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(54) **COUPLED RESOURCE POOLS**

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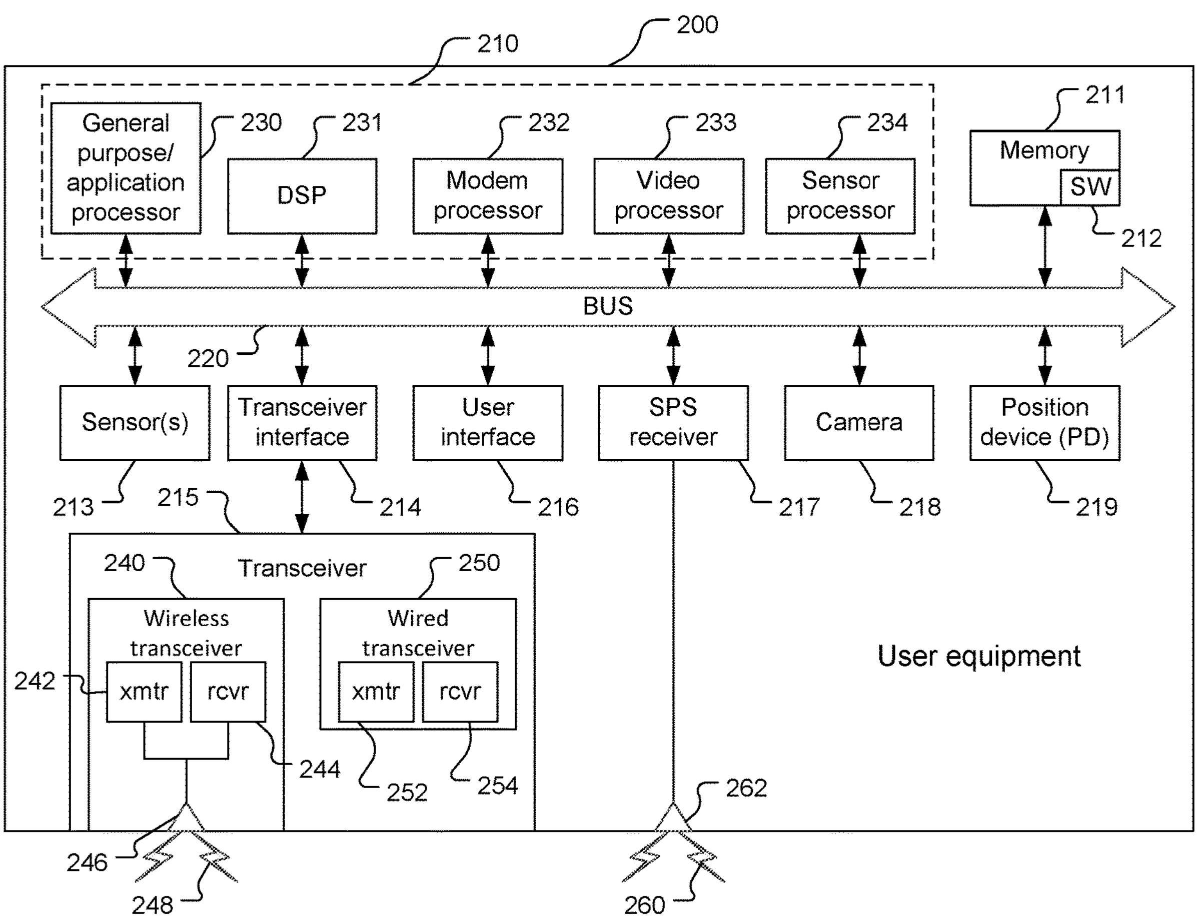
(57) **ABSTRACT**

A reference signal transmission method includes: obtaining, at a first UE, a first configuration of a first resource pool that comprises a plurality of first OFDM resources for sidelink signal transfer; obtaining, at the first UE, a second configuration of a second resource pool that comprises a plurality of second OFDM resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; transmitting, from the first UE to a second UE, control information in one or more of the plurality of first OFDM resources of the first resource pool, the control information indicating one or more of the plurality of second OFDM resources of the second resource pool; and transmitting, from the first UE to the second UE, a reference signal in one or more third OFDM resources of the second resource pool.



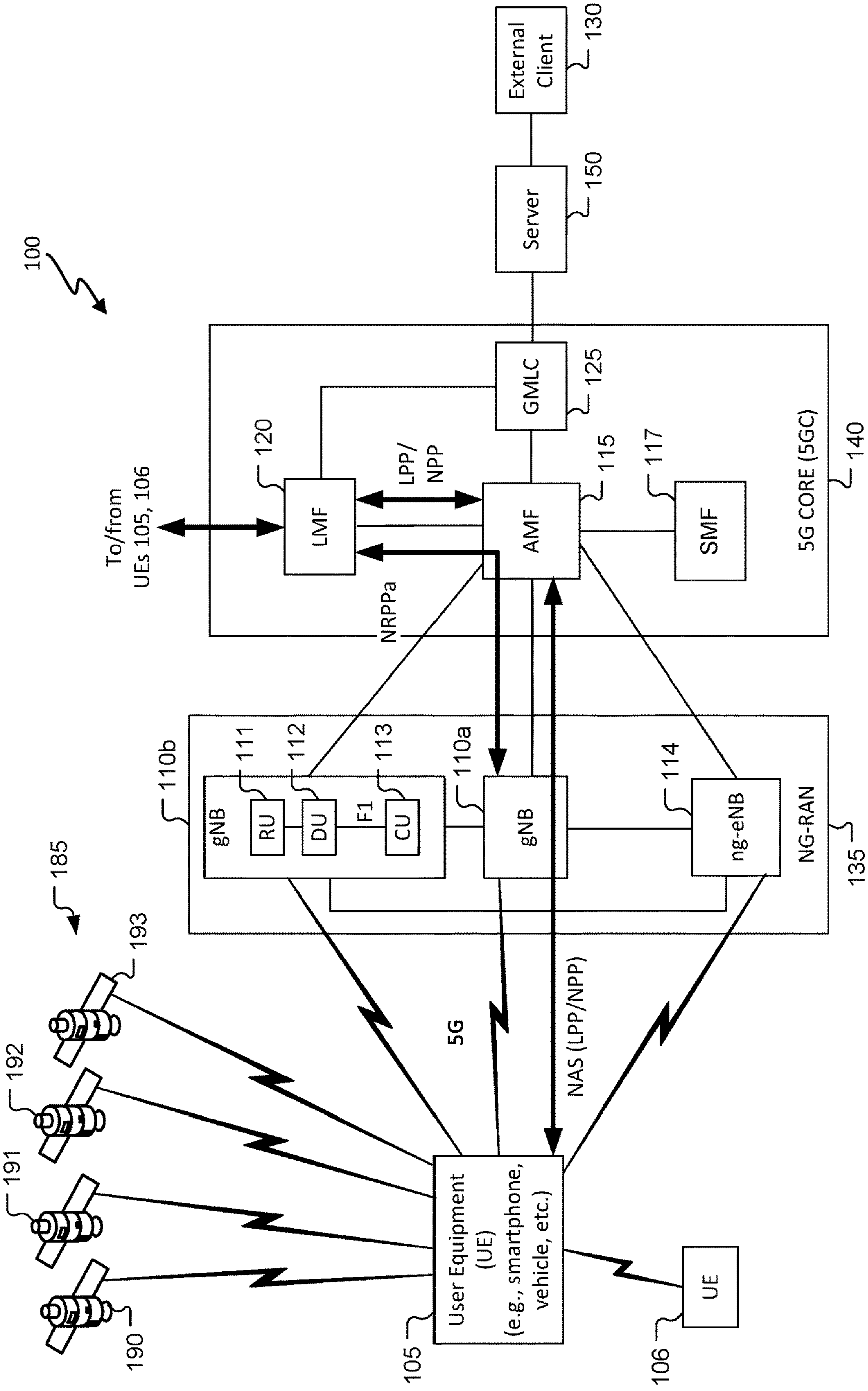

100
185
190
191
192
193
5G
User Equipment (UE) (e.g., smartphone, vehicle, etc.)
105
UE
106
NAS (LPP/NPP)
gNB
RU
DU
F1
CU
111
112
113
110b
gNB
110a
ng-eNB
114
NG-RAN
135
NRPPa
LMF
120
LPP/ NPP
AMF
115
SMF
117
GMLC
125
5G CORE (5GC)
140
To/from UEs 105, 106
Server
150
External Client
130

FIG. 1

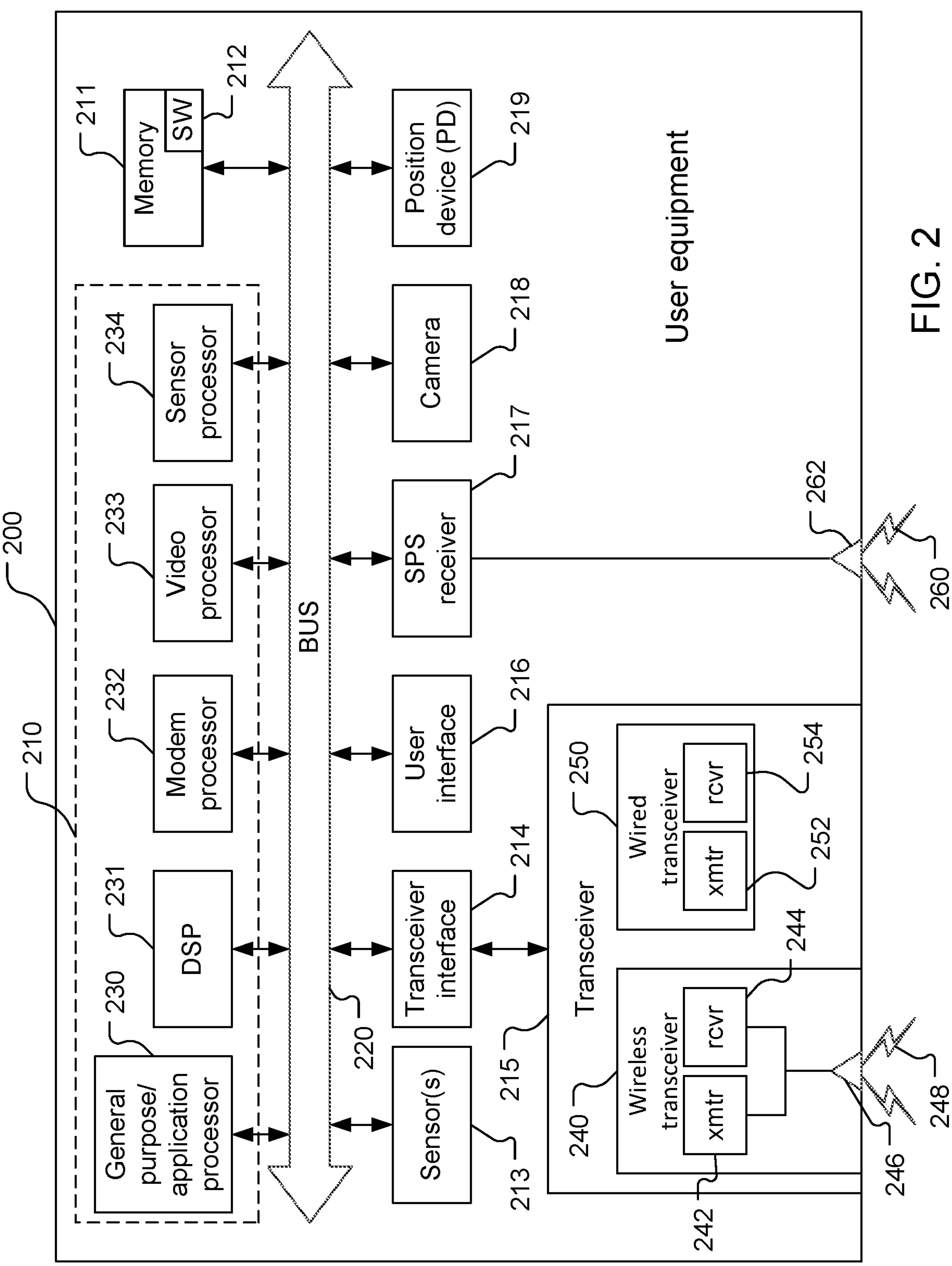

200
210
230
General purpose/ application processor
231
DSP
232
Modem processor
233
Video processor
234
Sensor processor
211
Memory
SW
212
BUS
220
213
Sensor(s)
214
Transceiver interface
216
User interface
217
SPS receiver
218
Camera
219
Position device (PD)
User equipment
215
Transceiver
240
Wireless transceiver
242
xmtr
244
rcvr
246
248
250
Wired transceiver
252
xmtr
254
rcvr
260
262

FIG. 2

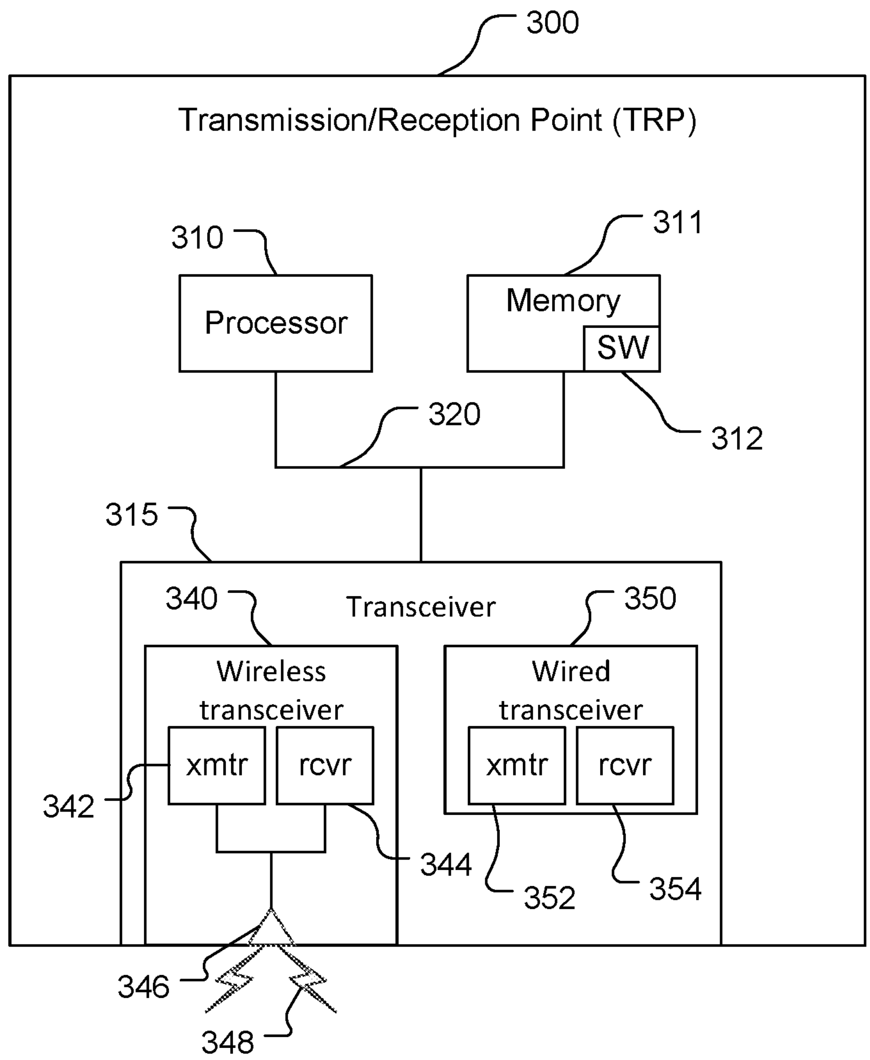

300
Transmission/Reception Point (TRP)
310
Processor
311
Memory
SW
312
320
315
340
Transceiver
350
Wireless transceiver
Wired transceiver
xmtr
rcvr
xmtr
rcvr
342
344
352
354
346
348

FIG. 3

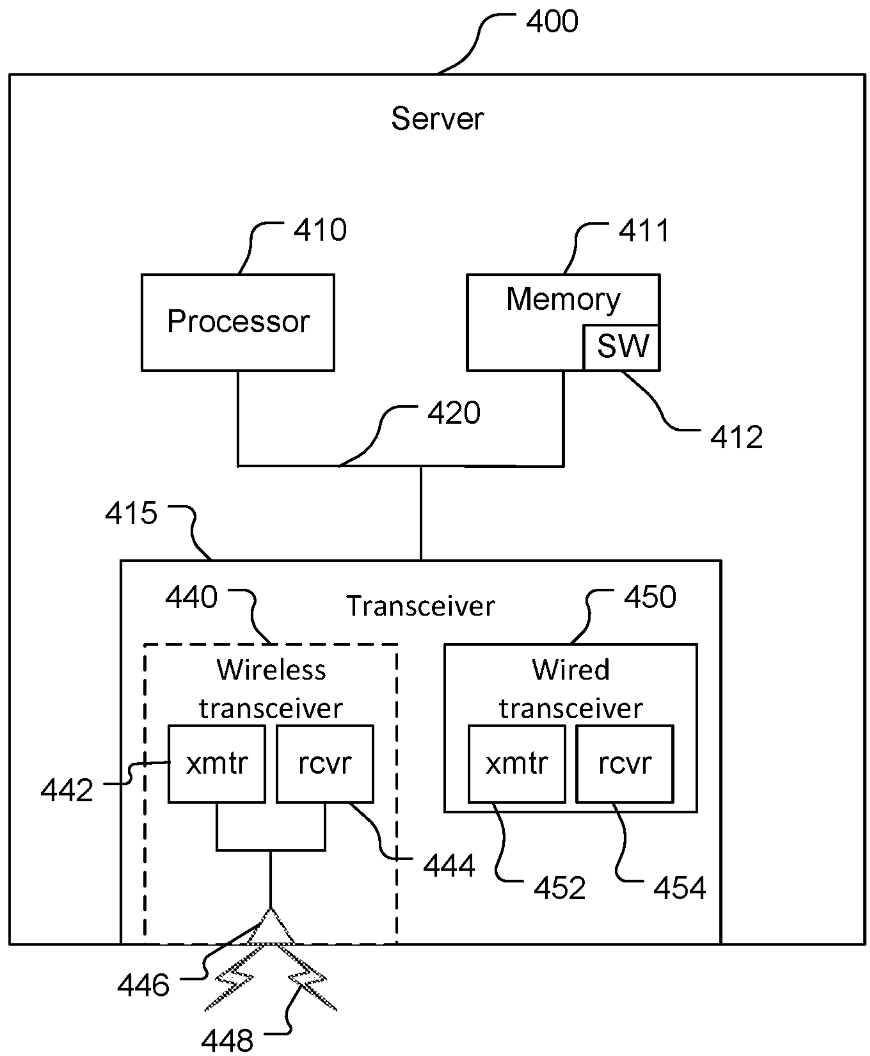

400
Server
410
Processor
411
Memory
SW
412
420
415
Transceiver
440
Wireless transceiver
xmtr
rcvr
442
444
446
448
450
Wired transceiver
xmtr
rcvr
452
454

FIG. 4

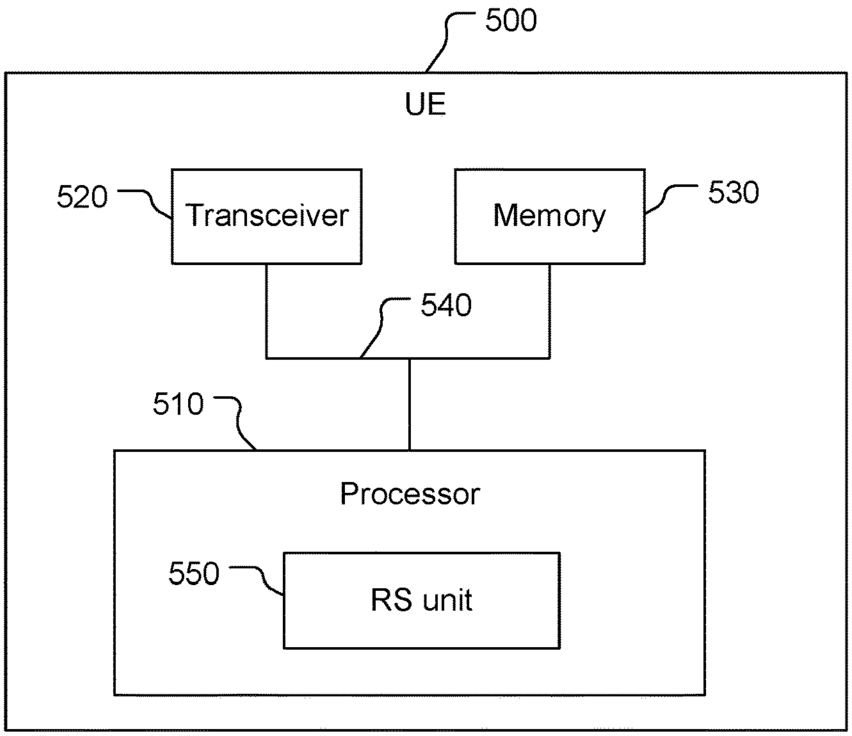

500
UE
520
Transceiver
Memory
530
540
510
Processor
550
RS unit

FIG. 5

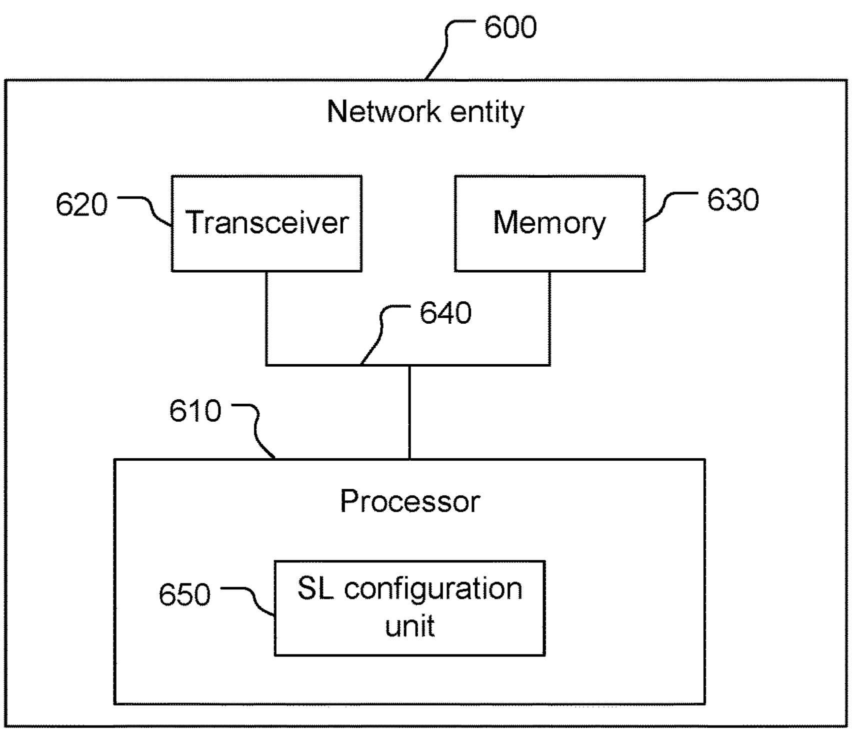

600
Network entity
620
Transceiver
Memory
630
640
610
Processor
650
SL configuration unit

FIG. 6

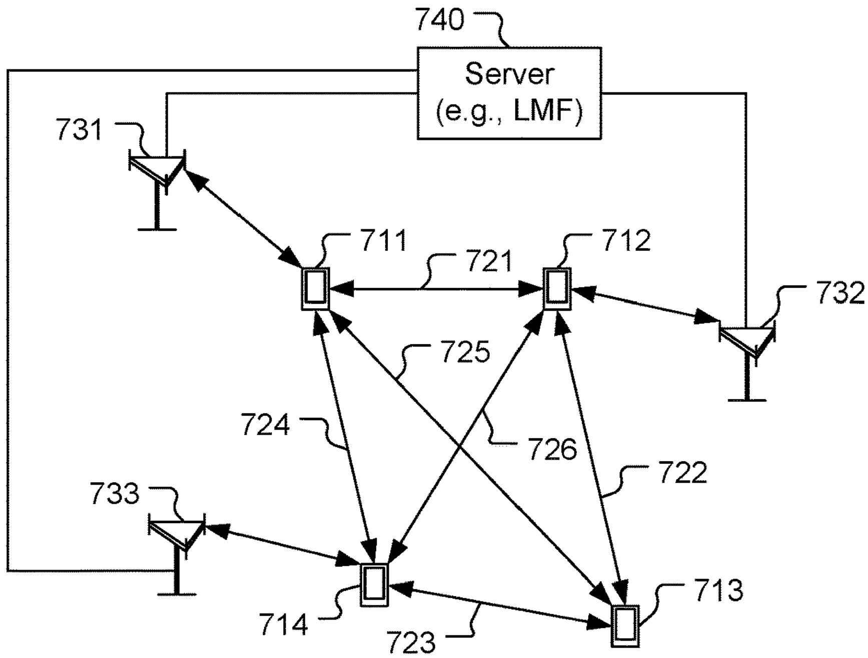

740
Server
(e.g., LMF)
731
711
721
712
732
725
724
726
722
733
714
723
713

FIG. 7

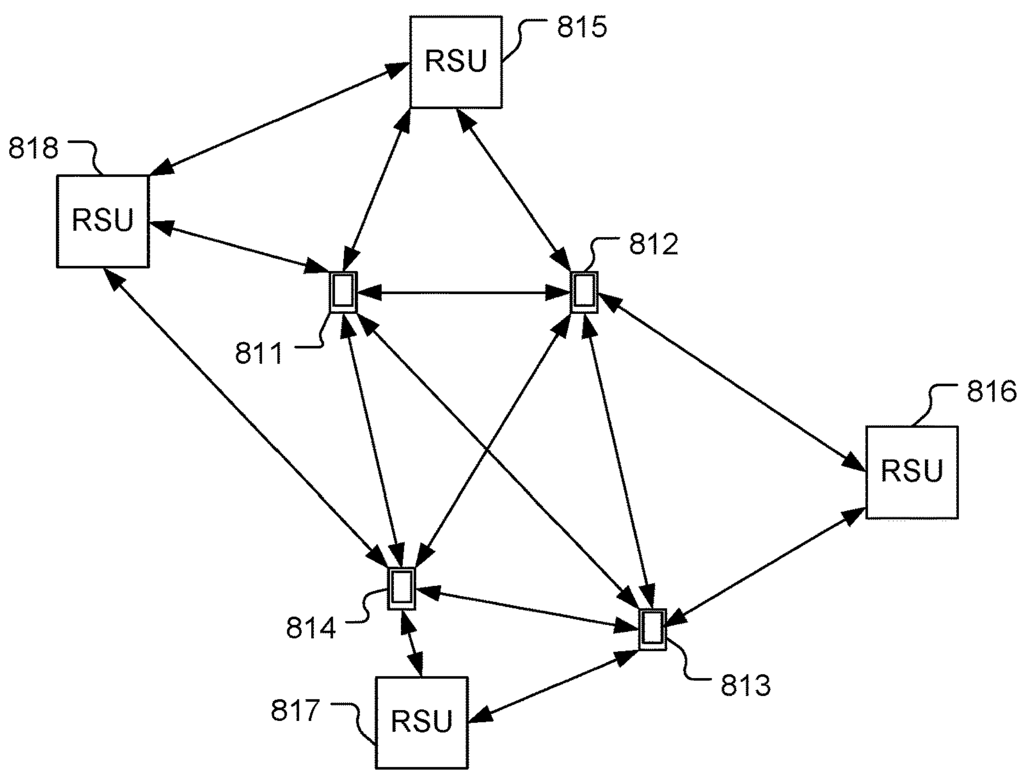

RSU
815
818
RSU
812
811
816
RSU
814
813
817
RSU

FIG. 8

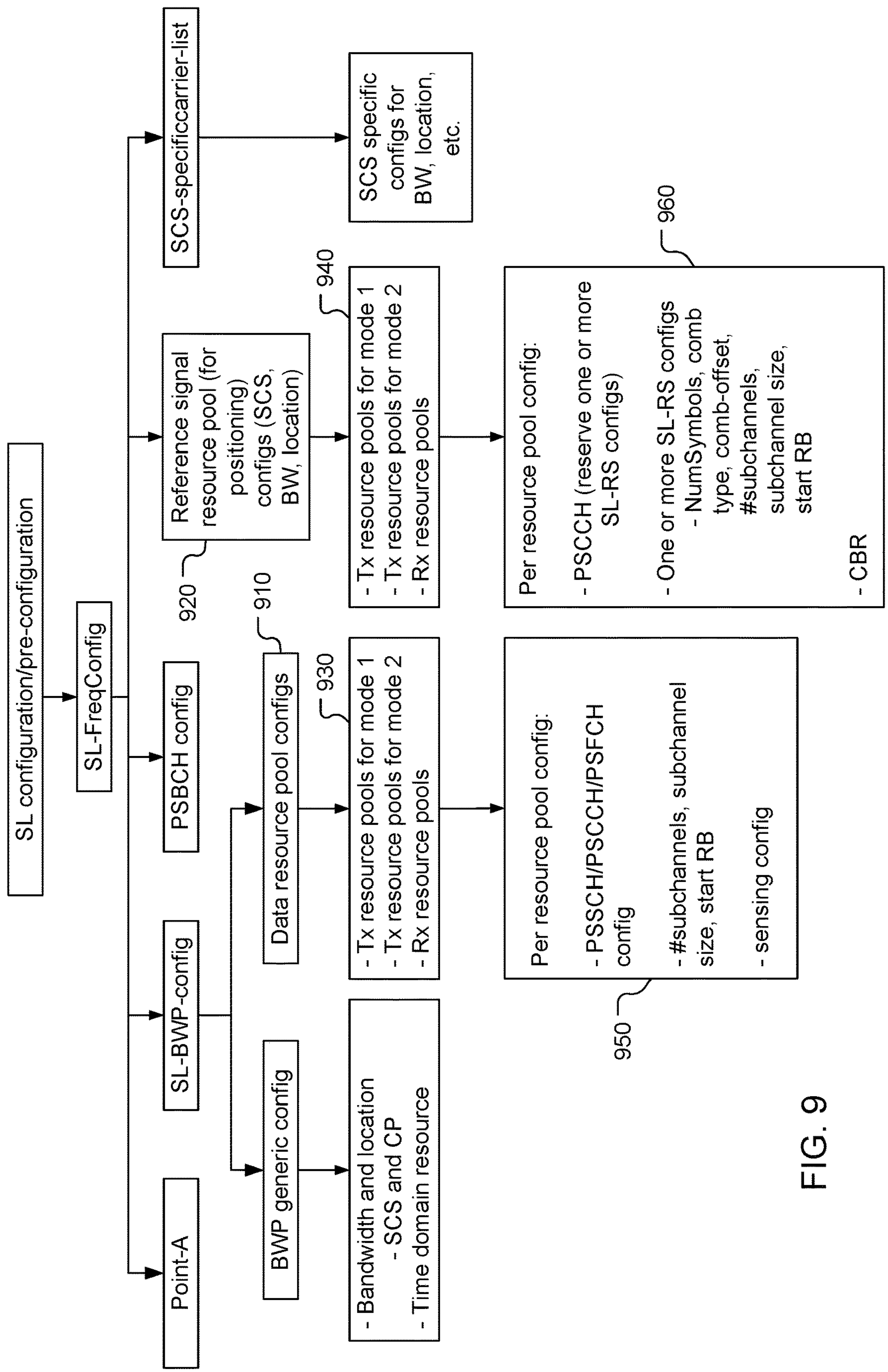

SL configuration/pre-configuration
SL-FreqConfig
Point-A
SL-BWP-config
PSBCH config
Reference signal resource pool (for positioning) configs (SCS, BW, location)
SCS-specificcarrier-list
SCS specific configs for BW, location, etc.
BWP generic config
Data resource pool configs
- Bandwidth and location
- SCS and CP
- Time domain resource
- Tx resource pools for mode 1
- Tx resource pools for mode 2
- Rx resource pools
- Tx resource pools for mode 1
- Tx resource pools for mode 2
- Rx resource pools
Per resource pool config:
- PSSCH/PSCCH/PSFCH config
- #subchannels, subchannel size, start RB
- sensing config
Per resource pool config:
- PSCCH (reserve one or more SL-RS configs)
- One or more SL-RS configs
- NumSymbols, comb type, comb-offset, #subchannels, subchannel size, start RB
- CBR
910
920
930
940
950
960

FIG. 9

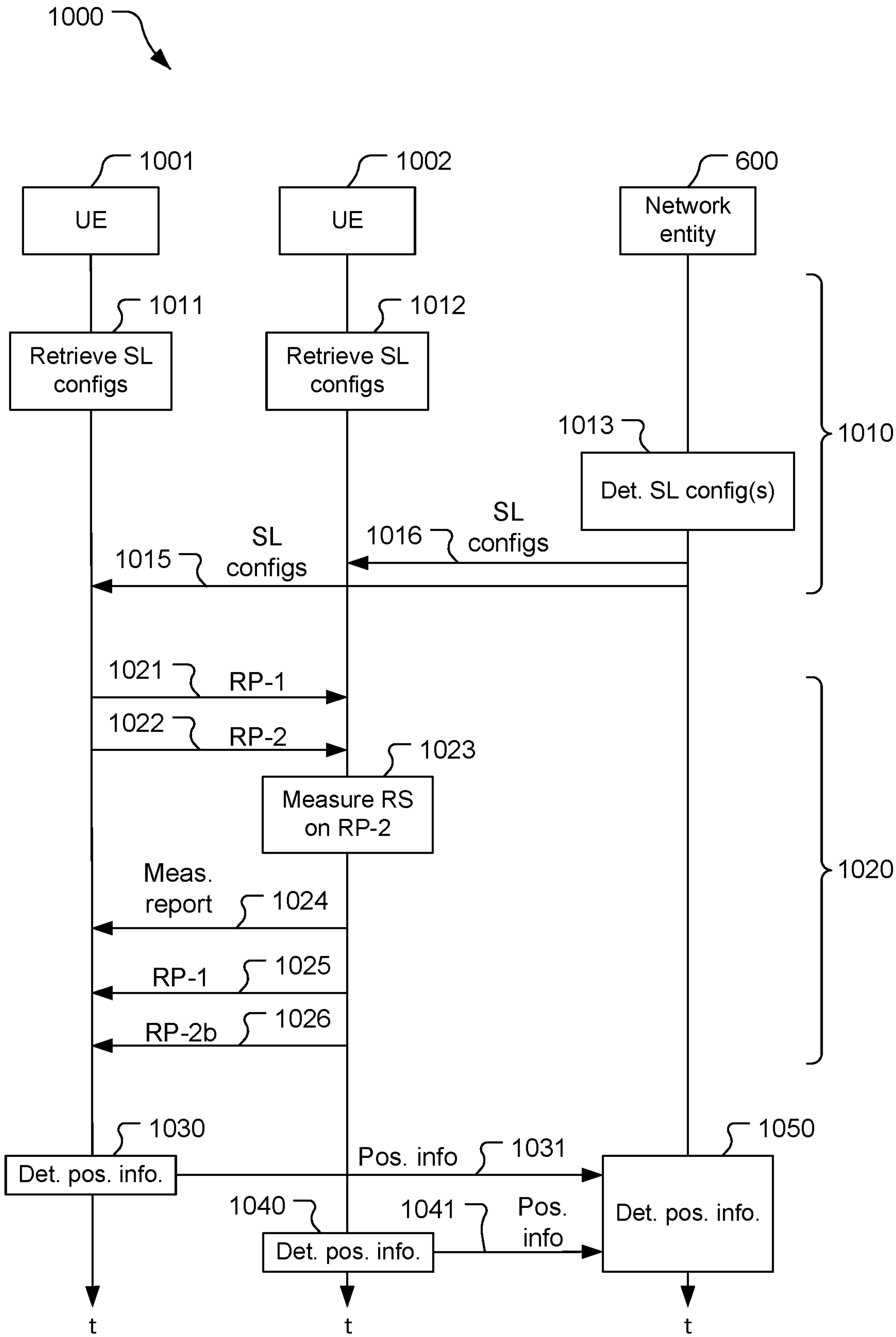

1000
1001
UE
1002
UE
600
Network entity
1011
Retrieve SL configs
1012
Retrieve SL configs
1013
Det. SL config(s)
1010
1016
SL configs
1015
SL configs
1021
RP-1
1022
RP-2
1023
Measure RS on RP-2
1020
Meas. report
1024
RP-1
1025
RP-2b
1026
1030
Det. pos. info.
Pos. info
1031
1050
Det. pos. info.
1040
Det. pos. info.
1041
Pos. info
t
t
t

FIG. 10

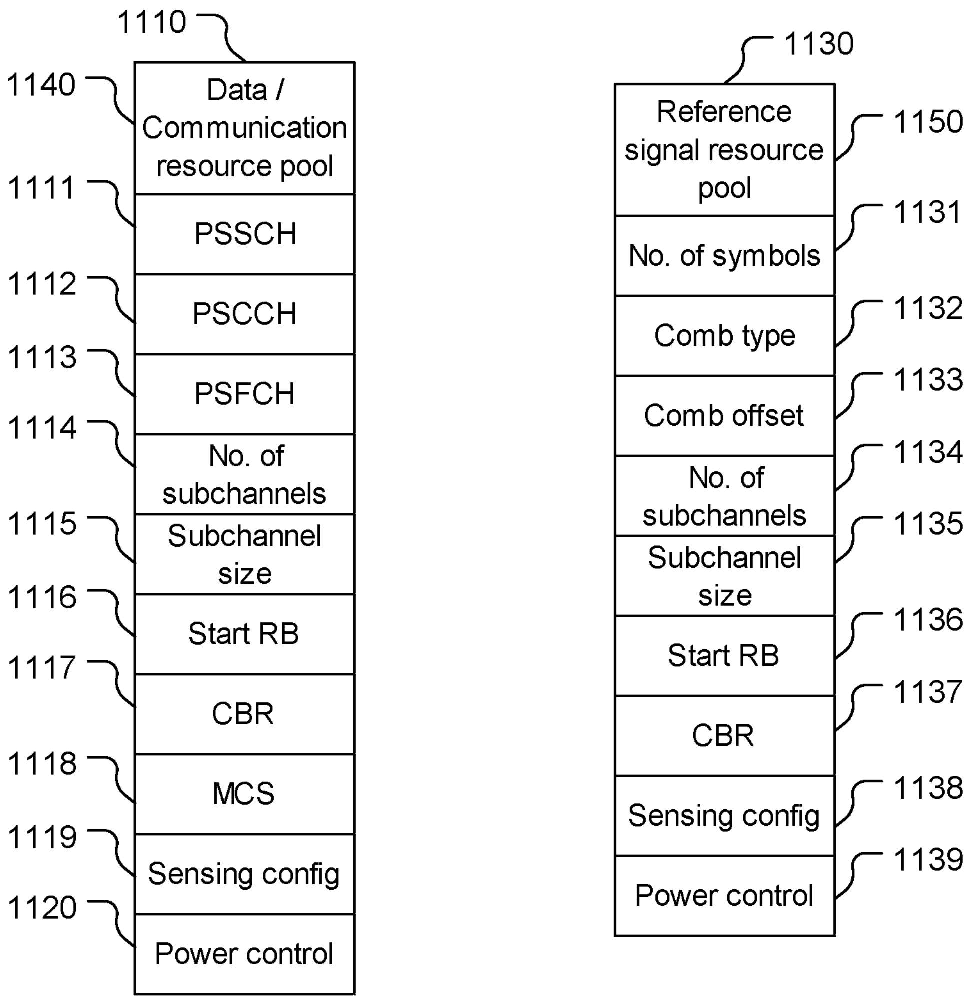

1110
1140
Data / Communication resource pool
1111
PSSCH
1112
PSCCH
1113
PSFCH
1114
No. of subchannels
1115
Subchannel size
1116
Start RB
1117
CBR
1118
MCS
1119
Sensing config
1120
Power control
1130
Reference signal resource pool
1150
No. of symbols
1131
Comb type
1132
Comb offset
1133
No. of subchannels
1134
Subchannel size
1135
Start RB
1136
CBR
1137
Sensing config
1138
Power control
1139

FIG. 11

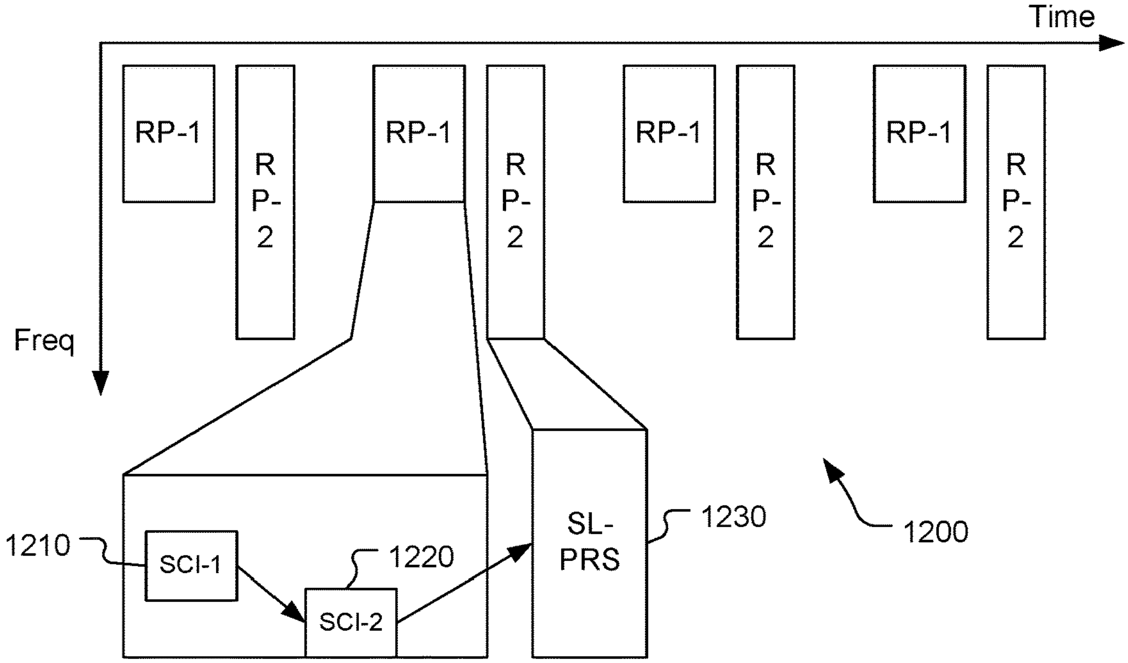

Time
RP-1
R
P-
2
RP-1
R
P-
2
RP-1
R
P-
2
RP-1
R
P-
2
Freq
1210
SCI-1
1220
SCI-2
SL-
PRS
1230
1200

FIG. 12

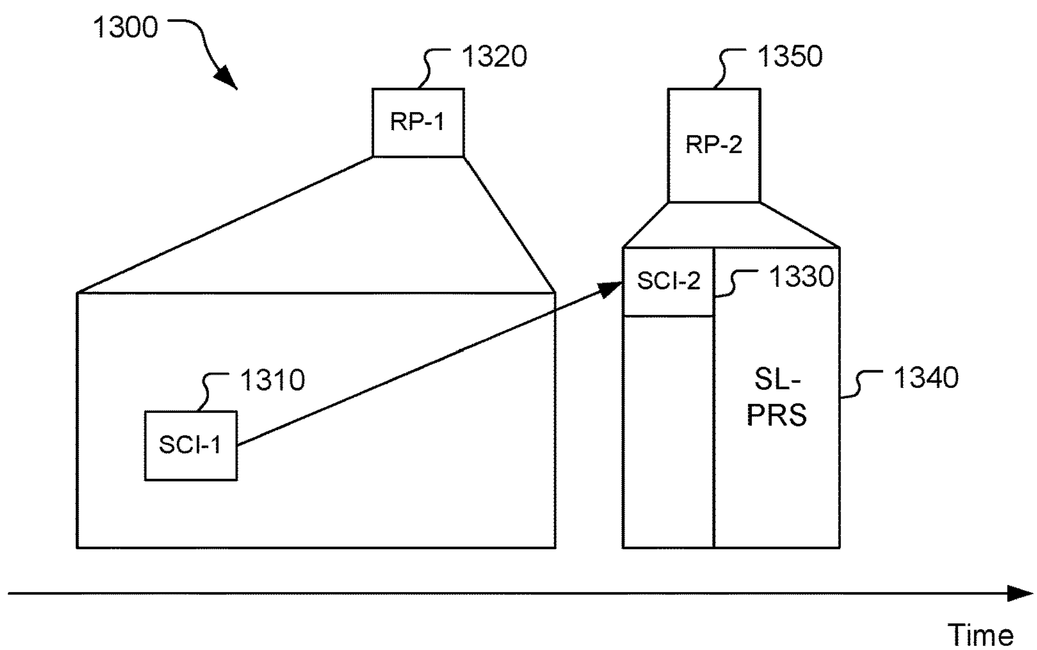

1300
1320
RP-1
1350
RP-2
SCI-2
1330
1310
SCI-1
SL-
PRS
1340
Time

FIG. 13

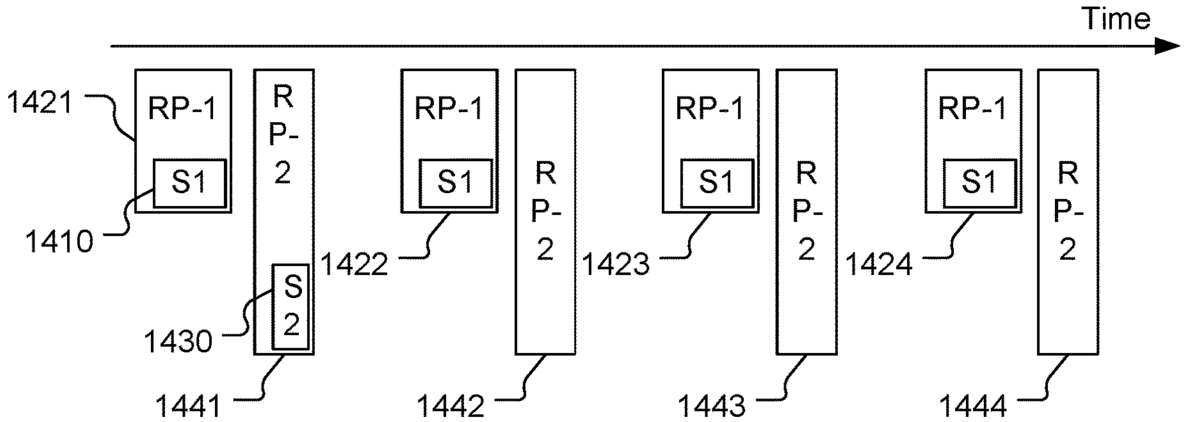

Time
1421
RP-1
S1
1410
R
P-
2
S
2
1430
1441
1422
RP-1
S1
R
P-
2
1442
1423
RP-1
S1
R
P-
2
1443
1424
RP-1
S1
R
P-
2
1444

FIG. 14

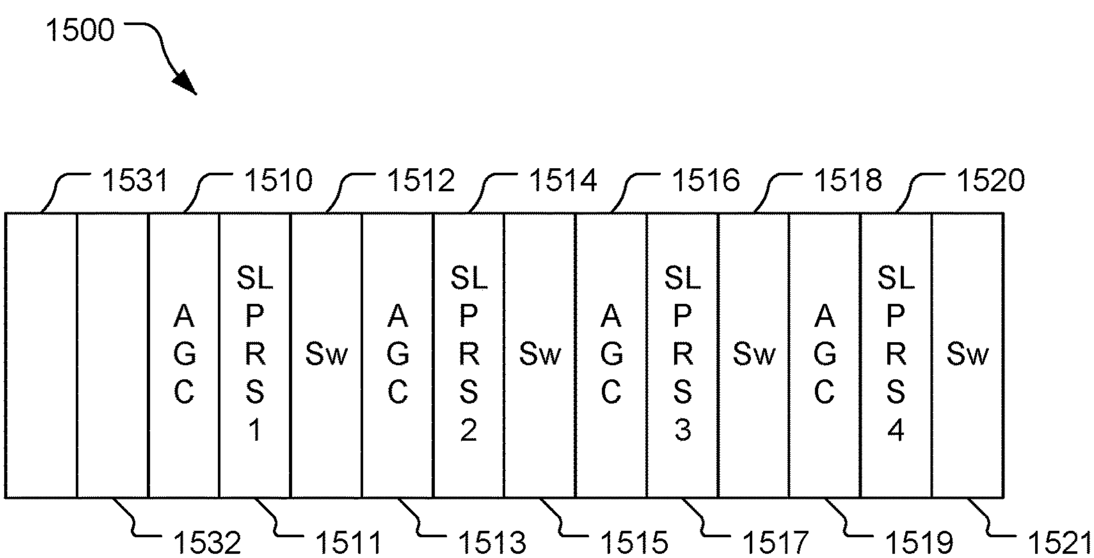

1500
1531
1510
1512
1514
1516
1518
1520
AGC
SL PRS 1
Sw
AGC
SL PRS 2
Sw
AGC
SL PRS 3
Sw
AGC
SL PRS 4
Sw
1532
1511
1513
1515
1517
1519
1521

FIG. 15

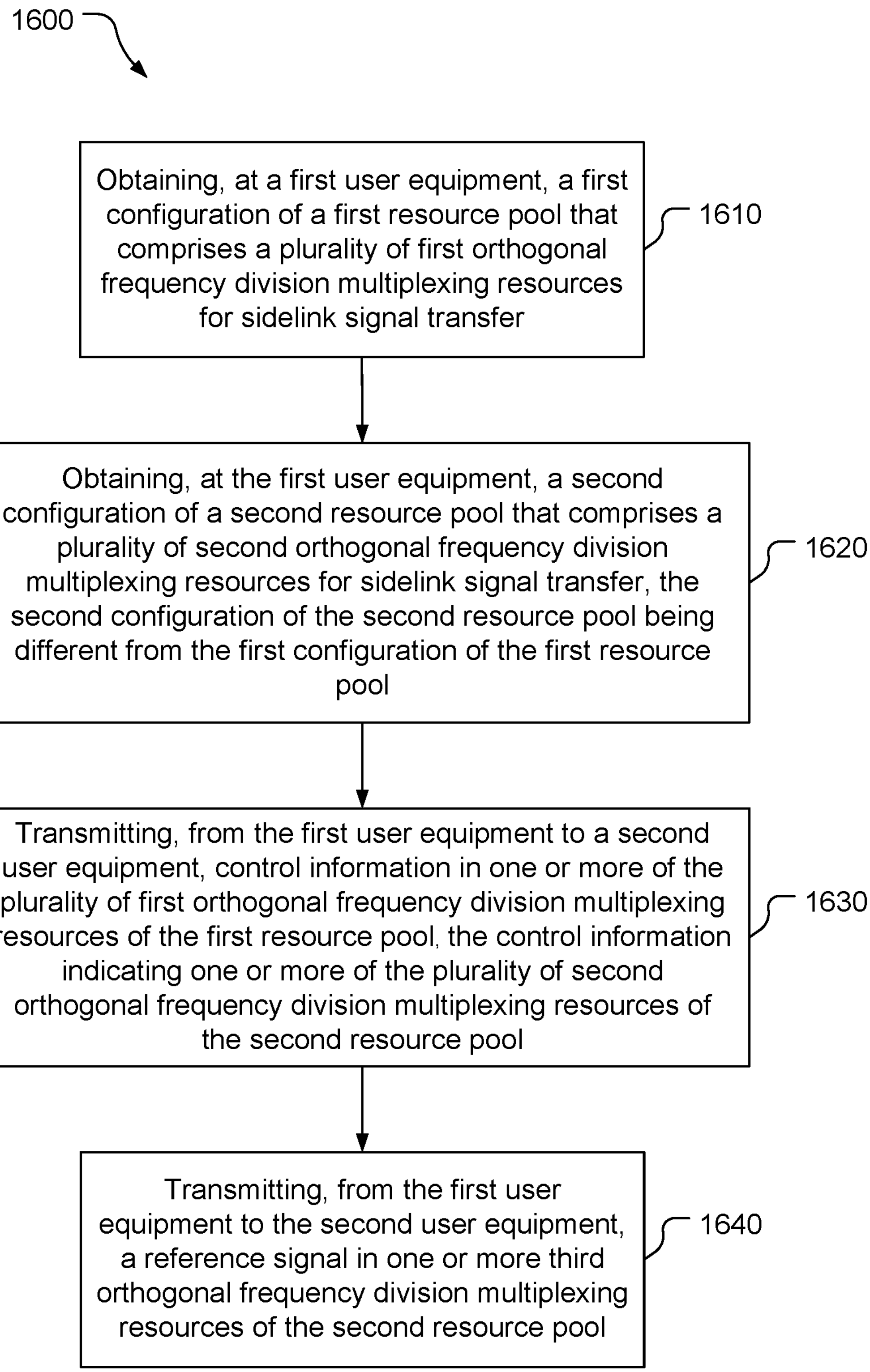

1600
Obtaining, at a first user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer
1610
Obtaining, at the first user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool
1620
Transmitting, from the first user equipment to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool
1630
Transmitting, from the first user equipment to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool
1640

FIG. 16

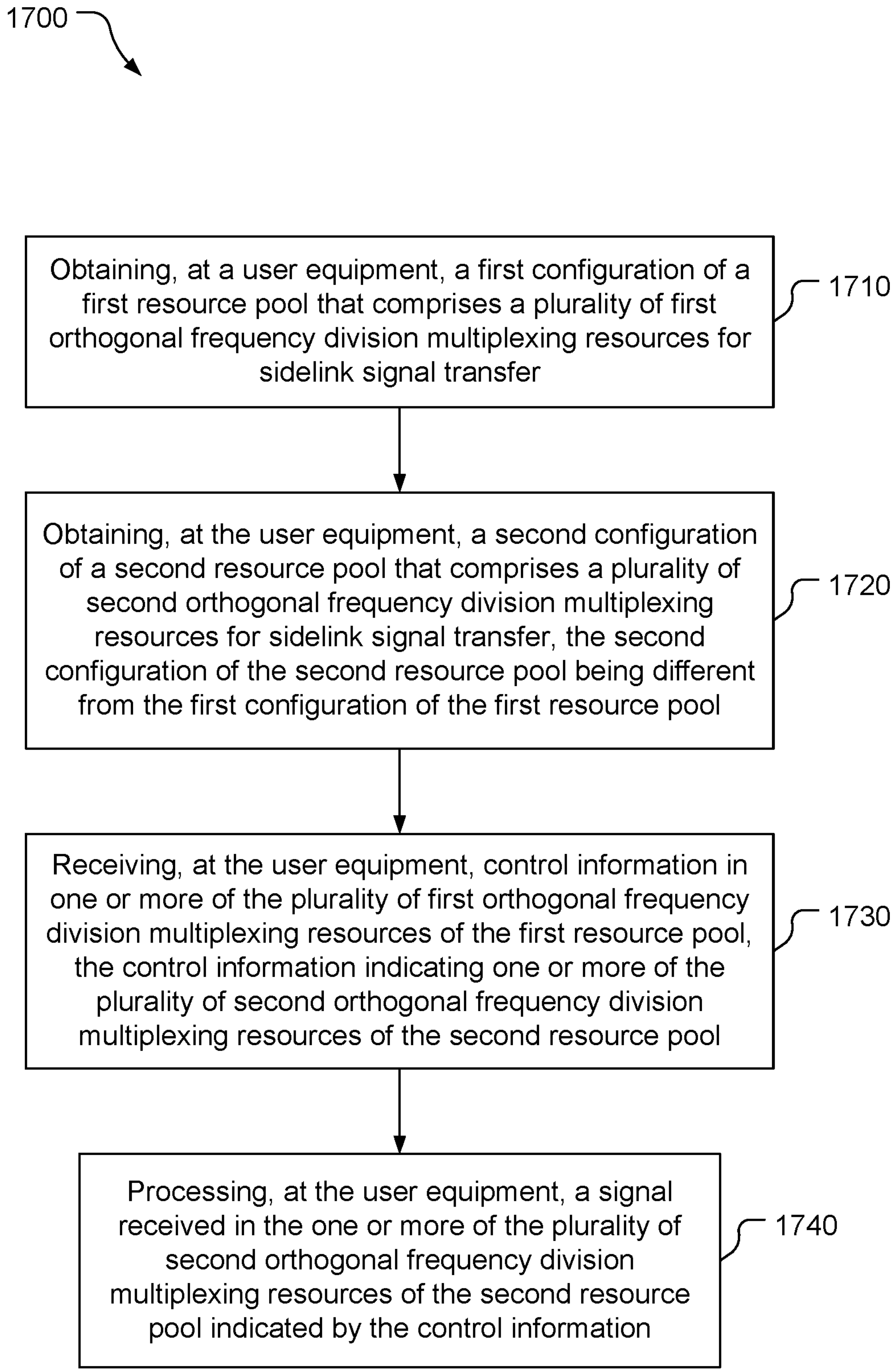

1700
Obtaining, at a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer
1710
Obtaining, at the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool
1720
Receiving, at the user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool
1730
Processing, at the user equipment, a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information
1740

FIG. 17

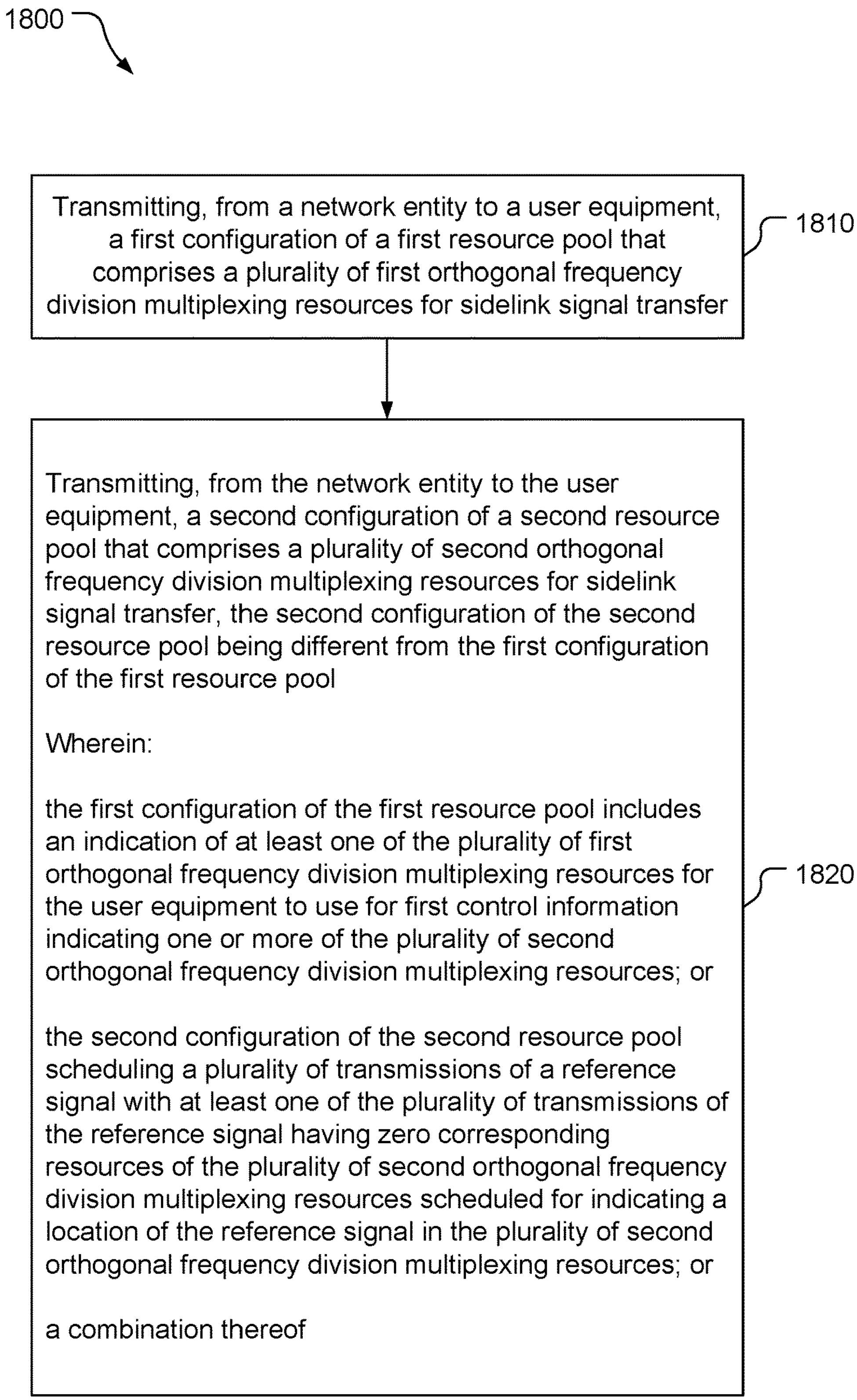

1800
Transmitting, from a network entity to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer
1810
Transmitting, from the network entity to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool
Wherein:
the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or
the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or
a combination thereof
1820

FIG. 18

COUPLED RESOURCE POOLS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Greek Patent Application Ser. No. 20210100750, filed Oct. 29, 2021, entitled "COUPLED RESOURCE POOLS," which is assigned to the assignee hereof, and the entire contents of which are hereby incorporated herein by reference for all purposes.

BACKGROUND

[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, a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax), a fifth-generation (5G) service, etc. 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), Orthogonal Frequency Division Multiple Access (OFDMA), Time Division Multiple Access (TDMA), the Global System for Mobile access (GSM) variation of TDMA, etc.

[0003] A fifth generation (5G) mobile standard calls for 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 data rates of several tens of megabits per second to each of tens of thousands of users, with 1 gigabit per second to tens of workers on an office floor. Several hundreds of thousands of simultaneous connections should be supported in order to support large sensor deployments. Consequently, the spectral efficiency of 5G mobile communications should be significantly enhanced compared to the current 4G standard. Furthermore, signaling efficiencies should be enhanced and latency should be substantially reduced compared to current standards.

SUMMARY

[0004] An example first user equipment includes: a transceiver; a memory; and a processor, communicatively coupled to the memory and the transceiver, configured to: obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; transmit control information via the transceiver to a second user equipment in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and transmit a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0005] An example reference signal transmission method includes: obtaining, at a first user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtaining, at the first user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; transmitting, from the first user equipment to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and transmitting, from the first user equipment to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0006] Another example first user equipment includes: means for obtaining a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; means for obtaining a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; means for transmitting, to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and means for transmitting, to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0007] An example non-transitory, processor-readable storage medium includes processor-readable instructions to cause a processor of a first user equipment to: obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; transmit, to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and transmit, to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0008] An example user equipment includes: a transceiver; a memory; and a processor, communicatively coupled to the memory and the transceiver, configured to: obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; receive control information via the transceiver in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and process a signal received via the transceiver in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0009] An example signal processing method includes: obtaining, at a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtaining, at the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; receiving, at the user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and processing, at the user equipment, a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0010] Another example user equipment includes: means for obtaining a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; means for obtaining a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; means for receiving control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and means for processing a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0011] Another example non-transitory, processor-readable storage medium includes processor-readable instructions to cause a processor of a user equipment to: obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; receive control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and process a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0012] An example network entity includes: a transceiver; a memory; and a processor, communicatively coupled to the memory and the transceiver, configured to: transmit, via the transceiver to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and transmit, via the transceiver to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; wherein: the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or a combination thereof.

[0013] An example resource pool configuration conveying method includes: transmitting, from a network entity to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and transmitting, from the network entity to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; wherein: the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or a combination thereof.

[0014] Another example network entity includes: means for transmitting, to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and means for transmitting, to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; wherein: the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or a combination thereof.

[0015] Another example non-transitory, processor-readable storage medium includes processor-readable instructions to cause a processor of a network entity to: transmit, to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and transmit, to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool; wherein: the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or a combination thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a simplified diagram of an example wireless communications system.

[0017] FIG. **2** is a block diagram of components of an example user equipment shown in FIG. **1**.

[0018] FIG. **3** is a block diagram of components of an example transmission/reception point.

[0019] FIG. **4** is a block diagram of components of an example server, various embodiments of which are shown in FIG. **1**.

[0020] FIG. **5** is a block diagram of an example user equipment.

[0021] FIG. **6** is a block diagram of an example network entity.

[0022] FIG. **7** is a simplified diagram of mode **1** operation of sidelink communication.

[0023] FIG. **8** is a simplified diagram of mode **2** operation of sidelink communication.

[0024] FIG. **9** is a block diagram of sidelink configuration/pre-configuration.

[0025] FIG. **10** is a signaling and process flow for obtaining and using coupled resource pools.

[0026] FIG. **11** shows a simplified example of control/data resource pool configuration parameters and a simplified example of reference signal resource pool configuration parameters.

[0027] FIG. **12** is a simplified diagram of multiple transmissions in a control/data resource pool and a reference signal resource pool with control information in the control/data resource pool for locating and processing a reference signal that is transmitted in the reference signal resource pool.

[0028] FIG. **13** is a simplified diagram of multiple transmissions in a control/data resource pool and a reference signal resource pool with control information in the control/data resource pool and the reference signal resource pool for locating and processing a reference signal that is transmitted in the reference signal resource pool.

[0029] FIG. **14** is a simplified diagram of multiple transmissions in a control/data resource pool and a reference signal resource pool with control information in fewer than all transmissions in the reference signal resource pool for locating and processing a reference signal that is transmitted in the reference signal resource pool.

[0030] FIG. **15** is a simplified diagram of time division multiplexing of control and reference signals in an orthogonal frequency division multiplexing slot.

[0031] FIG. **16** is a block flow diagram of a reference signal transmission method.

[0032] FIG. **17** is a block flow diagram of a signal processing method.

[0033] FIG. **18** is a block flow diagram of a resource pool configuration conveying method.

DETAILED DESCRIPTION

[0034] Techniques are discussed herein for establishing, disseminating, and using coupled resource pools, e.g., for transmitting and measuring reference signals. For example, coupled resource pools are scheduled such that control information in a first resource pool points to a resource location in a second resource pool. The control information may point to further control information that points to a resource location of a reference signal in the second resource pool. Alternatively, the control information may point to the resource location of the reference signal in the second resource pool. The second resource pool may have a larger bandwidth than the first resource pool. Control information, when scheduled for the second resource pool, may be scheduled for fewer than all transmissions of the reference signal in the second resource pool. These implementations are examples, and other implementations may be used.

[0035] Items and/or techniques described herein may provide one or more of the following capabilities, as well as other capabilities not mentioned. Reference signal measurement accuracy may be improved. Positioning accuracy may be improved, e.g., due to improved measurement accuracy of positioning reference signals. Channel state may be more accurately determined, e.g., due to improved measurement accuracy of a channel state information reference signal. Other capabilities may be provided and not every implementation according to the disclosure must provide any, let alone all, of the capabilities discussed.

[0036] Obtaining the locations of mobile devices that are accessing a wireless network may be useful for many applications including, for example, emergency calls, personal navigation, consumer asset tracking, locating a friend or family member, etc. Existing positioning methods include methods based on measuring radio signals transmitted from a variety of devices or entities including satellite vehicles (SVs) and terrestrial radio sources in a wireless network such as base stations and access points. It is expected that standardization for the 5G wireless networks will include support for various positioning methods, which may utilize reference signals transmitted by base stations in a manner similar to which LTE wireless networks currently utilize Positioning Reference Signals (PRS) and/or Cell-specific Reference Signals (CRS) for position determination.

[0037] The description herein may refer to sequences of actions to be performed, for example, by elements of a computing device. Various actions described herein can be performed by specific circuits (e.g., an application specific integrated circuit (ASIC)), by program instructions being executed by one or more processors, or by a combination of both. Sequences of actions described herein may be embodied within a non-transitory computer-readable medium having stored thereon a corresponding set of computer instructions that upon execution would cause an associated processor to perform the functionality described herein. Thus, the various examples described herein may be embodied in a number of different forms, all of which are within the scope of the disclosure, including claimed subject matter.

[0038] As used herein, the terms "user equipment" (UE) and "base station" are not specific to or otherwise limited to any particular Radio Access Technology (RAT), unless otherwise noted. In general, such UEs may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop computer, consumer asset tracking device, 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 terminal," a "mobile station," a "mobile device," 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, WiFi networks (e.g., based on IEEE (Institute of Electrical and Electronics Engineers) 802.11, 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. Examples of a base station include an Access Point (AP), a Network Node, a NodeB, an evolved NodeB (eNB), or a general Node B (gNodeB, gNB). In addition, 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.

[0040] UEs may be embodied by any of a number of types of devices including but not limited to printed circuit (PC) cards, compact flash devices, external or internal modems, wireless or wireline phones, smartphones, tablets, consumer asset tracking devices, asset tags, and so on. A communication link through which UEs can send signals to a RAN is called an uplink channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the RAN can send signals to UEs is called a downlink 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.

[0041] As used herein, the term "cell" or "sector" may correspond to one of a plurality of cells of a base station, or to the base station itself, depending on the context. The term "cell" may refer to a logical communication entity used for communication with a base station (for example, over a carrier), and may be associated with an identifier for distinguishing neighboring cells (for example, a physical cell identifier (PCID), a virtual cell identifier (VCID)) operating via the same or a different carrier. In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (for example, machine-type communication (MTC), narrowband Internet-of-Things (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of devices. In some examples, the term "cell" may refer to a portion of a geographic coverage area (for example, a sector) over which the logical entity operates.

[0042] Referring to FIG. **1**, an example of a communication system **100** includes a UE **105**, a UE **106**, a Radio Access Network (RAN), here a Fifth Generation (5G) Next Generation (NG) RAN (NG-RAN) **135**, a 5G Core Network (5GC) **140**, and a server **150**. The UE **105** and/or the UE **106** may be, e.g., an IoT device, a location tracker device, a cellular telephone, a vehicle (e.g., a car, a truck, a bus, a boat, etc.), or other device. A 5G network may also be referred to as a New Radio (NR) network; NG-RAN **135** may be referred to as a 5G RAN or as an NR RAN; and 5GC **140** may be referred to as an NG Core network (NGC). Standardization of an NG-RAN and 5GC is ongoing in the 3rd Generation Partnership Project (3GPP). Accordingly, the NG-RAN **135** and the 5GC **140** may conform to current or future standards for 5G support from 3GPP. The NG-RAN **135** may be another type of RAN, e.g., a 3G RAN, a 4G Long Term Evolution (LTE) RAN, etc. The UE **106** may be configured and coupled similarly to the UE **105** to send and/or receive signals to/from similar other entities in the system **100**, but such signaling is not indicated in FIG. **1** for the sake of simplicity of the figure. Similarly, the discussion focuses on the UE **105** for the sake of simplicity. The communication system **100** may utilize information from a constellation **185** of satellite vehicles (SVs) **190**, **191**, **192**, **193** for a Satellite Positioning System (SPS) (e.g., a Global Navigation Satellite System (GNSS)) like the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS), Galileo, or Beidou or some other local or regional SPS such as the Indian Regional Navigational

Satellite System (IRNSS), the European Geostationary Navigation Overlay Service (EGNOS), or the Wide Area Augmentation System (WAAS). Additional components of the communication system **100** are described below. The communication system **100** may include additional or alternative components.

[0043] As shown in FIG. **1**, the NG-RAN **135** includes NR nodeBs (gNBs) **110***a*, **110***b*, and a next generation eNodeB (ng-eNB) **114**, and the 5GC **140** includes an Access and Mobility Management Function (AMF) **115**, a Session Management Function (SMF) **117**, a Location Management Function (LMF) **120**, and a Gateway Mobile Location Center (GMLC) **125**. The gNBs **110***a*, **110***b* and the ng-eNB **114** are communicatively coupled to each other, are each configured to bi-directionally wirelessly communicate with the UE **105**, and are each communicatively coupled to, and configured to bi-directionally communicate with, the AMF **115**. The gNBs **110***a*, **110***b*, and the ng-eNB **114** may be referred to as base stations (BSs). The AMF **115**, the SMF **117**, the LMF **120**, and the GMLC **125** are communicatively coupled to each other, and the GMLC is communicatively coupled to an external client **130**. The SMF **117** may serve as an initial contact point of a Service Control Function (SCF) (not shown) to create, control, and delete media sessions. Base stations such as the gNBs **110***a*, **110***b* and/or the ng-eNB **114** may be a macro cell (e.g., a high-power cellular base station), or a small cell (e.g., a low-power cellular base station), or an access point (e.g., a short-range base station configured to communicate with short-range technology such as WiFi, WiFi-Direct (WiFi-D), Bluetooth®, Bluetooth®-low energy (BLE), Zigbee, etc. One or more base stations, e.g., one or more of the gNBs **110***a*, **110***b* and/or the ng-eNB **114** may be configured to communicate with the UE **105** via multiple carriers. Each of the gNBs **110***a*, **110***b* and/or the ng-eNB **114** may provide communication coverage for a respective geographic region, e.g., a cell. Each cell may be partitioned into multiple sectors as a function of the base station antennas.

[0044] FIG. **1** provides a generalized illustration of various components, any or all of which may be utilized as appropriate, and each of which may be duplicated or omitted as necessary. Specifically, although one UE **105** is illustrated, many UEs (e.g., hundreds, thousands, millions, etc.) may be utilized in the communication system **100**. Similarly, the communication system **100** may include a larger (or smaller) number of SVs (i.e., more or fewer than the four SVs **190-193** shown), gNBs **110***a*, **110***b*, ng-eNBs **114**, AMFs **115**, external clients **130**, and/or other components. The illustrated connections that connect the various components in the communication system **100** include data and signaling connections which may include additional (intermediary) components, direct or indirect physical and/or wireless connections, and/or additional networks. Furthermore, components may be rearranged, combined, separated, substituted, and/or omitted, depending on desired functionality.

[0045] While FIG. **1** illustrates a 5G-based network, similar network implementations and configurations may be used for other communication technologies, such as 3G, Long Term Evolution (LTE), etc. Implementations described herein (be they for 5G technology and/or for one or more other communication technologies and/or protocols) may be used to transmit (or broadcast) directional synchronization signals, receive and measure directional signals at UEs (e.g., the UE **105**) and/or provide location assistance to the UE **105** (via the GMLC **125** or other location server) and/or compute a location for the UE **105** at a location-capable device such as the UE **105**, the gNB **110***a*, **110***b*, or the LMF **120** based on measurement quantities received at the UE **105** for such directionally-transmitted signals. The gateway mobile location center (GMLC) **125**, the location management function (LMF) **120**, the access and mobility management function (AMF) **115**, the SMF **117**, the ng-eNB (eNodeB) **114** and the gNBs (gNodeBs) **110***a*, **110***b* are examples and may, in various embodiments, be replaced by or include various other location server functionality and/or base station functionality respectively.

[0046] The system **100** is capable of wireless communication in that components of the system **100** can communicate with one another (at least some times using wireless connections) directly or indirectly, e.g., via the gNBs **110***a*, **110***b*, the ng-eNB **114**, and/or the 5GC **140** (and/or one or more other devices not shown, such as one or more other base transceiver stations). For indirect communications, the communications may be altered during transmission from one entity to another, e.g., to alter header information of data packets, to change format, etc. The UE **105** may include multiple UEs and may be a mobile wireless communication device, but may communicate wirelessly and via wired connections. The UE **105** may be any of a variety of devices, e.g., a smartphone, a tablet computer, a vehicle-based device, etc., but these are examples as the UE **105** is not required to be any of these configurations, and other configurations of UEs may be used. Other UEs may include wearable devices (e.g., smart watches, smart jewelry, smart glasses or headsets, etc.). Still other UEs may be used, whether currently existing or developed in the future. Further, other wireless devices (whether mobile or not) may be implemented within the system **100** and may communicate with each other and/or with the UE **105**, the gNBs **110***a*, **110***b*, the ng-eNB **114**, the 5GC **140**, and/or the external client **130**. For example, such other devices may include internet of thing (IoT) devices, medical devices, home entertainment and/or automation devices, etc. The 5GC **140** may communicate with the external client **130** (e.g., a computer system), e.g., to allow the external client **130** to request and/or receive location information regarding the UE **105** (e.g., via the GMLC **125**).

[0047] The UE **105** or other devices may be configured to communicate in various networks and/or for various purposes and/or using various technologies (e.g., 5G, Wi-Fi communication, multiple frequencies of Wi-Fi communication, satellite positioning, one or more types of communications (e.g., GSM (Global System for Mobiles), CDMA (Code Division Multiple Access), LTE (Long Term Evolution), V2X (Vehicle-to-Everything, e.g., V2P (Vehicle-to-Pedestrian), V2I (Vehicle-to-Infrastructure), V2V (Vehicle-to-Vehicle), etc.), IEEE 802.11p, etc.). V2X communications may be cellular (Cellular-V2X (C-V2X)) and/or WiFi (e.g., DSRC (Dedicated Short-Range Connection)). The system **100** may support operation on multiple carriers (waveform signals of different frequencies). Multi-carrier transmitters can transmit modulated signals simultaneously on the multiple carriers. Each modulated signal may be a Code Division Multiple Access (CDMA) signal, a Time Division Multiple Access (TDMA) signal, an Orthogonal Frequency Division Multiple Access (OFDMA) signal, a Single-Carrier Frequency Division Multiple Access (SC-

FDMA) signal, etc. Each modulated signal may be sent on a different carrier and may carry pilot, overhead information, data, etc. The UEs **105**, **106** may communicate with each other through UE-to-UE sidelink (SL) communications by transmitting over one or more sidelink channels such as a physical sidelink synchronization channel (PSSCH), a physical sidelink broadcast channel (PSBCH), or a physical sidelink control channel (PSCCH). Direct device-to-device communications (without going through a network) may be referred to generally as sidelink communications without limiting the communications to a particular protocol.

[0048] The UE **105** may comprise and/or may be referred to as a device, a mobile device, a wireless device, a mobile terminal, a terminal, a mobile station (MS), a Secure User Plane Location (SUPL) Enabled Terminal (SET), or by some other name. Moreover, the UE **105** may correspond to a cellphone, smartphone, laptop, tablet, PDA, consumer asset tracking device, navigation device, Internet of Things (IoT) device, health monitors, security systems, smart city sensors, smart meters, wearable trackers, or some other portable or moveable device. Typically, though not necessarily, the UE **105** may support wireless communication using one or more Radio Access Technologies (RATs) such as Global System for Mobile communication (GSM), Code Division Multiple Access (CDMA), Wideband CDMA (WCDMA), LTE, High Rate Packet Data (HRPD), IEEE 802.11 WiFi (also referred to as Wi-Fi), Bluetooth® (BT), Worldwide Interoperability for Microwave Access (WiMAX), 5G new radio (NR) (e.g., using the NG-RAN **135** and the 5GC **140**), etc. The UE **105** may support wireless communication using a Wireless Local Area Network (WLAN) which may connect to other networks (e.g., the Internet) using a Digital Subscriber Line (DSL) or packet cable, for example. The use of one or more of these RATs may allow the UE **105** to communicate with the external client **130** (e.g., via elements of the 5GC **140** not shown in FIG. **1**, or possibly via the GMLC **125**) and/or allow the external client **130** to receive location information regarding the UE **105** (e.g., via the GMLC **125**).

[0049] The UE **105** may include a single entity or may include multiple entities such as in a personal area network where a user may employ audio, video and/or data I/O (input/output) devices and/or body sensors and a separate wireline or wireless modem. An estimate of a location of the UE **105** may be referred to as a location, location estimate, location fix, fix, position, position estimate, or position fix, and may be geographic, thus providing location coordinates for the UE **105** (e.g., latitude and longitude) which may or may not include an altitude component (e.g., height above sea level, height above or depth below ground level, floor level, or basement level). Alternatively, a location of the UE **105** may be expressed as a civic location (e.g., as a postal address or the designation of some point or small area in a building such as a particular room or floor). A location of the UE **105** may be expressed as an area or volume (defined either geographically or in civic form) within which the UE **105** is expected to be located with some probability or confidence level (e.g., 67%, 95%, etc.). A location of the UE **105** may be expressed as a relative location comprising, for example, a distance and direction from a known location. The relative location may be expressed as relative coordinates (e.g., X, Y (and Z) coordinates) defined relative to some origin at a known location which may be defined, e.g., geographically, in civic terms, or by reference to a point, area, or volume, e.g., indicated on a map, floor plan, or building plan. In the description contained herein, the use of the term location may comprise any of these variants unless indicated otherwise. When computing the location of a UE, it is common to solve for local x, y, and possibly z coordinates and then, if desired, convert the local coordinates into absolute coordinates (e.g., for latitude, longitude, and altitude above or below mean sea level).

[0050] The UE **105** may be configured to communicate with other entities using one or more of a variety of technologies. The UE **105** may be configured to connect indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links. The D2D P2P links may be supported with any appropriate D2D radio access technology (RAT), such as LTE Direct (LTE-D), WiFi Direct (WiFi-D), Bluetooth®, and so on. One or more of a group of UEs utilizing D2D communications may be within a geographic coverage area of a Transmission/Reception Point (TRP) such as one or more of the gNBs **110***a*, **110***b*, and/or the ng-eNB **114**. Other UEs in such a group may be outside such geographic coverage areas, or may be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP. One or more of a group of UEs utilizing D2D communications may be within a geographic coverage area of a TRP. Other UEs in such a group may be outside such geographic coverage areas, or be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP.

[0051] Base stations (BSs) in the NG-RAN **135** shown in FIG. **1** include NR Node Bs, referred to as the gNBs **110***a* and **110***b*. Pairs of the gNBs **110***a*, **110***b* in the NG-RAN **135** may be connected to one another via one or more other gNBs. Access to the 5G network is provided to the UE **105** via wireless communication between the UE **105** and one or more of the gNBs **110***a*, **110***b*, which may provide wireless communications access to the 5GC **140** on behalf of the UE **105** using 5G. In FIG. **1**, the serving gNB for the UE **105** is assumed to be the gNB **110***a*, although another gNB (e.g., the gNB **110***b*) may act as a serving gNB if the UE **105** moves to another location or may act as a secondary gNB to provide additional throughput and bandwidth to the UE **105**.

[0052] Base stations (BSs) in the NG-RAN **135** shown in FIG. **1** may include the ng-eNB **114**, also referred to as a next generation evolved Node B. The ng-eNB **114** may be connected to one or more of the gNBs **110***a*, **110***b* in the NG-RAN **135**, possibly via one or more other gNBs and/or one or more other ng-eNBs. The ng-eNB **114** may provide LTE wireless access and/or evolved LTE (eLTE) wireless access to the UE **105**. One or more of the gNBs **110***a*, **110***b* and/or the ng-eNB **114** may be configured to function as positioning-only beacons which may transmit signals to assist with determining the position of the UE **105** but may not receive signals from the UE **105** or from other UEs.

[0053] The gNBs **110***a*, **110***b* and/or the ng-eNB **114** may each comprise one or more TRPs. For example, each sector within a cell of a BS may comprise a TRP, although multiple TRPs may share one or more components (e.g., share a processor but have separate antennas). The system **100** may include macro TRPs exclusively or the system **100** may have TRPs of different types, e.g., macro, pico, and/or femto TRPs, etc. A macro TRP may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by terminals with service subscription. A pico TRP may cover a relatively small geographic area (e.g., a pico cell) and may allow unrestricted access by terminals with service subscription. A femto or home TRP may cover a relatively small geographic area (e.g., a femto cell) and may allow restricted access by terminals having association with the femto cell (e.g., terminals for users in a home).

[0054] Each of the gNBs **110***a*, **110***b* and/or the ng-eNB **114** may include a radio unit (RU), a distributed unit (DU), and a central unit (CU). For example, the gNB **110***b* includes an RU **111**, a DU **112**, and a CU **113**. The RU **111**, DU **112**, and CU **113** divide functionality of the gNB **110***b*. While the gNB **110***b* is shown with a single RU, a single DU, and a single CU, a gNB may include one or more RUs, one or more DUs, and/or one or more CUs. An interface between the CU **113** and the DU **112** is referred to as an F1 interface. The RU **111** is configured to perform digital front end (DFE) functions (e.g., analog-to-digital conversion, filtering, power amplification, transmission/reception) and digital beamforming, and includes a portion of the physical (PHY) layer. The RU **111** may perform the DFE using massive multiple input/multiple output (MIMO) and may be integrated with one or more antennas of the gNB **110***b*. The DU **112** hosts the Radio Link Control (RLC), Medium Access Control (MAC), and physical layers of the gNB **110***b*. One DU can support one or more cells, and each cell is supported by a single DU. The operation of the DU **112** is controlled by the CU **113**. The CU **113** is configured to perform functions for transferring user data, mobility control, radio access network sharing, positioning, session management, etc. although some functions are allocated exclusively to the DU **112**. The CU **113** hosts the Radio Resource Control (RRC), Service Data Adaptation Protocol (SDAP), and Packet Data Convergence Protocol (PDCP) protocols of the gNB **110***b*. The UE **105** may communicate with the CU **113** via RRC, SDAP, and PDCP layers, with the DU **112** via the RLC, MAC, and PHY layers, and with the RU **111** via the PHY layer.

[0055] As noted, while FIG. **1** depicts nodes configured to communicate according to 5G communication protocols, nodes configured to communicate according to other communication protocols, such as, for example, an LTE protocol or IEEE 802.11x protocol, may be used. For example, in an Evolved Packet System (EPS) providing LTE wireless access to the UE **105**, a RAN may comprise an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) which may comprise base stations comprising evolved Node Bs (eNBs). A core network for EPS may comprise an Evolved Packet Core (EPC). An EPS may comprise an E-UTRAN plus EPC, where the E-UTRAN corresponds to the NG-RAN **135** and the EPC corresponds to the 5GC **140** in FIG. **1**.

[0056] The gNBs **110***a*, **110***b* and the ng-eNB **114** may communicate with the AMF **115**, which, for positioning functionality, communicates with the LMF **120**. The AMF **115** may support mobility of the UE **105**, including cell change and handover and may participate in supporting a signaling connection to the UE **105** and possibly data and voice bearers for the UE **105**. The LMF **120** may communicate directly with the UE **105**, e.g., through wireless communications, or directly with the gNBs **110***a*, **110***b* and/or the ng-eNB **114**. The LMF **120** may support positioning of the UE **105** when the UE **105** accesses the NG-RAN **135** and may support position procedures/methods such as Assisted GNSS (A-GNSS), Observed Time Difference of Arrival (OTDOA) (e.g., Downlink (DL) OTDOA or Uplink (UL) OTDOA), Round Trip Time (RTT), Multi-Cell RTT, Real Time Kinematic (RTK), Precise Point Positioning (PPP), Differential GNSS (DGNSS), Enhanced Cell ID (E-CID), angle of arrival (AoA), angle of departure (AoD), and/or other position methods. The LMF **120** may process location services requests for the UE **105**, e.g., received from the AMF **115** or from the GMLC **125**. The LMF **120** may be connected to the AMF **115** and/or to the GMLC **125**. The LMF **120** may be referred to by other names such as a Location Manager (LM), Location Function (LF), commercial LMF (CLMF), or value added LMF (VLMF). A node/system that implements the LMF **120** may additionally or alternatively implement other types of location-support modules, such as an Enhanced Serving Mobile Location Center (E-SMLC) or a Secure User Plane Location (SUPL) Location Platform (SLP). At least part of the positioning functionality (including derivation of the location of the UE **105**) may be performed at the UE **105** (e.g., using signal measurements obtained by the UE **105** for signals transmitted by wireless nodes such as the gNBs **110***a*, **110***b* and/or the ng-eNB **114**, and/or assistance data provided to the UE **105**, e.g., by the LMF **120**). The AMF **115** may serve as a control node that processes signaling between the UE **105** and the 5GC **140**, and may provide QoS (Quality of Service) flow and session management. The AMF **115** may support mobility of the UE **105** including cell change and handover and may participate in supporting signaling connection to the UE **105**.

[0057] The server **150**, e.g., a cloud server, is configured to obtain and provide location estimates of the UE **105** to the external client **130**. The server **150** may, for example, be configured to run a microservice/service that obtains the location estimate of the UE **105**. The server **150** may, for example, pull the location estimate from (e.g., by sending a location request to) the UE **105**, one or more of the gNBs **110***a*, **110***b* (e.g., via the RU **111**, the DU **112**, and the CU **113**) and/or the ng-eNB **114**, and/or the LMF **120**. As another example, the UE **105**, one or more of the gNBs **110***a*, **110***b* (e.g., via the RU **111**, the DU **112**, and the CU **113**), and/or the LMF **120** may push the location estimate of the UE **105** to the server **150**.

[0058] The GMLC **125** may support a location request for the UE **105** received from the external client **130** via the server **150** and may forward such a location request to the AMF **115** for forwarding by the AMF **115** to the LMF **120** or may forward the location request directly to the LMF **120**. A location response from the LMF **120** (e.g., containing a location estimate for the UE **105**) may be returned to the GMLC **125** either directly or via the AMF **115** and the GMLC **125** may then return the location response (e.g., containing the location estimate) to the external client **130** via the server **150**. The GMLC **125** is shown connected to both the AMF **115** and LMF **120**, though may not be connected to the AMF **115** or the LMF **120** in some implementations.

[0059] As further illustrated in FIG. **1**, the LMF **120** may communicate with the gNBs **110***a*, **110***b* and/or the ng-eNB **114** using a New Radio Position Protocol A (which may be referred to as NPPa or NRPPa), which may be defined in 3GPP Technical Specification (TS) **38.455**. NRPPa may be the same as, similar to, or an extension of the LTE Positioning Protocol A (LPPa) defined in 3GPP TS 36.455, with NRPPa messages being transferred between the gNB **110***a* (or the gNB **110***b*) and the LMF **120**, and/or between the ng-eNB **114** and the LMF **120**, via the AMF **115**. As further illustrated in FIG. **1**, the LMF **120** and the UE **105** may communicate using an LTE Positioning Protocol (LPP), which may be defined in 3GPP TS 36.355. The LMF **120** and the UE **105** may also or instead communicate using a New Radio Positioning Protocol (which may be referred to as NPP or NRPP), which may be the same as, similar to, or an extension of LPP. Here, LPP and/or NPP messages may be transferred between the UE **105** and the LMF **120** via the AMF **115** and the serving gNB **110***a*, **110***b* or the serving ng-eNB **114** for the UE **105**. For example, LPP and/or NPP messages may be transferred between the LMF **120** and the AMF **115** using a 5G Location Services Application Protocol (LCS AP) and may be transferred between the AMF **115** and the UE **105** using a 5G Non-Access Stratum (NAS) protocol. The LPP and/or NPP protocol may be used to support positioning of the UE **105** using UE-assisted and/or UE-based position methods such as A-GNSS, RTK, OTDOA and/or E-CID. The NRPPa protocol may be used to support positioning of the UE **105** using network-based position methods such as E-CID (e.g., when used with measurements obtained by the gNB **110***a*, **110***b* or the ng-eNB **114**) and/or may be used by the LMF **120** to obtain location related information from the gNBs **110***a*, **110***b* and/or the ng-eNB **114**, such as parameters defining directional SS or PRS transmissions from the gNBs **110***a*, **110***b*, and/or the ng-eNB **114**. The LMF **120** may be co-located or integrated with a gNB or a TRP, or may be disposed remote from the gNB and/or the TRP and configured to communicate directly or indirectly with the gNB and/or the TRP.

[0060] With a UE-assisted position method, the UE **105** may obtain location measurements and send the measurements to a location server (e.g., the LMF **120**) for computation of a location estimate for the UE **105**. For example, the location measurements may include one or more of a Received Signal Strength Indication (RSSI), Round Trip signal propagation Time (RTT), Reference Signal Time Difference (RSTD), Reference Signal Received Power (RSRP) and/or Reference Signal Received Quality (RSRQ) for the gNBs **110***a*, **110***b*, the ng-eNB **114**, and/or a WLAN AP. The location measurements may also or instead include measurements of GNSS pseudorange, code phase, and/or carrier phase for the SVs **190**-**193**.

[0061] With a UE-based position method, the UE **105** may obtain location measurements (e.g., which may be the same as or similar to location measurements for a UE-assisted position method) and may compute a location of the UE **105** (e.g., with the help of assistance data received from a location server such as the LMF **120** or broadcast by the gNBs **110***a*, **110***b*, the ng-eNB **114**, or other base stations or APs).

[0062] With a network-based position method, one or more base stations (e.g., the gNBs **110***a*, **110***b*, and/or the ng-eNB **114**) or APs may obtain location measurements (e.g., measurements of RSSI, RTT, RSRP, RSRQ or Time of Arrival (ToA) for signals transmitted by the UE **105**) and/or may receive measurements obtained by the UE **105**. The one or more base stations or APs may send the measurements to a location server (e.g., the LMF **120**) for computation of a location estimate for the UE **105**.

[0063] Information provided by the gNBs **110***a*, **110***b*, and/or the ng-eNB **114** to the LMF **120** using NRPPa may include timing and configuration information for directional SS or PRS transmissions and location coordinates. The LMF **120** may provide some or all of this information to the UE **105** as assistance data in an LPP and/or NPP message via the NG-RAN **135** and the 5GC **140**.

[0064] An LPP or NPP message sent from the LMF **120** to the UE **105** may instruct the UE **105** to do any of a variety of things depending on desired functionality. For example, the LPP or NPP message could contain an instruction for the UE **105** to obtain measurements for GNSS (or A-GNSS), WLAN, E-CID, and/or OTDOA (or some other position method). In the case of E-CID, the LPP or NPP message may instruct the UE **105** to obtain one or more measurement quantities (e.g., beam ID, beam width, mean angle, RSRP, RSRQ measurements) of directional signals transmitted within particular cells supported by one or more of the gNBs **110***a*, **110***b*, and/or the ng-eNB **114** (or supported by some other type of base station such as an eNB or WiFi AP). The UE **105** may send the measurement quantities back to the LMF **120** in an LPP or NPP message (e.g., inside a 5G NAS message) via the serving gNB **110***a* (or the serving ng-eNB **114**) and the AMF **115**.

[0065] As noted, while the communication system **100** is described in relation to 5G technology, the communication system **100** may be implemented to support other communication technologies, such as GSM, WCDMA, LTE, etc., that are used for supporting and interacting with mobile devices such as the UE **105** (e.g., to implement voice, data, positioning, and other functionalities). In some such embodiments, the 5GC **140** may be configured to control different air interfaces. For example, the 5GC **140** may be connected to a WLAN using a Non-3GPP InterWorking Function (N3IWF, not shown FIG. **1**) in the 5GC **140**. For example, the WLAN may support IEEE 802.11 WiFi access for the UE **105** and may comprise one or more WiFi APs. Here, the N3IWF may connect to the WLAN and to other elements in the 5GC **140** such as the AMF **115**. In some embodiments, both the NG-RAN **135** and the 5GC **140** may be replaced by one or more other RANs and one or more other core networks. For example, in an EPS, the NG-RAN **135** may be replaced by an E-UTRAN containing eNBs and the 5GC **140** may be replaced by an EPC containing a Mobility Management Entity (MME) in place of the AMF **115**, an E-SMLC in place of the LMF **120**, and a GMLC that may be similar to the GMLC **125**. In such an EPS, the E-SMLC may use LPPa in place of NRPPa to send and receive location information to and from the eNBs in the E-UTRAN and may use LPP to support positioning of the UE **105**. In these other embodiments, positioning of the UE **105** using directional PRSs may be supported in an analogous manner to that described herein for a 5G network with the difference that functions and procedures described herein for the gNBs **110***a*, **110***b*, the ng-eNB **114**, the AMF **115**, and the LMF **120** may, in some cases, apply instead to other network elements such eNBs, WiFi APs, an MME, and an E-SMLC.

[0066] As noted, in some embodiments, positioning functionality may be implemented, at least in part, using the directional SS or PRS beams, sent by base stations (such as the gNBs **110***a*, **110***b*, and/or the ng-eNB **114**) that are within range of the UE whose position is to be determined (e.g., the UE **105** of FIG. **1**). The UE may, in some instances, use the directional SS or PRS beams from a plurality of base stations (such as the gNBs **110***a*, **110***b*, the ng-eNB **114**, etc.) to compute the UE's position.

[0067] Referring also to FIG. **2**, a UE **200** may be an example of one of the UEs **105**, **106** and may comprise a computing platform including a processor **210**, memory **211** including software (SW) **212**, one or more sensors **213**, a transceiver interface **214** for a transceiver **215** (that includes a wireless transceiver **240** and a wired transceiver **250**), a user interface **216**, a Satellite Positioning System (SPS) receiver **217**, a camera **218**, and a position device (PD) **219**. The processor **210**, the memory **211**, the sensor(s) **213**, the transceiver interface **214**, the user interface **216**, the SPS receiver **217**, the camera **218**, and the position device **219** may be communicatively coupled to each other by a bus **220** (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., the camera **218**, the position device **219**, and/or one or more of the sensor(s) **213**, etc.) may be omitted from the UE **200**. The processor **210** may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor **210** may comprise multiple processors including a general-purpose/application processor **230**, a Digital Signal Processor (DSP) **231**, a modem processor **232**, a video processor **233**, and/or a sensor processor **234**. One or more of the processors **230-234** may comprise multiple devices (e.g., multiple processors). For example, the sensor processor **234** may comprise, e.g., processors for RF (radio frequency) sensing (with one or more (cellular) wireless signals transmitted and reflection(s) used to identify, map, and/or track an object), and/or ultrasound, etc. The modem processor **232** may support dual SIM/dual connectivity (or even more SIMs). For example, a SIM (Subscriber Identity Module or Subscriber Identification Module) may be used by an Original Equipment Manufacturer (OEM), and another SIM may be used by an end user of the UE **200** for connectivity. The memory **211** may be a non-transitory storage medium that may include random access memory (RAM), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory **211** may store the software **212** which may be processor-readable, processor-executable software code containing instructions that may be configured to, when executed, cause the processor **210** to perform various functions described herein. Alternatively, the software **212** may not be directly executable by the processor **210** but may be configured to cause the processor **210**, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor **210** performing a function, but this includes other implementations such as where the processor **210** executes software and/or firmware. The description herein may refer to the processor **210** performing a function as shorthand for one or more of the processors **230-234** performing the function. The description herein may refer to the UE **200** performing a function as shorthand for one or more appropriate components of the UE **200** performing the function. The processor **210** may include a memory with stored instructions in addition to and/or instead of the memory **211**. Functionality of the processor **210** is discussed more fully below.

[0068] The configuration of the UE **200** shown in FIG. **2** is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, an example configuration of the UE may include one or more of the processors **230-234** of the processor **210**, the memory **211**, and the wireless transceiver **240**. Other example configurations may include one or more of the processors **230-234** of the processor **210**, the memory **211**, a wireless transceiver, and one or more of the sensor(s) **213**, the user interface **216**, the SPS receiver **217**, the camera **218**, the PD **219**, and/or a wired transceiver.

[0069] The UE **200** may comprise the modem processor **232** that may be capable of performing baseband processing of signals received and down-converted by the transceiver **215** and/or the SPS receiver **217**. The modem processor **232** may perform baseband processing of signals to be upconverted for transmission by the transceiver **215**. Also or alternatively, baseband processing may be performed by the general-purpose/application processor **230** and/or the DSP **231**. Other configurations, however, may be used to perform baseband processing.

[0070] The UE **200** may include the sensor(s) **213** that may include, for example, one or more of various types of sensors such as one or more inertial sensors, one or more magnetometers, one or more environment sensors, one or more optical sensors, one or more weight sensors, and/or one or more radio frequency (RF) sensors, etc. An inertial measurement unit (IMU) may comprise, for example, one or more accelerometers (e.g., collectively responding to acceleration of the UE **200** in three dimensions) and/or one or more gyroscopes (e.g., three-dimensional gyroscope(s)). The sensor(s) **213** may include one or more magnetometers (e.g., three-dimensional magnetometer(s)) to determine orientation (e.g., relative to magnetic north and/or true north) that may be used for any of a variety of purposes, e.g., to support one or more compass applications. The environment sensor(s) may comprise, for example, one or more temperature sensors, one or more barometric pressure sensors, one or more ambient light sensors, one or more camera imagers, and/or one or more microphones, etc. The sensor(s) **213** may generate analog and/or digital signals indications of which may be stored in the memory **211** and processed by the DSP **231** and/or the general-purpose/application processor **230** in support of one or more applications such as, for example, applications directed to positioning and/or navigation operations.

[0071] The sensor(s) **213** may be used in relative location measurements, relative location determination, motion determination, etc. Information detected by the sensor(s) **213** may be used for motion detection, relative displacement, dead reckoning, sensor-based location determination, and/or sensor-assisted location determination. The sensor(s) **213** may be useful to determine whether the UE **200** is fixed (stationary) or mobile and/or whether to report certain useful information to the LMF **120** regarding the mobility of the UE **200**. For example, based on the information obtained/measured by the sensor(s) **213**, the UE **200** may notify/report to the LMF **120** that the UE **200** has detected movements or that the UE **200** has moved, and may report the relative displacement/distance (e.g., via dead reckoning, or sensor-based location determination, or sensor-assisted location determination enabled by the sensor(s) **213**). In another example, for relative positioning information, the sensors/IMU may be used to determine the angle and/or orientation of the other device with respect to the UE **200**, etc.

[0072] The IMU may be configured to provide measurements about a direction of motion and/or a speed of motion of the UE **200**, which may be used in relative location determination. For example, one or more accelerometers and/or one or more gyroscopes of the IMU may detect, respectively, a linear acceleration and a speed of rotation of the UE **200**. The linear acceleration and speed of rotation measurements of the UE **200** may be integrated over time to determine an instantaneous direction of motion as well as a displacement of the UE **200**. The instantaneous direction of motion and the displacement may be integrated to track a location of the UE **200**. For example, a reference location of the UE **200** may be determined, e.g., using the SPS receiver **217** (and/or by some other means) for a moment in time and measurements from the accelerometer(s) and gyroscope(s) taken after this moment in time may be used in dead reckoning to determine present location of the UE **200** based on movement (direction and distance) of the UE **200** relative to the reference location.

[0073] The magnetometer(s) may determine magnetic field strengths in different directions which may be used to determine orientation of the UE **200**. For example, the orientation may be used to provide a digital compass for the UE **200**. The magnetometer(s) may include a two-dimensional magnetometer configured to detect and provide indications of magnetic field strength in two orthogonal dimensions. The magnetometer(s) may include a three-dimensional magnetometer configured to detect and provide indications of magnetic field strength in three orthogonal dimensions. The magnetometer(s) may provide means for sensing a magnetic field and providing indications of the magnetic field, e.g., to the processor **210**.

[0074] The transceiver **215** may include a wireless transceiver **240** and a wired transceiver **250** configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver **240** may include a wireless transmitter **242** and a wireless receiver **244** coupled to an antenna **246** for transmitting (e.g., on one or more uplink channels and/or one or more sidelink channels) and/or receiving (e.g., on one or more downlink channels and/or one or more sidelink channels) wireless signals **248** and transducing signals from the wireless signals **248** to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals **248**. The wireless transmitter **242** includes appropriate components (e.g., a power amplifier and a digital-to-analog converter). The wireless receiver **244** includes appropriate components (e.g., one or more amplifiers, one or more frequency filters, and an analog-to-digital converter). The wireless transmitter **242** may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver **244** may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver **240** may be configured to communicate signals (e.g., with TRPs and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. New Radio may use mm-wave frequencies and/or sub-6 GHz frequencies. The wired transceiver **250** may include a wired transmitter **252** and a wired receiver **254** configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN **135** to send communications to, and receive communications from, the NG-RAN **135**. The wired transmitter **252** may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver **254** may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver **250** may be configured, e.g., for optical communication and/or electrical communication. The transceiver **215** may be communicatively coupled to the transceiver interface **214**, e.g., by optical and/or electrical connection. The transceiver interface **214** may be at least partially integrated with the transceiver **215**. The wireless transmitter **242**, the wireless receiver **244**, and/or the antenna **246** may include multiple transmitters, multiple receivers, and/or multiple antennas, respectively, for sending and/or receiving, respectively, appropriate signals.

[0075] The user interface **216** may comprise one or more of several devices such as, for example, a speaker, microphone, display device, vibration device, keyboard, touch screen, etc. The user interface **216** may include more than one of any of these devices. The user interface **216** may be configured to enable a user to interact with one or more applications hosted by the UE **200**. For example, the user interface **216** may store indications of analog and/or digital signals in the memory **211** to be processed by DSP **231** and/or the general-purpose/application processor **230** in response to action from a user. Similarly, applications hosted on the UE **200** may store indications of analog and/or digital signals in the memory **211** to present an output signal to a user. The user interface **216** may include an audio input/output (I/O) device comprising, for example, a speaker, a microphone, digital-to-analog circuitry, analog-to-digital circuitry, an amplifier and/or gain control circuitry (including more than one of any of these devices). Other configurations of an audio I/O device may be used. Also or alternatively, the user interface **216** may comprise one or more touch sensors responsive to touching and/or pressure, e.g., on a keyboard and/or touch screen of the user interface **216**.

[0076] The SPS receiver **217** (e.g., a Global Positioning System (GPS) receiver) may be capable of receiving and acquiring SPS signals **260** via an SPS antenna **262**. The SPS antenna **262** is configured to transduce the SPS signals **260** from wireless signals to wired signals, e.g., electrical or optical signals, and may be integrated with the antenna **246**. The SPS receiver **217** may be configured to process, in whole or in part, the acquired SPS signals **260** for estimating a location of the UE **200**. For example, the SPS receiver **217** may be configured to determine location of the UE **200** by trilateration using the SPS signals **260**. The general-purpose/

application processor **230**, the memory **211**, the DSP **231** and/or one or more specialized processors (not shown) may be utilized to process acquired SPS signals, in whole or in part, and/or to calculate an estimated location of the UE **200**, in conjunction with the SPS receiver **217**. The memory **211** may store indications (e.g., measurements) of the SPS signals **260** and/or other signals (e.g., signals acquired from the wireless transceiver **240**) for use in performing positioning operations. The general-purpose/application processor **230**, the DSP **231**, and/or one or more specialized processors, and/or the memory **211** may provide or support a location engine for use in processing measurements to estimate a location of the UE **200**.

[0077] The UE **200** may include the camera **218** for capturing still or moving imagery. The camera **218** may comprise, for example, an imaging sensor (e.g., a charge coupled device or a CMOS (Complementary Metal-Oxide Semiconductor) imager), a lens, analog-to-digital circuitry, frame buffers, etc. Additional processing, conditioning, encoding, and/or compression of signals representing captured images may be performed by the general-purpose/application processor **230** and/or the DSP **231**. Also or alternatively, the video processor **233** may perform conditioning, encoding, compression, and/or manipulation of signals representing captured images. The video processor **233** may decode/decompress stored image data for presentation on a display device (not shown), e.g., of the user interface **216**.

[0078] The position device (PD) **219** may be configured to determine a position of the UE **200**, motion of the UE **200**, and/or relative position of the UE **200**, and/or time. For example, the PD **219** may communicate with, and/or include some or all of, the SPS receiver **217**. The PD **219** may work in conjunction with the processor **210** and the memory **211** as appropriate to perform at least a portion of one or more positioning methods, although the description herein may refer to the PD **219** being configured to perform, or performing, in accordance with the positioning method(s). The PD **219** may also or alternatively be configured to determine location of the UE **200** using terrestrial-based signals (e.g., at least some of the wireless signals **248**) for trilateration, for assistance with obtaining and using the SPS signals **260**, or both. The PD **219** may be configured to determine location of the UE **200** based on a cell of a serving base station (e.g., a cell center) and/or another technique such as E-CID. The PD **219** may be configured to use one or more images from the camera **218** and image recognition combined with known locations of landmarks (e.g., natural landmarks such as mountains and/or artificial landmarks such as buildings, bridges, streets, etc.) to determine location of the UE **200**. The PD **219** may be configured to use one or more other techniques (e.g., relying on the UE's self-reported location (e.g., part of the UE's position beacon)) for determining the location of the UE **200**, and may use a combination of techniques (e.g., SPS and terrestrial positioning signals) to determine the location of the UE **200**. The PD **219** may include one or more of the sensors **213** (e.g., gyroscope(s), accelerometer(s), magnetometer(s), etc.) that may sense orientation and/or motion of the UE **200** and provide indications thereof that the processor **210** (e.g., the general-purpose/application processor **230** and/or the DSP **231**) may be configured to use to determine motion (e.g., a velocity vector and/or an acceleration vector) of the UE **200**. The PD **219** may be configured to provide indications of uncertainty and/or error in the determined position and/or motion. Functionality of the PD **219** may be provided in a variety of manners and/or configurations, e.g., by the general-purpose/application processor **230**, the transceiver **215**, the SPS receiver **217**, and/or another component of the UE **200**, and may be provided by hardware, software, firmware, or various combinations thereof.

[0079] Referring also to FIG. **3**, an example of a TRP **300** of the gNBs **110***a*, **110***b* and/or the ng-eNB **114** comprises a computing platform including a processor **310**, memory **311** including software (SW) **312**, and a transceiver **315**. The processor **310**, the memory **311**, and the transceiver **315** may be communicatively coupled to each other by a bus **320** (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., a wireless transceiver) may be omitted from the TRP **300**. The processor **310** may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor **310** may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. **2**). The memory **311** may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory **311** may store the software **312** which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor **310** to perform various functions described herein. Alternatively, the software **312** may not be directly executable by the processor **310** but may be configured to cause the processor **310**, e.g., when compiled and executed, to perform the functions.

[0080] The description herein may refer to the processor **310** performing a function, but this includes other implementations such as where the processor **310** executes software and/or firmware. The description herein may refer to the processor **310** performing a function as shorthand for one or more of the processors contained in the processor **310** performing the function. The description herein may refer to the TRP **300** performing a function as shorthand for one or more appropriate components (e.g., the processor **310** and the memory **311**) of the TRP **300** (and thus of one of the gNBs **110***a*, **110***b* and/or the ng-eNB **114**) performing the function. The processor **310** may include a memory with stored instructions in addition to and/or instead of the memory **311**. Functionality of the processor **310** is discussed more fully below.

[0081] The transceiver **315** may include a wireless transceiver **340** and/or a wired transceiver **350** configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver **340** may include a wireless transmitter **342** and a wireless receiver **344** coupled to one or more antennas **346** for transmitting (e.g., on one or more uplink channels and/or one or more downlink channels) and/or receiving (e.g., on one or more downlink channels and/or one or more uplink channels) wireless signals **348** and transducing signals from the wireless signals **348** to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals **348**. Thus, the wireless transmitter **342** may include multiple transmitters that may be discrete components or combined/

integrated components, and/or the wireless receiver **344** may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver **340** may be configured to communicate signals (e.g., with the UE **200**, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5GNew Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. The wired transceiver **350** may include a wired transmitter **352** and a wired receiver **354** configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN **135** to send communications to, and receive communications from, the LMF **120**, for example, and/or one or more other network entities. The wired transmitter **352** may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver **354** may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver **350** may be configured, e.g., for optical communication and/or electrical communication.

[0082] The configuration of the TRP **300** shown in FIG. **3** is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the description herein discusses that the TRP **300** may be configured to perform or performs several functions, but one or more of these functions may be performed by the LMF **120** and/or the UE **200** (i.e., the LMF **120** and/or the UE **200** may be configured to perform one or more of these functions).

[0083] Referring also to FIG. **4**, a server **400**, of which the LMF **120** may be an example, may comprise a computing platform including a processor **410**, memory **411** including software (SW) **412**, and a transceiver **415**. The processor **410**, the memory **411**, and the transceiver **415** may be communicatively coupled to each other by a bus **420** (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., a wireless transceiver) may be omitted from the server **400**. The processor **410** may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor **410** may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. **2**). The memory **411** may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory **411** may store the software **412** which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor **410** to perform various functions described herein. Alternatively, the software **412** may not be directly executable by the processor **410** but may be configured to cause the processor **410**, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor **410** performing a function, but this includes other implementations such as where the processor **410** executes software and/or firmware. The description herein may refer to the processor **410** performing a function as shorthand for one or more of the processors contained in the processor **410** performing the function. The description herein may refer to the server **400** performing a function as shorthand for one or more appropriate components of the server **400** performing the function. The processor **410** may include a memory with stored instructions in addition to and/or instead of the memory **411**. Functionality of the processor **410** is discussed more fully below.

[0084] The transceiver **415** may include a wireless transceiver **440** and/or a wired transceiver **450** configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver **440** may include a wireless transmitter **442** and a wireless receiver **444** coupled to one or more antennas **446** for transmitting (e.g., on one or more downlink channels) and/or receiving (e.g., on one or more uplink channels) wireless signals **448** and transducing signals from the wireless signals **448** to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals **448**. Thus, the wireless transmitter **442** may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver **444** may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver **440** may be configured to communicate signals (e.g., with the UE **200**, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. The wired transceiver **450** may include a wired transmitter **452** and a wired receiver **454** configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN **135** to send communications to, and receive communications from, the TRP **300**, for example, and/or one or more other network entities. The wired transmitter **452** may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver **454** may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver **450** may be configured, e.g., for optical communication and/or electrical communication.

[0085] The description herein may refer to the processor **410** performing a function, but this includes other implementations such as where the processor **410** executes software (stored in the memory **411**) and/or firmware. The description herein may refer to the server **400** performing a function as shorthand for one or more appropriate components (e.g., the processor **410** and the memory **411**) of the server **400** performing the function.

[0086] The configuration of the server **400** shown in FIG. **4** is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the wireless transceiver **440** may be omitted. Also or alternatively, the description herein discusses that the server **400** is configured to perform or performs several functions, but one or more of these functions may be performed by the TRP **300** and/or the UE **200** (i.e., the TRP **300** and/or the UE **200** may be configured to perform one or more of these functions).

Positioning Techniques

[0087] For terrestrial positioning of a UE in cellular networks, techniques such as Advanced Forward Link Trilateration (AFLT) and Observed Time Difference Of Arrival (OTDOA) often operate in "UE-assisted" mode in which measurements of reference signals (e.g., PRS, CRS, etc.) transmitted by base stations are taken by the UE and then provided to a location server. The location server then calculates the position of the UE based on the measurements and known locations of the base stations. Because these techniques use the location server to calculate the position of the UE, rather than the UE itself, these positioning techniques are not frequently used in applications such as car or cell-phone navigation, which instead typically rely on satellite-based positioning.

[0088] A UE may use a Satellite Positioning System (SPS) (a Global Navigation Satellite System (GNSS)) for high-accuracy positioning using precise point positioning (PPP) or real time kinematic (RTK) technology. These technologies use assistance data such as measurements from ground-based stations. LTE Release 15 allows the data to be encrypted so that the UEs subscribed to the service exclusively can read the information. Such assistance data varies with time. Thus, a UE subscribed to the service may not easily "break encryption" for other UEs by passing on the data to other UEs that have not paid for the subscription. The passing on would need to be repeated every time the assistance data changes.

[0089] In UE-assisted positioning, the UE sends measurements (e.g., TDOA, Angle of Arrival (AoA), etc.) to the positioning server (e.g., LMF/eSMLC). The positioning server has the base station almanac (BSA) that contains multiple 'entries' or 'records', one record per cell, where each record contains geographical cell location but also may include other data. An identifier of the 'record' among the multiple 'records' in the BSA may be referenced. The BSA and the measurements from the UE may be used to compute the position of the UE.

[0090] In conventional UE-based positioning, a UE computes its own position, thus avoiding sending measurements to the network (e.g., location server), which in turn improves latency and scalability. The UE uses relevant BSA record information (e.g., locations of gNBs (more broadly base stations)) from the network. The BSA information may be encrypted. But since the BSA information varies much less often than, for example, the PPP or RTK assistance data described earlier, it may be easier to make the BSA information (compared to the PPP or RTK information) available to UEs that did not subscribe and pay for decryption keys. Transmissions of reference signals by the gNBs make BSA information potentially accessible to crowd-sourcing or war-driving, essentially enabling BSA information to be generated based on in-the-field and/or over-the-top observations.

[0091] Positioning techniques may be characterized and/or assessed based on one or more criteria such as position determination accuracy and/or latency. Latency is a time elapsed between an event that triggers determination of position-related data and the availability of that data at a positioning system interface, e.g., an interface of the LMF **120**. At initialization of a positioning system, the latency for the availability of position-related data is called time to first fix (TTFF), and is larger than latencies after the TTFF. An inverse of a time elapsed between two consecutive position-related data availabilities is called an update rate, i.e., the rate at which position-related data are generated after the first fix. Latency may depend on processing capability, e.g., of the UE. For example, a UE may report a processing capability of the UE as a duration of DL PRS symbols in units of time (e.g., milliseconds) that the UE can process every T amount of time (e.g., T ms) assuming 272 PRB (Physical Resource Block) allocation. Other examples of capabilities that may affect latency are a number of TRPs from which the UE can process PRS, a number of PRS that the UE can process, and a bandwidth of the UE.

[0092] One or more of many different positioning techniques (also called positioning methods) may be used to determine position of an entity such as one of the UEs **105**, **106**. For example, known position-determination techniques include RTT, multi-RTT, OTDOA (also called TDOA and including UL-TDOA and DL-TDOA), Enhanced Cell Identification (E-CID), DL-AoD, UL-AoA, etc. RTT uses a time for a signal to travel from one entity to another and back to determine a range between the two entities. The range, plus a known location of a first one of the entities and an angle between the two entities (e.g., an azimuth angle) can be used to determine a location of the second of the entities. In multi-RTT (also called multi-cell RTT), multiple ranges from one entity (e.g., a UE) to other entities (e.g., TRPs) and known locations of the other entities may be used to determine the location of the one entity. In TDOA techniques, the difference in travel times between one entity and other entities may be used to determine relative ranges from the other entities and those, combined with known locations of the other entities may be used to determine the location of the one entity. Angles of arrival and/or departure may be used to help determine location of an entity. For example, an angle of arrival or an angle of departure of a signal combined with a range between devices (determined using signal, e.g., a travel time of the signal, a received power of the signal, etc.) and a known location of one of the devices may be used to determine a location of the other device. The angle of arrival or departure may be an azimuth angle relative to a reference direction such as true north. The angle of arrival or departure may be a zenith angle relative to directly upward from an entity (i.e., relative to radially outward from a center of Earth). E-CID uses the identity of a serving cell, the timing advance (i.e., the difference between receive and transmit times at the UE), estimated timing and power of detected neighbor cell signals, and possibly angle of arrival (e.g., of a signal at the UE from the base station or vice versa) to determine location of the UE. In TDOA, the difference in arrival times at a receiving device of signals from different sources along with known locations of the sources and known offset of transmission times from the sources are used to determine the location of the receiving device.

[0093] In a network-centric RTT estimation, the serving base station instructs the UE to scan for/receive RTT measurement signals (e.g., PRS) on serving cells of two or more neighboring base stations (and typically the serving base station, as at least three base stations are needed). The one of more base stations transmit RTT measurement signals on low reuse resources (e.g., resources used by the base station to transmit system information) allocated by the network (e.g., a location server such as the LMF **120**). The UE records the arrival time (also referred to as a receive time, a reception time, a time of reception, or a time of arrival (ToA)) of each RTT measurement signal relative to the UE's current downlink timing (e.g., as derived by the UE from a DL signal received from its serving base station), and transmits a common or individual RTT response message (e.g., SRS (sounding reference signal) for positioning, i.e., UL-PRS) to the one or more base stations (e.g., when instructed by its serving base station) and may include the time difference $T_{Rx\rightarrow Tx}$ (i.e., UE T_{Rx-Tx} or UE_{Rx-Tx}) between the ToA of the RTT measurement signal and the transmission time of the RTT response message in a payload of each RTT response message. The RTT response message would include a reference signal from which the base station can deduce the ToA of the RTT response. By comparing the difference $T_{Tx\rightarrow Rx}$ between the transmission time of the RTT measurement signal from the base station and the ToA of the RTT response at the base station to the UE-reported time difference $T_{Rx\rightarrow Tx}$, the base station can deduce the propagation time between the base station and the UE, from which the base station can determine the distance between the UE and the base station by assuming the speed of light during this propagation time.

[0094] A UE-centric RTT estimation is similar to the network-based method, except that the UE transmits uplink RTT measurement signal(s) (e.g., when instructed by a serving base station), which are received by multiple base stations in the neighborhood of the UE. Each involved base station responds with a downlink RTT response message, which may include the time difference between the ToA of the RTT measurement signal at the base station and the transmission time of the RTT response message from the base station in the RTT response message payload.

[0095] For both network-centric and UE-centric procedures, the side (network or UE) that performs the RTT calculation typically (though not always) transmits the first message(s) or signal(s) (e.g., RTT measurement signal(s)), while the other side responds with one or more RTT response message(s) or signal(s) that may include the difference between the ToA of the first message(s) or signal(s) and the transmission time of the RTT response message(s) or signal(s).

[0096] A multi-RTT technique may be used to determine position. For example, a first entity (e.g., a UE) may send out one or more signals (e.g., unicast, multicast, or broadcast from the base station) and multiple second entities (e.g., other TSPs such as base station(s) and/or UE(s)) may receive a signal from the first entity and respond to this received signal. The first entity receives the responses from the multiple second entities. The first entity (or another entity such as an LMF) may use the responses from the second entities to determine ranges to the second entities and may use the multiple ranges and known locations of the second entities to determine the location of the first entity by trilateration.

[0097] In some instances, additional information may be obtained in the form of an angle of arrival (AoA) or angle of departure (AoD) that defines a straight-line direction (e.g., which may be in a horizontal plane or in three dimensions) or possibly a range of directions (e.g., for the UE from the locations of base stations). The intersection of two directions can provide another estimate of the location for the UE.

[0098] For positioning techniques using PRS (Positioning Reference Signal) signals (e.g., TDOA and RTT), PRS signals sent by multiple TRPs are measured and the arrival times of the signals, known transmission times, and known locations of the TRPs used to determine ranges from a UE to the TRPs. For example, an RSTD (Reference Signal Time Difference) may be determined for PRS signals received from multiple TRPs and used in a TDOA technique to determine position (location) of the UE. A positioning reference signal may be referred to as a PRS or a PRS signal. The PRS signals are typically sent using the same power and PRS signals with the same signal characteristics (e.g., same frequency shift) may interfere with each other such that a PRS signal from a more distant TRP may be overwhelmed by a PRS signal from a closer TRP such that the signal from the more distant TRP may not be detected. PRS muting may be used to help reduce interference by muting some PRS signals (reducing the power of the PRS signal, e.g., to zero and thus not transmitting the PRS signal). In this way, a weaker (at the UE) PRS signal may be more easily detected by the UE without a stronger PRS signal interfering with the weaker PRS signal. The term RS, and variations thereof (e.g., PRS, SRS, CSI-RS (Channel State Information—Reference Signal)), may refer to one reference signal or more than one reference signal.

[0099] Positioning reference signals (PRS) include downlink PRS (DL PRS, often referred to simply as PRS) and uplink PRS (UL PRS) (which may be called SRS (Sounding Reference Signal) for positioning). A PRS may comprise a PN code (pseudorandom number code) or be generated using a PN code (e.g., by modulating a carrier signal with the PN code) such that a source of the PRS may serve as a pseudo-satellite (a pseudolite). The PN code may be unique to the PRS source (at least within a specified area such that identical PRS from different PRS sources do not overlap). PRS may comprise PRS resources and/or PRS resource sets of a frequency layer. A DL PRS positioning frequency layer (or simply a frequency layer) is a collection of DL PRS resource sets, from one or more TRPs, with PRS resource(s) that have common parameters configured by higher-layer parameters DL-PRS-PositioningFrequencyLayer, DL-PRS-ResourceSet, and DL-PRS-Resource. Each frequency layer has a DL PRS subcarrier spacing (SCS) for the DL PRS resource sets and the DL PRS resources in the frequency layer. Each frequency layer has a DL PRS cyclic prefix (CP) for the DL PRS resource sets and the DL PRS resources in the frequency layer. In 5G, a resource block occupies **12** consecutive subcarriers and a specified number of symbols. Common resource blocks are the set of resource blocks that occupy a channel bandwidth. A bandwidth part (BWP) is a set of contiguous common resource blocks and may include all the common resource blocks within a channel bandwidth or a subset of the common resource blocks. Also, a DL PRS Point A parameter defines a frequency of a reference resource block (and the lowest subcarrier of the resource block), with DL PRS resources belonging to the same DL PRS resource set having the same Point A and all DL PRS resource sets belonging to the same frequency layer having the same Point A. A frequency layer also has the same DL PRS bandwidth, the same start PRB (and center frequency), and the same value of comb size (i.e., a frequency of PRS resource elements per symbol such that for comb-N, every N^{th} resource element is a PRS resource element). A PRS resource set is identified by a PRS resource set ID and may be associated with a particular TRP (identified by a cell ID) transmitted by an antenna panel of a base station. A PRS resource ID in a PRS resource set may be associated with an omnidirectional signal, and/or with a single beam (and/or beam ID) transmitted from a single base station (where a base station may transmit one or more beams). Each PRS resource of a PRS resource set may be transmitted on a different beam and as such, a PRS resource (or simply resource) can also be referred to as a beam. This does not have any implications on whether the base stations and the beams on which PRS are transmitted are known to the UE.

[0100] A TRP may be configured, e.g., by instructions received from a server and/or by software in the TRP, to send DL PRS per a schedule. According to the schedule, the TRP may send the DL PRS intermittently, e.g., periodically at a consistent interval from an initial transmission. The TRP may be configured to send one or more PRS resource sets. A resource set is a collection of PRS resources across one TRP, with the resources having the same periodicity, a common muting pattern configuration (if any), and the same repetition factor across slots. Each of the PRS resource sets comprises multiple PRS resources, with each PRS resource comprising multiple OFDM (Orthogonal Frequency Division Multiplexing) Resource Elements (REs) that may be in multiple Resource Blocks (RBs) within N (one or more) consecutive symbol(s) within a slot. PRS resources (or reference signal (RS) resources generally) may be referred to as OFDM PRS resources (or OFDM RS resources). An RB is a collection of REs spanning a quantity of one or more consecutive symbols in the time domain and a quantity (12 for a 5G RB) of consecutive sub-carriers in the frequency domain. Each PRS resource is configured with an RE offset, slot offset, a symbol offset within a slot, and a number of consecutive symbols that the PRS resource may occupy within a slot. The RE offset defines the starting RE offset of the first symbol within a DL PRS resource in frequency. The relative RE offsets of the remaining symbols within a DL PRS resource are defined based on the initial offset. The slot offset is the starting slot of the DL PRS resource with respect to a corresponding resource set slot offset. The symbol offset determines the starting symbol of the DL PRS resource within the starting slot. Transmitted REs may repeat across slots, with each transmission being called a repetition such that there may be multiple repetitions in a PRS resource. The DL PRS resources in a DL PRS resource set are associated with the same TRP and each DL PRS resource has a DL PRS resource ID. A DL PRS resource ID in a DL PRS resource set is associated with a single beam transmitted from a single TRP (although a TRP may transmit one or more beams).

[0101] A PRS resource may also be defined by quasi-co-location and start PRB parameters. A quasi-co-location (QCL) parameter may define any quasi-co-location information of the DL PRS resource with other reference signals. The DL PRS may be configured to be QCL type D with a DL PRS or SS/PBCH (Synchronization Signal/Physical Broadcast Channel) Block from a serving cell or a non-serving cell. The DL PRS may be configured to be QCL type C with an SS/PBCH Block from a serving cell or a non-serving cell. The start PRB parameter defines the starting PRB index of the DL PRS resource with respect to reference Point A. The starting PRB index has a granularity of one PRB and may have a minimum value of 0 and a maximum value of 2176 PRBs.

[0102] A PRS resource set is a collection of PRS resources with the same periodicity, same muting pattern configuration (if any), and the same repetition factor across slots. Every time all repetitions of all PRS resources of the PRS resource set are configured to be transmitted is referred as an "instance". Therefore, an "instance" of a PRS resource set is a specified number of repetitions for each PRS resource and a specified number of PRS resources within the PRS resource set such that once the specified number of repetitions are transmitted for each of the specified number of PRS resources, the instance is complete. An instance may also be referred to as an "occasion." A DL PRS configuration including a DL PRS transmission schedule may be provided to a UE to facilitate (or even enable) the UE to measure the DL PRS.

[0103] Multiple frequency layers of PRS may be aggregated to provide an effective bandwidth that is larger than any of the bandwidths of the layers individually. Multiple frequency layers of component carriers (which may be consecutive and/or separate) and meeting criteria such as being quasi co-located (QCLed), and having the same antenna port, may be stitched to provide a larger effective PRS bandwidth (for DL PRS and UL PRS) resulting in increased time of arrival measurement accuracy. Stitching comprises combining PRS measurements over individual bandwidth fragments into a unified piece such that the stitched PRS may be treated as having been taken from a single measurement. Being QCLed, the different frequency layers behave similarly, enabling stitching of the PRS to yield the larger effective bandwidth. The larger effective bandwidth, which may be referred to as the bandwidth of an aggregated PRS or the frequency bandwidth of an aggregated PRS, provides for better time-domain resolution (e.g., of TDOA). An aggregated PRS includes a collection of PRS resources and each PRS resource of an aggregated PRS may be called a PRS component, and each PRS component may be transmitted on different component carriers, bands, or frequency layers, or on different portions of the same band.

[0104] RTT positioning is an active positioning technique in that RTT uses positioning signals sent by TRPs to UEs and by UEs (that are participating in RTT positioning) to TRPs. The TRPs may send DL-PRS signals that are received by the UEs and the UEs may send SRS (Sounding Reference Signal) signals that are received by multiple TRPs. A sounding reference signal may be referred to as an SRS or an SRS signal. In 5G multi-RTT, coordinated positioning may be used with the UE sending a single UL-SRS for positioning that is received by multiple TRPs instead of sending a separate UL-SRS for positioning for each TRP. A TRP that participates in multi-RTT will typically search for UEs that are currently camped on that TRP (served UEs, with the TRP being a serving TRP) and also UEs that are camped on neighboring TRPs (neighbor UEs). Neighbor TRPs may be TRPs of a single BTS (Base Transceiver Station) (e.g., gNB), or may be a TRP of one BTS and a TRP of a separate BTS. For RTT positioning, including multi-RTT positioning, the DL-PRS signal and the UL-SRS for positioning signal in a PRS/SRS for positioning signal pair used to determine RTT (and thus used to determine range between the UE and the TRP) may occur close in time to each other such that errors due to UE motion and/or UE clock drift and/or TRP clock drift are within acceptable limits. For example, signals in a PRS/SRS for positioning signal pair may be transmitted from the TRP and the UE, respectively, within about 10 ms of each other. With SRS for positioning being sent by UEs, and with PRS and SRS for positioning being conveyed close in time to each other, it has been found that radio-frequency (RF) signal congestion may result (which may cause excessive noise, etc.) especially if many UEs attempt positioning concurrently and/or that computational congestion may result at the TRPs that are trying to measure many UEs concurrently.

[0105] RTT positioning may be UE-based or UE-assisted. In UE-based RTT, the UE **200** determines the RTT and corresponding range to each of the TRPs **300** and the position of the UE **200** based on the ranges to the TRPs **300** and known locations of the TRPs **300**. In UE-assisted RTT, the UE **200** measures positioning signals and provides measurement information to the TRP **300**, and the TRP **300** determines the RTT and range. The TRP **300** provides ranges to a location server, e.g., the server **400**, and the server determines the location of the UE **200**, e.g., based on ranges to different TRPs **300**. The RTT and/or range may be determined by the TRP **300** that received the signal(s) from the UE **200**, by this TRP **300** in combination with one or more other devices, e.g., one or more other TRPs **300** and/or the server **400**, or by one or more devices other than the TRP **300** that received the signal(s) from the UE **200**.

[0106] Various positioning techniques are supported in 5G NR. The NR native positioning methods supported in 5G NR include DL-only positioning methods, UL-only positioning methods, and DL+UL positioning methods. Downlink-based positioning methods include DL-TDOA and DL-AoD. Uplink-based positioning methods include UL-TDOA and UL-AoA. Combined DL+UL-based positioning methods include RTT with one base station and RTT with multiple base stations (multi-RTT).

[0107] A position estimate (e.g., for a UE) may be referred to by other names, such as a location estimate, location, position, position fix, fix, or the like. A position estimate may be geodetic and comprise coordinates (e.g., latitude, longitude, and possibly altitude) or may be civic and comprise a street address, postal address, or some other verbal description of a location. A position estimate may further be defined relative to some other known location or defined in absolute terms (e.g., using latitude, longitude, and possibly altitude). A position estimate may include an expected error or uncertainty (e.g., by including an area or volume within which the location is expected to be included with some specified or default level of confidence).

[0108] Referring also to FIG. **5**, a UE **500** includes a processor **510**, a transceiver **520**, and a memory **530** communicatively coupled to each other by a bus **540**. The UE **500** may include the components shown in FIG. **5**. The UE **500** may include one or more other components such as any of those shown in FIG. **2** such that the UE **200** may be an example of the UE **500**. For example, the processor **510** may include one or more of the components of the processor **210**. The transceiver **520** may include one or more of the components of the transceiver **215**, e.g., the wireless transmitter **242** and the antenna **246**, or the wireless receiver **244** and the antenna **246**, or the wireless transmitter **242**, the wireless receiver **244**, and the antenna **246**. Also or alternatively, the transceiver **520** may include the wired transmitter **252** and/or the wired receiver **254**. The memory **530** may be configured similarly to the memory **211**, e.g., including software with processor-readable instructions configured to cause the processor **510** to perform functions.

[0109] The description herein may refer to the processor **510** performing a function, but this includes other implementations such as where the processor **510** executes software (stored in the memory **530**) and/or firmware. The description herein may refer to the UE **500** performing a function as shorthand for one or more appropriate components (e.g., the processor **510** and the memory **530**) of the UE **500** performing the function. The processor **510** (possibly in conjunction with the memory **530** and, as appropriate, the transceiver **520**) may include an RS unit **550** (reference signal unit). The RS unit **550** is discussed further below, and the description may refer to the processor **510** generally, or the UE **500** generally, as performing any of the functions of the RS unit **550**. The UE **500** is configured to perform the functions of the RS unit **550** discussed herein.

[0110] Referring also to FIG. **6**, a network entity **600** includes a processor **610**, a transceiver **620**, and a memory **630** communicatively coupled to each other by a bus **640**. The network entity **600** may include the components shown in FIG. **6**. The network entity **600** may include one or more other components such as any of those shown in FIG. **3** and/or FIG. **4** such that the TRP **300** and/or the server **400** may be an example of the network entity **600**. For example, the processor **610** may include one or more of the components of the processor **310** and/or the processor **410**. The transceiver **620** may include one or more of the components of the transceiver **315** and/or the transceiver **415**. The memory **630** may be configured similarly to the memory **311** and/or the memory **411**, e.g., including software with processor-readable instructions configured to cause the processor **610** to perform functions.

[0111] The description herein may refer to the processor **610** performing a function, but this includes other implementations such as where the processor **610** executes software (stored in the memory **630**) and/or firmware. The description herein may refer to the network entity **600** performing a function as shorthand for one or more appropriate components (e.g., the processor **610** and the memory **630**) of the network entity **600** performing the function. The processor **610** (possibly in conjunction with the memory **630** and, as appropriate, the transceiver **620**) may include an SL configuration unit **650**. The SL configuration unit **650** is discussed further below, and the description may refer to the processor **610** generally, or the network entity **600** generally, as performing any of the functions of the SL configuration unit **650**. The network entity **600** is configured to perform the functions of the SL configuration unit **650** discussed herein.

[0112] Referring also to FIG. **7**, multiple UEs **711**, **712**, **713**, **714** (e.g., examples of the UE **500**) may transmit and/or receive positioning signals and/or data signals with each other through sidelink (SL) connections **721**, **722**, **723**, **724**, **725**, **726** assisted by one or more TRPs **731**, **732**, **733** (e.g., examples of the TRP **300**) connected to a server **740** (e.g., an example of the server **400**). Network-assisted sidelink operation as shown in FIG. **7** is referred to as mode **1**. In mode **1**, for each of the UEs **711-714**, PRS resources are scheduled, or at least some PRS configuration parameters provided by, a respective serving TRP (which may be the same TRP for multiple UEs). For positioning, the server **740** coordinates PRS deployment across the TRPs **731-733** and the UEs **711-714**, configuring resource pools and configuring SL-PRS resource sets for each UE. Each resource pool defines available OFDM (orthogonal frequency division multiplexing) resources (e.g., specifying slots, resource blocks, and resource elements) for either sidelink transmission or sidelink reception. The resource pool provides a time/frequency opportunity for UEs to transmit or receive signals in sidelink. For UE-based positioning, the UE **711** may use sidelink and Uu measurements (e.g., measurements of signals transferred between the UE **711** and the TRP **731**) to compute a position estimate for the UE **711**. The server **740** may provide the UE **711** with one or more measurements from one or more of the UEs **712-714**. For UE-assisted positioning, the server **740** may compute a position estimate for the UE **711** using sidelink measurements and Uu measurements reported to the server **740**.

[0113] Referring also to FIG. **8**, multiple UEs **811**, **812**, **813**, **814**, **815**, **816**, **817**, **818** (e.g., examples of the UE **500**) may transmit and/or receive positioning signals and/or data signals with each other through sidelink (SL) connections without assistance from any TRPs in an operational mode commonly referred to as mode **2**. In mode **2**, based on a configured resource pool of OFDM resources (e.g., as indicated by one or more layers of the UEs **811-818** above the physical layer), and based on channel sensing using a control signal (e.g., SCI-1 (sidelink control information-1), the UEs **811-818** may choose some resources from the pool to use for SL-PRS transmission. The UEs **811-818** may broadcast SL-PRS assistance data using one or more SL data channels. Each of the UEs **811-818** may perform measurements and distribute information (e.g., RTT delay within the UE) to nearby UEs. Each of the UEs **811-814** may compute a position estimate based on SL-PRS measurements made by that UE and based on indications, received by the UE, of measurements made by other UEs. The UEs **815-818** in this example are roadside units (RSUs) that may be stationary with well-known locations to facilitate determination of position estimates for the UEs **811-814**.

[0114] Resource pools presently exist for data communications, but not for positioning. In the data communication resource pools, each slot contains control information, e.g., for locating and decoding data. Control information in the PSCCH (physical sidelink control channel) can schedule data in the PSSCH (physical sidelink shared channel) and manage channel sensing within the resource pool. All the control data for operating the resource pool is contained within the resource pool. Techniques are discussed herein for an alternative approach, using control information in a first resource pool to schedule one or more resources in a second resource pool, e.g., a resource pool with a larger bandwidth than the first resource pool. The second resource pool may be dedicated to a particular purpose, e.g., for reference signals such as positioning reference signals.

[0115] Referring also to FIG. **9**, which shows various SL configuration items that the network entity **600**, e.g., the SL configuration unit **650**, is configured to establish and disseminate. For example, the SL configuration unit **650** can establish data resource pool configurations **910** and reference signal resource pool configurations **920**. The reference signal resource pool configurations **920** may be dedicated for transmitting and receiving reference signals such as PRS such that all or nearly all of the bandwidth of a reference signal (RS) resource pool (RP) is reserved for transfer of reference signals. Some amount of an RS RP may be reserved or used for another purpose, e.g., control information such as dynamic control information, and may be reserved intermittently, for less than all transmissions on the RS RP (e.g., such that 10%, or 20%, or another percentage, of slots containing an RS using the RS RP also contain control information). As indicated in blocks **930**, **940**, the data resource pool configurations **910** and the reference signal resource pool configurations **920** may include separate configurations for transmit (Tx) resource pools for mode **1**, Tx resource pools for mode **2**, and receive (Rx) resource pools. As indicated by block **950**, each of the data resource pool configurations **910** may indicate PSCCH, PSSCH, and PSFCH (physical sidelink feedback channel) configurations, a number of subchannels, subchannel size, a start resource block (RB), and a channel sensing configuration. As indicated by block **960**, each of the reference signal resource pool configurations **920** may indicate one or more SL-RS configurations (including a number of symbols, comb type, comb-offset, a number of subchannels, subchannel size, and a start RB), and a CBR.

[0116] Referring to FIG. **10**, with further reference to FIGS. **1-9**, a timing diagram shows a signaling and process flow **1000** that includes the stages shown. The flow **1000** is for obtaining and using coupled resource pools to transmit and receive signals, and determining position information based on measured reference signals. Other flows are possible, e.g., with one or more stages shown omitted, one or more stages added, and/or one or more stages shown altered. For example, sub-stage **1013** may be omitted, e.g., for mode **2** sidelink operation. As another example, stages **1030**, **1040**, **1050** may be omitted if PRS are not transmitted and measured at stage **1020**, e.g., one or more other types of reference signals are transmitted and measured instead of PRS. Still other alterations of the flow **1000** may be implemented.

[0117] At stage **1010**, UEs **1001**, **1002** (which are examples of the UE **500**) obtain SL configurations. For example, at sub-stages **1011**, **1012**, each of the UEs **1001**, **1002** retrieve SL configurations, e.g., of SL resource pools, from the memory **530** of the respective UE **1001**, **1002** for mode **2** operation (or as default configurations for mode **1** operation that may be replaced by configurations provided by the network entity **600**). In particular, the RS unit **550** of each of the UEs **1001**, **1002** may retrieve coupled resource pools designated for helping with RS transfer, e.g., PRS transfer for use in determining position estimates of UEs. One or more resource pools may be designated for control information and/or data, and one or more resource pools may be designated for reference signals. For example, a first resource pool, RP-1, may carry control information and/or data (e.g., communication, measurement reports, etc.), e.g., carrying the PSCCH and the PSSCH/PSFCH combination, and a second resource pool, RP-2, may carry RS (and possibly some small amount of dynamic control information). The second resource pool RP-2 may have a larger bandwidth than the first resource pool RP-1, e.g., as measurement accuracy of RS may increase with increased bandwidth. The resource pools RP-1, RP-2 are coupled in that the second resource pool RP-2 is dependent upon the first resource pool RP-1 in order to provide a complete set of information for a UE to process reference signals conveyed by the second resource pool RP-2. For example, all control information for performing channel sensing and processing on RP-2 may be transmitted on RP-1, or some of the control information may be carried on RP-1 and some on RP-2, as discussed further with respect to stage **1020**.

[0118] At sub-stage **1013**, the network entity **600**, e.g., the SL configuration unit **650**, may determine the SL configurations. For example, the TRP **300** and the server **400** may communicate to determine SL configurations **1015**, **1016** of the resource pools RP-**1**, RP-**2**. Referring also to FIG. **11**, a control/data resource pool configuration **1110** is an example of one of the SL configurations **1015** and a reference signal resource pool configuration **1130** is an example of one of the SL configurations **1016**. The configurations **1110**, **1130** provide separate configurations, with respective sets of configuration parameters for control/data and reference signals, respectively. The configuration **1110** may include an explicit indication **1140** that the configuration is for control/data or the purpose of the configuration **1110** may be implicit, e.g., based on being provided in a portion of a message dedicated to including the resource pool configuration for control/data. The configuration **1130** may include an explicit indication **1150** that the configuration is for reference signals or the purpose of the configuration **1130** may be implicit, e.g., based on being provided in a portion of a message dedicated to including the resource pool configuration for reference signals. The configuration **1130** may be for a specific type of reference signal, e.g., PRS, and the purpose of the configuration **1130** may be explicitly or implicitly indicated. As shown, the control/data resource pool configuration **1110** includes a PSSCH configuration field **1111**, a PSCCH configuration field **1112**, a PSFCH configuration field **1113**, a number of subchannels field **1114**, a subchannel size field **1115**, a start RB field **1116**, a CBR field **1117**, an MCS field **1118**, a sensing configuration field **1119**, and a power control field **1120**. The fields **1111-1113** indicate configurations of the PSSCH, PSCCH, and PSFCH, respectively, e.g., including information such as information included in the configuration **1130**. The reference signal resource pool configuration **1130** includes a number of symbols field **1131**, a comb type field **1132**, a comb offset field **1133**, a number of subchannels field **1134**, a subchannel size field **1135**, a start RB field **1136**, a CBR field **1137**, a sensing configuration field **1138**, and a power control field **1139**. The configurations **1110**, **1130** are examples of the SL configurations retrieved by the UEs **1001**, **1002** at sub-stages **1011**, **1012**.

[0119] The network entity **600** transmits SL configurations **1015**, **1016** to the UEs **1001**, **1002** for mode **1** operation. The SL configurations **1015**, **1016** may indicate the purpose(s) for resource pools in the SL configurations **1015**, **1016**, e.g., for control/data or for reference signals. The UEs **1001**, **1002** may store the SL configurations **1015**, **1016**, e.g., overriding any default SL configurations, for use in transmitting and/or receiving SL signals, e.g., data signals, RS, measurement reports, etc. Sub-stage **1013** may be omitted, e.g., for mode **2** operation. Alternatively, sub-stage **1013** may be performed before the UEs **1001**, **1002** leave the range of the network entity **600** and the SL configurations **1015**, **1016** may be used by the UEs **1001**, **1002** for mode **2** operation after leaving the range of the network entity **600**.

[0120] At stage **1020**, sidelink messages are transmitted, decoded or measured as appropriate, and one or more measurements possibly reported. The UE **1001** transmits sidelink messages **1021**, **1022** using the two resource pools, RP-**1**, RP-**2**, respectively, indicated in the SL configurations **1015**. The sidelink message **1021** may contain full control information for processing of a reference signal of the sidelink message **1022**, or the control information for processing the reference signal may be split between the sidelink messages **1021**, **1022**.

[0121] Referring also to FIG. **12**, a timing diagram **1200** illustrates transmission of full control information using RP-1 for processing of a reference signal in RP-2. As shown, signals are sent multiple times in resources from the first resource pool RP-1 and the second resource pool RP-2. Control information for locating and processing a reference signal in RP-2 may or may not be sent in each transmission using the first resource pool RP-1. When the control information is sent, all of the control information for locating and processing (e.g., measuring) the reference signal is included in the RP-1 information. As shown, both an SCI-1 signal **1210** and an SCI-2 signal **1220** (sidelink control information-2) are transmitted using resources from the first resource pool RP-1. The SCI-1 signal **1210** includes a UE ID indicating for which UE the SCI-1 signal **1210** is intended, includes a pointer to the SCI-2 signal **1220**, and includes information (as appropriate) for decoding the SCI-2 signal **1220**. The UE for which the SCI-1 signal **1210** is intended can decode the information in the SCI-1 signal **1210** to determine the location of the SCI-2 signal **1220**. Another UE, for which the SCI-1 signal **1210** is not intended, can ignore the SCI-1 signal **1210** and the SCI-2 signal **1220** once the other UE determines that the SCI-1 signal **1210** is intended for a different UE. The SCI-2 signal includes information about the location of (e.g., the resources containing) an SL-RS, e.g., an SL-PRS **1230**, of the second resource pool RP-2. From the SCI-2 signal **1220**, a UE can obtain resource allocation, MCS, HARQ ID (hybrid automatic repeat request identity), retransmission parameters, ACK/NACK parameters (acknowledge/negative acknowledge parameters), etc. With full control information (here the SCI-1 signal **1210** and the SCI-2 signal **1220**) in the control/data resource pool and thus not in the reference signal resource pool, significantly more resources may be used for the reference signal (e.g., SL-PRS, SL-CSI-RS, etc.) than if the control information was in the reference signal resource pool. This may help improve measurement accuracy of the RS, which may improve positioning accuracy of the RS is a PRS. Instead of the SCI-1 signal **1210** and the SCI-2 signal **1220**, a single signal could be used to provide the information for locating and processing the SL-RS.

[0122] Referring also to FIGS. **13** and **14**, a timing diagram **1300** illustrates transmission of partial control information using RP-1 for processing of a reference signal in RP-2. As shown, an SCI-1 signal **1310** is transmitted using a first resource pool **1320**, here RP-1, and an SCI-2 signal **1330** and a reference signal, here an SL-PRS **1340**, are transmitted using a second resource pool **1350**, here RP-2. The SCI-2 signal **1330** may not be transmitted every time the SL-PRS **1340** is transmitted, e.g., because reference signals are typically transmitted multiple times using the same configuration. For example, as shown in FIG. **14**, control information **1410** (e.g., an SCI-1 signal) is provided in each of multiple control/data resource pool transmissions **1421**, **1422**, **1423**, **1424** using a control/data resource pool while control information **1430** (e.g., an SCI-2 signal) is provided in fewer than all reference signal resource pool transmissions **1441**, **1442**, **1443**, **1444** using a reference signal resource pool and corresponding to the control/data resource pool transmissions **1421-1424**. For example, the control information **1430** may be provided in 10% or 20% of reference signal transmissions (e.g., in one slot of every 10 slots transmitted, or one slot of every five slots transmitted). The control information **1410** may vary depending on whether the control information **1430** will be present. For example, if the control information **1430** will not be present, then the control information **1410** may not point to a location of a corresponding one of the reference signal resource pool transmissions **1441-1444**.

[0123] The SL configurations **1015**, **1016** may allocate resources for the control information and may indicate that one or more resources are allocated in the control/data resource pool for control information to direct a recipient of the control information to one or more resources in the reference signal resource pool. For example, the network entity **600** (e.g., the SL configuration unit **650**) may indicate, e.g., in the PSCCH configuration field **1112** one or more resource elements that are to be used for control information indicating one or more resources in the reference signal resource pool. The network entity **600** may allocate infrequent resources to be used for control information in the reference signal resource pool to indicate a reference signal in the reference signal resource pool (e.g., see FIGS. **13** and **14**). The network entity **600** may allocate zero resources for control information in the reference signal resource pool to indicate a reference signal in the reference signal resource pool (e.g., see FIG. **12**).

[0124] At sub-stage **1023**, the UE **1002** measures the reference signal transmitted using the reference signal resource pool in the sidelink message **1022**. Thus, in a scenario with full control on the control/data resource pool, the UE **1001** transmits the sidelink message **1021** in the control/data resource pool with full control information (e.g., SCI-1 and SCI-2) for locating and processing a reference signal in the reference signal resource pool. The UE **1002** receives the sidelink message **1021**, performs control information (e.g., SCI-1 and SCI-2) detection on the control/data resource pool and determines the location of a reference signal (e.g., PRS) in the reference signal resource pool, e.g., without performing channel sensing using the reference signal resource pool (e.g., because channel reservation was in the control/data resource pool). The UE **1001** transmits the sidelink message **1022** including a reference signal in the reference signal resource pool and the UE **1002** uses the control information from the sidelink message **1021** to measure the reference signal. In a scenario with partial control information in the control/data resource pool, the UE **1001** transmits a first portion of control information (e.g., SCI-1) in the control/data resource pool and the first portion of control information indicates a location of a second portion of control information (e.g., SCI-2) in the reference signal resource pool. The UE **1001** transmits, in the reference signal resource pool, the sidelink message **1022** including the second portion of control information and a reference signal at a location specified in the second portion of control information. The UE **1002** detects the first portion of control information in the sidelink message **1021** in the control/data resource pool, detects the second portion of control information in the sidelink message **1022** in the reference signal resource pool, and measures the reference signal in the reference signal resource pool. Detection of the second portion of control information is conditioned on the location of the second portion of control information specified in the first portion of control information. The UE **1002** may transmit a report **1024** to the UE **1001**, e.g. indicating one or more measurements of the reference signal. The UE **1002** transmits the report **1024** in the control/data resource pool.

[0125] A UE may measure and transmit RS in different reference signal resource pools. For example, the UE **1002**, e.g., the RS unit **550** of the UE **1002**, may receive a first control message on the control/data resource pool RP-1 in the sidelink message **1021** indicating the presence of a first SL-RS in a first reference signal resource pool RP-2a. The UE **1002** may switch to the configuration of the first reference signal resource pool RP-2a and measure the first SL-RS. The UE **1002** may transmit a second control message in a sidelink message **1025** on the control/data resource pool RP-1 indicating a second SL-RS in a second reference signal resource pool RP-2b, switch to the second reference signal resource pool RP-2b, and transmit a second SL-RS in a sidelink message **1026** in the second reference signal resource pool RP-2b.

[0126] At stages **1030**, **1040** the UEs **1001**, **1002** may determine position information. For example, the UEs **1001**, **1002** may determine PRS measurements, one or more ranges to one or more other entities (e.g., anchor UE(s), TRP(s)), and/or position estimates for the UEs **1001**, **1002**, respectively. The UEs **1001**, **1002** may transmit position information **1031**, **1041** to the network entity **600**, with the position information **1031**, **1041** including some or all of the position information determined by the UEs **1001**, **1002**, respectively.

[0127] At stage **1050**, the network entity **600** may determine position information. For example, the network entity **600** may use some or all of the position information **1031**, **1041** to determine a position estimate for the UE **1001** and/or the UE **1002**.

[0128] The flow **1000** is an example, and numerous variations are possible. For example, as discussed below, various resource allocations for the resource pools may be used, signals may be multiplexed, resource pool configurations may be semi-static or dynamic, various signal formats for control information may be used, and resource pools may have priorities.

[0129] Multiple primary resource pools (e.g., control/data resource pools) may be used to schedule resources in the same secondary resource pool (e.g., reference signal resource pool) and/or a single primary resource pool may be used to schedule RS in multiple secondary resource pools. For example, the UE **1001** (e.g., the RS unit **550**) may transmit multiple sidelink messages in different control/data resource pools (e.g., RP-1a, RP-1b, RP-1c) that each provide the location of a respective reference signal, or a location of a respective control signal that provides the location of the respective reference signal, in the same reference signal resource pool (e.g., RP-2). As another example, the UE **1001** may provide multiple control signals in the same primary resource pool, e.g., control/data resource pool RP-1, with the control signals providing locations in different secondary resource pools (e.g., reference signal resource pools RP-2a, RP-2b) of RS or further control information that each provide a location of RS in a respective secondary resource pool.

[0130] Potential resources may be allocated between a primary resource pool and a secondary resource pool. For example, resources may be allocated on a time division multiplexed (TDM) basis for a control/data resource pool and a reference signal resource pool. The allocation may, for example, be on a slot level, with the different resource pools being carried by different slots, e.g., with some slots dedicated to the control/data resource pool and other slots dedicated to the reference signal resource pool. Some of the resources allocated to the control/data resource pool in one slot may also be allocated to the reference signal resource pool in another slot.

[0131] Referring to FIG. **15**, As another example, resources may be allocated to different resource pools on a TDM basis on a sub-slot level, with different symbols of a slot being allocated to different resource pools. As with slot-level TDM, the different resource pools may overlap in bandwidth and/or use one or more of the same bandwidth resources in different symbols. A gap (e.g., of one symbol) may be provided between resources for different resource pools, e.g., to allow for automatic gain control (AGC) correction. In the example shown in FIG. **15**, a single slot **1500** includes a one-symbol gap **1510** for AGC, a symbol **1511** for transmission/reception of a first RS, here SL-PRS1, a one-symbol gap **1512** to allow for switching between RS transmission and RS reception, a one-symbol gap **1513** for AGC, a symbol **1514** for transmission/reception of a second RS, here SL-PRS2, a one-symbol gap **1515** to allow for switching between RS Tx/Rx, a one-symbol gap **1516** for AGC, a symbol **1517** for transmission/reception of a second RS, here SL-PRS3, a one-symbol gap **1518** to allow for switching between RS Tx/Rx, a one-symbol gap **1519** for AGC, a symbol **1520** for transmission/reception of a second RS, here SL-PRS2, a one-symbol gap **1521** to allow for switching between RS Tx/Rx. The AGC may be used to adapt to receiving RS from different UEs that may be a very different distances from the UE receiving the RS. A symbol **1531** and/or a symbol **1532** may be left vacant for SCI decoding, especially if PSSCH, PSCCH, and SL-RS are frequency division multiplexed. In this example, with each RS transmitted in a single slot, four reference signals are multiplexed into the single slot **1500**. Without control information (e.g., without SCI-1/SCI-2) for locating and processing the RS being in the reference signal resource pool, the ability to multiplex reference signals is improved and overall resource utilization is reduced because resources not used for control information are available for PRS, which can reduce the overall channel loading in the reference signal resource pool.

[0132] As another example of resource allocation between resource pools, resources may be allocated on a frequency division multiplexed (FDM) basis, e.g., within a slot, between a primary resource pool and a second resource pool. Resources for different resource pools may be allocated within the same symbol, e.g., if AGC correction between use of the different resource pools is unnecessary.

[0133] The configuration of a reference signal resource pool may be semi-static or dynamic. For example, a reference signal resource pool may be semi-static, being fixed by higher layers (e.g., above a physical layer) of multiple UEs **500** such that the UEs know and follow the reference signal resource pool configuration (e.g., periodicity (e.g., 5 ms out of every 100 ms is for reference signals) and resource allocation (comb, TDM, FDM) for multiplexing between the UEs). As another example, the reference signal resource pool configuration may be dynamic, being configured dynamically through received control information, e.g., SCI-1 and SCI-2 on the control/data resource pool, or an SL-MAC-CE (sidelink—medium access control—control element). For example, at the start of a positioning session, the UE **500** receives a PRS configuration and uses that configuration for PRS reception and/or transmission. As another example, a pre-configured reference signal configuration may be selectively used or not based on dynamic signaling received, e.g., a request for the UE **500** to transmit PRS, or to start positioning operations, or to stop positioning operations.

[0134] Reference signal resources may be reserved on a periodic basis. For example, sidelink transmissions may be reserved until a UE transmitting on sidelink misses a transmission. An on-duration may be as long as the transmitting UE continues to transmit the reserved occasions. Similarly, the same framework may be applied to SL-RS transmissions such that as long as the UE **500** continues to transmit SCI, the corresponding SL-RS (e.g., SL-PRS) will be reserved. The UE **500** may reserve periodic transmissions because reference signals are often transmitted multiple times.

[0135] The UE **500** may indicate a reserved resources for RS transmission, and whether the transmission will be periodic (and parameters of the repeated transmissions if so). The UE **500** may receive a response from another UE based on the requested reservation, e.g., objecting to the requested reservation, and the UE **500** may negotiate with the other UE to reserve resources.

[0136] Various formats of SCI may be used by the UE **500**. For example, a new SCI-2 format may be used for SL-RS interpretation. As another example, bits previously reserved for future use in SCI-1 may be used to indicate that a new SCI-2 format is being used. Further, based on the values of the previously-reserved bits indicating that a new SCI-2 format is being used, other portions of the SCI-1 message may be interpreted differently than if the previously-reserved bits did not indicate that a new SCI-2 format is being used.

[0137] Various configurations of control information may be used to point to the location of the RS. For example, a fixed mapping may be used from the sub-channel containing the SCI with the SL-RS indicator to the resources of the SL-RS. A single bit may be used in the SCI to indicate whether the SCI reserves an SL-RS. A receiving UE would know (e.g., as per a standard) the mapping of the single bit to an RS location such that if the single bit indicates that the SL-RS is reserved, then the receiving UE would look for the SL-RS at the known location corresponding to the single-bit indicator. This technique saves overhead to signal the location of the SL-RS, and reduces power consumption to determine the location of the SL-RS (e.g., to decode the control information). As another example, the SCI may use several bits to indicate the location of the SL-RS explicitly. The SCI-1 may be modified to include the bits for indicating the SL-RS location, or the SCI-2 may be modified to include the location of the SL-RS. Collisions of RS from different UEs on the same symbol may be acceptable, e.g., if the different RS have different comb numbers and/or have different scrambling sequences such that the different RS are orthogonal or quasi-orthogonal.

[0138] The different resource pools may have different priorities. For example, a fixed priority of the resource pools may be used, e.g., as indicated by higher layers or written in an industry standard (e.g., from 3GPP). The reference signal resource pool may, for example, have priority over the control/data resource pool. As another example, priority of the resource pools may be dynamic, e.g., as indicated in the sidelink control information. The control information may, for example, indicate for a receiving UE not to look for RS at certain resources, e.g., by indicating that RS will not be transmitted.

[0139] Various options may be implemented for reacting to SL resources in the control/data resource pool being preempted. For example, if SL resources in the control/data resource pool get preempted (e.g., by higher-priority data), then the SL-RS corresponding to the preempted resources may be affected immediately, e.g., by the UE **500** cancelling transmission of the SL-RS. As another example, if SL resources in the control/data resource pool get preempted, then the SL-RS corresponding to the preempted resources may not be affected until a reservation time for the SL-RS expires. Thus, if SL-RS resources have already been reserved, then the UE **500** transmits the SL-RS using the reserved resources and then the resources may be used for another purpose, e.g., a higher-priority transmission, thereafter.

[0140] Different measurement value thresholds may be used for SL-RS detection in the reference signal resource pool versus for medium reservation in the control/data resource pool. For example, different RSRP thresholds may be used for SL-RS detection versus medium reservation detection (i.e., determining whether a medium is in use). The measurement value thresholds may be configured as standalone values, or as differences (deltas) relative to a baseline value.

[0141] Referring to FIG. **16**, with further reference to FIGS. **1-15**, a reference signal transmission method **1600** includes the stages shown. The method **1600** is, however, an example and not limiting. The method **1600** may be altered, e.g., by having stages added, removed, rearranged, combined, performed concurrently, and/or having single stages split into multiple stages.

[0142] At stage **1610**, the method **1600** includes obtaining, at a first user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer. For example, at stage **1010**, the processor **510** of the UE **1001** may retrieve a configuration of a control/data resource pool from the memory **530** of the UE **1001** and/or the processor **510** may receive the configuration of the control/data resource pool via the transceiver **520** from the network entity **600**. The processor **510**, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the first configuration of the first resource pool.

[0143] At stage **1620**, the method **1600** includes obtaining, at the first user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool. For example, at stage **1010**, the processor **510** of the UE **1001** may retrieve a configuration of a reference signal resource pool from the memory **530** of the UE **1001** and/or the processor **510** may receive the configuration of the reference signal resource pool via the transceiver **520** from the network entity **600**. The processor **510**, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the second configuration of the second resource pool.

[0144] At stage **1630**, the method **1600** includes transmitting, from the first user equipment to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool. For example, the UE **1001** transmits the sidelink message **1021** with control information pointing to one or more resources in the reference signal resource pool, e.g., the SCI-2 signal **1220** pointing to the SL-PRS **1230** or the SCI-1 signal **1310** pointing to the SCI-2 signal **1330**. The processor **510**, possibly in combination with the memory **530**, in combination with the transceiver **520** (e.g., the wireless transmitter **242** and the antenna **246**) may comprise means for transmitting control information in one or more of the plurality of first OFDM resources of the first resource pool.

[0145] At stage **1640**, the method **1600** includes transmitting, from the first user equipment to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool. For example, the UE **1001** transmits the sidelink message **1022** including a reference signal, e.g., the SL-PRS **1230** or the SL-PRS **1340** or another RS (e.g., an SL-CSI-RS). The processor **510**, possibly in combination with the memory **530**, in combination with the transceiver **520** (e.g., the wireless transmitter **242** and the antenna **246**) may comprise means for transmitting the reference signal. By transmitting the reference signal in a different resource pool than the control information, more resources may be used for the reference signal than if the control information and the reference signal were in the same resource pool, thus improving an ability of a receiving UE to measure the reference signal accurately.

[0146] Implementations of the method **1600** may include one or more of the following features. In an example implementation, the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool. For example, the control information, e.g., the SCI-2 signal **1220**, points to the resource location of the reference signal, e.g., the SL-PRS **1230**. In another example implementation, the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool. For example, the first control information, e.g., the SCI-1 signal **1310**, points to the resource location of the second control information, e.g., the SCI-2 signal **1330**, which points to the resource location of the reference signal, e.g., the SL-PRS **1340**. In a further example implementation, transmitting the reference signal comprises transmitting the reference signal a plurality of times, with the second control information transmitted in conjunction with the reference signal at least once in the plurality of times, and with the reference signal being transmitted without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times. For example, control information, e.g., the control information **1410**, is provided in each of the control/data resource pool transmissions **1421-1424** and control information, e.g., the control information **1430**, is provided in at least one of, but fewer than all of, the reference signal resource pool transmissions **1441-1444**, e.g., in only the reference signal resource pool transmission **1441** of the four reference signal resource pool transmissions **1441-1444**.

[0147] Also or alternatively, implementations of the method **1600** may include one or more of the following features. In an example implementation, the second resource pool has a greater bandwidth than the first resource pool. For example, the reference signal resource pool (e.g., the second resource pool RP-2) has a greater bandwidth than the control/data resource pool (e.g., the first resource pool RP-1) in order to facilitate accurate measurement of reference signals. In another example implementation, the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool are transmitted at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources. For example, the UE **1001** may transmit OFDM resources for control information TDM and/or FDM with OFDM resources for one or more reference signals. In another example implementation, the control information includes an indication of priority between the first resource pool and the second resource pool.

[0148] Also or alternatively, implementations of the method **1600** may include one or more of the following features. In an example implementation, the reference signal is a first reference signal, and the method **1600** further includes: obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and transmitting, from the first user equipment, a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool. For example, the UE **500** may retrieve or receive a second reference signal resource pool and transmit a second reference signal in the second reference signal resource pool. Thus, a single primary resource pool (e.g., control/data resource pool) may schedule multiple RS on multiple secondary resource pools (e.g., reference signal resource pools). The processor **510**, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the third configuration of the third resource pool. The processor **510**, possibly in combination with the memory **530**, in combination with the transceiver **520** (e.g., the wireless transmitter **242** and the antenna **246**) may comprise means for transmitting the second reference signal. In another example implementation, the reference signal is a first reference signal and the control information is first control information, and wherein the reference signal transmission method further comprises: obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; transmitting, from the first user equipment, second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and transmitting, from the first user equipment, a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information. For example, the UE **500** may retrieve or receive a second control/data resource pool and transmit a second reference signal in the reference signal resource pool. Thus, multiple primary resource pools (e.g., control/data resource pools) may schedule RS on a single secondary resource pool (e.g., reference signal resource pool). The processor **510**, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the third configuration of the third resource pool. The processor **510**, possibly in combination with the memory **530**, in combination with the transceiver **520** (e.g., the wireless transmitter **242** and the antenna **246**) may comprise means for transmitting the second control information and means for transmitting the second reference signal.

[0149] Referring to FIG. **17**, with further reference to FIGS. **1-15**, a signal processing method **1700** includes the stages shown. The method **1700** is, however, an example and not limiting. The method **1700** may be altered, e.g., by having stages added, removed, rearranged, combined, performed concurrently, and/or having single stages split into multiple stages.

[0150] At stage **1710**, the method **1700** includes obtaining, at a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer. For example, at stage **1010**, the processor **510** of the UE **1002** may retrieve a configuration of a control/data resource pool from the memory **530** of the UE **1002** and/or the processor **510** may receive the configuration of the control/data resource pool via the transceiver **520** from the network entity **600**. The processor **510**, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the first configuration of the first resource pool.

[0151] At stage **1720**, the method **1700** includes obtaining, at the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool. For example, at stage **1010**, the processor **510** of the UE **1002** may retrieve a configuration of a reference signal resource pool from the memory **530** of the UE **1002** and/or the processor **510** may receive the configuration of the reference signal resource pool via the transceiver **520** from the network entity **600**. The processor

510, possibly in combination with the memory **530**, possibly in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for obtaining the second configuration of the second resource pool.

[0152] At stage **1730**, the method **1700** includes receiving, at the user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool. For example, the processor **510** of the UE **1002** receives the sidelink message **1021** including control information pointing to one or more resources in the reference signal resource pool, e.g., the SCI-2 signal **1220** pointing to the SL-PRS **1230** or the SCI-1 signal **1310** pointing to the SCI-2 signal **1330**. The processor **510**, possibly in combination with the memory **530**, in combination with the transceiver **520** (e.g., the wireless receiver **244** and the antenna **246**) may comprise means for receiving control information in one or more of the plurality of first OFDM resources of the first resource pool.

[0153] At stage **1740**, the method **1700** includes processing, at the user equipment, a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information. For example, the RS unit **550** of the UE **1002** reads the control information, and processes a signal (e.g., reads a control information signal or measures a reference signal) pointed to by the control information. The processor **510**, possibly in combination with the memory **530**, may comprise means for processing the signal. By being configured to read control information in a first resource pool that points to a resource location in a second resource pool, a higher-bandwidth reference signal may be transmitted in the second resource pool than if the same resource pool is used for the reference signal and control information for locating and processing the reference signal. The higher-bandwidth signal may be more accurately measured (e.g., a time of arrival of the reference signal more accurately determined).

[0154] Implementations of the method **1700** may include one or more of the following features. In an example implementation, the signal comprises a reference signal and processing the signal comprises measuring the reference signal. For example, the control information, e.g., the SCI-2 signal **1220**, points to the reference signal in the reference signal resource pool, e.g., the SL-PRS **1230**, and the RS unit **550** of the UE **1002** measures the reference signal based on the location of the reference signal indicated by the control information. The processor **510**, possibly in combination with the memory **530**, may comprise means for measuring the signal. In another example implementation, the control information is first control information, the signal is a control signal comprising second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal, processing the control signal comprises decoding the control signal to determine the second control information, and the method **1700** further includes measuring the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information. For example, the RS unit **550** of the UE **1002** reads the first control information, e.g., the SCI-1 signal **1310**, to determine the resource location of the second control information, e.g., the SCI-2 signal **1330**, in the reference signal resource pool. The RS unit **550** of the UE **1002** measures the reference signal, e.g., the SL-PRS **1340**, using the resource location indicated by the second control information. The processor **510**, possibly in combination with the memory **530**, may comprise means for measuring the reference signal.

[0155] Referring to FIG. **18**, with further reference to FIGS. **1-15**, a resource pool configuration conveying method **1800** includes the stages shown. The method **1800** is, however, an example and not limiting. The method **1800** may be altered, e.g., by having stages added, removed, rearranged, combined, performed concurrently, and/or having single stages split into multiple stages.

[0156] At stage **1810**, the method **1800** includes transmitting, from a network entity to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer. For example, the network entity **600**, e.g., the SL configuration unit **650**, transmits (after determining) a control/data resource pool configuration of the SL configurations **1015** to the UE **1001**. The processor **610** (e.g., the processor **310** and/or the processor **410**), possibly in combination with the memory **630** (e.g., the memory **311** and/or the memory **411**), in combination with the transceiver **620** (e.g., the transceiver **315** and/or the transceiver **415** (e.g., the wireless transmitter **342** and the antenna **346**, or the wired transmitter **452** and the wireless transmitter **342** and the antenna **346**, or the wireless transmitter **442** and the antenna **446**, etc.)) may comprise means for transmitting the first configuration.

[0157] At stage **1820**, the method **1800** includes transmitting, from the network entity to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool, wherein: the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or a combination thereof. For example, the network entity **600**, e.g., the SL configuration unit **650**, transmits (after determining) a reference signal resource pool configuration of the SL configurations **1015** to the UE **1001**, with the control/data resource pool configuration including an indication of one or more resources for the UE **1001** to use for control information pointing to a resource location of the reference signal resource pool (e.g., for further control information or for a reference signal) and/or the reference signal resource pool configuration scheduling multiple transmissions of the reference signal with fewer than all (e.g., none) of the transmissions having corresponding control information in the reference signal resource pool (e.g., as shown in FIG. **12** or FIG. **14**). The processor **610** (e.g., the processor **310** and/or the processor **410**), possibly in combination with the memory **630** (e.g., the memory **311** and/or the memory **411**), in combination with the transceiver **620** (e.g., the transceiver **315** and/or the transceiver **415** (e.g., the wireless transmitter **342** and the antenna **346**, or the wired transmitter **452** and the wireless transmitter **342** and the antenna **346**, or the wireless transmitter **442** and the antenna **446**, etc.)) may comprise means for transmitting the second configuration.

IMPLEMENTATION EXAMPLES

[0158] Implementation examples are provided in the following numbered clauses.

[0159] Clause 1. A first user equipment comprising:

[0160] a transceiver;

[0161] a memory; and

[0162] a processor, communicatively coupled to the memory and the transceiver, configured to:

- **[0163]** obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;
- **[0164]** obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;
- **[0165]** transmit control information via the transceiver to a second user equipment in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and
- **[0166]** transmit a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0167] Clause 2. The first user equipment of clause 1, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

[0168] Clause 3. The first user equipment of clause 1, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0169] Clause 4. The first user equipment of clause 3, wherein the processor is configured to transmit the reference signal a plurality of times, to include the second control information in conjunction with the reference signal at least once in the plurality of times, and to transmit the reference signal without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

[0170] Clause 5. The first user equipment of clause 1, wherein the second resource pool has a greater bandwidth than the first resource pool.

[0171] Clause 6. The first user equipment of clause 1, wherein the processor is configured to transmit the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

[0172] Clause 7. The first user equipment of clause 1, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

[0173] Clause 8. The first user equipment of clause 1, wherein the reference signal is a first reference signal, and wherein the processor is configured to:

[0174] obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

[0175] transmit a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

[0176] Clause 9. The first user equipment of clause 1, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the processor is configured to:

[0177] obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

[0178] transmit, via the transceiver, second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

[0179] transmit, via the transceiver, a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0180] Clause 10. A reference signal transmission method comprising:

[0181] obtaining, at a first user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0182] obtaining, at the first user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0183] transmitting, from the first user equipment to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0184] transmitting, from the first user equipment to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0185] Clause 11. The reference signal transmission method of clause 10, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

[0186] Clause 12. The reference signal transmission method of clause 10, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0187] Clause 13. The reference signal transmission method of clause 12, wherein transmitting the reference signal comprises transmitting the reference signal a plurality of times, with the second control information transmitted in conjunction with the reference signal at least once in the plurality of times, and with the reference signal being transmitted without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

[0188] Clause 14. The reference signal transmission method of clause 10, wherein the second resource pool has a greater bandwidth than the first resource pool.

[0189] Clause 15. The reference signal transmission method of clause 10, wherein the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool are transmitted at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

[0190] Clause 16. The reference signal transmission method of clause 10, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

[0191] Clause 17. The reference signal transmission method of clause 10, wherein the reference signal is a first reference signal, and wherein the reference signal transmission method further comprises:

[0192] obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

[0193] transmitting, from the first user equipment, a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

[0194] Clause 18. The reference signal transmission method of clause 10, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the reference signal transmission method further comprises:

[0195] obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

[0196] transmitting, from the first user equipment, second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

[0197] transmitting, from the first user equipment, a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0198] Clause 19. A first user equipment comprising:

[0199] means for obtaining a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0200] means for obtaining a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0201] means for transmitting, to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0202] means for transmitting, to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0203] Clause 20. The first user equipment of clause 19, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

[0204] Clause 21. The first user equipment of clause 19, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0205] Clause 22. The first user equipment of clause 21, wherein the means for transmitting the reference signal comprise means for transmitting the reference signal a plurality of times, with the second control information transmitted in conjunction with the reference signal at least once in the plurality of times, and with the reference signal being transmitted without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

[0206] Clause 23. The first user equipment of clause 19, wherein the second resource pool has a greater bandwidth than the first resource pool.

[0207] Clause 24. The first user equipment of clause 19, wherein the means for transmitting the control information and the means for transmitting the reference signal comprise means for transmitting the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

[0208] Clause 25. The first user equipment of clause 19, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

[0209] Clause 26. The first user equipment of clause 19, wherein the reference signal is a first reference signal, and wherein the first user equipment further comprises:

[0210] means for obtaining a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

[0211] means for transmitting a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

[0212] Clause 27. The first user equipment of clause 19, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the first user equipment further comprises:

[0213] means for obtaining a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

[0214] means for transmitting second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

[0215] means for transmitting a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0216] Clause 28. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a first user equipment to:

[0217] obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0218] obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0219] transmit, to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0220] transmit, to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0221] Clause 29. The non-transitory, processor-readable storage medium of clause 28, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

[0222] Clause 30. The non-transitory, processor-readable storage medium of clause 28, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

[0223] Clause 31. The non-transitory, processor-readable storage medium of clause 30, wherein the processor-readable instructions to cause the processor to transmit the reference signal comprise processor-readable instructions to cause the processor to transmit the reference signal a plurality of times, with the second control information transmitted in conjunction with the reference signal at least once in the plurality of times, and with the reference signal being transmitted without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

[0224] Clause 32. The non-transitory, processor-readable storage medium of clause 28, wherein the second resource pool has a greater bandwidth than the first resource pool.

[0225] Clause 33. The non-transitory, processor-readable storage medium of clause 28, wherein the processor-readable instructions to cause the processor to transmit the control information and the reference signal comprise processor-readable instructions to cause the processor to transmit the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

[0226] Clause 34. The non-transitory, processor-readable storage medium of clause 28, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

[0227] Clause 35. The non-transitory, processor-readable storage medium of clause 28, wherein the reference signal is a first reference signal, and wherein the non-transitory, processor-readable storage medium further comprises processor-readable instructions to cause the processor to:

[0228] obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

[0229] transmit a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

[0230] Clause 36. The non-transitory, processor-readable storage medium of clause 28, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the non-transitory, processor-readable storage medium further comprises processor-readable instructions to cause the processor to:

[0231] obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

[0232] transmit second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

[0233] transmit a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0234] Clause 37. A user equipment comprising:

[0235] a transceiver;

[0236] a memory; and

[0237] a processor, communicatively coupled to the memory and the transceiver, configured to:

[0238] obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0239] obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0240] receive control information via the transceiver in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0241] process a signal received via the transceiver in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0242] Clause 38. The user equipment of clause 37, wherein the signal comprises a reference signal and to process the signal the processor is configured to measure the reference signal.

[0243] Clause 39. The user equipment of clause 37, wherein:

[0244] the control information is first control information;

[0245] the signal comprises second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal;

[0246] to process the signal the processor is configured to decode the signal to determine the second control information; and

[0247] the processor is further configured to measure the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0248] Clause 40. A signal processing method comprising:

[0249] obtaining, at a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0250] obtaining, at the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0251] receiving, at the user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0252] processing, at the user equipment, a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0253] Clause 41. The signal processing method of clause 40, wherein the signal comprises a reference signal and processing the signal comprises measuring the reference signal.

[0254] Clause 42. The signal processing method of clause 40, wherein:

[0255] the control information is first control information;

[0256] the signal is a control signal comprising second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal;

[0257] processing the control signal comprises decoding the control signal to determine the second control information; and

[0258] the signal processing method further comprises measuring the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0259] Clause 43. A user equipment comprising:

[0260] means for obtaining a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0261] means for obtaining a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0262] means for receiving control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and means for processing a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0263] Clause 44. The user equipment of clause 43, wherein the signal comprises a reference signal and the means for processing the signal comprise means for measuring the reference signal.

[0264] Clause 45. The user equipment of clause 43, wherein:

[0265] the control information is first control information;

[0266] the signal is a control signal comprising second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal;

[0267] the means for processing the control signal comprise means for decoding the control signal to determine the second control information; and

[0268] the user equipment further comprises means for measuring the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0269] Clause 46. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a user equipment to:

[0270] obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

[0271] obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0272] receive control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

[0273] process a signal received in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

[0274] Clause 47. The non-transitory, processor-readable storage medium of clause 46, wherein the signal comprises a reference signal and the processor-readable instructions to cause the processor to process the signal comprise processor-readable instructions to cause the processor to measure the reference signal.

[0275] Clause 48. The non-transitory, processor-readable storage medium of clause 46, wherein:

[0276] the control information is first control information;

[0277] the signal is a control signal comprising second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal;

[0278] the processor-readable instructions to cause the processor to process the control signal comprise processor-readable instructions to cause the processor to decode the control signal to determine the second control information; and

[0279] the non-transitory, processor-readable storage medium further comprises processor-readable instructions to cause the processor to measure the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

[0280] Clause 49. A network entity comprising:

[0281] a transceiver;

[0282] a memory; and

[0283] a processor, communicatively coupled to the memory and the transceiver, configured to:

[0284] transmit, via the transceiver to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and

[0285] transmit, via the transceiver to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0286] wherein:

[0287] the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or

[0288] the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or

[0289] a combination thereof.

[0290] Clause 50. The network entity of clause 49, wherein the second configuration of the second resource pool schedules the plurality of transmissions of the reference signal with all of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources for the user equipment to use for second control information indicating the location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources.

[0291] Clause 51. A resource pool configuration conveying method comprising:

[0292] transmitting, from a network entity to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and

[0293] transmitting, from the network entity to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0294] wherein:

[0295] the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or

[0296] the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or

[0297] a combination thereof.

[0298] Clause 52. The resource pool configuration conveying method of clause 51, wherein the second configuration of the second resource pool schedules the plurality of transmissions of the reference signal with all of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources for the user equipment to use for second control information indicating the location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources.

[0299] Clause 53. A network entity comprising:

[0300] means for transmitting, to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and

[0301] means for transmitting, to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0302] wherein:

[0303] the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or

[0304] the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or

[0305] a combination thereof.

[0306] Clause 54. The network entity of clause 53, wherein the second configuration of the second resource pool schedules the plurality of transmissions of the reference signal with all of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources for the user equipment to use for second control information indicating the location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources.

[0307] Clause 55. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a network entity to:

[0308] transmit, to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and

[0309] transmit, to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

[0310] wherein:

[0311] the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or

[0312] the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or

[0313] a combination thereof.

[0314] Clause 56. The non-transitory, processor-readable storage medium of clause 55, wherein the second configuration of the second resource pool schedules the plurality of transmissions of the reference signal with all of the plurality of transmissions of the reference signal having have zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources for the user equipment to use for second control information indicating the location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources.

OTHER CONSIDERATIONS

[0315] Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software and computers, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or a combination of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0316] As used herein, the singular forms "a," "an," and "the" include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "includes," and/or "including," as used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0317] Also, as used herein, "or" as used in a list of items (possibly prefaced by "at least one of" or prefaced by "one or more of") indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C," or a list of "one or more of A, B, or C" or a list of "A or B or C" means A, or B, or C, or AB (A and B), or AC (A and C), or BC (B and C), or ABC (i.e., A and B and C), or combinations with more than one feature (e.g., AA, AAB, ABBC, etc.). Thus, a recitation that an item, e.g., a processor, is configured to perform a function regarding at least one of A or B, or a recitation that an item is configured to perform a function A or a function B, means that the item may be configured to perform the function regarding A, or may be configured to perform the function regarding B, or may be configured to perform the function regarding A and B. For example, a phrase of "a processor configured to measure at least one of A or B" or "a processor configured to measure A or measure B" means that the processor may be configured to measure A (and may or may not be configured to measure B), or may be configured to measure B (and may or may not be configured to measure A), or may be configured to measure A and measure B (and may be configured to select which, or both, of A and B to measure). Similarly, a recitation of a means for measuring at least one of A or B includes means for measuring A (which may or may not be able to measure B), or means for measuring B (and may or may not be configured to measure A), or means for measuring A and B (which may be able to select which, or both, of A and B to measure). As another example, a recitation that an item, e.g., a processor, is configured to at least one of perform function X or perform function Y means that the item may be configured to perform the function X, or may be configured to perform the function Y, or may be configured to perform the function X and to perform the function Y. For example, a phrase of "a processor configured to at least one of measure X or measure Y" means that the processor may be configured to measure X (and may or may not be configured to measure Y), or may be configured to measure Y (and may or may not be configured to measure X), or may be configured to measure X and to measure Y (and may be configured to select which, or both, of X and Y to measure).

[0318] As used herein, unless otherwise stated, a statement that a function or operation is "based on" an item or condition means that the function or operation is based on the stated item or condition and may be based on one or more items and/or conditions in addition to the stated item or condition.

[0319] Substantial variations may be made in accordance with specific requirements. For example, customized hardware might also be used, and/or particular elements might be implemented in hardware, software (including portable software, such as applets, etc.) executed by a processor, or both. Further, connection to other computing devices such as network input/output devices may be employed. Components, functional or otherwise, shown in the figures and/or discussed herein as being connected or communicating with each other are communicatively coupled unless otherwise noted. That is, they may be directly or indirectly connected to enable communication between them.

[0320] The systems and devices discussed above are examples. Various configurations may omit, substitute, or add various procedures or components as appropriate. For instance, features described with respect to certain configurations may be combined in various other configurations. Different aspects and elements of the configurations may be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims.

[0321] A wireless communication system is one in which communications are conveyed wirelessly, i.e., by electromagnetic and/or acoustic waves propagating through atmospheric space rather than through a wire or other physical connection, between wireless communication devices. A wireless communication system (also called a wireless communications system, a wireless communication network, or a wireless communications network) may not have all communications transmitted wirelessly, but is configured to have at least some communications transmitted wirelessly. Further, the term "wireless communication device," or similar term, does not require that the functionality of the device is exclusively, or even primarily, for communication, or that communication using the wireless communication device is exclusively, or even primarily, wireless, or that the device be a mobile device, but indicates that the device includes wireless communication capability (one-way or two-way), e.g., includes at least one radio (each radio being part of a transmitter, receiver, or transceiver) for wireless communication.

[0322] Specific details are given in the description herein to provide a thorough understanding of example configurations (including implementations). However, configurations may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the configurations. The description herein provides example configurations, and does not limit the scope, applicability, or configurations of the claims. Rather, the preceding description of the configurations provides a description for implementing described techniques. Various changes may be made in the function and arrangement of elements.

[0323] The terms "processor-readable medium," "machine-readable medium," and "computer-readable medium," as used herein, refer to any medium that participates in providing data that causes a machine to operate in a specific fashion. Using a computing platform, various processor-readable media might be involved in providing instructions/code to processor(s) for execution and/or might be used to store and/or carry such instructions/code (e.g., as signals). In many implementations, a processor-readable medium is a physical and/or tangible storage medium. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media include, for example, optical and/or magnetic disks. Volatile media include, without limitation, dynamic memory.

[0324] Having described several example configurations, various modifications, alternative constructions, and equivalents may be used. For example, the above elements may be components of a larger system, wherein other rules may take precedence over or otherwise modify the application of the disclosure. Also, a number of operations may be undertaken before, during, or after the above elements are considered. Accordingly, the above description does not bound the scope of the claims.

[0325] Unless otherwise indicated, "about" and/or "approximately" as used herein when referring to a measurable value such as an amount, a temporal duration, and the like, encompasses variations of ±20% or ±10%, ±5%, or +0.10% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein. Unless otherwise indicated, "substantially" as used herein when referring to a measurable value such as an amount, a temporal duration, a physical attribute (such as frequency), and the like, also encompasses variations of ±20% or ±10%, ±5%, or +0.10% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein.

[0326] A statement that a value exceeds (or is more than or above) a first threshold value is equivalent to a statement that the value meets or exceeds a second threshold value that is slightly greater than the first threshold value, e.g., the second threshold value being one value higher than the first threshold value in the resolution of a computing system. A statement that a value is less than (or is within or below) a first threshold value is equivalent to a statement that the value is less than or equal to a second threshold value that is slightly lower than the first threshold value, e.g., the second threshold value being one value lower than the first threshold value in the resolution of a computing system.

1. A first user equipment comprising:

a transceiver;

a memory; and

a processor, communicatively coupled to the memory and the transceiver, configured to:

obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

transmit control information via the transceiver to a second user equipment in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

transmit a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

2. The first user equipment of claim **1**, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

3. The first user equipment of claim **1**, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

4. The first user equipment of claim **3**, wherein the processor is configured to transmit the reference signal a plurality of times, to include the second control information in conjunction with the reference signal at least once in the plurality of times, and to transmit the reference signal without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

5. The first user equipment of claim **1**, wherein the second resource pool has a greater bandwidth than the first resource pool.

6. The first user equipment of claim **1**, wherein the processor is configured to transmit the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

7. The first user equipment of claim **1**, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

8. The first user equipment of claim **1**, wherein the reference signal is a first reference signal, and wherein the processor is configured to:

obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

transmit a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

9. The first user equipment of claim **1**, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the processor is configured to:

obtain a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

transmit, via the transceiver, second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

transmit, via the transceiver, a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

10. A reference signal transmission method comprising:

obtaining, at a first user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

obtaining, at the first user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

transmitting, from the first user equipment to a second user equipment, control information in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

transmitting, from the first user equipment to the second user equipment, a reference signal in one or more third orthogonal frequency division multiplexing resources of the second resource pool.

11. The reference signal transmission method of claim **10**, wherein the one or more third orthogonal frequency division multiplexing resources of the second resource pool are the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool.

12. The reference signal transmission method of claim **10**, wherein the control information is first control information, and wherein the one or more of the plurality of second orthogonal frequency division multiplexing resources comprise second control information indicating the one or more third orthogonal frequency division multiplexing resources of the second resource pool.

13. The reference signal transmission method of claim **12**, wherein transmitting the reference signal comprises transmitting the reference signal a plurality of times, with the second control information transmitted in conjunction with the reference signal at least once in the plurality of times, and with the reference signal being transmitted without transmitting the second control information in conjunction with the reference signal at least once in the plurality of times.

14. The reference signal transmission method of claim **10**, wherein the second resource pool has a greater bandwidth than the first resource pool.

15. The reference signal transmission method of claim **10**, wherein the one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool are transmitted at least one of time division multiplexed or frequency division multiplexed with the one or more third orthogonal frequency division multiplexing resources.

16. The reference signal transmission method of claim **10**, wherein the control information includes an indication of priority between the first resource pool and the second resource pool.

17. The reference signal transmission method of claim **10**, wherein the reference signal is a first reference signal, and wherein the reference signal transmission method further comprises:

obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool; and

transmitting, from the first user equipment, a second reference signal in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool based on the control information indicating the one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool.

18. The reference signal transmission method of claim **10**, wherein the reference signal is a first reference signal and the control information is first control information, and wherein the reference signal transmission method further comprises:

obtaining, at the first user equipment, a third configuration of a third resource pool that comprises a plurality of fourth orthogonal frequency division multiplexing resources for sidelink signal transfer, the third configuration of the third resource pool being different from the first configuration of the first resource pool and from the second configuration of the second resource pool;

transmitting, from the first user equipment, second control information in one or more of the plurality of fourth orthogonal frequency division multiplexing resources of the third resource pool, the second control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool other than indicated by the first control information; and

transmitting, from the first user equipment, a second reference signal in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

19. A user equipment comprising:

a transceiver;

a memory; and

a processor, communicatively coupled to the memory and the transceiver, configured to:

obtain a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer;

obtain a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

receive control information via the transceiver in one or more of the plurality of first orthogonal frequency division multiplexing resources of the first resource pool, the control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool; and

process a signal received via the transceiver in the one or more of the plurality of second orthogonal frequency division multiplexing resources of the second resource pool indicated by the control information.

20. The user equipment of claim **19**, wherein the signal comprises a reference signal and to process the signal the processor is configured to measure the reference signal.

21. The user equipment of claim **19**, wherein:

the control information is first control information;

the signal comprises second control information indicating one or more third orthogonal frequency division multiplexing resources of the second resource pool for a reference signal;

to process the signal the processor is configured to decode the signal to determine the second control information; and

the processor is further configured to measure the reference signal in the one or more third orthogonal frequency division multiplexing resources of the second resource pool indicated by the second control information.

22. A network entity comprising:

a transceiver;

a memory; and

a processor, communicatively coupled to the memory and the transceiver, configured to:

transmit, via the transceiver to a user equipment, a first configuration of a first resource pool that comprises a plurality of first orthogonal frequency division multiplexing resources for sidelink signal transfer; and

transmit, via the transceiver to the user equipment, a second configuration of a second resource pool that comprises a plurality of second orthogonal frequency division multiplexing resources for sidelink signal transfer, the second configuration of the second resource pool being different from the first configuration of the first resource pool;

wherein:

the first configuration of the first resource pool includes an indication of at least one of the plurality of first orthogonal frequency division multiplexing resources for the user equipment to use for first control information indicating one or more of the plurality of second orthogonal frequency division multiplexing resources; or

the second configuration of the second resource pool scheduling a plurality of transmissions of a reference signal with at least one of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources scheduled for indicating a location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources; or

a combination thereof.

23. The network entity of claim **22**, wherein the second configuration of the second resource pool schedules the plurality of transmissions of the reference signal with all of the plurality of transmissions of the reference signal having zero corresponding resources of the plurality of second orthogonal frequency division multiplexing resources for the user equipment to use for second control information indicating the location of the reference signal in the plurality of second orthogonal frequency division multiplexing resources.

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