readable medium of any of clauses 85 to 99, wherein the instructions to receive the configuration of the sensing pattern comprise instructions to receive configuration of the sensing pattern for a plurality of carriers, wherein the sensing time resources include sensing time resources for each of the plurality of carriers, and wherein the sensing time resources for a first carrier of the plurality of carriers overlap the sensing time resources for a second carrier of the plurality of carriers.

[0279] Clause 101. The non-transitory computer-readable medium of any of clauses 85 to 100, further comprising computer-executable instructions that, when executed by the user equipment, cause the user equipment to: receive configuration of a second sensing pattern, wherein the second sensing pattern indicates second sensing time resources during which the UE is configured to perform sensing operations.

[0280] Clause 102. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the user equipment to: receive a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations; receive an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and perform one or more communication operations during the communication time resources.

[0281] Clause 103. The non-transitory computer-readable medium of clause 102, wherein the computer-executable instructions that, when executed by the user equipment, cause the user equipment to perform the one or more communication operations during the communication time resources comprise instructions to perform rate matching around the sensing time resources.

[0282] Clause 104. The non-transitory computer-readable medium of any of clauses 102 to 103, wherein the sensing pattern further indicates communication time resources during which the UE is configured to perform communication operations; and perform communication operations during the communication time resources included in the sensing pattern.

[0283] Clause 105. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a network entity, cause the network entity to: transmit configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and transmit configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

[0284] Clause 106. The non-transitory computer-readable medium of clause 105, wherein the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and wherein the instructions further comprise instructions to: perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0285] Clause 107. The non-transitory computer-readable medium of clause 106, wherein the sensing time resources during which the RAN node is configured to perform sensing operations comprise sensing time resources configured for full duplex sensing operations, and wherein the instructions to performe the one or more RAN node sensing operations comprise instructions to perform RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations.

[0286] Clause 108. The non-transitory computer-readable medium of any of clauses 105 to 107, wherein the configuration of the sensing pattern includes configuration of one or more sensing modes for at least one UE of the one or more UEs, at least one Transmission Reception Point (TRP) of one or more Radio Access Network (RAN) nodes, or a combination thereof, and wherein the one or more sensing modes include: a UE monostatic sensing mode; a TRP monostatic sensing mode; a TRP-TRP bistatic sensing mode; a UE-TRP bistatic sensing mode; a TRP-UE bistatic sensing mode; a UE-UE bistatic sensing mode; or a combination thereof.

[0287] Clause 109. The non-transitory computer-readable medium of any of clauses 105 to 108, wherein the configuration of the sensing pattern further includes configuration of at least some communication time resources.

[0288] Clause 110. The non-transitory computer-readable medium of any of clauses 105 to 109, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: receive sensing request information from a different network entity, the sensing request information including information indicative of a target object; and wherein the instructions to transmit the configuration of a sensing pattern to the one or more UEs comprise instructions to transmit the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information.

[0289] Clause 111. The non-transitory computer-readable medium of clause 110, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: transmit sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources.

[0290] Clause 112. The non-transitory computer-readable medium of any of clauses 110 to 111, wherein the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and wherein the instructions further comprise instructions to: perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations; and transmit sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

[0291] Those of skill in the art will appreciate that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0292] Further, those of skill in the art will appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the aspects disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

[0293] The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an ASIC, a field-programable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0294] The methods, sequences and/or algorithms described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in random access memory (RAM), flash memory, read-only memory (ROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An example storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal (e.g., UE). In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[0295] In one or more example aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0296] While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. For example, the functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Further, no component, function, action, or instruction described or claimed herein should be construed as critical or essential unless explicitly described as such. Furthermore, as used herein, the terms "set," "group," and the like are intended to include one or more of the stated elements. Also, as used herein, the terms "has," "have," "having," "comprises," "comprising," "includes," "including," and the like does not preclude the presence of one or more additional elements (e.g., an element "having" A may also have B). Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise. Also, as used herein, the term "or" is intended to be inclusive when used in a series and may be used interchangeably with "and/or," unless explicitly stated otherwise (e.g., if used in combination with "either" or "only one of") or the alternatives are mutually exclusive (e.g., "one or more" should not be interpreted as "one and more"). Furthermore, although components, functions, actions, and instructions may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Accordingly, as used herein, the articles "a," "an," "the," and "said" are intended to include one or more of the stated elements. Additionally, as used herein, the terms "at least one" and "one or more" encompass "one" component, function, action, or instruction performing or capable of performing a described or claimed functionality and also "two or more" components, functions, actions, or instructions performing or capable of performing a described or claimed functionality in combination.

What is claimed is:

1. A user equipment (UE), comprising:

one or more memories;

one or more transceivers; and

one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to:

receive, via the one or more transceivers, a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and

perform one or more sensing operations during the sensing time resources.

2. The user equipment of claim **1**, wherein, to perform the one or more sensing operations, the one or more processors, either alone or in combination, are configured to transmit sensing signals, detect sensing signals, or both for monostatic sensing, bistatic sensing, or multistatic sensing for more than two entities.

3. The user equipment of claim **1**, wherein the configuration of the sensing pattern includes configuration of the sensing time resources as downlink, uplink, or flexible.

4. The user equipment of claim **3**, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE monostatic sensing operations during at least some sensing time resources configured as uplink.

5. The user equipment of claim **3**, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE bistatic sensing operations during at least some sensing time resources configured as uplink.

6. The user equipment of claim **3**, wherein, to perform the one or more sensing operations during the sensing time resources, the one or more processors, either alone or in combination, are configured to perform UE bistatic sensing operations during at least some sensing time resources configured as downlink.

7. The user equipment of claim **1**, wherein the configuration of the sensing pattern includes configuration of at least some of the sensing time resources as full duplex, and wherein performing the one or more sensing operations during the sensing time resources comprises performing UE monostatic sensing operations during at least some of the sensing time resources configured as full duplex.

8. The user equipment of claim **1**, wherein the configuration of the sensing pattern includes an indication of a sensing mode.

9. The user equipment of claim **8**, wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

10. The user equipment of claim **1**, wherein the configuration of the sensing pattern further includes configuration of sensing frequency resources, and wherein the configuration of the sensing pattern includes configuration of at least some of the sensing pattern as frequency division duplex (FDD).

11. The user equipment of claim **10**, wherein the configuration of the sensing pattern includes configuration of some of the sensing pattern as frequency division duplex and some of the sensing pattern as time division duplex.

12. The user equipment of claim **1**, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of communication resources included in the sensing pattern.

13. The user equipment of claim **12**, wherein, to receive the configuration of the communication resources included in the sensing pattern, the one or more processors, either alone or in combination, are configured to receive Radio Resource Control (RRC) configuration of the communication resources included in the sensing pattern, to receive Downlink Control Information (DCI) configuration of the communication resources included in the sensing pattern, to receive Media Access Control (MAC) Control Element (CE) configuration of the communication resources included in the sensing pattern, or a combination thereof.

14. The user equipment of claim **1**, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of sensing time resources for an Orthogonal Frequency Division Multiplex (OFDM) sensing waveform.

15. The user equipment of claim **1**, wherein, to receive the configuration of the sensing pattern, the one or more processors, either alone or in combination, are configured to receive configuration of sensing time resources for a Frequency Modulated Continuous Waveform (FMCW) sensing waveform.

16. The user equipment of claim **1**, wherein receiving the configuration of the sensing pattern comprises receiving configuration of the sensing pattern for a plurality of carriers, wherein the sensing time resources include sensing time resources for each of the plurality of carriers, and wherein the sensing time resources for a first carrier of the plurality of carriers overlap the sensing time resources for a second carrier of the plurality of carriers.

17. The user equipment of claim **1**, wherein the one or more processors, either alone or in combination, are further configured to:

receive, via the one or more transceivers, configuration of a second sensing pattern, wherein the second sensing pattern indicates second sensing time resources during which the UE is configured to perform sensing operations.

18. A user equipment (UE), comprising:

one or more memories;

one or more transceivers; and

one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to:

receive, via the one or more transceivers, a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the one or more non-sensing TDD communication patterns indicate communication time resources during which the UE is configured to perform communication operations;

receive, via the one or more transceivers, an indication of a sensing pattern, wherein the sensing pattern indicates sensing time resources for performing sensing operations for a sensing mode not supported by the UE; and

perform one or more communication operations during the communication time resources.

19. The user equipment of claim **18**, wherein, to perform the one or more communication operations during the communication time resources, the one or more processors, either alone or in combination, are configured to perform rate matching around the sensing time resources.

20. The user equipment of claim **18**, wherein the sensing pattern further indicates communication time resources during which the UE is configured to perform communication operations, and wherein the one or more processors, either alone or in combination, are further configured to:

perform communication operations during the communication time resources included in the sensing pattern.

21. A network entity, comprising:

one or more memories;

one or more transceivers; and

one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to:

transmit, via the one or more transceivers, configuration of a sensing pattern to one or more user equipments (UEs), wherein the sensing pattern indicates sensing time resources during which the one or more UEs are configured to perform UE sensing operations; and

transmit, via the one or more transceivers, configuration of one or more non-sensing time division duplex (TDD) communication patterns to the one or more UEs, wherein the non-sensing TDD communication patterns indicate communication time resources during which the one or more UEs are configured to perform communications operations.

22. The network entity of claim **21**, wherein the network entity comprises a Radio Access Network (RAN) node, wherein the sensing pattern further indicates sensing time resources during which the RAN node is configured to perform sensing operations, and wherein the one or more processors, either alone or in combination, are further configured to:

perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

23. The network entity of claim **22**, wherein the sensing time resources during which the RAN node is configured to perform sensing operations comprise sensing time resources configured for full duplex sensing operations, and wherein, to perform the one or more RAN node sensing operations, the one or more processors, either alone or in combination, are configured to perform RAN node monostatic sensing during the sensing time resources configured for full duplex sensing operations.

24. The network entity of claim **21**, wherein the configuration of the sensing pattern includes configuration of one or more sensing modes for at least one UE of the one or more UEs, at least one Transmission Reception Point (TRP) of one or more Radio Access Network (RAN) nodes, or a combination thereof, and wherein the one or more sensing modes include:

a UE monostatic sensing mode;

a TRP monostatic sensing mode;

a TRP-TRP bistatic sensing mode;

a UE-TRP bistatic sensing mode;

a TRP-UE bistatic sensing mode;

a UE-UE bistatic sensing mode;

or a combination thereof.

25. The network entity of claim **21**, wherein the configuration of the sensing pattern further includes configuration of at least some communication time resources.

26. The network entity of claim **21**, wherein the one or more processors, either alone or in combination, are further configured to:

receive, via the one or more transceivers, sensing request information from a different network entity, the sensing request information including information indicative of a target object; and

wherein, to transmit the configuration of a sensing pattern to the one or more UEs, the one or more processors, either alone or in combination, are configured to transmit the configuration of the sensing pattern to the one or more UEs in accordance with the sensing request information.

27. The network entity of claim **26**, wherein the one or more processors, either alone or in combination, are further configured to:

transmit, via the one or more transceivers, sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained from the one or more UEs performing sensing operations during at least some of the sensing time resources.

28. The network entity of claim **26**, wherein the sensing pattern further indicates sensing time resources during which the network entity is configured to perform sensing operations, wherein the network entity is a RAN node, and wherein the one or more processors, either alone or in combination, are further configured to:

perform one or more RAN node sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations; and

transmit, via the one or more transceivers, sensing measurement information to the different network entity, wherein the sensing measurement information includes at least some sensing measurement information obtained by the RAN node performing sensing operations during the sensing time resources during which the RAN node is configured to perform RAN node sensing operations.

29. A method of wireless transmission at a user equipment (UE) comprising:

receiving a configuration of a sensing pattern and a configuration of one or more non-sensing time division duplex (TDD) communication patterns, wherein the sensing pattern indicates sensing time resources during which the UE is configured to perform sensing operations; and

performing one or more sensing operations during the sensing time resources.

30. The method of claim **29**, wherein the configuration of the sensing pattern includes an indication of a sensing mode, and wherein the indication of the sensing mode comprises an indication of monostatic sensing, an indication of bistatic sensing, an indication of UE sensing, an indication of Radio Access Network (RAN node sensing), or a combination thereof.

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