US012395813B2

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

(10) **Patent No.: US 12,395,813 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **RELATIVE LOCATION ANCHOR GROUP AND LOCAL COORDINATE SYSTEM**

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(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

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

(21) Appl. No.: **18/764,037**

(22) Filed: **Jul. 3, 2024**

(65) **Prior Publication Data**

US 2024/0357316 A1 Oct. 24, 2024

Related U.S. Application Data

(62) Division of application No. 17/399,982, filed on Aug. 11, 2021, now Pat. No. 12,089,111.

(51) **Int. Cl.**
H04W 4/02 (2018.01)
H04W 4/029 (2018.01)
H04W 72/51 (2023.01)

(52) **U.S. Cl.**
CPC ***H04W 4/023*** (2013.01); ***H04W 4/029*** (2018.02); ***H04W 72/51*** (2023.01)

(58) **Field of Classification Search**
CPC H04W 4/023; H04W 4/029; H04W 72/51; G01S 5/0284
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,239,792 B2 * 8/2012 Arunachalam G06F 30/392 716/132
10,267,892 B2 4/2019 Edge et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 118310516 A * 7/2024
EP 4090092 A1 11/2022
(Continued)

OTHER PUBLICATIONS

H. Ochi, S. Tagashira and S. Fujita, "A localization scheme for sensor networks based on wireless communication with anchor groups," 11th International Conference on Parallel and Distributed Systems (ICPADS'05), Fukuoka, Japan, 2005, pp. 299-305 vol. 1 (Year: 2005).*

(Continued)

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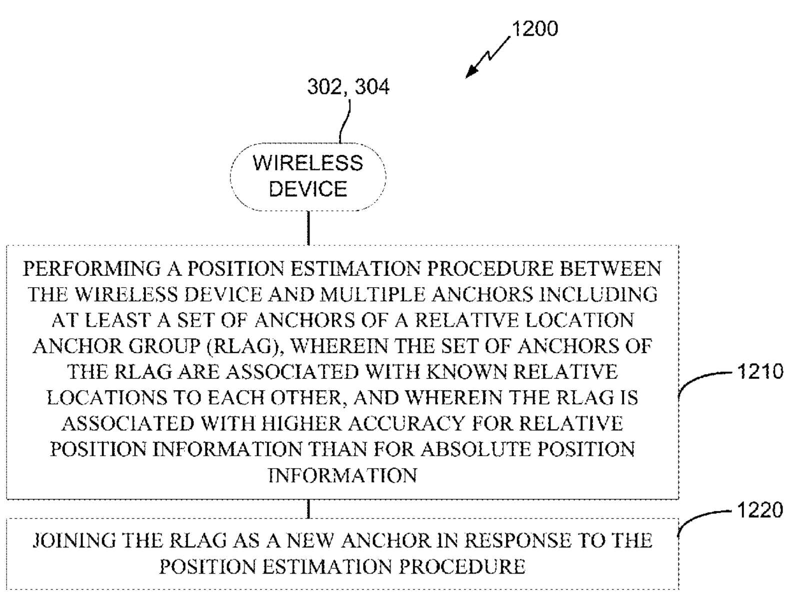
(57) **ABSTRACT**

Disclosed are techniques for wireless communication. In an aspect, a relative location anchor group (RLAG) may facilitate a position estimation procedure in an environment where absolute position estimation accuracy is below a threshold. An absolute position estimate derived via the RLAG may optionally be transformed to a true (or more accurate) position estimate via transformation information. In some cases, new anchors may be added to the RLAG after performing a position estimation procedure with the RLAG. In other designs, a local coordinate system (LCS) may be used for position estimation in lieu of a global coordinate system (GCS), such as WGS 84.

12 Claims, 17 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0125161	A1*	5/2008	Ergen	G01S 5/0289 455/524
2012/0172055	A1*	7/2012	Edge	G01S 5/0249 455/456.1
2014/0087754	A1	3/2014	Siomina et al.	
2016/0377697	A1	12/2016	Sella	
2017/0212206	A1	7/2017	Kim et al.	
2017/0223655	A1	8/2017	Huang et al.	
2019/0041487	A1*	2/2019	Edge	G01S 5/0236
2019/0239181	A1*	8/2019	Gangakhedkar	H04W 76/10
2020/0322756	A1*	10/2020	Sosnin	H04W 4/029
2022/0043099	A1	2/2022	Da et al.	
2022/0061043	A1*	2/2022	Yoon	H04W 72/1263
2022/0124664	A1*	4/2022	Cha	H04L 5/0048
2022/0201423	A1*	6/2022	Freda	H04W 64/003
2023/0049626	A1	2/2023	Bao	
2023/0116323	A1*	4/2023	Cha	H04L 5/0091 370/329
2023/0199802	A1*	6/2023	Ganesan	H04W 72/25 370/329
2023/0217403	A1*	7/2023	Koskela	H04W 64/00 370/252
2023/0273283	A1	8/2023	Kurras et al.	
2023/0319777	A1	10/2023	Taira	
2023/0379860	A1*	11/2023	Rao	H04W 64/00
2023/0388959	A1*	11/2023	Hasegawa	G01S 5/0036
2023/0403114	A1*	12/2023	Ko	G01S 5/02
2024/0069148	A1	2/2024	Baek et al.	
2024/0357317	A1	10/2024	Bao et al.	

FOREIGN PATENT DOCUMENTS

WO	2012047767		4/2012	
WO	2012094270	A1	7/2012	
WO	2018068817	A1	4/2018	
WO	2021228406	A1	11/2021	
WO	2021240479	A1	12/2021	
WO	WO-2023014795	A1 *	2/2023	G01S 5/0072
WO	WO-2024057189	A1 *	3/2024	G01S 5/01

OTHER PUBLICATIONS

A. Boustani, N. Alamatsaz, M. Jadliwala and V. Namboodiri, "LocJam: A novel jamming-based approach to secure localization in wireless networks," 2014 IEEE 11th Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, USA, 2014, pp. 336-344, doi: 10.1109/CCNC.2014.6866592. (Year: 2014).*

H. Ochi, S. Tagashira and S. Fujita, "A localization scheme for sensor networks based on wireless communication with anchor groups," 11th Intenational Conference on Parallel and Distributed Systems (ICPADS'05), Fukuoka, Japan, 2005 pp. 299-305 vol. 1 (Year: 2005).*

A. Boustani, N. Alamatsaz, M. Jadilwala and V. Namboodiri, "LocJam: A novel jamming-based approach to secure localization in wireless networks," 2014 IEEE 11th Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, USA, 2014, pp. 336-344, doi: 10.1109/CCNC.2014.6866592. (Year: 2014).*

C. Laoudias, A. Moreira, S. Kim, S. Lee, L. Wirola and C. Fischione, "A Survey of Enabling Technologies for Network Localization, Tracking, and Navigation," in IEEE Communications Surveys & Tutorials, vol. 20, No. 4, pp. 3607-3644, Fourthquarter 2018, doi: 10.1109/COMST.2018.2855063. (Year: 2018).*

An Overview on Integrated Localization and Communication Towards 6G, Zhiqiang Xiao and Yong Zeng, Member, IEEE, Jun. 2, 2020 (Year: 2020).*

Boustani A., et al., "LocJam: A Novel Jamming-Based Approach to Secure Localization in Wireless Networks", 2014 IEEE 11th Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, USA, Jul. 26, 2014, pp. 336-344.

Chukhno N., et al., "D2D-based Cooperative Positioning Paradigm for Future Wireless Systems: A Survey", IEEE Sensors Journal, vol. 22, No. 6, Mar. 15, 2022, 11 Pages.

International Preliminary Report on Patentability—PCT/US2022/072650—The International Bureau of WIPO—Geneva, Switzerland—Feb. 22, 2024.

International Search Report and Written Opinion—PCT/US2022/072650—ISA/EPO—Jan. 9, 2023.

Laoudias C., et al., "A Survey of Enabling Technologies for Network Localization, Tracking, and Navigation," in IEEE Communications Surveys Tutorials, Fourthquarter, vol. 20, No. 4, Jul. 11, 2018, pp. 3607-3644.

Ochi H., et al., "A Localization Scheme for Sensor Networks Based on Wireless Communication with Anchor Groups," 11th International Conference on Parallel and Distributed Systems, Fukuoka, Japan, vol. 1, Nov. 14, 2005, pp. 299-305.

Partial International Search Report—PCT/US2022/072650—ISA/EPO—Oct. 17, 2022.

Xiao Z., et al., "An Overview on Integrated Localization and Communication Towards 6G", Science China, Mar. 2022 (2020), vol. 65, 46 Pages.

* cited by examiner

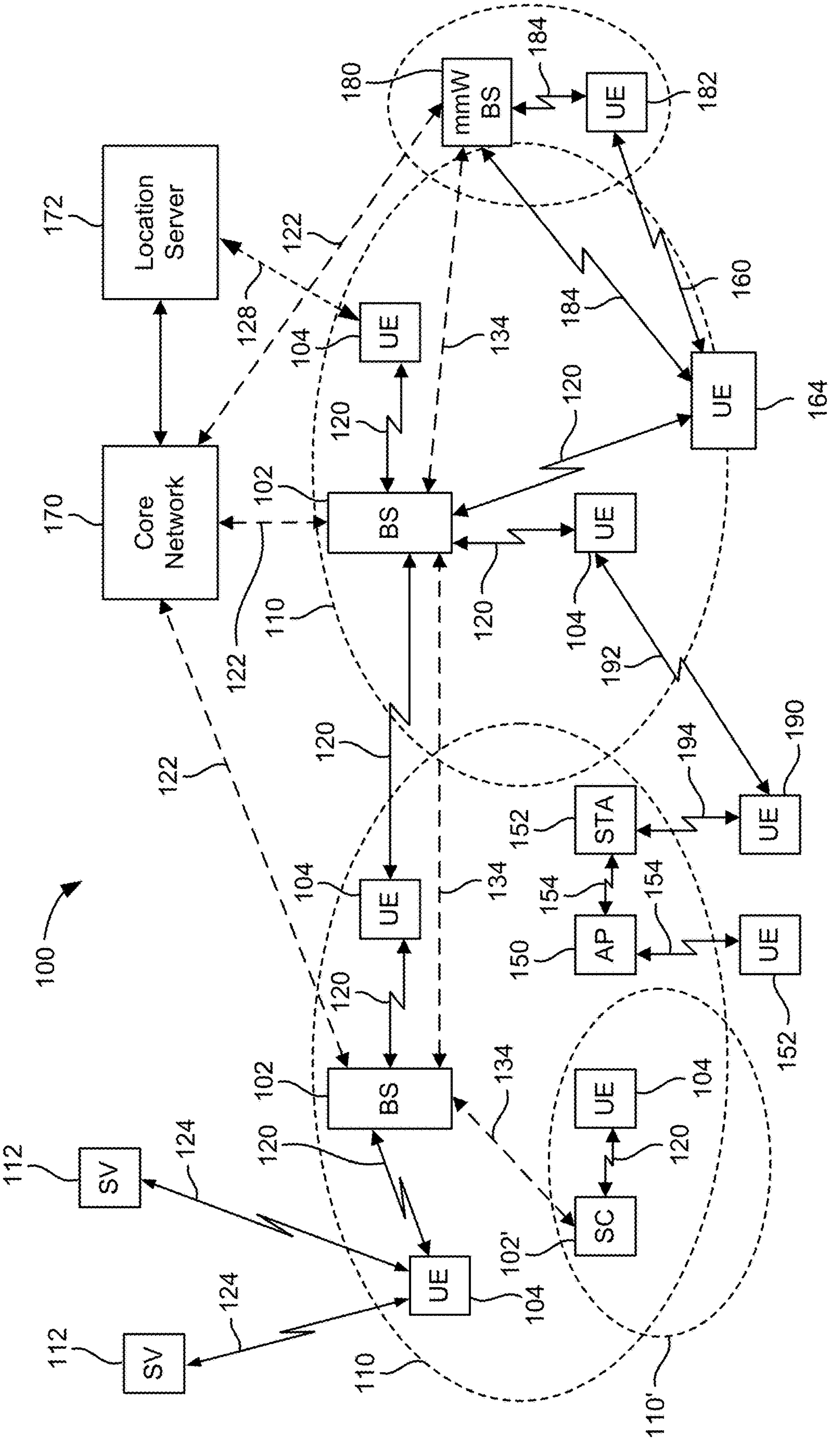

100
Location Server
172
Core Network
170
mmW BS
180
UE
182
184
122
128
134
104
102
BS
120
160
164
110
192
190
194
STA
152
154
AP
150
SC
102'
110'
SV
112
124

FIG. 1

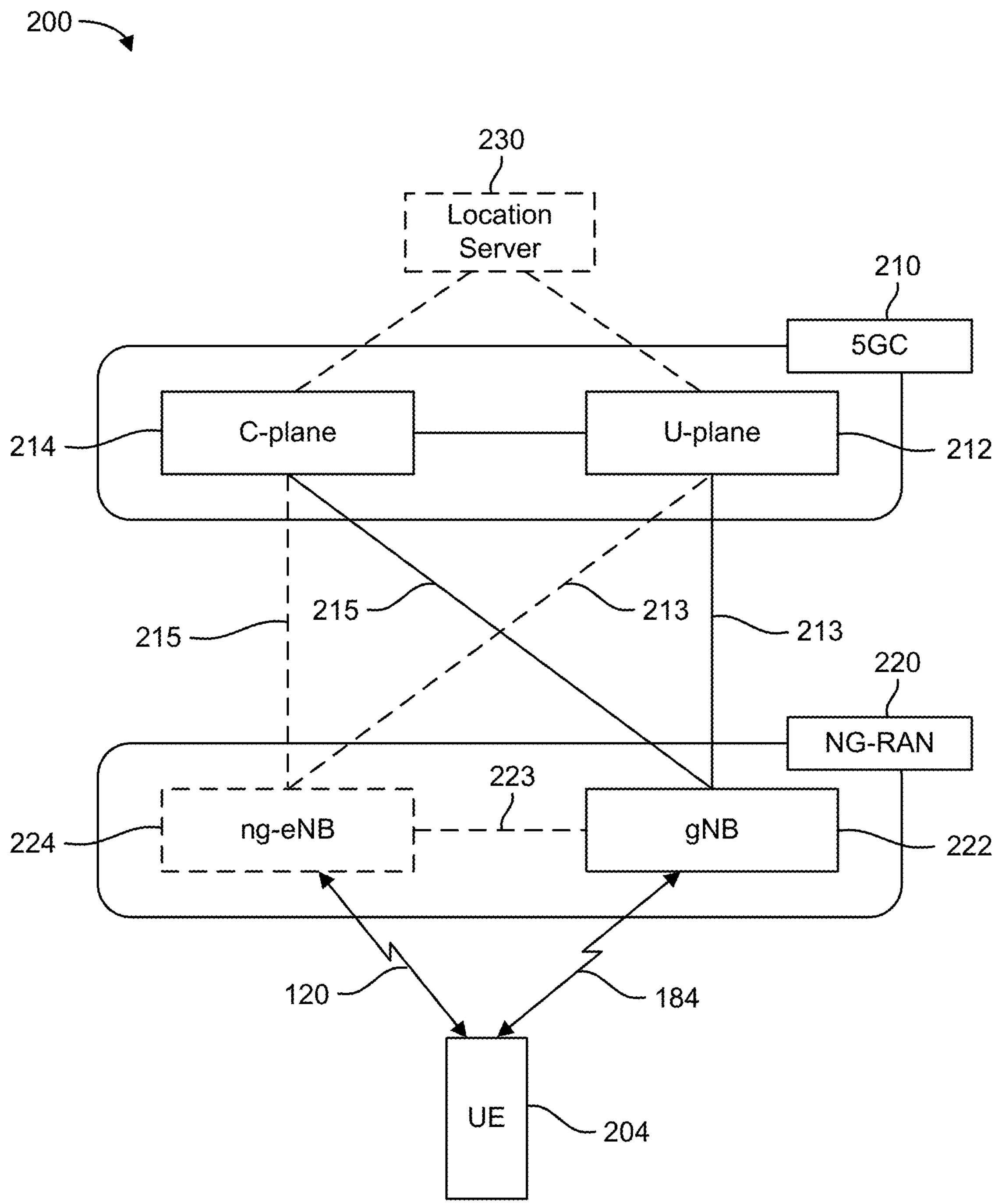

200
230
Location Server
210
5GC
C-plane
U-plane
214
212
215
215
213
213
220
NG-RAN
223
ng-eNB
gNB
224
222
120
184
UE
204

FIG. 2A

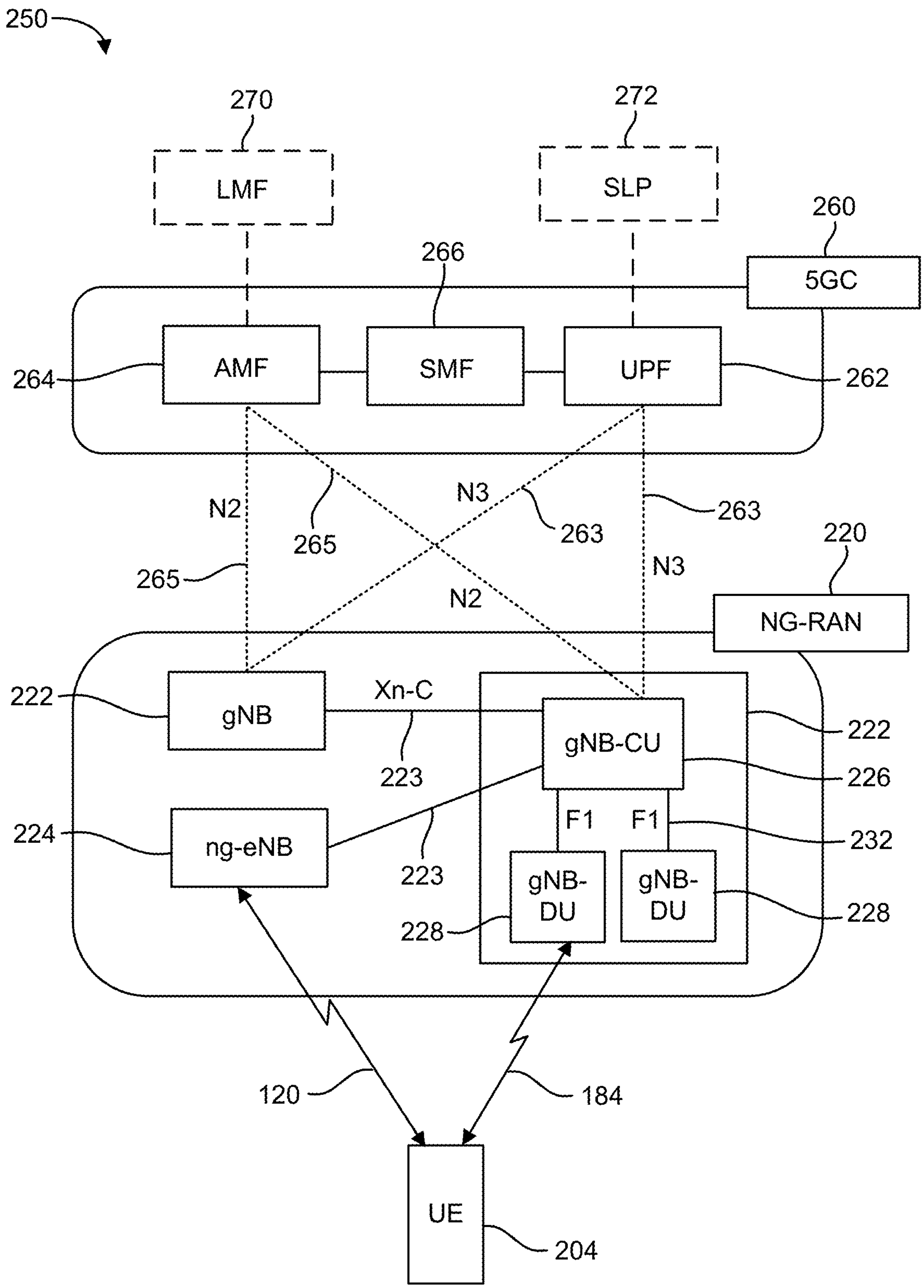

250
270
LMF
272
SLP
260
5GC
266
264
AMF
SMF
UPF
262
N2
265
N3
263
263
265
220
N3
N2
NG-RAN
222
gNB
Xn-C
gNB-CU
222
223
226
224
ng-eNB
F1
F1
232
223
gNB-DU
gNB-DU
228
228
120
184
UE
204

FIG. 2B

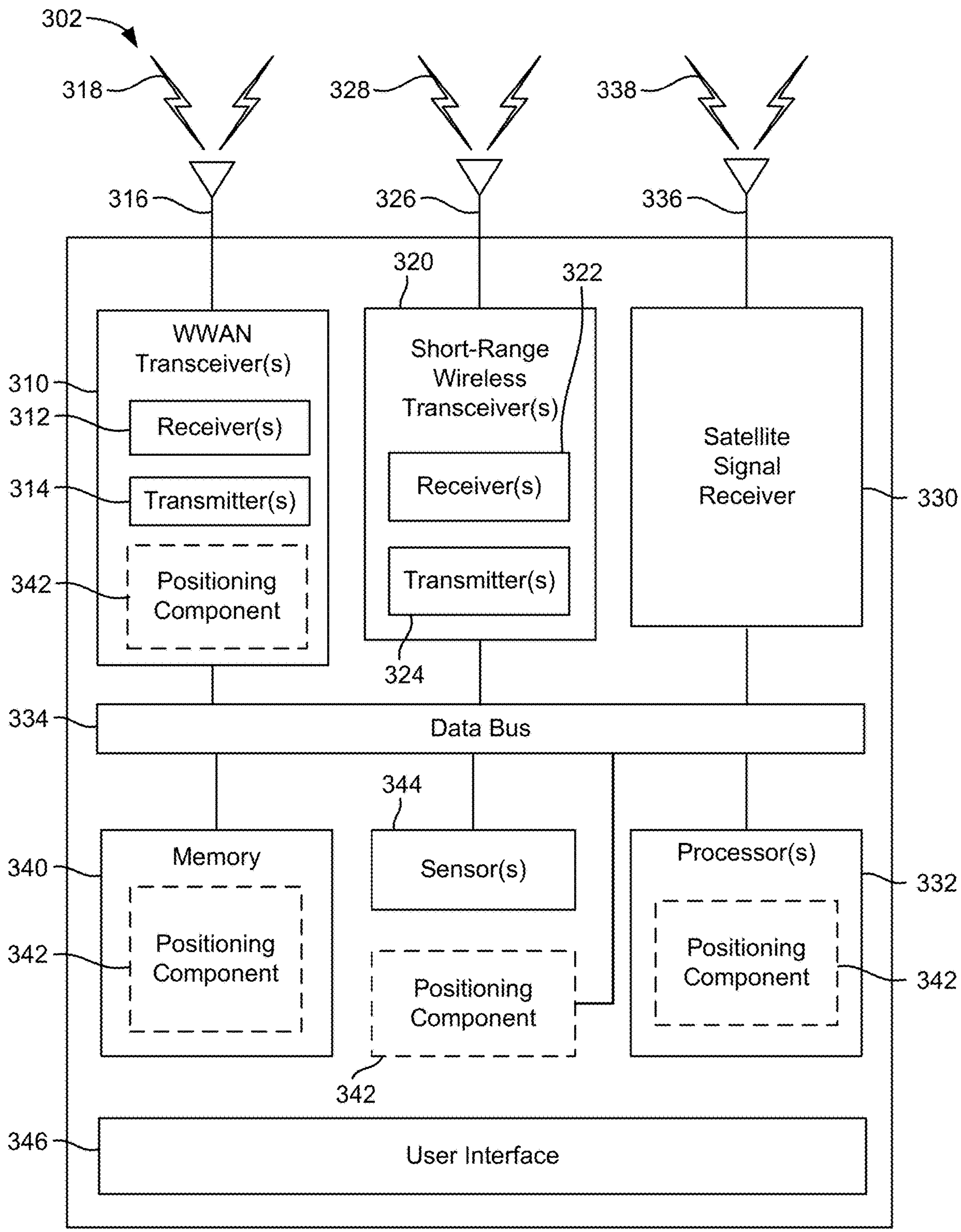

302
318
328
338
316
326
336
320
322
WWAN Transceiver(s)
310
312
Receiver(s)
314
Transmitter(s)
342
Positioning Component
Short-Range Wireless Transceiver(s)
Receiver(s)
Transmitter(s)
324
Satellite Signal Receiver
330
334
Data Bus
344
340
Memory
342
Positioning Component
Sensor(s)
Positioning Component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

FIG. 3A

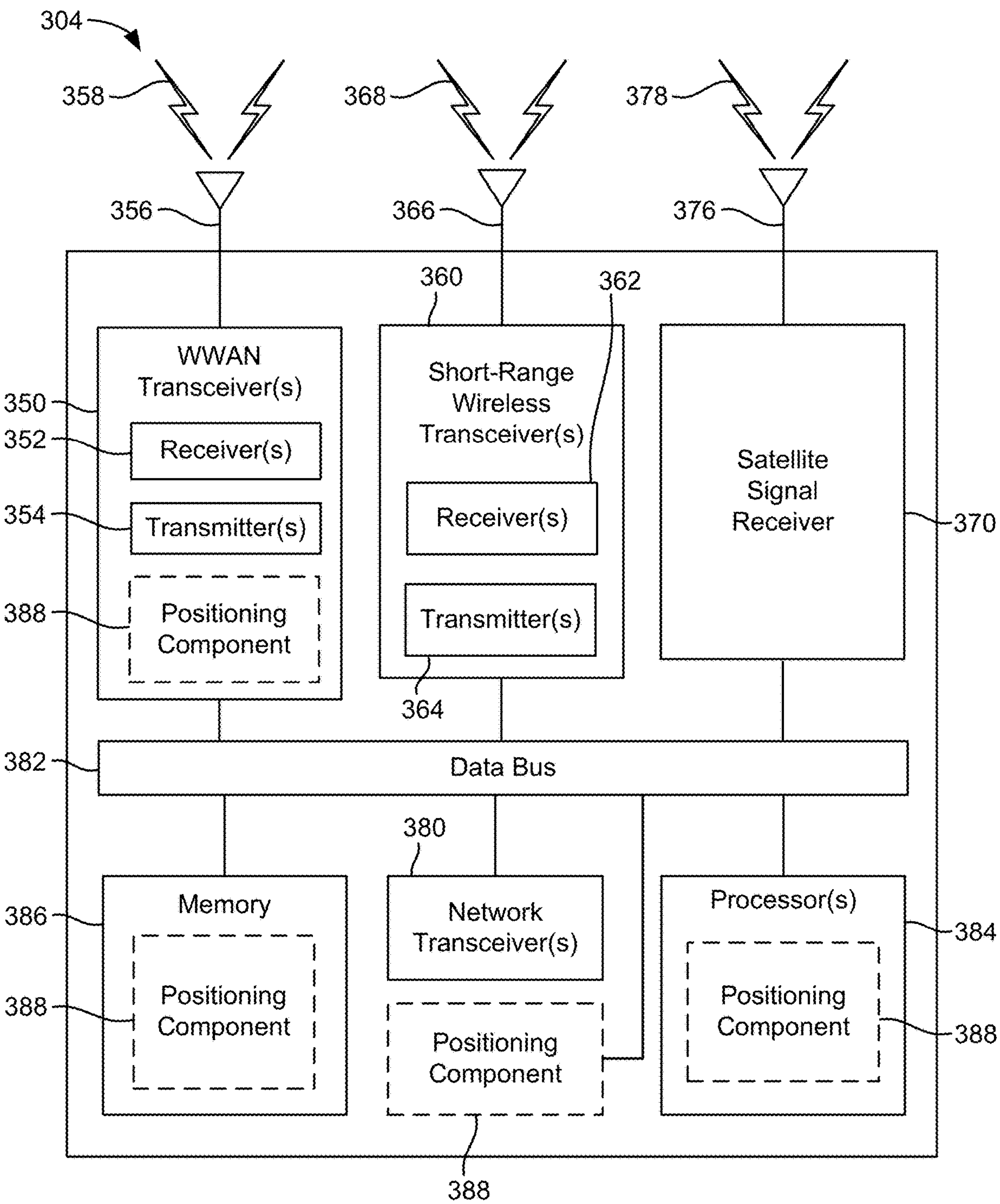

304
358
368
378
356
366
376
360
362
WWAN Transceiver(s)
350
352
Receiver(s)
354
Transmitter(s)
388
Positioning Component
Short-Range Wireless Transceiver(s)
Receiver(s)
Transmitter(s)
364
Satellite Signal Receiver
370
382
Data Bus
380
386
Memory
Positioning Component
388
Network Transceiver(s)
Positioning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

FIG. 3B

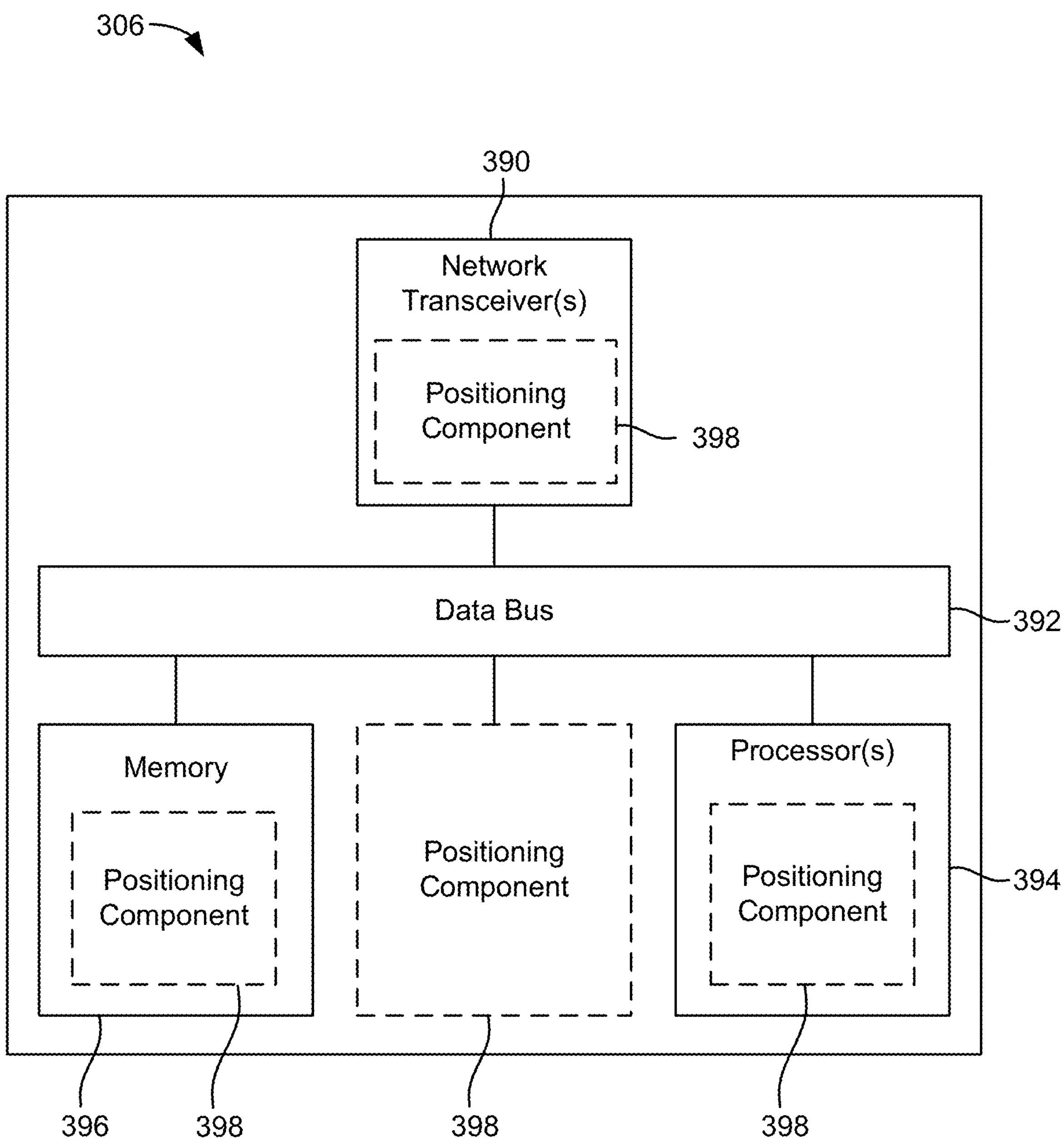

306
390
Network Transceiver(s)
Positioning Component
398
Data Bus
392
Memory
Positioning Component
Positioning Component
Processor(s)
Positioning Component
394
396
398
398
398

FIG. 3C

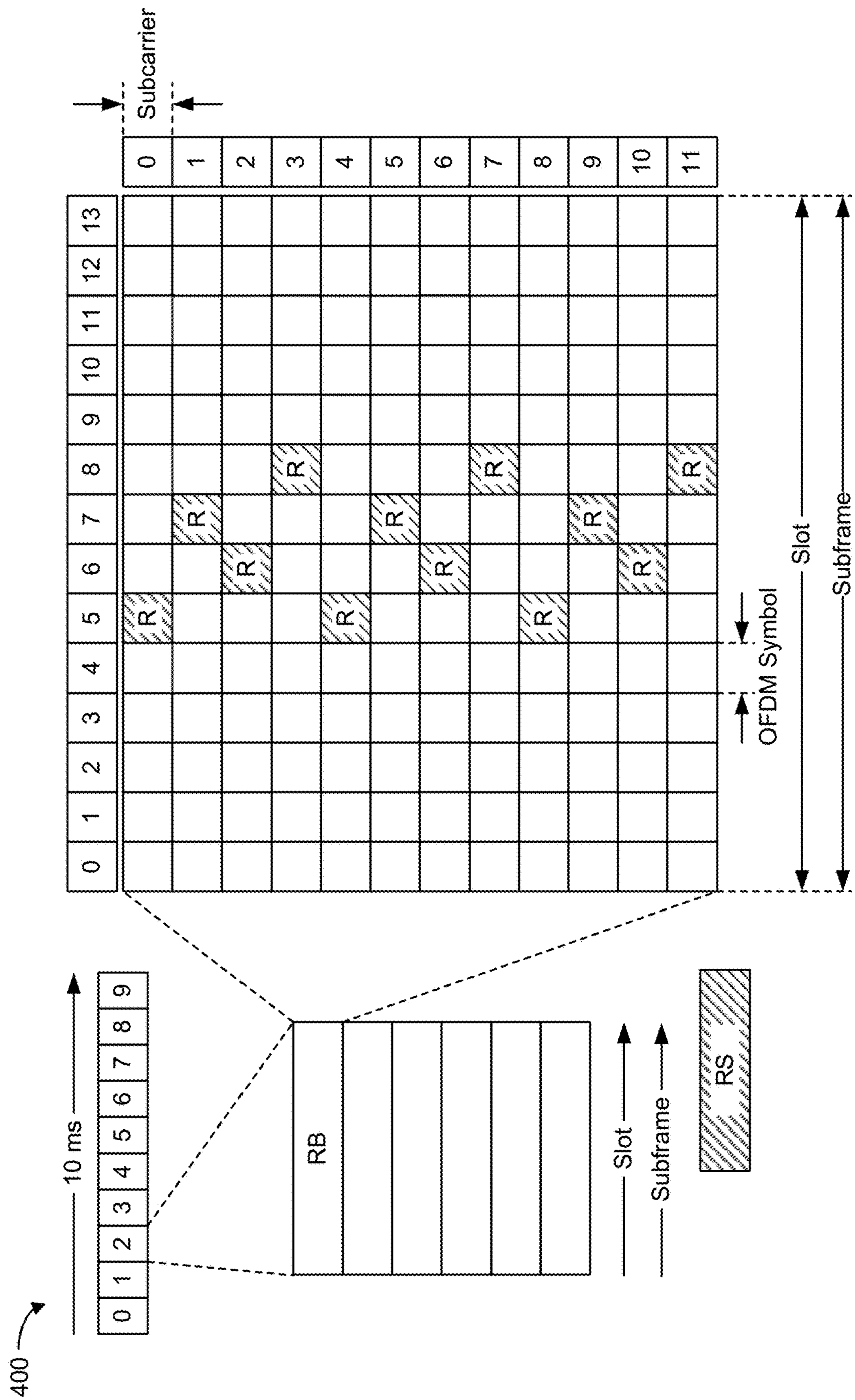

400
10 ms
0
1
2
3
4
5
6
7
8
9
RB
Slot
Subframe
RS
Subcarrier
OFDM Symbol
R

FIG. 4

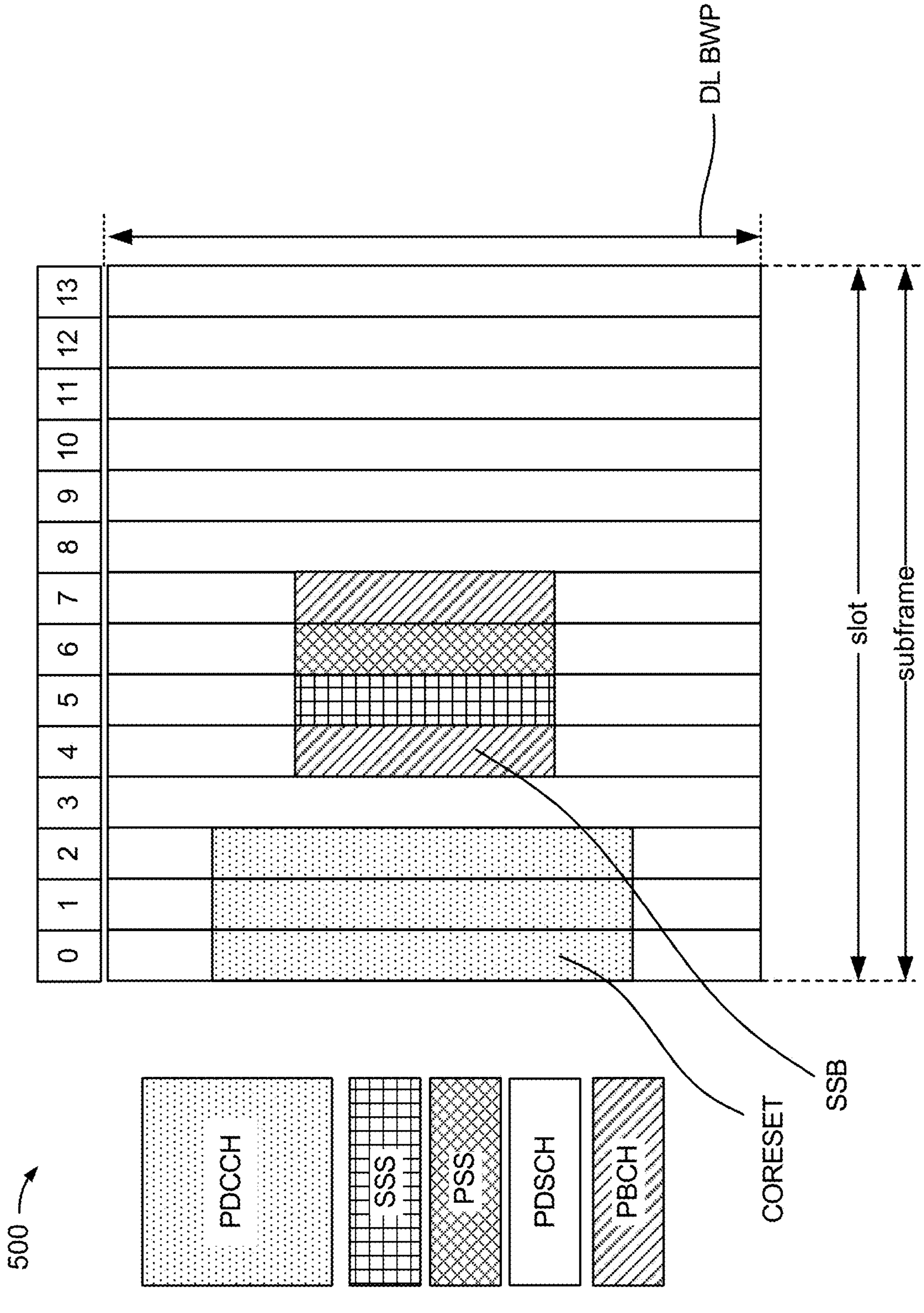

500
PDCCH
SSS
PSS
PDSCH
PBCH
CORESET
SSB
DL BWP
slot
subframe
0
1
2
3
4
5
6
7
8
9
10
11
12
13

FIG. 5

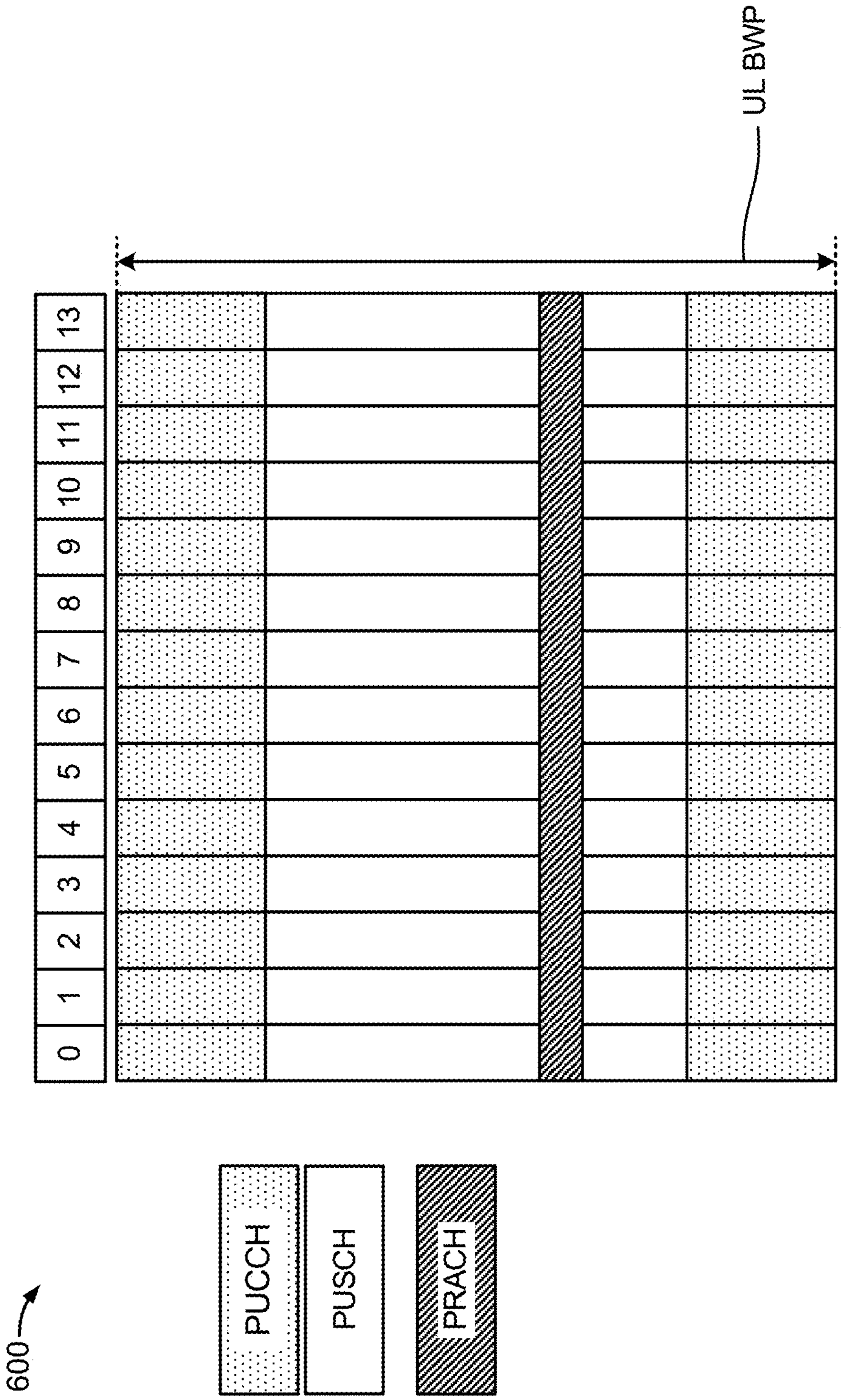


FIG. 6

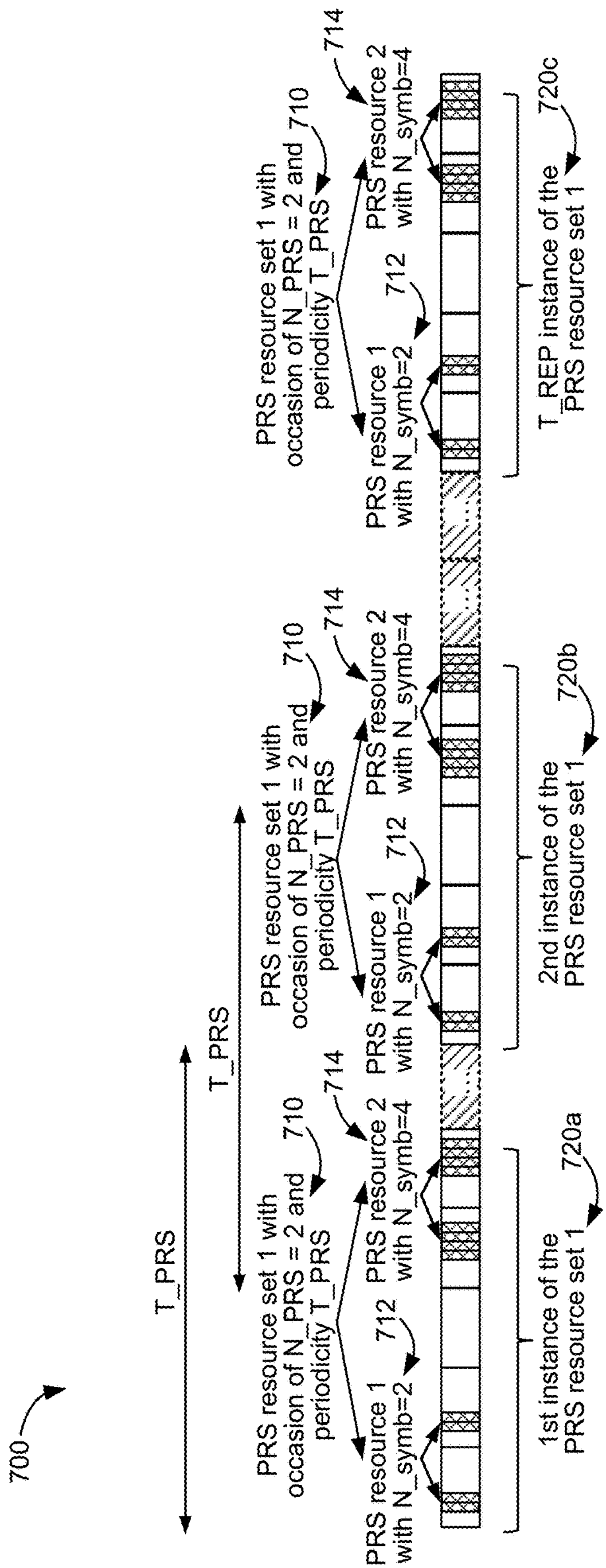

700
T_PRS
T_PRS
PRS resource set 1 with occasion of N_PRS = 2 and periodicity T_PRS
710
712
714
PRS resource 1 with N_symb=2
PRS resource 2 with N_symb=4
1st instance of the PRS resource set 1
720a
2nd instance of the PRS resource set 1
720b
T_REP instance of the PRS resource set 1
720c

FIG. 7

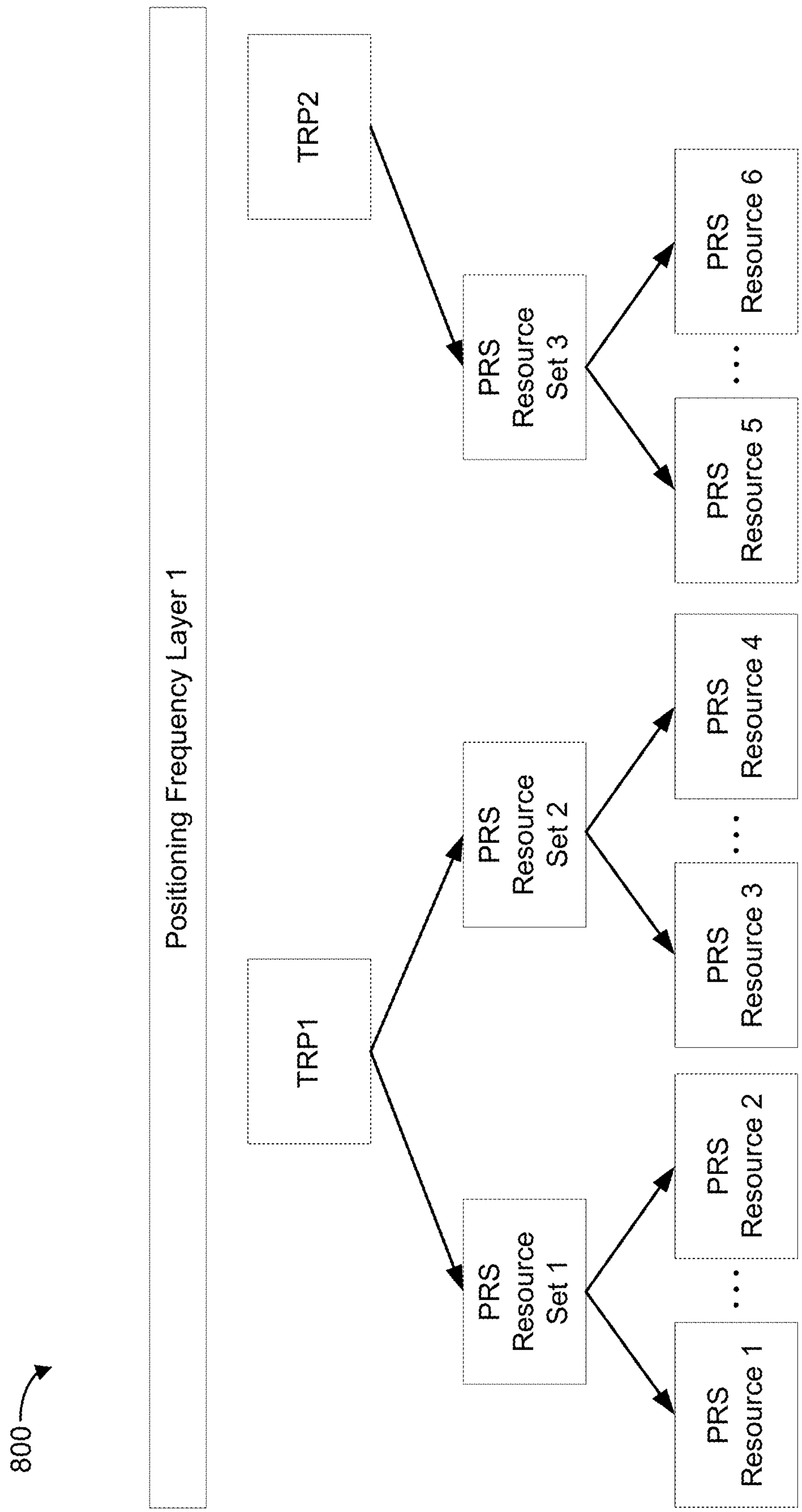

800
Positioning Frequency Layer 1
TRP1
TRP2
PRS Resource Set 1
PRS Resource Set 2
PRS Resource Set 3
PRS Resource 1
PRS Resource 2
PRS Resource 3
PRS Resource 4
PRS Resource 5
PRS Resource 6

FIG. 8

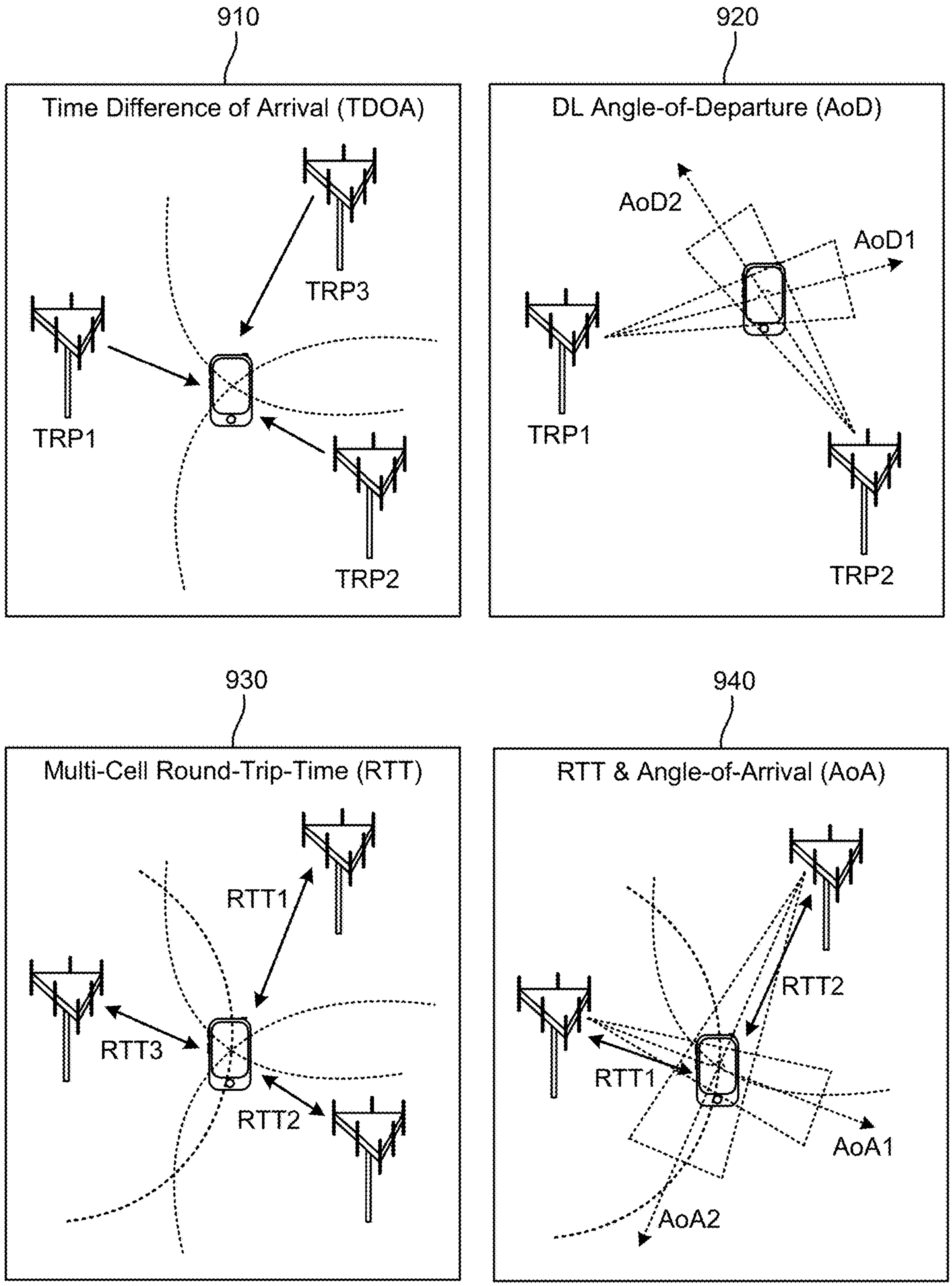

910
Time Difference of Arrival (TDOA)
TRP3
TRP1
TRP2
920
DL Angle-of-Departure (AoD)
AoD2
AoD1
TRP1
TRP2
930
Multi-Cell Round-Trip-Time (RTT)
RTT1
RTT3
RTT2
940
RTT & Angle-of-Arrival (AoA)
RTT2
RTT1
AoA1
AoA2

FIG. 9

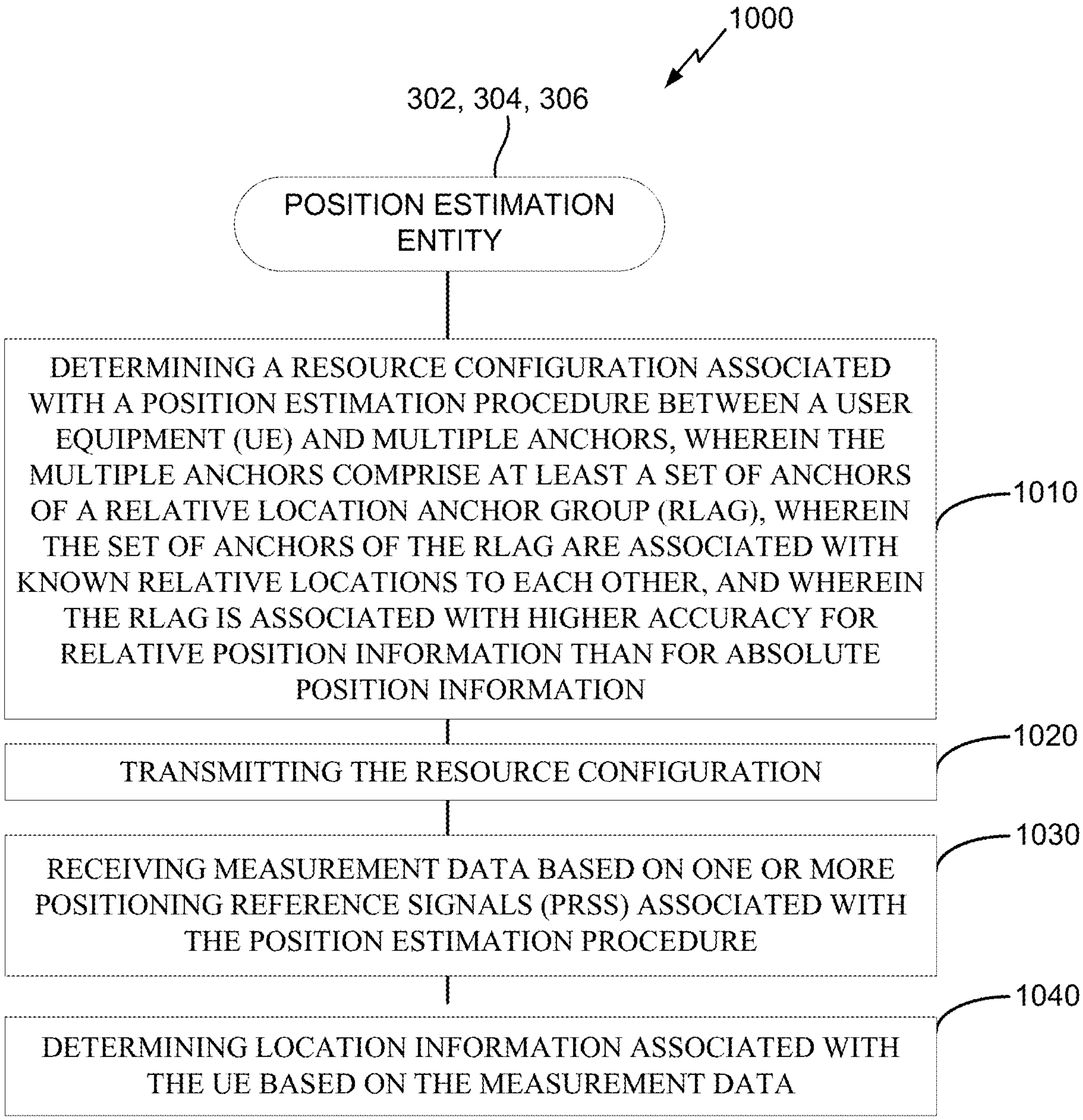

1000
302, 304, 306
POSITION ESTIMATION ENTITY
DETERMINING A RESOURCE CONFIGURATION ASSOCIATED WITH A POSITION ESTIMATION PROCEDURE BETWEEN A USER EQUIPMENT (UE) AND MULTIPLE ANCHORS, WHEREIN THE MULTIPLE ANCHORS COMPRISE AT LEAST A SET OF ANCHORS OF A RELATIVE LOCATION ANCHOR GROUP (RLAG), WHEREIN THE SET OF ANCHORS OF THE RLAG ARE ASSOCIATED WITH KNOWN RELATIVE LOCATIONS TO EACH OTHER, AND WHEREIN THE RLAG IS ASSOCIATED WITH HIGHER ACCURACY FOR RELATIVE POSITION INFORMATION THAN FOR ABSOLUTE POSITION INFORMATION
1010
TRANSMITTING THE RESOURCE CONFIGURATION
1020
RECEIVING MEASUREMENT DATA BASED ON ONE OR MORE POSITIONING REFERENCE SIGNALS (PRSS) ASSOCIATED WITH THE POSITION ESTIMATION PROCEDURE
1030
DETERMINING LOCATION INFORMATION ASSOCIATED WITH THE UE BASED ON THE MEASUREMENT DATA
1040

FIG. 10

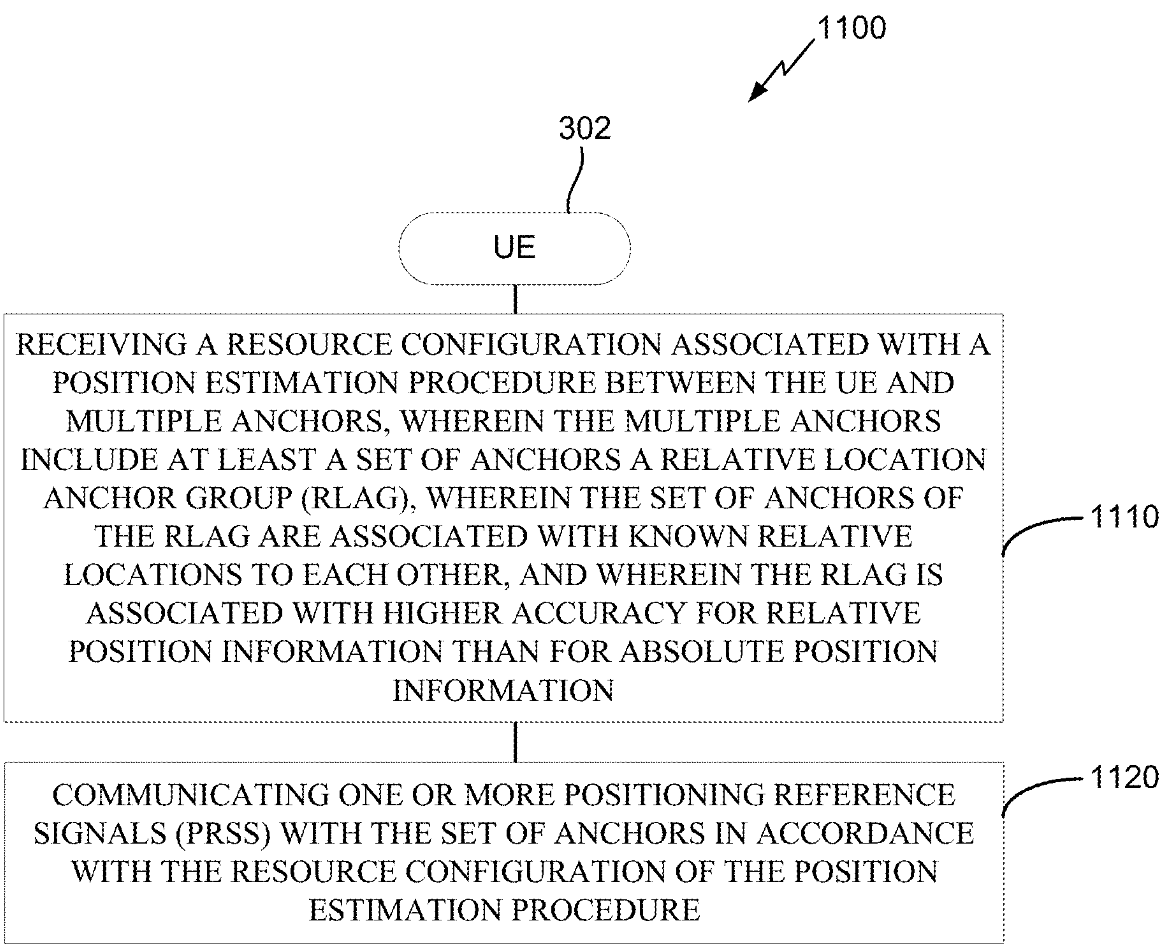

1100
302
UE
RECEIVING A RESOURCE CONFIGURATION ASSOCIATED WITH A POSITION ESTIMATION PROCEDURE BETWEEN THE UE AND MULTIPLE ANCHORS, WHEREIN THE MULTIPLE ANCHORS INCLUDE AT LEAST A SET OF ANCHORS A RELATIVE LOCATION ANCHOR GROUP (RLAG), WHEREIN THE SET OF ANCHORS OF THE RLAG ARE ASSOCIATED WITH KNOWN RELATIVE LOCATIONS TO EACH OTHER, AND WHEREIN THE RLAG IS ASSOCIATED WITH HIGHER ACCURACY FOR RELATIVE POSITION INFORMATION THAN FOR ABSOLUTE POSITION INFORMATION
1110
COMMUNICATING ONE OR MORE POSITIONING REFERENCE SIGNALS (PRSS) WITH THE SET OF ANCHORS IN ACCORDANCE WITH THE RESOURCE CONFIGURATION OF THE POSITION ESTIMATION PROCEDURE
1120

FIG. 11

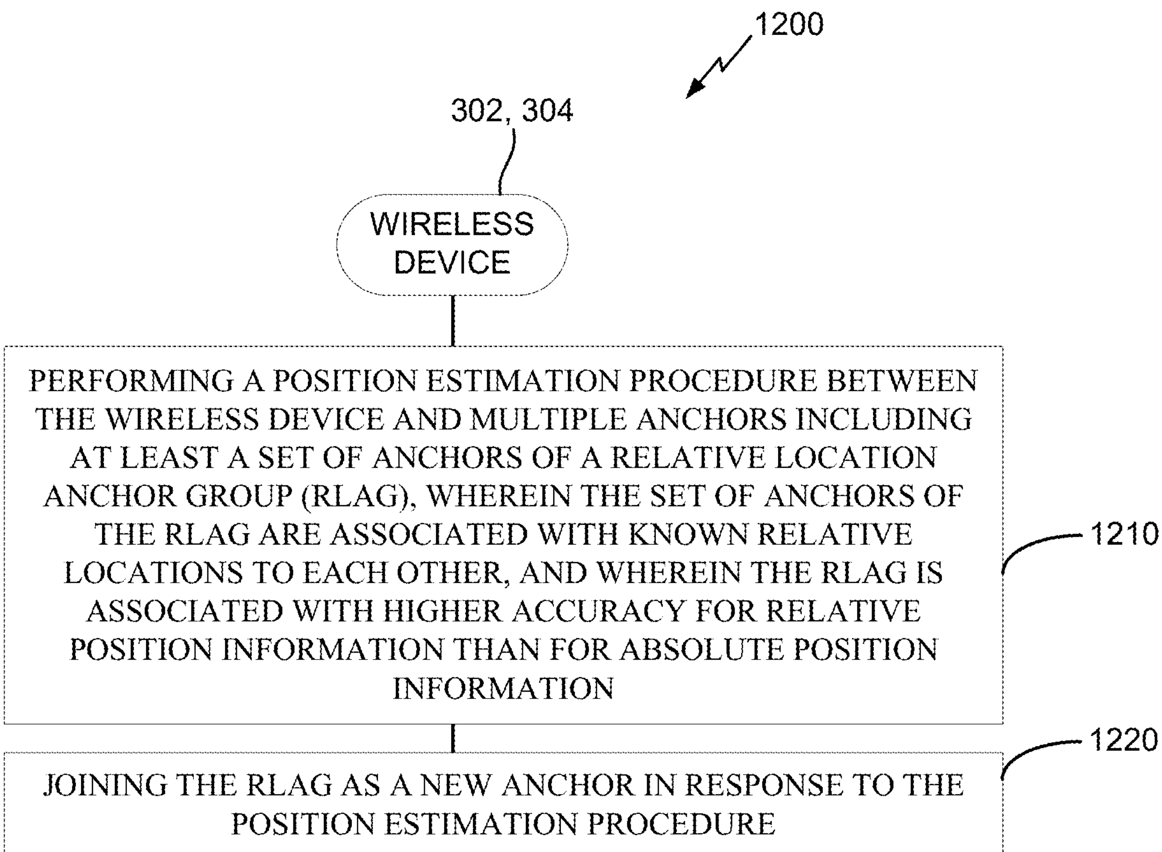

1200
302, 304
WIRELESS DEVICE
PERFORMING A POSITION ESTIMATION PROCEDURE BETWEEN THE WIRELESS DEVICE AND MULTIPLE ANCHORS INCLUDING AT LEAST A SET OF ANCHORS OF A RELATIVE LOCATION ANCHOR GROUP (RLAG), WHEREIN THE SET OF ANCHORS OF THE RLAG ARE ASSOCIATED WITH KNOWN RELATIVE LOCATIONS TO EACH OTHER, AND WHEREIN THE RLAG IS ASSOCIATED WITH HIGHER ACCURACY FOR RELATIVE POSITION INFORMATION THAN FOR ABSOLUTE POSITION INFORMATION
1210
JOINING THE RLAG AS A NEW ANCHOR IN RESPONSE TO THE POSITION ESTIMATION PROCEDURE
1220

FIG. 12

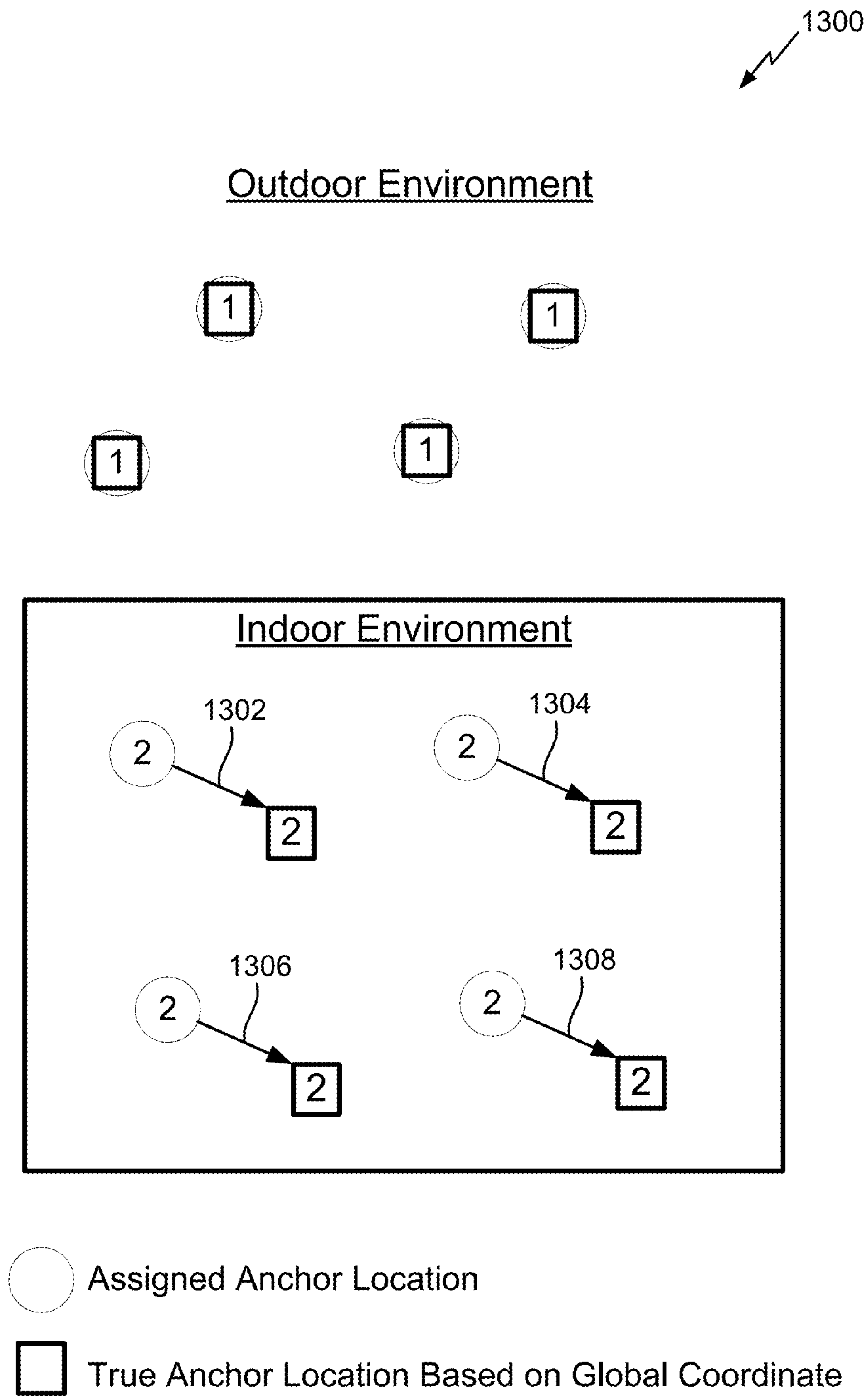

1300
Outdoor Environment
1
1
1
1
Indoor Environment
1302
2
2
1304
2
2
1306
2
2
1308
2
2
Assigned Anchor Location
True Anchor Location Based on Global Coordinate

FIG. 13

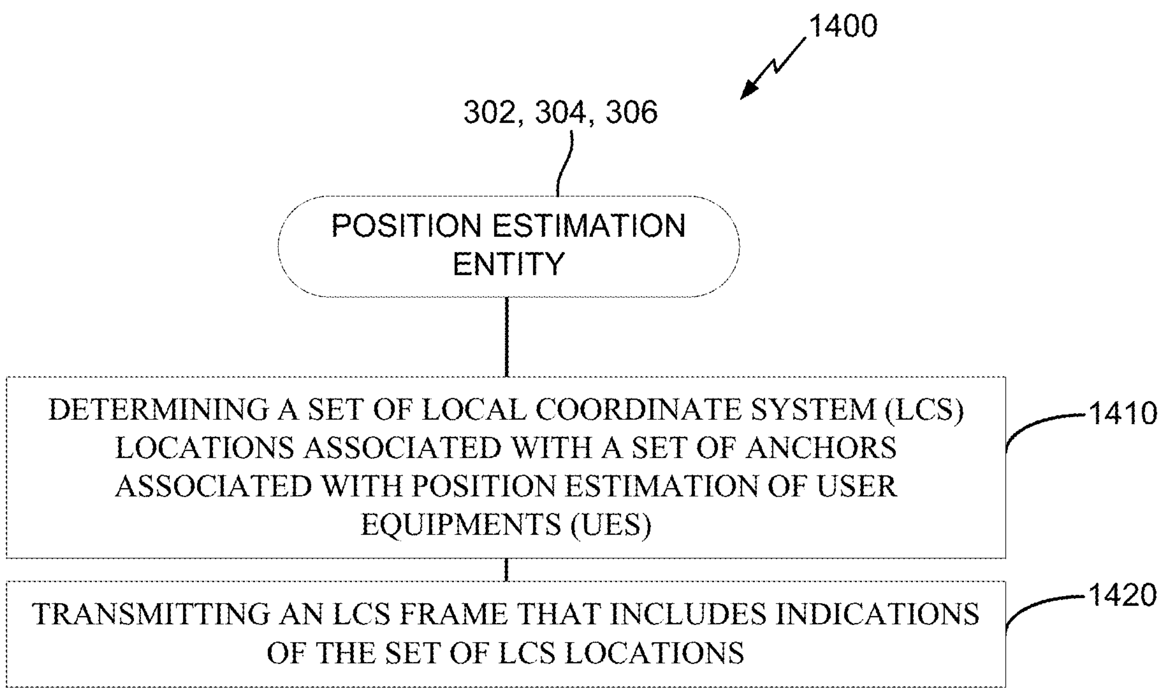

1400
302, 304, 306
POSITION ESTIMATION ENTITY
DETERMINING A SET OF LOCAL COORDINATE SYSTEM (LCS) LOCATIONS ASSOCIATED WITH A SET OF ANCHORS ASSOCIATED WITH POSITION ESTIMATION OF USER EQUIPMENTS (UES)
1410
TRANSMITTING AN LCS FRAME THAT INCLUDES INDICATIONS OF THE SET OF LCS LOCATIONS
1420

FIG. 14

RELATIVE LOCATION ANCHOR GROUP AND LOCAL COORDINATE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application for patent is a Divisional of U.S. Non-Provisional application Ser. No. 17/399,982, entitled "RELATIVE LOCATION ANCHOR GROUP AND LOCAL COORDINATE SYSTEM," filed Aug. 11, 2021, assigned to the assignee hereof, and expressly incorporated herein by reference in its entirety.

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

Aspects of the disclosure relate generally to wireless communications.

2. Description of the Related Art

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

A fifth generation (5G) wireless standard, referred to as New Radio (NR), 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

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

In an aspect, a method of operating a position estimation entity includes determining a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmitting the resource configuration; receiving measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determining location information associated with the UE based on the measurement data.

In some aspects, the location information comprises relative location information.

In some aspects, the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

In some aspects, the location information comprises a derived absolute position estimate of the UE based on the measurement data.

In some aspects, the derived absolute position estimate is associated with transformation information.

In some aspects, the method includes applying the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

In some aspects, the method includes transmitting the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the position estimation procedure is associated with anchors from one RLAG only.

In some aspects, the method includes receiving, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

In some aspects, the method includes transmitting, to the UE, an indication of a RLAG identifier of the RLAG.

In some aspects, the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

In some aspects, the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

In some aspects, the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

In an aspect, a method of operating a user equipment (UE) includes receiving a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicating one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

In some aspects, absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

In some aspects, the method includes receiving, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

In some aspects, the method includes applying the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the method includes receiving an indication of a RLAG identifier of the RLAG.

In an aspect, a method of operating a wireless device includes performing a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and joining the RLAG as a new anchor in response to the position estimation procedure.

In some aspects, the method includes determining a RLAG identifier associated with the RLAG.

In some aspects, the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

In some aspects, the method includes transmitting, to a position estimation entity, an indication of the RLAG identifier.

In an aspect, a method of operating a position estimation entity includes determining a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmitting an LCS frame that includes indications of the set of LCS locations.

In some aspects, each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

In some aspects, the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

In some aspects, the set of LCS locations is defined by cartesian coordinates or polar coordinates.

In an aspect, a position estimation entity includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmit, via the at least one transceiver, the resource configuration; receive, via the at least one transceiver, measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determine location information associated with the UE based on the measurement data.

In some aspects, the location information comprises relative location information.

In some aspects, the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

In some aspects, the location information comprises a derived absolute position estimate of the UE based on the measurement data.

In some aspects, the derived absolute position estimate is associated with transformation information.

In some aspects, the at least one processor is further configured to: apply the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

In some aspects, the at least one processor is further configured to: transmit, via the at least one transceiver, the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the position estimation procedure is associated with anchors from one RLAG only.

In some aspects, the at least one processor is further configured to: receive, via the at least one transceiver, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

In some aspects, the at least one processor is further configured to: transmit, via the at least one transceiver, to the UE, an indication of a RLAG identifier of the RLAG.

In some aspects, the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

In some aspects, the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

In some aspects, the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

In an aspect, a user equipment (UE) includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: receive, via the at least one transceiver, a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicate, via the at least one transceiver, one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

In some aspects, absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

In some aspects, the at least one processor is further configured to: receive, via the at least one transceiver, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

In some aspects, the at least one processor is further configured to: apply the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the at least one processor is further configured to: receive, via the at least one transceiver, an indication of a RLAG identifier of the RLAG.

In an aspect, a wireless device includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and join the RLAG as a new anchor in response to the position estimation procedure.

In some aspects, the at least one processor is further configured to: determine a RLAG identifier associated with the RLAG.

In some aspects, the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

In some aspects, the at least one processor is further configured to: transmit, via the at least one transceiver, to a position estimation entity, an indication of the RLAG identifier.

In an aspect, a position estimation entity includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmit, via the at least one transceiver, an LCS frame that includes indications of the set of LCS locations.

In some aspects, each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

In some aspects, the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

In some aspects, the set of LCS locations is defined by cartesian coordinates or polar coordinates.

In an aspect, a position estimation entity includes means for determining a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; means for transmitting the resource configuration; means for receiving measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and means for determining location information associated with the UE based on the measurement data.

In some aspects, the location information comprises relative location information.

In some aspects, the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

In some aspects, the location information comprises a derived absolute position estimate of the UE based on the measurement data.

In some aspects, the derived absolute position estimate is associated with transformation information.

In some aspects, the method includes means for applying the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

In some aspects, the method includes means for transmitting the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the position estimation procedure is associated with anchors from one RLAG only.

In some aspects, the method includes means for receiving, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

In some aspects, the method includes means for transmitting, to the UE, an indication of a RLAG identifier of the RLAG.

In some aspects, the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

In some aspects, the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

In some aspects, the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

In an aspect, a user equipment (UE) includes means for receiving a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and means for communicating one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

In some aspects, absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

In some aspects, the method includes means for receiving, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

In some aspects, the method includes means for applying the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the method includes means for receiving an indication of a RLAG identifier of the RLAG.

In an aspect, a wireless device includes means for performing a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and means for joining the RLAG as a new anchor in response to the position estimation procedure.

In some aspects, the method includes means for determining a RLAG identifier associated with the RLAG.

In some aspects, the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

In some aspects, the method includes means for transmitting, to a position estimation entity, an indication of the RLAG identifier.

In an aspect, a position estimation entity includes means for determining a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and means for transmitting an LCS frame that includes indications of the set of LCS locations.

In some aspects, each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

In some aspects, the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

In some aspects, the set of LCS locations is defined by cartesian coordinates or polar coordinates.

In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a position estimation entity, cause the position estimation entity to: determine a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmit the resource configuration; receive measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determine location information associated with the UE based on the measurement data.

In some aspects, the location information comprises relative location information.

In some aspects, the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

In some aspects, the location information comprises a derived absolute position estimate of the UE based on the measurement data.

In some aspects, the derived absolute position estimate is associated with transformation information.

In some aspects, instructions that, when executed by position estimation entity, further cause the position estimation entity to:

In some aspects, instructions that, when executed by position estimation entity, further cause the position estimation entity to:

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, the position estimation procedure is associated with anchors from one RLAG only.

In some aspects, instructions that, when executed by position estimation entity, further cause the position estimation entity to:

In some aspects, instructions that, when executed by position estimation entity, further cause the position estimation entity to:

In some aspects, the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

In some aspects, the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

In some aspects, the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: receive a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicate one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

In some aspects, absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

In some aspects, instructions that, when executed by UE, further cause the UE to:

In some aspects, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

In some aspects, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

In some aspects, instructions that, when executed by UE, further cause the UE to:

In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a wireless device, cause the wireless device to: perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and join the RLAG as a new anchor in response to the position estimation procedure.

In some aspects, instructions that, when executed by wireless device, further cause the wireless device to:

In some aspects, the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

In some aspects, instructions that, when executed by wireless device, further cause the wireless device to:

In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a position estimation entity, cause the position estimation entity to: determine a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmit an LCS frame that includes indications of the set of LCS locations.

In some aspects, each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

In some aspects, the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

In some aspects, the set of LCS locations is defined by cartesian coordinates or polar coordinates.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

FIGS. 2A and 2B illustrate example wireless network structures, according to aspects of the disclosure.

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

FIG. 4 is a diagram illustrating an example frame structure, according to aspects of the disclosure.

FIG. 5 is a diagram illustrating various downlink channels within an example downlink slot, according to aspects of the disclosure.

FIG. 6 is a diagram illustrating various uplink channels within an example uplink slot, according to aspects of the disclosure.

FIG. 7 is a diagram of an example positioning reference signal (PRS) configuration for the PRS transmissions of a given base station, according to aspects of the disclosure.

FIG. 8 is a diagram illustrating an example downlink positioning reference signal (DL-PRS) configuration for two transmission-reception points (TRPs) operating in the same positioning frequency layer, according to aspects of the disclosure.

FIG. 9 illustrates examples of various positioning methods supported in New Radio (NR), according to aspects of the disclosure.

FIG. 10 illustrates an exemplary process of wireless communication, according to aspects of the disclosure.

FIG. 11 illustrates an exemplary process of wireless communication, according to aspects of the disclosure.

FIG. 12 illustrates an exemplary process of wireless communication, according to aspects of the disclosure.

FIG. 13 illustrates an example implementation of the processes 10-12 in accordance with aspects of the disclosure.

FIG. 14 illustrates an exemplary process of wireless communication, according to aspects of the disclosure.

DETAILED DESCRIPTION

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

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

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

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

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

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

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

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

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

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

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

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

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

While neighboring macro cell base station **102** geographic coverage areas **110** may partially overlap (e.g., in a handover region), some of the geographic coverage areas **110** may be substantially overlapped by a larger geographic coverage area **110**. For example, a small cell base station **102'** (labeled "SC" for "small cell") may have a geographic coverage area

110' that substantially overlaps with the geographic coverage area **110** of one or more macro cell base stations **102**. A network that includes both small cell and macro cell base stations may be known as a heterogeneous network. A heterogeneous network may also include home eNBs (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG).

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

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

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

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

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

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

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

Transmit and receive beams may be spatially related. A spatial relation means that parameters for a second beam (e.g., a transmit or receive beam) for a second reference signal can be derived from information about a first beam (e.g., a receive beam or a transmit beam) for a first reference signal. For example, a UE may use a particular receive beam to receive a reference downlink reference signal (e.g., synchronization signal block (SSB)) from a base station. The

UE can then form a transmit beam for sending an uplink reference signal (e.g., sounding reference signal (SRS)) to that base station based on the parameters of the receive beam.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

FIG. **2**B illustrates another example wireless network structure **250**. A 5GC **260** (which may correspond to 5GC **210** in FIG. **2**A) can be viewed functionally as control plane functions, provided by an access and mobility management function (AMF) **264**, and user plane functions, provided by a user plane function (UPF) **262**, which operate cooperatively to form the core network (i.e., 5GC **260**). The functions of the AMF **264** include registration management, connection management, reachability management, mobility management, lawful interception, transport for session management (SM) messages between one or more UEs **204** (e.g., any of the UEs described herein) and a session management function (SMF) **266**, transparent proxy services for routing SM messages, access authentication and access authorization, transport for short message service (SMS) messages between the UE **204** and the short message service function (SMSF) (not shown), and security anchor functionality (SEAF). The AMF **264** also interacts with an authentication server function (AUSF) (not shown) and the UE **204**, and receives the intermediate key that was established as a result of the UE **204** authentication process. In the case of authentication based on a UMTS (universal mobile telecommunications system) subscriber identity module (USIM), the AMF **264** retrieves the security material from the AUSF. The functions of the AMF **264** also include security context management (SCM). The SCM receives a key from the SEAF that it uses to derive access-network specific keys. The functionality of the AMF **264** also includes location services management for regulatory services, transport for location services messages between the UE **204** and a location management function (LMF) **270** (which acts as a location server **230**), transport for location services messages between the NG-RAN **220** and the LMF **270**, evolved packet system (EPS) bearer identifier allocation for interworking with the EPS, and UE **204** mobility event notification. In addition, the AMF **264** also supports functionalities for non-3GPP (Third Generation Partnership Project) access networks.

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

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

Another optional aspect may include an LMF **270**, which may be in communication with the 5GC **260** to provide location assistance for UEs **204**. The LMF **270** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The LMF **270** can be configured to support one or more location services for UEs **204** that can connect to the LMF **270** via the core network, 5GC **260**, and/or via the Internet (not illustrated). The SLP **272** may support similar functions to the LMF **270**, but whereas the LMF **270** may communicate with the AMF **264**, NG-RAN **220**, and UEs **204** over a control plane (e.g., using interfaces and protocols intended to convey signaling messages and not voice or data), the SLP **272** may communicate with UEs **204** and external clients (not shown in FIG. **2**B) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).

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

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

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

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

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

The UE **302** and the base station **304** also include, at least in some cases, satellite signal receivers **330** and **370**. The satellite signal receivers **330** and **370** may be connected to one or more antennas **336** and **376**, respectively, and may provide means for receiving and/or measuring satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal receivers **330** and **370** are satellite positioning system receivers, the satellite positioning/communication signals **338** and **378** may be global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC), Quasi-Zenith Satellite System (QZSS), etc. Where the satellite signal receivers **330** and **370** are non-terrestrial network (NTN) receivers, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal receivers **330** and **370** may comprise any suitable hardware and/or software for receiving and processing satellite positioning/communication signals **338** and **378**, respectively. The satellite signal receivers **330** and **370** may request information and operations as appropriate from the other systems, and, at least in some cases, perform calculations to determine locations of the UE **302** and the base station **304**, respectively, using measurements obtained by any suitable satellite positioning system algorithm.

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

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

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

The UE **302**, the base station **304**, and the network entity **306** also include other components that may be used in conjunction with the operations as disclosed herein. The UE **302**, the base station **304**, and the network entity **306** include one or more processors **332**, **384**, and **394**, respectively, for providing functionality relating to, for example, wireless communication, and for providing other processing functionality. The processors **332**, **384**, and **394** may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processors **332**, **384**, and **394** may include, for example, one or more general purpose processors, multi-core processors, central processing units (CPUs), ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGAs), other programmable logic devices or processing circuitry, or various combinations thereof.

The UE **302**, the base station **304**, and the network entity **306** include memory circuitry implementing memories **340**, **386**, and **396** (e.g., each including a memory device), respectively, for maintaining information (e.g., information indicative of reserved resources, thresholds, parameters, and so on). The memories **340**, **386**, and **396** may therefore provide means for storing, means for retrieving, means for maintaining, etc. In some cases, the UE **302**, the base station **304**, and the network entity **306** may include positioning component **342**, **388**, and **398**, respectively. The positioning component **342**, **388**, and **398** may be hardware circuits that are part of or coupled to the processors **332**, **384**, and **394**, respectively, that, when executed, cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. In other aspects, the positioning component **342**, **388**, and **398** may be external to the processors **332**, **384**, and **394** (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the positioning component **342**, **388**, and **398** may be memory modules stored in the memories **340**, **386**, and **396**, respectively, that, when executed by the processors **332**, **384**, and **394** (or a modem processing system, another processing system, etc.), cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. FIG. **3**A illustrates possible locations of the positioning component **342**, which may be, for example, part of the one or more WWAN transceivers **310**, the memory **340**, the one or more processors **332**, or any combination thereof, or may be a standalone component. FIG. **3**B illustrates possible locations of the positioning component **388**, which may be, for example, part of the one or more WWAN transceivers **350**, the memory **386**, the one or more processors **384**, or any combination thereof, or may be a standalone component. FIG. **3**C illustrates possible locations of the positioning component **398**, which may be, for example, part of the one or more network transceivers **390**, the memory **396**, the one or more processors **394**, or any combination thereof, or may be a standalone component.

The UE **302** may include one or more sensors **344** coupled to the one or more processors **332** to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the one or more WWAN transceivers **310**, the one or more short-range wireless transceivers **320**, and/or the satellite signal receiver **330**. By way of example, the sensor(s) **344** may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor. Moreover, the sensor(s) **344** may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s) **344** may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in two-dimensional (2D) and/or three-dimensional (3D) coordinate systems.

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

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

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

At the UE **302**, the receiver **312** receives a signal through its respective antenna(s) **316**. The receiver **312** recovers information modulated onto an RF carrier and provides the information to the one or more processors **332**. The transmitter **314** and the receiver **312** implement Layer-1 functionality associated with various signal processing functions. The receiver **312** may perform spatial processing on the information to recover any spatial streams destined for the UE **302**. If multiple spatial streams are destined for the UE **302**, they may be combined by the receiver **312** into a single OFDM symbol stream. The receiver **312** then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **304**. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to recover the data and control signals that were originally transmitted by the base station **304** on the physical channel. The data and control signals are then provided to the one or more processors **332**, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

In the uplink, the one or more processors **332** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The one or more processors **332** are also responsible for error detection.

Similar to the functionality described in connection with the downlink transmission by the base station **304**, the one or more processors **332** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.

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

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

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

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

The various components of the UE **302**, the base station **304**, and the network entity **306** may be communicatively coupled to each other over data buses **334**, **382**, and **392**, respectively. In an aspect, the data buses **334**, **382**, and **392** may form, or be part of, a communication interface of the UE **302**, the base station **304**, and the network entity **306**, respectively. For example, where different logical entities are embodied in the same device (e.g., gNB and location server functionality incorporated into the same base station **304**), the data buses **334**, **382**, and **392** may provide communication between them.

The components of FIGS. **3**A, **3**B, and **3**C may be implemented in various ways. In some implementations, the components of FIGS. **3**A, **3**B, and **3**C may be implemented in one or more circuits such as, for example, one or more processors and/or one or more ASICS (which may include one or more processors). Here, each circuit may use and/or incorporate at least one memory component for storing information or executable code used by the circuit to provide this functionality. For example, some or all of the functionality represented by blocks **310** to **346** may be implemented by processor and memory component(s) of the UE **302** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Similarly, some or all of the functionality represented by blocks **350** to **388** may be implemented by processor and memory component(s) of the base station **304** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Also, some or all of the functionality represented by blocks **390** to **398** may be implemented by processor and memory component(s) of the network entity **306** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). For simplicity, various operations, acts, and/or functions are described herein as being performed "by a UE," "by a base station," "by a network entity," etc. However, as will be appreciated, such operations, acts, and/or functions may actually be performed by specific components or combinations of components of the UE **302**, base station **304**, network entity **306**, etc., such as the processors **332**, **384**, **394**, the transceivers **310**, **320**, **350**, and **360**, the memories **340**, **386**, and **396**, the positioning component **342**, **388**, and **398**, etc.

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

Various frame structures may be used to support downlink and uplink transmissions between network nodes (e.g., base stations and UEs). FIG. **4** is a diagram **400** illustrating an example frame structure, according to aspects of the disclosure. The frame structure may be a downlink or uplink frame structure. Other wireless communications technologies may have different frame structures and/or different channels.

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

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

In the example of FIG. **4**, a numerology of 15 kHz is used. Thus, in the time domain, a 10 ms frame is divided into 10 equally sized subframes of 1 ms each, and each subframe includes one time slot. In FIG. **4**, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top.

A resource grid may be used to represent time slots, each time slot including one or more time-concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)) in the frequency domain. The resource grid is further divided into multiple resource elements (REs). An RE may correspond to one symbol length in the time domain and one subcarrier in the frequency domain. In the numerology of FIG. **4**, for a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and seven consecutive symbols in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and six consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

Some of the REs may carry reference (pilot) signals (RS). The reference signals may include positioning reference signals (PRS), tracking reference signals (TRS), phase tracking reference signals (PTRS), cell-specific reference signals (CRS), channel state information reference signals (CSI-RS), demodulation reference signals (DMRS), primary synchronization signals (PSS), secondary synchronization signals (SSS), synchronization signal blocks (SSBs), sounding reference signals (SRS), etc., depending on whether the illustrated frame structure is used for uplink or downlink communication. FIG. **4** illustrates example locations of REs carrying a reference signal (labeled "R").

FIG. **5** is a diagram **500** illustrating various downlink channels within an example downlink slot. In FIG. **5**, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top. In the example of FIG. **5**, a numerology of 15 kHz is used. Thus, in the time domain, the illustrated slot is one millisecond (ms) in length, divided into 14 symbols.

In NR, the channel bandwidth, or system bandwidth, is divided into multiple bandwidth parts (BWPs). A BWP is a contiguous set of RBs selected from a contiguous subset of the common RBs for a given numerology on a given carrier. Generally, a maximum of four BWPs can be specified in the downlink and uplink. That is, a UE can be configured with up to four BWPs on the downlink, and up to four BWPs on the uplink. Only one BWP (uplink or downlink) may be active at a given time, meaning the UE may only receive or transmit over one BWP at a time. On the downlink, the bandwidth of each BWP should be equal to or greater than the bandwidth of the SSB, but it may or may not contain the SSB.

Referring to FIG. **5**, a primary synchronization signal (PSS) is used by a UE to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a PCI. Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form an SSB (also referred to as an SS/PBCH). The MIB provides a number of RBs in the downlink system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH, such as system information blocks (SIBs), and paging messages.

The physical downlink control channel (PDCCH) carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including one or more RE group (REG) bundles (which may span multiple symbols in the time domain), each REG bundle including one or more REGs, each REG corresponding to 12 resource elements (one resource block) in the frequency domain and one OFDM symbol in the time domain. The set of physical resources used to carry the PDCCH/DCI is referred to in NR as the control resource set (CORESET). In NR, a PDCCH is confined to a single CORESET and is transmitted with its own DMRS. This enables UE-specific beamforming for the PDCCH.

In the example of FIG. **5**, there is one CORESET per BWP, and the CORESET spans three symbols (although it may be only one or two symbols) in the time domain. Unlike LTE control channels, which occupy the entire system bandwidth, in NR, PDCCH channels are localized to a specific region in the frequency domain (i.e., a CORESET). Thus, the frequency component of the PDCCH shown in FIG. **5** is illustrated as less than a single BWP in the frequency domain. Note that although the illustrated CORESET is contiguous in the frequency domain, it need not be. In addition, the CORESET may span less than three symbols in the time domain.

The DCI within the PDCCH carries information about uplink resource allocation (persistent and non-persistent) and descriptions about downlink data transmitted to the UE, referred to as uplink and downlink grants, respectively. More specifically, the DCI indicates the resources scheduled for the downlink data channel (e.g., PDSCH) and the uplink data channel (e.g., physical uplink shared channel (PUSCH)). Multiple (e.g., up to eight) DCIs can be configured in the PDCCH, and these DCIs can have one of multiple formats. For example, there are different DCI formats for uplink scheduling, for downlink scheduling, for uplink transmit power control (TPC), etc. A PDCCH may be transported by 1, 2, 4, 8, or 16 CCEs in order to accommodate different DCI payload sizes or coding rates.

FIG. **6** is a diagram **600** illustrating various uplink channels within an example uplink slot. In FIG. **6**, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top. In the example of FIG. **6**, a numerology of 15 kHz is used. Thus, in the time domain, the illustrated slot is one millisecond (ms) in length, divided into 14 symbols.

A random-access channel (RACH), also referred to as a physical random-access channel (PRACH), may be within one or more slots within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a slot. The PRACH allows the UE to perform initial system access and achieve uplink synchronization. A physical uplink control channel (PUCCH) may be located on edges of the uplink system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, CSI reports, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The physical uplink shared channel (PUSCH) carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

FIG. **7** is a diagram of an example PRS configuration **700** for the PRS transmissions of a given base station, according to aspects of the disclosure. In FIG. **7**, time is represented horizontally, increasing from left to right. Each long rectangle represents a slot and each short (shaded) rectangle represents an OFDM symbol. In the example of FIG. **7**, a PRS resource set **710** (labeled "PRS resource set 1") includes two PRS resources, a first PRS resource **712** (labeled "PRS resource 1") and a second PRS resource **714** (labeled "PRS resource 2"). The base station transmits PRS on the PRS resources **712** and **714** of the PRS resource set **710**.

The PRS resource set **710** has an occasion length (N_PRS) of two slots and a periodicity (T_PRS) of, for example, 160 slots or 160 milliseconds (ms) (for 15 kHz subcarrier spacing). As such, both the PRS resources **712** and **714** are two consecutive slots in length and repeat every T_PRS slots, starting from the slot in which the first symbol of the respective PRS resource occurs. In the example of FIG. **7**, the PRS resource **712** has a symbol length (N_symb) of two symbols, and the PRS resource **714** has a symbol length (N_symb) of four symbols. The PRS resource **712** and the PRS resource **714** may be transmitted on separate beams of the same base station.

Each instance of the PRS resource set **710**, illustrated as instances **720***a*, **720***b*, and **720***c*, includes an occasion of length '2' (i.e., N_PRS=2) for each PRS resource **712**, **714** of the PRS resource set. The PRS resources **712** and **714** are repeated every T_PRS slots up to the muting sequence periodicity T_REP. As such, a bitmap of length T_REP would be needed to indicate which occasions of instances **720***a*, **720***b*, and **720***c* of PRS resource set **710** are muted (i.e., not transmitted).

In an aspect, there may be additional constraints on the PRS configuration **700**. For example, for all PRS resources (e.g., PRS resources **712**, **714**) of a PRS resource set (e.g., PRS resource set **710**), the base station can configure the following parameters to be the same: (a) the occasion length

(N_PRS), (b) the number of symbols (N_symb), (c) the comb type, and/or (d) the bandwidth. In addition, for all PRS resources of all PRS resource sets, the subcarrier spacing and the cyclic prefix can be configured to be the same for one base station or for all base stations. Whether it is for one base station or all base stations may depend on the UE's capability to support the first and/or second option.

FIG. **8** is a diagram **800** illustrating an example PRS configuration for two TRPs (labeled "TRP1" and "TRP2") operating in the same positioning frequency layer (labeled "Positioning Frequency Layer 1"), according to aspects of the disclosure. For a positioning session, a UE may be provided with assistance data indicating the illustrated PRS configuration. In the example of FIG. **8**, the first TRP ("TRP1") is associated with (e.g., transmits) two PRS resource sets, labeled "PRS Resource Set 1" and "PRS Resource Set 2," and the second TRP ("TRP2") is associated with one PRS resource set, labeled "PRS Resource Set 3." Each PRS resource set comprises at least two PRS resources. Specifically, the first PRS resource set ("PRS Resource Set 1") includes PRS resources labeled "PRS Resource 1" and "PRS Resource 2," the second PRS resource set ("PRS Resource Set 2") includes PRS resources labeled "PRS Resource 3" and "PRS Resource 4," and the third PRS resource set ("PRS Resource Set 3") includes PRS resources labeled "PRS Resource 5" and "PRS Resource 6."

NR supports a number of cellular network-based positioning technologies, including downlink-based, uplink-based, and downlink-and-uplink-based positioning methods. Downlink-based positioning methods include observed time difference of arrival (OTDOA) in LTE, downlink time difference of arrival (DL-TDOA) in NR, and downlink angle-of-departure (DL-AoD) in NR. FIG. **9** illustrates examples of various positioning methods, according to aspects of the disclosure. In an OTDOA or DL-TDOA positioning procedure, illustrated by scenario **910**, a UE measures the differences between the times of arrival (ToAs) of reference signals (e.g., positioning reference signals (PRS)) received from pairs of base stations, referred to as reference signal time difference (RSTD) or time difference of arrival (TDOA) measurements, and reports them to a positioning entity. More specifically, the UE receives the identifiers (IDs) of a reference base station (e.g., a serving base station) and multiple non-reference base stations in assistance data. The UE then measures the RSTD between the reference base station and each of the non-reference base stations. Based on the known locations of the involved base stations and the RSTD measurements, the positioning entity (e.g., the UE for UE-based positioning or a location server for UE-assisted positioning) can estimate the UE's location.

For DL-AoD positioning, illustrated by scenario **920**, the positioning entity uses a beam report from the UE of received signal strength measurements of multiple downlink transmit beams to determine the angle(s) between the UE and the transmitting base station(s). The positioning entity can then estimate the location of the UE based on the determined angle(s) and the known location(s) of the transmitting base station(s).

Uplink-based positioning methods include uplink time difference of arrival (UL-TDOA) and uplink angle-of-arrival (UL-AoA). UL-TDOA is similar to DL-TDOA, but is based on uplink reference signals (e.g., sounding reference signals (SRS)) transmitted by the UE. For UL-AoA positioning, one or more base stations measure the received signal strength of one or more uplink reference signals (e.g., SRS) received from a UE on one or more uplink receive beams. The positioning entity uses the signal strength measurements and the angle(s) of the receive beam(s) to determine the angle(s) between the UE and the base station(s). Based on the determined angle(s) and the known location(s) of the base station(s), the positioning entity can then estimate the location of the UE.

Downlink-and-uplink-based positioning methods include enhanced cell-ID (E-CID) positioning and multi-round-trip-time (RTT) positioning (also referred to as "multi-cell RTT" and "multi-RTT"). In an RTT procedure, a first entity (e.g., a base station or a UE) transmits a first RTT-related signal (e.g., a PRS or SRS) to a second entity (e.g., a UE or base station), which transmits a second RTT-related signal (e.g., an SRS or PRS) back to the first entity. Each entity measures the time difference between the time of arrival (ToA) of the received RTT-related signal and the transmission time of the transmitted RTT-related signal. This time difference is referred to as a reception-to-transmission (Rx-Tx) time difference. The Rx-Tx time difference measurement may be made, or may be adjusted, to include only a time difference between nearest subframe boundaries for the received and transmitted signals. Both entities may then send their Rx-Tx time difference measurement to a location server (e.g., an LMF **270**), which calculates the round trip propagation time (i.e., RTT) between the two entities from the two Rx-Tx time difference measurements (e.g., as the sum of the two Rx-Tx time difference measurements). Alternatively, one entity may send its Rx-Tx time difference measurement to the other entity, which then calculates the RTT. The distance between the two entities can be determined from the RTT and the known signal speed (e.g., the speed of light). For multi-RTT positioning, illustrated by scenario **930**, a first entity (e.g., a UE or base station) performs an RTT positioning procedure with multiple second entities (e.g., multiple base stations or UEs) to enable the location of the first entity to be determined (e.g., using multilateration) based on distances to, and the known locations of, the second entities. RTT and multi-RTT methods can be combined with other positioning techniques, such as UL-AoA and DL-AoD, to improve location accuracy, as illustrated by scenario **940**.

The E-CID positioning method is based on radio resource management (RRM) measurements. In E-CID, the UE reports the serving cell ID, the timing advance (TA), and the identifiers, estimated timing, and signal strength of detected neighbor base stations. The location of the UE is then estimated based on this information and the known locations of the base station(s).

To assist positioning operations, a location server (e.g., location server **230**, LMF **270**, SLP **272**) may provide assistance data to the UE. For example, the assistance data may include identifiers of the base stations (or the cells/TRPs of the base stations) from which to measure reference signals, the reference signal configuration parameters (e.g., the number of consecutive positioning subframes, periodicity of positioning subframes, muting sequence, frequency hopping sequence, reference signal identifier, reference signal bandwidth, etc.), and/or other parameters applicable to the particular positioning method. Alternatively, the assistance data may originate directly from the base stations themselves (e.g., in periodically broadcasted overhead messages, etc.). In some cases, the UE may be able to detect neighbor network nodes itself without the use of assistance data.

In the case of an OTDOA or DL-TDOA positioning procedure, the assistance data may further include an expected RSTD value and an associated uncertainty, or search window, around the expected RSTD. In some cases, the value range of the expected RSTD may be +/−500 microseconds (μs). In some cases, when any of the resources used for the positioning measurement are in FR1, the value range for the uncertainty of the expected RSTD may be +/−32 μs. In other cases, when all of the resources used for the positioning measurement(s) are in FR2, the value range for the uncertainty of the expected RSTD may be +/−8 μs.

A location estimate may be referred to by other names, such as a position estimate, location, position, position fix, fix, or the like. A location 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 location 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 location 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).

3GPP position estimation framework supports computing absolute positions (Global coordinate system (GCS) defined in WGS-84). Anchor (e.g., gNB/TRP) locations are known to LMF (for UE-assisted positioning), or indicated to UE (for UE-based positioning). The indications UE specify to absolute position (latitude/longitude/elevation). In 3GPP Rel. 16, different panels of a TRP can be indicated as separate positions (e.g., the TRP is assigned an absolute position, and the panels can be assigned relative positions with respect to that absolute position).

In many cases, absolute position is not needed and relative position with respect to certain landmarks is sufficient (e.g., relative location to other vehicles, road features, pedestrians in V2X positioning, or relative location to factory walls, ceilings, and other static or dynamic features in IIoT, etc.).

In many cases, absolute global anchor locations may be relatively poorly known, but their relative distance is accurate. For example, in some indoor environment, GNSS may not unavailable, but the mutual distance can be measured with high accurate distance measurer (e.g., laser distance meter).

Aspects of the disclosure are directed to a relative location anchor group (RLAG) which may be used for relative position estimation. Such aspects may provide various technical advantages, such as providing information which is not dependent upon absolute location (e.g., speed/velocity, object proximity, etc.), particularly in environments where absolute position estimation accuracy performed via the RLAG is below a threshold (e.g., below an accuracy requirement). In further aspects, transformation information (e.g., rotation, reflection, coordinate offset(s), translation, etc.) may be used to transform an absolute location derived via measurement data associated with the RLAG into a more accurate or 'true' absolute position estimate, which may provide technical advantages such as improved absolute position estimate accuracy and/or improving security (e.g., RLAG may intentionally obfuscate position estimates for entities that do not have knowledge of the transformation information).

FIG. **10** illustrates an exemplary process **1000** of wireless communication, according to aspects of the disclosure. In an aspect, the process **1000** may be performed by a position estimation entity. In some designs, the position estimation entity may correspond to UE **302** (e.g., for UE-based position estimation) or BS **304** (e.g., LMF integrated in RAN) or network entity **306** (e.g., LMF integrated in core network component, a location server, etc.).

Referring to FIG. **10**, at **1010**, the position estimation entity (e.g., processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, etc.) determines a resource configuration (e.g., for SL PRS, DL PRS, UL PRS, etc.) associated with a position estimation procedure between a user equipment (UE) (e.g., a target UE for which a position estimate is desired, etc.) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information (e.g., higher accuracy for relative position estimation than absolute position estimation, etc.). Anchors may be grouped within the RLAG based on various criteria (e.g., a new device that performs position estimation via the RLAG may then be onboarded onto the RLAG, etc.). In some designs, some or all of the anchors in the RLAG may be located in a shared environment (e.g., an indoor environment, or an outdoor environment with obstructions that lower absolute position estimation accuracy, etc.). A means for performing the determination of **1010** may include processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, of UE **302** or BS **304** or network entity **306**.

Referring to FIG. **10**, at **1020**, the position estimation entity (e.g., transmitter **314** or **324** or **354** or **364**, network transceiver(s) **390**, data bus **334** or **382** or **392**, etc.) transmits the resource configuration. For example, the resource configuration may be transmitted to the UE and one or more of the anchors, such as (for Uu position estimation) a serving base station of the UE (e.g., the serving gNB may control one or more of the anchors or TRPs in the RLAG, and may forward the resource configuration to one or more other neighbor gNBs with anchor TRPs), or (for SL position estimation) to one or more anchor UEs, or a combination thereof. A means for performing the transmission of **1020** may include transmitter **314** or **324** or **354** or **364**, network transceiver(s) **390**, data bus **334** or **382** or **392**, of UE **302** or BS **304** or network entity **306**.

Referring to FIG. **10**, at **1030**, the position estimation entity (e.g., receiver **312** or **322** or **352** or **362**, network transceiver(s) **380** or **390**, data bus **334** or **382** or **392**, etc.) receives measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure. In some designs, the measurement data may include measurement(s) associated with UL PRS, DL PRS and/or SL PRS. In other designs, the measurement data may include measurement(s) of non-3GPP PRS, such as laser distance meter measurement(s). In some designs, the measurement data may be received from the UE, some or all of the anchors in the RLAG, or a combination thereof. In some designs, the measurement data may be timing-based (e.g., RTT, TDOA, etc.), angle-based (e.g. AoD or AoA), or a combination thereof. A means for performing the reception of **1030** may include receiver **312** or **322** or **352** or **362**, network transceiver(s) **380** or **390**, data bus **334** or **382** or **392**, of UE **302** or BS **304** or network entity **306**.

Referring to FIG. **10**, at **1040**, the position estimation entity (e.g., processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, etc.) determines location information associated with the UE based on the measurement data. In some designs, the location information may include information that is not dependent on absolute position estimates for the UE and/or the anchors in the RLAG, such as object/collision detection, speed/velocity, and so on. In other designs, as will be discussed below in more detail, the location information may include an absolute location estimate via an application of transformation information. A means for performing the determination of **1040** may include processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, of UE **302** or BS **304** or network entity **306**.

FIG. **11** illustrates an exemplary process **1100** of wireless communication, according to aspects of the disclosure. In an aspect, the process **1100** may be performed by a UE (e.g., a UE for which position estimation is desired), such as UE **302**.

Referring to FIG. **11**, at **1110**, UE **302** (e.g., receiver **312** or **322**, data bus **334**, etc.) receives a resource configuration (e.g., for SL PRS, DL PRS, UL PRS, etc.) associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information (e.g., higher accuracy for relative position estimation than absolute position estimation, etc.). Anchors may be grouped within the RLAG based on various criteria (e.g., a new device that performs position estimation via the RLAG may then be onboarded onto the RLAG, etc.). In some designs, some or all of the anchors in the RLAG may be located in a shared environment (e.g., an indoor environment, or an outdoor environment with obstructions that lower absolute position estimation accuracy, etc.). In case of UE-based position estimation, the reception of **1110** corresponds to an internal transfer of data between logical components. A means for performing the reception of **1110** may include receiver **312** or **322**, data bus **334**, etc., of UE **302**.

Referring to FIG. **11**, at **1120**, UE **302** (e.g., receiver **312** or **322**, transmitter **314** or **324**, positioning component **342**, etc.) communicates one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure. In some designs, the PRS(s) communicated at **1120** may include SL PRS or UL PRS transmitted by UE **302**, SL PRS or DL PRS received at (and measured by) UE **302**, or a combination thereof. A means for performing the communication of **1120** may include receiver **312** or **322**, transmitter **314** or **324**, etc., of UE **302**.

FIG. **12** illustrates an exemplary process **1200** of wireless communication, according to aspects of the disclosure. In an aspect, the process **1200** may be performed by a wireless device such as a UE (e.g., a UE for which position estimation is desired or alternatively a UE with a known location) or a gNB with one or more TRPs.

Referring to FIG. **12**, at **1210**, the wireless device (e.g., receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **356**, positioning component **342** or **388**, etc.) performs a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information. In some designs, the position estimation procedure may include a SL PRS exchange (e.g., a two-way exchange for RTT-type measurement as example, or a one-way exchange to/from the anchor(s) for TDOA-type measurement, etc.) or transmit UL PRS (e.g., or non-3GPP PRS, such as laser distance meter signaling) to/from one or more anchors of the RLAG. A means for performing the position estimation procedure of **1210** may include receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **356**, positioning component **342** or **388**, etc., of UE **302** or BS **304**.

Referring to FIG. **12**, at **1220**, the wireless device (e.g., receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **356**, positioning component **342** or **388**, etc.) joins the RLAG as a new anchor in response to the position estimation procedure. In some designs, the wireless device may coordinate with (or register with) the position estimation entity to facilitate the joinder at **1220**. Hence, for a subsequent RLAG-based position estimation procedure, the wireless device may (optionally) be included as one of the activated anchors in the RLAG. A means for performing the joinder of **1220** may include receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **356**, positioning component **342** or **388**, etc., of UE **302** or BS **304**.

Referring to FIGS. **10-12**, in some designs, the locations for the anchors in the RLAG are provided using precisely the current reporting format (e.g., no need to define any new messages). In some designs, the location information comprises relative location information. For example, the relative location information may include a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection (e.g., object or proximity detection) between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof. In some designs, the location information may include a combination of a low accuracy absolute location estimate along with higher accuracy relative distances to one or more anchors of one or more RLAGs (e.g., as noted above, relative distances between anchors are known within a respective RLAG, but are not necessarily known between anchors of different RLAGs). In other words, in some designs, legacy absolute position estimation may be performed using RLAG-based measurement data, such as speed estimation (e.g., only the differences between two consecutive absolute position estimations matters) or collision detection (e.g., only the difference between the obstacles (e.g., walls, desks, etc.) and UE matters).

Referring to FIGS. **10-12**, in some designs as noted above, absolute position estimation need not be performed at all. However, if performed, absolute position estimation via the RLAG may be associated with transformation information. In some designs, the position estimation entity may derive an absolute position estimate of the UE based on the measurement data, and may then (optionally) apply the transformation information to the derived absolute position estimate of the UE to obtain a more accurate (e.g., true) absolute position estimate of the UE (e.g., because 'normal' absolute position estimates via the RLAG may be highly inaccurate). In other designs, the transformation information may be applied to the anchor locations of the RLAG rather than the position estimate of the UE (e.g., apply transformation information to the inputs to the derivation rather than the output of the derivation).

Referring to FIGS. **10-12**, in some designs, the derived absolute position estimate is transmitted to one or more external entities with knowledge of the transformation information. In this case, the transformation information acts as a security key for unlocking the true (or at least, more accurate) absolute position estimate of the RLAG anchors and/or the UE. In some designs, the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof. The transformation information may thereby be known and/or applied at various entities (e.g., the position estimation entity such as LMF or target UE or another UE for sidelink position estimation), at the AMF or gNB, at the LCS client (e.g., outside of 3GPP framework), and so on. In some designs, the transformation may be used to provide some location information (e.g., proximity detect to avoid collisions, speed, etc.) while obfuscating the anchor locations. Obfuscation may keep unauthorized nodes from access to the true anchor locations. In an example, 'unauthorized nodes' themselves could be one or more of UE (target or other helper UE), gNB, AMF, LMF, etc. The level of obfuscation (or intentional anchor location error) may also be configurable and may vary between devices (e.g., depending on level of access nodes are authorized to receive, e.g., 10 meters of error, 10 miles of error, etc.). In some designs, the transformation information may include metrics such magnitudes of applied translation and/or rotation, and how the metrics (fixed, drawn from a distribution, etc.), and so on.

Referring to FIGS. **10-12**, in some designs, the set of anchors comprises a group of indoor anchors, or the set of anchors comprises a group of outdoor anchors, or the set of anchors comprises one or more anchor UEs, or the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Referring to FIGS. **10-12**, in some designs, the position estimation procedure is associated with anchors from one RLAG only (e.g., different RLAGs may be associated with different transformation information, so mixing anchors from different RLAGs may result in high error).

Referring to FIGS. **10-12**, in some designs, the position estimation entity may receive, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG (e.g., to register the reporting anchor(s) to the RLAG so the position estimation entity may select those anchor(s) for position estimation procedures).

Referring to FIGS. **10-12**, in some designs, the position estimation entity may transmit, to the UE, an indication of a RLAG identifier of the RLAG. This transmission may occur in various ways.

In one example, the indication may include a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors. For example, the position estimation entity may define the list of RLAGs. Each RLAG contains more information elements (IE), such as ID, (optional) offset info, (optional) uncertainty (e.g., ellipse/rectangle uncertainty, etc.). In some designs, one particular RLAG ID may be defined (e.g., pre-defined or network-configured) as the default global coordinate system defined in WGS-84. In some designs, each anchor (e.g., UE or TRP) is tagged with one RLAG ID. For TRP, RLAG can be added to IE such as TRP-ID, NR-DL-PRS-Assistance-DataPerTRP-r16 (for UE-assisted), NR-TRP-LocationInfo (for UE-based), or the like. In some designs, an anchor without an explicit RLAG association could imply that the anchor is defined as the default GCS with higher accuracy (e.g., the anchor has yet to be onboard to a RLAG, or if a particular anchor is more accurate for absolute position estimation than relative position estimation, this particular anchor can be kept separate from the RLAG).

In an alternative example, the indication may include a list of anchors, with each listed anchor associated with a respective RLAG identifier.

In another alternative example, the indication may include a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped. For example, each UE maybe configured with multiple PRS configurations. Each PRS configuration might be tagged with one RLAG.

In some designs, the RLAG ID may be provided (e.g., via assistance data) by RLAG anchors to LMF (e.g., via NRPPa). In some designs, the RLAG ID may be preconfigured (e.g., indoor factory sensors may be static members of RLAG). In some designs, the RLAG ID may be provided from the position estimation entity (e.g., LMF, TRP or UE anchor, etc.) to a target UE via LPP. In some designs, the RLAG ID may be decided by the anchors, or alternatively may be assigned by the position estimation entity (e.g., LMF, etc.). In some designs, for obfuscation purpose, LMF may apply operation (e.g., transformation or translation) to genie or reported estimation of absolute locations of a set anchors, then assign same RLAG ID to these anchors, as will be described below in more detail with respect to FIG. **13**. As used herein, a "genie" refers to a true location of a device (i.e., error below some threshold), in contrast to a location for the device that has error (e.g., intentional and/or unintentional) above some threshold.

Referring to FIGS. **10-12**, in some designs, the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG. In some designs, the new anchor(s) may determine a RLAG identifier associated with the RLAG, the new anchor(s) join the RLAG by inheriting the RLAG identifier associated with the RLAG (e.g., via reporting of the RLAG ID to the position estimation entity, etc.). For example, an indoor UE anchor should inherit the ID from the TRPs used for location estimation.

Referring to FIGS. **10-12**, in legacy 3GPP designs, NR-TRP-LocationInfo may be used by the location server to provide the coordinates of the antenna reference points for a set of TRPs. For each TRP, the TRP location can be provided for each associated PRS Resource ID per PRS Resource Set. In some designs, a similar LPP IE can be modified so as to convey the relative locations of the RLAG anchors. For example, the IE ReferencePoint may a suitable LPP IE which may provide a well-defined location relative to which other locations may be defined (e.g., may be used to convey the relative RLAG anchor locations).

Referring to FIGS. **10-12**, in some designs, the RLAG anchors may either be static or dynamic. A single static RLAG is the simplest case, and may be assumed by default. In other designs, multiple static RLAGs may be configured. For example, assume that RLAG anchors are in two buildings, and only all the anchors in the same building have been accurately positioned relative to each other (e.g., setup one RLAG per building, and do not mix RLAG anchors from different buildings). In some designs, an indication of relative location across different RLAGs may be allowed. In the above example, the relative location of the buildings (relative to each other) or of the anchors across the two buildings may be known.

Referring to FIGS. **10-12**, in other designs, multiple dynamic RLAGs may be configured. For example, assume that RLAG anchors with good relative positioning obtained this via an SL (or Uu+SL) positioning procedure. Thus, all participants in that procedure are marked as belonging to same RLAG. Some participants may be mobile to an extent faster than the positioning procedure could track (e.g., these fast-moving devices may later need to be removed from the

RLAG, and possibly added in another RLAG). In some designs, the RLAG ID may be implemented as a toggle bit or a circular counter.

FIG. **13** illustrates an example implementation **1300** of the processes **10-12** in accordance with aspects of the disclosure. In FIG. **13**, an outdoor RLAG 1 and an indoor RLAG 2 are depicted with four anchors per RLAG. The outdoor RLAG 1 is associated with good absolute position estimation, while the indoor RLAG 2 is associated with poor absolute position estimation. Hence, for indoor RLAG 2, the true anchor absolute locations are separated from the derived absolute locations by offsets **1302**, **1304**, **1306** and **1308**.

Referring to FIG. **13**, in some designs, for indoor anchors, assume that genie location (or true location) in GCS is X, and assigned location in GCS is X_hat (e.g., whereby X_hat is offset from X due to intentional and/or unintentional error). Now, further assume a genic location in GCS near an indoor/outdoor boundary is B, with an assigned location in GCS of B_hat (e.g., equivalent to a local coordinate in the same format of WGS 84, but with transformation information such as translation and/or rotation). Similar to X_hat, B_hat is offset from B due to intentional and/or unintentional error. For positioning, a position estimation entity may use only the indoor TRPs in RLAG2 (the relative location is consistent within this group). The location fix of certain UE also suffers from the same offset as RLAG1 (e.g., this offset can be either known or unknown to the position estimation entity). Such a location fix is still useful for certain applications as noted above. In some designs, as noted above, using anchors from multiple groups may cause large positioning errors, which is not preferred. Therefore, even for UE-assisted, providing the RLAG information to UE could help UE to better select measurements for positioning measurement reports (e.g., UE can avoid selecting anchors from different RLAGs to improve the position estimation).

In yet other aspects, a local coordinate system (LCS) may be used in place of an absolute coordinate system such as WGS 84. Such aspects may provide various technical advantages, such as a simple implementation in environments where absolute position estimation is inaccurate, although LCS may also be associated with high signaling overhead.

FIG. **14** illustrates an exemplary process **1400** of wireless communication, according to aspects of the disclosure. In an aspect, the process **1400** may be performed by a position estimation entity. In some designs, the position estimation entity may correspond to UE **302** (e.g., for UE-based position estimation) or BS **304** (e.g., LMF integrated in RAN) or network entity **306** (e.g., LMF integrated in core network component, a location server, etc.).

Referring to FIG. **14**, at **1410**, the position estimation entity (e.g., processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, etc.) determines a set of local coordinate system (LCS) locations associated with a set of anchors for position estimation of user equipments (UEs). A means for performing the determination of **1410** may include processor(s) **332** or **384** or **394**, positioning component **342** or **388** or **398**, etc., of UE **302** or BS **304** or network entity **306**.

Referring to FIG. **14**, at **1420**, the position estimation entity (e.g., transmitter **314** or **324** or **354** or **364**, network transceiver(s) **390**, data bus **334** or **382** or **392**, etc.) transmits an LCS frame that includes indications of the set of LCS locations. In case of UE-based position estimation, the transmission of **1420** corresponds to an internal transfer of data between logical components. A means for performing the transmission of **1420** may include transmitter **314** or **324** or **354** or **364**, network transceiver(s) **390**, data bus **334** or **382** or **392**, etc., of UE **302** or BS **304** or network entity **306**.

Referring to FIG. **14**, in some designs, each LCS location in the set of LCS locations is associated with transformation information (e.g., coordinate offset(s), etc.) for transforming the respective LCS location to an absolute location associated with an absolute coordinate system. For example, the transformation information is applied to one or more of an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof. In some designs, the set of LCS locations is defined by cartesian coordinates or polar coordinates.

Referring to FIG. **14**, in some designs, the LCS frame itself may be specified relative to the global coordinate frame in which anchor locations are provided as of 3GPP Rel. 16. In some designs, this specification may be omitted, partial, or complete. An example of 'partial' specification is where only the origin and/or the z-axis is specified, and the x and y axes are not specified. In some designs, this may have poor accuracy, whereas the locations in LCS frame may be high accuracy.

Referring to FIG. **14**, in some designs, the LCS frame may require the definition of new signaling messages including the new location formats. For example, every message that currently includes location data in the current formats (e.g., WGS 84) would instead be modified to include location data in accordance with the LCS format. This may involve changes to a large number of such messages (e.g., including support of not just 3GPP RAT-based but also other RAT-based positioning (such as Bluetooth/WiFi), for which 3GPP supports message exchange). Hence, setting up an ad-hoc LCS may cause high impact to the relevant 3GPP specification. In terms of LCS, various location formats may be used (e.g., cartesian or polar coordinates, etc.). In some designs, existing formats (e.g., as in WGS 840 may be re-used at least in part (e.g., re-use latitude/longitude with possible rotation of the earth's position, etc.).

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

Implementation examples are described in the following numbered clauses:

Clause 1. A method of operating a position estimation entity, comprising: determining a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmitting the resource configuration; receiving measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determining location information associated with the UE based on the measurement data.

Clause 2. The method of clause 1, wherein the location information comprises relative location information.

Clause 3. The method of clause 2, wherein the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

Clause 4. The method of any of clauses 1 to 3, wherein the location information comprises a derived absolute position estimate of the UE based on the measurement data.

Clause 5. The method of clause 4, wherein the derived absolute position estimate is associated with transformation information.

Clause 6. The method of clause 5, further comprising: applying the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

Clause 7. The method of any of clauses 5 to 6, further comprising: transmitting the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

Clause 8. The method of any of clauses 5 to 7, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 9. The method of any of clauses 1 to 8, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 10. The method of any of clauses 1 to 9, wherein the position estimation procedure is associated with anchors from one RLAG only.

Clause 11. The method of any of clauses 1 to 10, further comprising: receiving, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

Clause 12. The method of any of clauses 1 to 11, further comprising: transmitting, to the UE, an indication of a RLAG identifier of the RLAG.

Clause 13. The method of clause 12, wherein the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or wherein the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

Clause 14. The method of any of clauses 1 to 13, wherein the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

Clause 15. The method of any of clauses 1 to 14, wherein the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

Clause 16. A method of operating a user equipment (UE), comprising: receiving a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicating one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

Clause 17. The method of clause 16, wherein absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

Clause 18. The method of clause 17, further comprising: receiving, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

Clause 19. The method of clause 18, further comprising: applying the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

Clause 20. The method of any of clauses 17 to 19, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 21. The method of any of clauses 16 to 20, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 22. The method of any of clauses 16 to 21, further comprising: receiving an indication of a RLAG identifier of the RLAG.

Clause 23. A method of operating a wireless device, comprising: performing a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and joining the RLAG as a new anchor in response to the position estimation procedure.

Clause 24. The method of clause 23, further comprising: determining a RLAG identifier associated with the RLAG.

Clause 25. The method of clause 24, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

Clause 26. The method of any of clauses 24 to 25, further comprising: transmitting, to a position estimation entity, an indication of the RLAG identifier.

Clause 27. A method of operating a position estimation entity, comprising: determining a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmitting an LCS frame that includes indications of the set of LCS locations.

Clause 28. The method of clause 27, wherein each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

Clause 29. The method of clause 28, wherein the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

Clause 30. The method of any of clauses 27 to 29, wherein the set of LCS locations is defined by cartesian coordinates or polar coordinates.

Clause 31. A position estimation entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmit, via the at least one transceiver, the resource configuration; receive, via the at least one transceiver, measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determine location information associated with the UE based on the measurement data.

Clause 32. The position estimation entity of clause 31, wherein the location information comprises relative location information.

Clause 33. The position estimation entity of clause 32, wherein the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

Clause 34. The position estimation entity of any of clauses 31 to 33, wherein the location information comprises a derived absolute position estimate of the UE based on the measurement data.

Clause 35. The position estimation entity of clause 34, wherein the derived absolute position estimate is associated with transformation information.

Clause 36. The position estimation entity of clause 35, wherein the at least one processor is further configured to: apply the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

Clause 37. The position estimation entity of any of clauses 35 to 36, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

Clause 38. The position estimation entity of any of clauses 35 to 37, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 39. The position estimation entity of any of clauses 31 to 38, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 40. The position estimation entity of any of clauses 31 to 39, wherein the position estimation procedure is associated with anchors from one RLAG only.

Clause 41. The position estimation entity of any of clauses 31 to 40, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

Clause 42. The position estimation entity of any of clauses 31 to 41, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, to the UE, an indication of a RLAG identifier of the RLAG.

Clause 43. The position estimation entity of clause 42, wherein the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or wherein the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

Clause 44. The position estimation entity of any of clauses 31 to 43, wherein the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

Clause 45. The position estimation entity of any of clauses 31 to 44, wherein the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

Clause 46. A user equipment (UE), comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: receive, via the at least one transceiver, a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicate, via the at least one transceiver, one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

Clause 47. The UE of clause 46, wherein absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

Clause 48. The UE of clause 47, wherein the at least one processor is further configured to: receive, via the at least one transceiver, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

Clause 49. The UE of clause 48, wherein the at least one processor is further configured to: apply the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

Clause 50. The UE of any of clauses 47 to 49, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 51. The UE of any of clauses 46 to 50, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 52. The UE of any of clauses 46 to 51, wherein the at least one processor is further configured to: receive, via the at least one transceiver, an indication of a RLAG identifier of the RLAG.

Clause 53. A wireless device, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and join the RLAG as a new anchor in response to the position estimation procedure.

Clause 54. The wireless device of clause 53, wherein the at least one processor is further configured to: determine a RLAG identifier associated with the RLAG.

Clause 55. The wireless device of clause 54, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

Clause 56. The wireless device of any of clauses 54 to 55, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, to a position estimation entity, an indication of the RLAG identifier.

Clause 57. A position estimation entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmit, via the at least one transceiver, an LCS frame that includes indications of the set of LCS locations.

Clause 58. The position estimation entity of clause 57, wherein each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

Clause 59. The position estimation entity of clause 58, wherein the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

Clause 60. The position estimation entity of any of clauses 57 to 59, wherein the set of LCS locations is defined by cartesian coordinates or polar coordinates.

Clause 61. A position estimation entity, comprising: means for determining a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; means for transmitting the resource configuration; means for receiving measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and means for determining location information associated with the UE based on the measurement data.

Clause 62. The position estimation entity of clause 61, wherein the location information comprises relative location information.

Clause 63. The position estimation entity of clause 62, wherein the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

Clause 64. The position estimation entity of any of clauses 61 to 63, wherein the location information comprises a derived absolute position estimate of the UE based on the measurement data.

Clause 65. The position estimation entity of clause 64, wherein the derived absolute position estimate is associated with transformation information.

Clause 66. The position estimation entity of clause 65, further comprising: means for applying the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

Clause 67. The position estimation entity of any of clauses 65 to 66, further comprising: means for transmitting the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

Clause 68. The position estimation entity of any of clauses 65 to 67, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 69. The position estimation entity of any of clauses 61 to 68, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 70. The position estimation entity of any of clauses 61 to 69, wherein the position estimation procedure is associated with anchors from one RLAG only.

Clause 71. The position estimation entity of any of clauses 61 to 70, further comprising: means for receiving, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

Clause 72. The position estimation entity of any of clauses 61 to 71, further comprising: means for transmitting, to the UE, an indication of a RLAG identifier of the RLAG.

Clause 73. The position estimation entity of clause 72, wherein the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or wherein the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

Clause 74. The position estimation entity of any of clauses 61 to 73, wherein the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

Clause 75. The position estimation entity of any of clauses 61 to 74, wherein the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

Clause 76. A user equipment (UE), comprising: means for receiving a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and means for communicating one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

Clause 77. The UE of clause 76, wherein absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

Clause 78. The UE of clause 77, further comprising: means for receiving, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

Clause 79. The UE of clause 78, further comprising: means for applying the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

Clause 80. The UE of any of clauses 77 to 79, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 81. The UE of any of clauses 76 to 80, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 82. The UE of any of clauses 76 to 81, further comprising: means for receiving an indication of a RLAG identifier of the RLAG.

Clause 83. A wireless device, comprising: means for performing a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and means for joining the RLAG as a new anchor in response to the position estimation procedure.

Clause 84. The wireless device of clause 83, further comprising: means for determining a RLAG identifier associated with the RLAG.

Clause 85. The wireless device of clause 84, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

Clause 86. The wireless device of any of clauses 84 to 85, further comprising: means for transmitting, to a position estimation entity, an indication of the RLAG identifier.

Clause 87. A position estimation entity, comprising: means for determining a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and means for transmitting an LCS frame that includes indications of the set of LCS locations.

Clause 88. The position estimation entity of clause 87, wherein each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

Clause 89. The position estimation entity of clause 88, wherein the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

Clause 90. The position estimation entity of any of clauses 87 to 89, wherein the set of LCS locations is defined by cartesian coordinates or polar coordinates.

Clause 91. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a position estimation entity, cause the position estimation entity to: determine a resource configuration associated with a position estimation procedure between a user equipment (UE) and multiple anchors, wherein the multiple anchors comprise at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; transmit the resource configuration; receive measurement data based on one or more positioning reference signals (PRSs) associated with the position estimation procedure; and determine location information associated with the UE based on the measurement data.

Clause 92. The non-transitory computer-readable medium of clause 91, wherein the location information comprises relative location information.

Clause 93. The non-transitory computer-readable medium of clause 92, wherein the relative location information comprises: a relative position estimate or a relative distance of the UE to one or more anchors of the RLAG, or a speed estimate of the UE, or collision detection between the UE and one or more objects with one or more known relative locations to the RLAG, or a combination thereof.

Clause 94. The non-transitory computer-readable medium of any of clauses 91 to 93, wherein the location information comprises a derived absolute position estimate of the UE based on the measurement data.

Clause 95. The non-transitory computer-readable medium of clause 94, wherein the derived absolute position estimate is associated with transformation information.

Clause 96. The non-transitory computer-readable medium of clause 95, further comprising instructions that, when executed by position estimation entity, further cause the position estimation entity to: apply the transformation information to the derived absolute position estimate of the UE to obtain a more accurate absolute position estimate of the UE.

Clause 97. The non-transitory computer-readable medium of any of clauses 95 to 96, further comprising instructions that, when executed by position estimation entity, further cause the position estimation entity to: transmit the derived absolute position estimate to one or more external entities with knowledge of the transformation information.

Clause 98. The non-transitory computer-readable medium of any of clauses 95 to 97, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 99. The non-transitory computer-readable medium of any of clauses 91 to 98, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 100. The non-transitory computer-readable medium of any of clauses 91 to 99, wherein the position estimation procedure is associated with anchors from one RLAG only.

Clause 101. The non-transitory computer-readable medium of any of clauses 91 to 100, further comprising instructions that, when executed by position estimation entity, further cause the position estimation entity to: receive, from at least one anchor among the set of anchors of the RLAG, an indication of a RLAG identifier of the RLAG.

Clause 102. The non-transitory computer-readable medium of any of clauses 91 to 101, further comprising instructions that, when executed by position estimation entity, further cause the position estimation entity to: transmit, to the UE, an indication of a RLAG identifier of the RLAG.

Clause 103. The non-transitory computer-readable medium of clause 102, wherein the indication includes a list of RLAGs, with each listed RLAG associated with a respective RLAG identifier and a respective set of anchors, or wherein the indication includes a list of anchors, with each listed anchor associated with a respective RLAG identifier, or wherein the indication includes a positioning reference signal (PRS) configuration to which the RLAG identifier is mapped.

Clause 104. The non-transitory computer-readable medium of any of clauses 91 to 103, wherein the set of anchors comprises at least one anchor that is added to the RLAG in response to at least one position estimation procedure of the at least one anchor via the RLAG.

Clause 105. The non-transitory computer-readable medium of any of clauses 91 to 104, wherein the position estimation entity corresponds to the UE, an anchor UE, a base station, or a network component remote from the base station.

Clause 106. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: receive a resource configuration associated with a position estimation procedure between the UE and multiple anchors, wherein the multiple anchors include at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and communicate one or more positioning reference signals (PRSs) with the set of anchors in accordance with the resource configuration of the position estimation procedure.

Clause 107. The non-transitory computer-readable medium of clause 106, wherein absolute position estimation based on position estimation procedures with the RLAG is associated with transformation information.

Clause 108. The non-transitory computer-readable medium of clause 107, further comprising instructions that, when executed by UE, further cause the UE to: receive, from a position estimation entity, an indication of a derived absolute position estimate based on measurement data that is based on the one or more PRSs.

Clause 109. The non-transitory computer-readable medium of clause 108, further comprising instructions that, when executed by UE, further cause the UE to: apply the transformation information to the derived absolute position estimate of the UE to obtain a true absolute position estimate of the UE.

Clause 110. The non-transitory computer-readable medium of any of clauses 107 to 109, wherein the transformation information is configured to correct an intentional error in the derived absolute position estimate in accordance with a position estimate security protocol, or wherein the transformation information is configured to correct an unintentional RLAG-specific position estimation error in the derived absolute position estimate, or a combination thereof.

Clause 111. The non-transitory computer-readable medium of any of clauses 106 to 110, wherein the set of anchors comprises a group of indoor anchors, or wherein the set of anchors comprises a group of outdoor anchors, or wherein the set of anchors comprises one or more anchor UEs, or wherein the set of anchors comprises one or more anchor transmission reception points (TRPs), or a combination thereof.

Clause 112. The non-transitory computer-readable medium of any of clauses 106 to 111, further comprising instructions that, when executed by UE, further cause the UE to: receive an indication of a RLAG identifier of the RLAG.

Clause 113. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a wireless device, cause the wireless device to: perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other, and wherein the RLAG is associated with higher accuracy for relative position information than for absolute position information; and join the RLAG as a new anchor in response to the position estimation procedure.

Clause 114. The non-transitory computer-readable medium of clause 113, further comprising instructions that, when executed by wireless device, further cause the wireless device to: determine a RLAG identifier associated with the RLAG.

Clause 115. The non-transitory computer-readable medium of clause 114, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

Clause 116. The non-transitory computer-readable medium of any of clauses 114 to 115, further comprising instructions that, when executed by wireless device, further cause the wireless device to: transmit, to a position estimation entity, an indication of the RLAG identifier.

Clause 117. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a position estimation entity, cause the position estimation entity to: determine a set of local coordinate system (LCS) locations associated with a set of anchors associated with position estimation of user equipments (UEs); and transmit an LCS frame that includes indications of the set of LCS locations.

Clause 118. The non-transitory computer-readable medium of clause 117, wherein each LCS location in the set of LCS locations is associated with transformation information for transforming the respective LCS location to an absolute location associated with an absolute coordinate system.

Clause 119. The non-transitory computer-readable medium of clause 118, wherein the transformation information is applied to one or more of: an origin of the LCS, or a x-axis position of the LCS location, or a y-axis position of the LCS location, or a z-axis position of the LCS location, or a combination thereof.

Clause 120. The non-transitory computer-readable medium of any of clauses 117 to 119, wherein the set of LCS locations is defined by cartesian coordinates or polar coordinates.

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

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

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

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

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

While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. The functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Furthermore, although elements of the disclosure may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated.

What is claimed is:

1. A method of operating a wireless device, comprising:
performing a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other; and
joining the RLAG as a new anchor in response to the position estimation procedure,
wherein the RLAG is associated with an environment where absolute position estimation is unavailable or does not satisfy an accuracy requirement of the position estimation procedure.

2. The method of claim **1**, further comprising:
determining a RLAG identifier associated with the RLAG.

3. The method of claim **2**, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

4. The method of claim **2**, further comprising:
transmitting, to a position estimation entity, an indication of the RLAG identifier.

5. A wireless device, comprising:
a memory;
at least one transceiver; and
at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to:
perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other; and
join the RLAG as a new anchor in response to the position estimation procedure,
wherein the RLAG is associated with an environment where absolute position estimation is unavailable or does not satisfy an accuracy requirement of the position estimation procedure.

6. The wireless device of claim **5**, wherein the at least one processor is further configured to:
determine a RLAG identifier associated with the RLAG.

7. The wireless device of claim **6**, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

8. The wireless device of claim **6**, wherein the at least one processor is further configured to:
transmit, via the at least one transceiver, to a position estimation entity, an indication of the RLAG identifier.

9. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a wireless device, cause the wireless device to:
perform a position estimation procedure between the wireless device and multiple anchors including at least a set of anchors of a relative location anchor group (RLAG), wherein the set of anchors of the RLAG are associated with known relative locations to each other; and
join the RLAG as a new anchor in response to the position estimation procedure,
wherein the RLAG is associated with an environment where absolute position estimation is unavailable or does not satisfy an accuracy requirement of the position estimation procedure.

10. The non-transitory computer-readable medium of claim **9**, further comprising computer-executable instructions that, when executed by the wireless device, cause the wireless device to:
determine a RLAG identifier associated with the RLAG.

11. The non-transitory computer-readable medium of claim **10**, wherein the wireless device joins the RLAG by inheriting the RLAG identifier associated with the RLAG.

12. The non-transitory computer-readable medium of claim **10**, further comprising computer-executable instructions that, when executed by the wireless device, cause the wireless device to:
transmit, to a position estimation entity, an indication of the RLAG identifier.

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