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FIELD OF VIEW DETERMINATION BASED ON AN ELEVATION ANGLE BETWEEN DEVICES

Abstract

Particular aspects of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. Aspects of the disclosure are directed to FoV determination based on an estimated elevation angle between devices. In some designs, the elevation angle is estimated based on a height differential between the devices and a distance between the devices. In other designs, the elevation angle is estimated based on a pitch of one of the devices when held at a target orientation. Such aspects may provide various technical advantages, such as initiating a pairing function between devices at a higher confidence.

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Background/Summary

BACKGROUND OF THE DISCLOSURE
1. Field of the Disclosure
[0001] Aspects of the disclosure relate generally to wireless technologies.
2. Description of the Related Art
[0002] Wireless communication systems have developed through various generations, including a first-generation analog wireless phone service (1G), a second-generation (2G) digital wireless phone service (including interim 2.5G and 2.75G networks), a third-generation (3G) high speed data, Internet-capable wireless service and a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax). There are presently many different types of wireless communication systems in use, including cellular and personal communications service (PCS) systems. Examples of known cellular systems include the cellular analog advanced mobile phone system (AMPS), and digital cellular systems based on code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), the Global System for Mobile communications (GSM), etc.
[0003] A fifth generation (5G) wireless standard, referred to as New Radio (NR), enables higher data transfer speeds, greater numbers of connections, and better coverage, among other improvements. The 5G standard, according to the Next Generation Mobile Networks Alliance, is designed to provide higher data rates as compared to previous standards, more accurate positioning (e.g., based on reference signals for positioning (RS-P), such as downlink, uplink, or sidelink positioning reference signals (PRS)), and other technical enhancements. These enhancements, as well as the use of higher frequency bands, advances in PRS processes and technology, and high-density deployments for 5G, enable highly accurate 5G-based positioning.
SUMMARY
[0004] The following presents a simplified summary relating to one or more aspects disclosed herein. Thus, the following summary should not be considered an extensive overview relating to all contemplated aspects, nor should the following summary be

considered to identify key or critical elements relating to all contemplated aspects or to delineate the scope associated with any particular aspect. Accordingly, the following summary has the sole purpose to present certain concepts relating to one or more aspects relating to the mechanisms disclosed herein in a simplified form to precede the detailed description presented below.

[0005] In an aspect, a method of operating a communications device includes determining first information associated with a first height of a user equipment (UE); determining second information associated with a second height of a target device; determining a distance between the UE and the target device; determining an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.

[0006] In an aspect, a method of operating a communications device includes prompting a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtaining pitch measurement information associated with the UE while the UE is configured with the target orientation; determining an elevation angle between the UE and the target device based on the pitch measurement information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.

[0007] In an aspect, a communications device includes one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: determine first information associated with a first height of a user equipment (UE); determine second information associated with a second height of a target device; determine a distance between the UE and the target device; determine an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.

[0008] In an aspect, a communications device includes one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: prompt a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtain pitch measurement information associated with the UE while the UE is configured with the target orientation; determine an elevation angle between the UE and the target device based on the pitch measurement information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.

[0009] In an aspect, a communications device includes means for determining first information associated with a first height of a user equipment (UE); means for determining second information associated with a second height of a target device; means for determining a distance between the UE and the target device; means for determining an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; means for determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and means for performing at least one action based on the FoV determination.

[0010] In an aspect, a communications device includes means for prompting a user of a user equipment (UE) to achieve a target orientation relative to a target device; means for obtaining pitch measurement information associated with the UE while the UE is configured with the target orientation; means for determining an elevation angle between the UE and the target device based on the pitch measurement information; means for determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and means for performing at least one action based on the FoV determination.

[0011] In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a communications device, cause the communications device to: determine first information associated with a first height of a user equipment (UE); determine second information associated with a second height of a target device; determine a distance between the UE and the target device; determine an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.

[0012] In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a communications device, cause the communications device to: prompt a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtain pitch measurement information associated with the UE while the UE is configured with the target orientation; determine an elevation angle between the UE and the target device based on the pitch measurement information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.

[0013] 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.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] 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.

[0015] FIG. **1** illustrates an example wireless communications system, according to aspects of the disclosure.

[0016] FIGS. **2**A, **2**B, and **2**C illustrate example wireless network structures, according to aspects of the disclosure.

[0017] FIGS. **3**A, **3**B, and **3**C are simplified block diagrams of several sample aspects of components that may be employed in a user equipment (UE), a base station, and a network entity, respectively, and configured to support communications as taught herein.

[0018] FIG. **4** depicts an IoT use-case with several nearby smart devices (UEs 1-4), in accordance with aspects of the disclosure.

[0019] FIG. **5** illustrates an X-Y-Z plane associated with AoA estimation, in accordance with aspects of the disclosure.

[0020] FIG. **6** illustrates a graph that depicts an Azimuth angle error (in degrees) on Y-axis and an elevation angle (in degrees) on X-axis, in accordance with aspects of the disclosure.

[0021] FIG. **7** illustrates an exemplary process of communications according to an aspect of the disclosure.
[0022] FIG. **8** illustrates an example implementation of the process of FIG. **7**, in accordance with aspects of the disclosure.
[0023] FIG. **9** illustrates an exemplary process of communications according to an aspect of the disclosure.
[0024] FIG. **10** illustrates an example implementation of the process of FIG. **9**, in accordance with aspects of the disclosure.

DETAILED DESCRIPTION

[0025] 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.

[0026] Various aspects relate generally to field of view (FoV) determination based on an elevation angle between devices. If a smartphone (UE1) is oriented towards such a smart device (UE2), ultra wideband (UWB) may be used to confirm the direction using angle of arrival (AoA). Accordingly, the corresponding application may be triggered on the smart phone. Additionally, being within a certain range and/or inside of a certain field of view (FoV) could trigger a similar action. Example use-cases include pointing a phone towards the thermostat to trigger the corresponding application to configure the thermostat, or pointing a phone towards another phone to trigger the corresponding application to exchange data or to share content (audio, video, webpage, etc.). However, the impact of elevation angle (i.e., between the UE and the target device) on the estimation accuracy of the azimuth angle, and the resultant field-of-view for the above use-cases, has not been well-studied. In some applications, the impact attributable to the elevation angle is exacerbated in the case of linear antenna array systems (in some designs, linear array systems include 2 antennas) that cannot estimate an elevation angle (because a planar antenna array is required).

[0027] Particular aspects of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. Aspects of the disclosure are directed to FoV determination based on an estimated elevation angle between devices. In some designs, the elevation angle is estimated based on a height differential between the devices and a distance between the devices. In other designs, the elevation angle is estimated based on a pitch of one of the devices when held at a target orientation. Such aspects may provide various technical advantages, such as initiating a pairing function between devices at a higher confidence.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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).

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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.

[0039] 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**.

[0040] 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).

[0041] 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).

[0042] 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.

[0043] 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®.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR two initial operating bands have been identified as frequency range designations FR1 (410 MHz-7.125 GHZ) and FR2

(24.25 GHz-52.6 GHZ). It should be understood that although a portion of FR1 is greater than 6 GHZ, FR1 is often referred to (interchangeably) as a “Sub-6 GHz” band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a “millimeter wave” band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHZ-300 GHz) which is identified by the INTERNATIONAL TELECOMMUNICATION UNION® as a “millimeter wave” band.

[0051] 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.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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**.

[0056] 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 (eV2X) 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**.

[0057] 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.

[0058] 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**.

[0059] 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**.

[0060] 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.

[0061] 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**.

[0062] The wireless communications system **100** may further include one or more UEs, such as UE **190**, that connects indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links (referred to as “sidelinks”). In the example of FIG. **1**, UE **190** has a D2D P2P link **192** with one of the UEs **104** connected to one of the base stations **102** (e.g., through which UE **190** may indirectly obtain cellular connectivity) and a D2D P2P link **194** with WLAN STA **152** connected to the WLAN AP **150** (through which UE **190** may indirectly obtain WLAN-based Internet connectivity). In an example, the D2D P2P links **192** and **194** may be supported with any well-known D2D RAT, such as LTE Direct (LTE-D), WI-FI DIRECT®, BLUETOOTH®, and so on.

[0063] FIG. **2**A illustrates an example wireless network structure **200**. For example, a 5GC **210** (also referred to as a Next Generation Core (NGC)) can be viewed functionally as control plane (C-plane) functions **214** (e.g., UE registration, authentication, network access, gateway selection, etc.) and user plane (U-plane) functions **212**, (e.g., UE gateway function, access to data networks, IP routing, etc.) which operate cooperatively to form the core network. User plane interface (NG-U) **213** and control plane interface (NG-C) **215** connect the gNB **222** to the 5GC **210** and specifically to the user plane functions **212** and control plane functions **214**, respectively. In an additional configuration, an ng-eNB **224** may also be connected to the 5GC **210** via NG-C **215** to the control plane functions **214** and NG-U **213** to user plane functions **212**. Further, ng-eNB **224** may directly communicate with gNB **222** via a backhaul connection **223**. In some configurations, a Next Generation RAN (NG-RAN) **220** may have one or more gNBs **222**, while other configurations include one or more of both ng-eNBs **224** and gNBs **222**. Either (or both) gNB **222** or ng-eNB **224** may communicate with one or more UEs **204** (e.g., any of the UEs described herein).

[0064] 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).

[0065] FIG. **2**B illustrates another example wireless network structure **240**. 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.
[0066] 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**.
[0067] 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.
[0068] Another optional aspect may include an LMF **270**, which may be in communication with the 5GC **260** to provide location assistance for UEs **204**. The LMF **270** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The LMF **270** can be configured to support one or more location services for UEs **204** that can connect to the LMF **270** via the core network, 5GC **260**, and/or via the Internet (not illustrated). The SLP **272** may support similar functions to the LMF **270**, but whereas the LMF **270** may communicate with the AMF **264**, NG-RAN **220**, and UEs **204** over a control plane (e.g., using interfaces and protocols intended to convey signaling messages and not voice or data), the SLP **272** may communicate with UEs **204** and external clients (e.g., third-party server **274**) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).
[0069] Yet another optional aspect may include a third-party server **274**, which may be in communication with the LMF **270**, the SLP **272**, the 5GC **260** (e.g., via the AMF **264** and/or the UPF **262**), the NG-RAN **220**, and/or the UE **204** to obtain location information (e.g., a location estimate) for the UE **204**. As such, in some cases, the third-party server **274** may be referred to as a location services (LCS) client or an external client. The third-party server **274** can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server.
[0070] 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-cNB(s) **224** and the AMF **264** is referred to as the "N2" interface, and the interface between gNB(s) **222** and/or ng-eNB(s) **224** and the UPF **262** is referred to as the "N3" interface. The gNB(s) **222** and/or ng-cNB(s) **224** of the NG-RAN **220** may communicate directly with each other via backhaul connections **223**, referred to as the "Xn-C" interface. One or more of gNBs **222** and/or ng-eNBs **224** may communicate with one or more UEs **204** over a wireless interface, referred to as the "Uu" interface.
[0071] The functionality of a gNB **222** may be divided between a gNB central unit (gNB-CU) **226**, one or more gNB distributed units (gNB-DUs) **228**, and one or more gNB radio units (gNB-RUs) **229**. A gNB-CU **226** is a logical node that includes the base station functions of transferring user data, mobility control, radio access network sharing, positioning, session management, and the like, except for those functions allocated exclusively to the gNB-DU(s) **228**. More specifically, the gNB-CU **226** generally host the radio resource control (RRC), service data adaptation protocol (SDAP), and packet data convergence protocol (PDCP) protocols of the gNB **222**. A gNB-DU **228** is a logical node that generally hosts the radio link control (RLC) and medium access control (MAC) layer of the gNB **222**. Its operation is controlled by the gNB-CU **226**. One gNB-DU **228** can support one or more cells, and one cell is supported by only one gNB-DU **228**. The interface **232** between the gNB-CU **226** and the one or more gNB-DUs **228** is referred to as the "F1" interface. The physical (PHY) layer functionality of a gNB **222** is generally hosted by one or more standalone gNB-RUs **229** that perform functions such as power amplification and signal transmission/reception. The interface between a gNB-DU **228** and a gNB-RU **229** is referred to as the "Fx" interface. Thus, a UE **204** communicates with the gNB-CU **226** via the RRC, SDAP, and PDCP layers, with a gNB-DU **228** via the RLC and MAC layers, and with a gNB-RU **229** via the PHY layer.
[0072] Deployment of communication systems, such as 5G NR systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a network, a RAN node, a core network node, a network element, or a network equipment, such as a base station, or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a base station (such as a Node B (NB), evolved NB (eNB), NR base station, 5G NB, AP, TRP, cell, etc.) may be implemented as an aggregated base station (also known as a standalone base station or a monolithic base station) or a disaggregated base station.
[0073] An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUs)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CU, DU and RU also can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).
[0074] Base station-type operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN ALLIANCE®)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be

configured for wired or wireless communication with at least one other unit.
[0075] FIG. **2**C illustrates an example disaggregated base station architecture **250**, according to aspects of the disclosure. The disaggregated base station architecture **250** may include one or more central units (CUs) **280** (e.g., gNB-CU **226**) that can communicate directly with a core network **267** (e.g., 5GC **210**, 5GC **260**) via a backhaul link, or indirectly with the core network **267** through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) **259** via an E2 link, or a Non-Real Time (Non-RT) RIC **257** associated with a Service Management and Orchestration (SMO) Framework **255**, or both). A CU **280** may communicate with one or more DUs **285** (e.g., gNB-DUs **228**) via respective midhaul links, such as an F1 interface. The DUs **285** may communicate with one or more radio units (RUs) **287** (e.g., gNB-RUs **229**) via respective fronthaul links. The RUs **287** may communicate with respective UEs **204** via one or more radio frequency (RF) access links. In some implementations, the UE **204** may be simultaneously served by multiple RUs **287**.
[0076] Each of the units, i.e., the CUS **280**, the DUs **285**, the RUs **287**, as well as the Near-RT RICs **259**, the Non-RT RICs **257** and the SMO Framework **255**, may include one or more interfaces or be coupled to one or more interfaces configured to receive or transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or transmit signals over a wired transmission medium to one or more of the other units. Additionally, the units can include a wireless interface, which may include a receiver, a transmitter or transceiver (such as a RF transceiver), configured to receive or transmit signals, or both, over a wireless transmission medium to one or more of the other units.
[0077] In some aspects, the CU **280** may host one or more higher layer control functions. Such control functions can include RRC, PDCP, service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU **280**. The CU **280** may be configured to handle user plane functionality (i.e., Central Unit-User Plane (CU-UP)), control plane functionality (i.e., Central Unit-Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU **280** can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as the E1 interface when implemented in an O-RAN configuration. The CU **280** can be implemented to communicate with the DU **285**, as necessary, for network control and signaling.
[0078] The DU **285** may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs **287**. In some aspects, the DU **285** may host one or more of a RLC layer, a MAC layer, and one or more high PHY layers (such as modules for forward error correction (FEC) encoding and decoding, scrambling, modulation and demodulation, or the like) depending, at least in part, on a functional split, such as those defined by the 3rd Generation Partnership Project (3GPP®). In some aspects, the DU **285** may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU **285**, or with the control functions hosted by the CU **280**.
[0079] Lower-layer functionality can be implemented by one or more RUs **287**. In some deployments, an RU **287**, controlled by a DU **285**, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (iFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) **287** can be implemented to handle over the air (OTA) communication with one or more UEs **204**. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) **287** can be controlled by the corresponding DU **285**. In some scenarios, this configuration can enable the DU(s) **285** and the CU **280** to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.
[0080] The SMO Framework **255** may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework **255** may be configured to support the deployment of dedicated physical resources for RAN coverage requirements which may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework **255** may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) **269**) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs **280**, DUs **285**, RUS **287** and Near-RT RICs **259**. In some implementations, the SMO Framework **255** can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-cNB) **261**, via an O1 interface. Additionally, in some implementations, the SMO Framework **255** can communicate directly with one or more RUs **287** via an O1 interface. The SMO Framework **255** also may include a Non-RT RIC **257** configured to support functionality of the SMO Framework **255**.
[0081] The Non-RT RIC **257** may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, artificial intelligence/machine learning (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC **259**. The Non-RT RIC **257** may be coupled to or communicate with (such as via an A1 interface) the Near-RT RIC **259**. The Near-RT RIC **259** may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs **280**, one or more DUs **285**, or both, as well as an O-eNB, with the Near-RT RIC **259**.
[0082] In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC **259**, the Non-RT RIC **257** may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC **259** and may be received at the SMO Framework **255** or the Non-RT RIC **257** from non-network data sources or from network functions. In some examples, the Non-RT RIC **257** or the Near-RT RIC **259** may be configured to tune RAN behavior or performance. For example, the Non-RT RIC **257** may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO Framework **255** (such as reconfiguration via O1) or via creation of RAN management policies (such as A1 policies).
[0083] 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 operations described herein. It will be appreciated that these components may be implemented in different types of apparatuses in different implementations (e.g., in an ASIC, in a system-on-chip (SoC), etc.). The illustrated components may also be incorporated into other apparatuses in a communication system. For example, other apparatuses in a system may include components similar to those described to provide similar functionality. Also, a given apparatus may contain one or more of the components. For example, an apparatus may include multiple transceiver components that enable the apparatus to operate on multiple carriers and/or communicate via different technologies.

[0084] 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., cNBs, 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.

[0085] The UE **302** and the base station **304** each also include, at least in some cases, one or more short-range wireless transceivers **320** and **360**, respectively. The short-range wireless transceivers **320** and **360** may be connected to one or more antennas **326** and **366**, respectively, and provide means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) with other network nodes, such as other UEs, access points, base stations, etc., via at least one designated RAT (e.g., Wi-Fi, LTE Direct, BLUETOOTH®, ZIGBEE®, Z-WAVE®, PC5, dedicated short-range communications (DSRC), wireless access for vehicular environments (WAVE), near-field communication (NFC), ultra-wideband (UWB), etc.) over a wireless communication medium of interest. The short-range wireless transceivers **320** and **360** may be variously configured for transmitting and encoding signals **328** and **368** (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals **328** and **368** (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the short-range wireless transceivers **320** and **360** include one or more transmitters **324** and **364**, respectively, for transmitting and encoding signals **328** and **368**, respectively, and one or more receivers **322** and **362**, respectively, for receiving and decoding signals **328** and **368**, respectively. As specific examples, the short-range wireless transceivers **320** and **360** may be Wi-Fi transceivers, BLUETOOTH® transceivers, ZIGBEER and/or Z-WAVE® transceivers, NFC transceivers, UWB transceivers, or vehicle-to-vehicle (V2V) and/or vehicle-to-everything (V2X) transceivers.

[0086] The UE **302** and the base station **304** also include, at least in some cases, satellite signal interfaces **330** and **370**, which each include one or more satellite signal receivers **332** and **372**, respectively, and may optionally include one or more satellite signal transmitters **334** and **374**, respectively. In some cases, the base station **304** may be a terrestrial base station that may communicate with space vehicles (e.g., space vehicles **112**) via the satellite signal interface **370**. In other cases, the base station **304** may be a space vehicle (or other non-terrestrial entity) that uses the satellite signal interface **370** to communicate with terrestrial networks and/or other space vehicles.

[0087] The satellite signal receivers **332** and **372** may be connected to one or more antennas **336** and **376**, respectively, and may provide means for receiving and/or measuring satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal receiver(s) **332** and **372** are satellite positioning system receivers, the satellite positioning/communication signals **338** and **378** may be global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC), Quasi-Zenith Satellite System (QZSS) signals, etc. Where the satellite signal receiver(s) **332** and **372** are non-terrestrial network (NTN) receivers, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal receiver(s) **332** and **372** may comprise any suitable hardware and/or software for receiving and processing satellite positioning/communication signals **338** and **378**, respectively. The satellite signal receiver(s) **332** and **372** may request information and operations as appropriate from the other systems, and, at least in some cases, perform calculations to determine locations of the UE **302** and the base station **304**, respectively, using measurements obtained by any suitable satellite positioning system algorithm.

[0088] The optional satellite signal transmitter(s) **334** and **374**, when present, may be connected to the one or more antennas **336** and **376**, respectively, and may provide means for transmitting satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal transmitter(s) **374** are satellite positioning system transmitters, the satellite positioning/communication signals **378** may be GPS signals, GLONASS® signals, Galileo signals, Beidou signals, NAVIC, QZSS signals, etc. Where the satellite signal transmitter(s) **334** and **374** are NTN transmitters, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal transmitter(s) **334** and **374** may comprise any suitable hardware and/or software for transmitting satellite positioning/communication signals **338** and **378**, respectively. The satellite signal transmitter(s) **334** and **374** may request information and operations as appropriate from the other systems.

[0089] 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.

[0090] 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.

[0091] 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.

[0092] The UE **302**, the base station **304**, and the network entity **306** also include other components that may be used in conjunction with the operations as disclosed herein. The UE **302**, the base station **304**, and the network entity **306** include one or more processors **342**, **384**, and **394**, respectively, for providing functionality relating to, for example, wireless communication, and for providing other processing functionality. The processors **342**, **384**, and **394** may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processors **342**, **384**, and **394** may include, for example, one or more general purpose processors, multi-core processors, central processing units (CPUs), ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGAs), other programmable logic devices or processing circuitry, or various combinations thereof.

[0093] 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 FoV determination component **348**, **388**, and **398**, respectively. The FoV determination component **348**, **388**, and **398** may be hardware circuits that are part of or coupled to the processors **342**, **384**, and **394**, respectively, that, when executed, cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. In other aspects, the FoV determination component **348**, **388**, and **398** may be external to the processors **342**, **384**, and **394** (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the FoV determination component **348**, **388**, and **398** may be memory modules stored in the memories **340**, **386**, and **396**, respectively, that, when executed by the processors **342**, **384**, and **394** (or a modem processing system, another processing system, etc.), cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. FIG. **3**A illustrates possible locations of the FoV determination component **348**, which may be, for example, part of the one or more WWAN transceivers **310**, the memory **340**, the one or more processors **342**, or any combination thereof, or may be a standalone component. FIG. **3**B illustrates possible locations of the FoV determination 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 FoV determination 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.

[0094] The UE **302** may include one or more sensors **344** coupled to the one or more processors **342** to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the one or more WWAN transceivers **310**, the one or more short-range wireless transceivers **320**, and/or the satellite signal interface **330**. By way of example, the sensor(s) **344** may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor. Moreover, the sensor(s) **344** may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s) **344** may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in two-dimensional (2D) and/or three-dimensional (3D) coordinate systems.

[0095] 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.

[0096] 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.

[0097] 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.

[0098] At the UE **302**, the receiver **312** receives a signal through its respective antenna(s) **316**. The receiver **312** recovers information modulated onto an RF carrier and provides the information to the one or more processors **342**. The transmitter **314** and the receiver **312** implement Layer-1 functionality associated with various signal processing functions. The receiver **312** may perform spatial processing on the information to recover any spatial streams destined for the UE **302**. If multiple spatial streams are destined for the UE **302**, they may be combined by the receiver **312** into a single OFDM symbol stream. The receiver **312** then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **304**. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to recover the data and control signals that were originally transmitted by the base station **304** on the physical channel. The data and control signals are then provided to the one or more processors **342**, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

[0099] In the downlink, the one or more processors **342** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The one or more processors **342** are also responsible for error detection.

[0100] Similar to the functionality described in connection with the downlink transmission by the base station **304**, the one or more processors **342** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.

[0101] 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.

[0102] 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**.

[0103] 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.

[0104] For convenience, the UE **302**, the base station **304**, and/or the network entity **306** are shown in FIGS. **3**A, **3**B, and **3**C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated components may have different functionality in different designs. In particular, various components in FIGS. **3**A to **3**C are optional in alternative configurations and the various aspects include configurations that may vary due to design choice, costs, use of the device, or other considerations. For example, in case of FIG. **3**A, a particular implementation of UE **302** may omit the WWAN transceiver(s) **310** (e.g., a wearable device or tablet computer or personal computer (PC) or laptop may have Wi-Fi and/or BLUETOOTH® capability without cellular capability), or may omit the short-range wireless transceiver(s) **320** (e.g., cellular-only, etc.), or may omit the satellite signal interface **330**, or may omit the sensor(s) **344**, and so on. In another example, in case of FIG. **3**B, a particular implementation of the base station **304** may omit the WWAN transceiver(s) **350** (e.g., a Wi-Fi "hotspot" access point without cellular capability), or may omit the short-range wireless transceiver(s) **360** (e.g., cellular-only, etc.), or may omit the satellite signal interface **370**, and so on. For brevity, illustration of the various alternative configurations is not provided herein, but would be readily understandable to one skilled in the art.

[0105] The various components of the UE **302**, the base station **304**, and the network entity **306** may be communicatively coupled to each other over data buses **308**, **382**, and **392**, respectively. In an aspect, the data buses **308**, **382**, and **392** may form, or be part of, a communication interface of the UE **302**, the base station **304**, and the network entity **306**, respectively. For example, where different logical entities are embodied in the same device (e.g., gNB and location server functionality incorporated into the same base station **304**), the data buses **308**, **382**, and **392** may provide communication between them.
[0106] 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 **342**, **384**, **394**, the transceivers **310**, **320**, **350**, and **360**, the memories **340**, **386**, and **396**, the FoV determination component **348**, **388**, and **398**, etc.
[0107] In some designs, the network entity **306** may be implemented as a core network component. In other designs, the network entity **306** may be distinct from a network operator or operation of the cellular network infrastructure (e.g., NG RAN **220** and/or 5GC **210**/**260**). For example, the network entity **306** may be a component of a private network that may be configured to communicate with the UE **302** via the base station **304** or independently from the base station **304** (e.g., over a non-cellular communication link, such as Wi-Fi).
[0108] Note that the UE **302** illustrated in FIG. **3**A may represent a "reduced capability" ("RedCap") UE or a "premium" UE. As described further below, while RedCap and premium UEs may have the same types of components (e.g., both may have one or more WWAN transceivers **310**, one or more short-range wireless transceivers **320**, satellite signal interface **330**, one or more processors **342**, memory **340**, etc.), the components may have different degrees of functionality (e.g., increased or decreased performance, more or fewer capabilities, etc.) depending on whether the UE **302** corresponds to a RedCap UE or a premium UE.
[0109] UEs may be classified as RedCap UEs (e.g., wearables, such as smart watches, glasses, rings, etc.) and premium UEs (e.g., smartphones, tablet computers, laptop computers, etc.). RedCap UEs may alternatively be referred to as low-tier UEs, light UEs, or super light UEs. Premium UEs may alternatively be referred to as full-capability UEs or simply UEs. RedCap UEs generally have lower baseband processing capability, fewer antennas (e.g., one receiver antenna as baseline in FR1 or FR2, two receiver antennas optionally), lower operational bandwidth capabilities (e.g., 20 MHz for FRI with no supplemental uplink or carrier aggregation, or 50 or 100 MHz for FR2), only half duplex frequency division duplex (HD-FDD) capability, smaller HARQ buffer, reduced physical downlink control channel (PDCCH) monitoring, restricted modulation (e.g., 64 QAM for downlink and 16 QAM for uplink), relaxed processing timeline requirements, and/or lower uplink transmission power compared to premium UEs. Different UE tiers can be differentiated by UE category and/or by UE capability. For example, certain types of UEs may be assigned a classification (e.g., by the original equipment manufacturer (OEM), the applicable wireless communications standards, or the like) of "RedCap" and other types of UEs may be assigned a classification of "premium." Certain tiers of UEs may also report their type (e.g., "RedCap" or "premium") to the network. Additionally, certain resources and/or channels may be dedicated to certain types of UEs.
[0110] As will be appreciated, the accuracy of RedCap UE positioning may be limited. For example, a RedCap UE may operate on a reduced bandwidth, such as 5 to 20 MHz for wearable devices and "relaxed" IoT devices (i.e., IoT devices with relaxed, or lower, capability parameters, such as lower throughput, relaxed delay requirements, lower energy consumption, etc.), which results in lower positioning accuracy. As another example, a RedCap UE's receive processing capability may be limited due to its lower cost RF/baseband. As such, the reliability of measurements and positioning computations would be reduced. In addition, such a RedCap UE may not be able to receive multiple PRS from multiple TRPs, further reducing positioning accuracy. As yet another example, the transmit power of a RedCap UE may be reduced, meaning there would be a lower quality of uplink measurements for RedCap UE positioning.
[0111] Premium UEs generally have a larger form factor and are costlier than RedCap UEs, and have more features and capabilities than RedCap UEs. For example, with respect to positioning, a premium UE may operate on the full PRS bandwidth, such as 100 MHZ, and measure PRS from more TRPs than RedCap UEs, both of which result in higher positioning accuracy. As another example, a premium UE's receive processing capability may be higher (e.g., faster) due to its higher-capability RF/baseband. In addition, the transmit power of a premium UE may be higher than that of a RedCap UE. As such, the reliability of measurements and positioning computations would be increased.
[0112] FIG. **4** depicts an IoT use-case **400** with several nearby smart devices (UEs 1-4), in accordance with aspects of the disclosure. If a smartphone (UE1) is oriented towards such a smart device (UE2), ultra wideband (UWB) may be used to confirm the direction using angle of arrival (AoA). Accordingly, the corresponding application may be triggered on the smart phone. Additionally, being within a certain range and/or inside of a certain field of view (FoV) (e.g., FoV **410** in FIG. **4**) could trigger a similar action. Example use-cases include pointing a phone towards the thermostat to trigger the corresponding application to configure the thermostat, or pointing a phone towards another phone to trigger the corresponding application to exchange data or to share content (audio, video, webpage, etc.).
[0113] However, the impact of elevation angle (i.e., between the UE and the target device) on the estimation accuracy of the azimuth angle, and the resultant field-of-view for the above use-cases, has not been well-studied. In some applications, the impact attributable to the elevation angle is exacerbated in the case of linear antenna array systems (in some designs, linear array systems include 2 antennas) that cannot estimate an elevation angle (because a planar antenna array is required).
[0114] FIG. **5** illustrates an X-Y-Z plane **500** associated with AoA estimation, in accordance with aspects of the disclosure. Referring

to FIG. **5**, 1Let r, θ, ϕ denote the range, elevation AoA, and azimuth AoA respectively, for a given point {right arrow over (p)} (in spherical coordinates). In some designs, these values pertain to the Local Coordinate System (LCS) and may be transformed to a Global Coordinate System (GCS) through a rotation vector provided by the phone's IMU (e.g., using the gyroscope and magnetometer).

[0115] Referring to FIG. **5**, consider a point {right arrow over (p)} with a direction vector {right arrow over (u)}, e.g.:

[00001] $\overset{.fwdarw.}{u} = \cos(\ )\sin(\ ') \text{ .Math. } \hat{I} + \sin(\ ) \text{ .Math. } \hat{J} - \cos(\ )\cos(\ ') \text{ .Math. } \hat{k}$

[0116] The reported azimuth AoA for a linear antenna array is estimated as if the target lies in same plane as the antenna array, e.g.:

[00002]

$\overset{.fwdarw.}{u} = \sin(\ ) \text{ .Math. } \hat{I} + \sin(\ ) \text{ .Math. } \hat{J} - \sqrt{1 - \sin^2(\ ) - \sin^2(\ )} \text{ .Math. } \hat{k} = \sin(\ ) \text{ .Math. } \hat{I} + \sin(\ ) \text{ .Math. } \hat{J} - \sqrt{\cos^2(\ ) - \sin^2(\ )} \text{ .Math. }$

$(\ '):\ \ ' = \cos^{-1}\left(\frac{\sqrt{\cos^2(\ ) - \sin^2(\ )}}{\cos(\ )}\right)$

By equating the reported phase difference-of-arrival estimate to the expected (theoretical) estimate, we obtain the following expression for the corrected azimuth AoA estimate

[00003] $(\ '):\ \ ' = \cos^{-1}\left(\frac{\sqrt{\cos^2(\ ) - \sin^2(\ )}}{\cos(\ )}\right)$

[0117] FIG. **6** illustrates a graph **600** that depicts an Azimuth angle error (in degrees) on Y-axis and an elevation angle (in degrees) on X-axis, in accordance with aspects of the disclosure. As shown in FIG. **6**, as the elevation angle (θ) increases, the azimuth AoA estimation accuracy decreases. This can be interpreted as the azimuthal field-of-view to be expanding (since uncertainty is higher).

[0118] Aspects of the disclosure are directed to FoV determination based on an estimated elevation angle between devices. In some designs, the elevation angle is estimated based on a height differential between the devices and a distance between the devices. In other designs, the elevation angle is estimated based on a pitch of one of the devices when held at a target orientation. Such aspects may provide various technical advantages, such as initiating a pairing function between devices at a higher confidence.

[0119] FIG. **7** illustrates an exemplary process **700** of communications according to an aspect of the disclosure. The process **700** of FIG. **7** is performed by a communications device. In some designs, the communications device may correspond to a network component (e.g., gNB/BS **304** or O-RAN component or a remote location server such as network entity **306**, etc.). In other designs, the communications device may correspond to a UE (e.g., a device trying to pair another device or a target device for pairing, etc.).

[0120] Referring to FIG. **7**, at **710**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines first information associated with a first height of a user equipment (UE). In some designs, a means for performing the determination of **710** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0121] Referring to FIG. **7**, at **720**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines second information associated with a second height of a target device. In some designs, a means for performing the determination of **720** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0122] Referring to FIG. **7**, at **730**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines a distance between the UE and the target device. In some designs, a means for performing the determination of **730** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0123] Referring to FIG. **7**, at **740**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information. In some designs, a means for performing the determination of **740** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0124] Referring to FIG. **7**, at **750**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle. In an aspect, the FoV may be defined relative to the UE itself. In some designs, a RF-FoV relative to an antenna array of the UE is first estimated, after which the RF-FoV is mapped or translated to a UE-FoV (e.g., relative to the back of the phone, a screen facing the user, etc.). In some designs, a means for performing the determination of **750** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0125] Referring to FIG. **7**, at **760**, the communications device (e.g., receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) performs at least one action based on the FoV determination. In some designs, a means for performing the at least one action of **760** includes receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.

[0126] Referring to FIG. **7**, in some designs, the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.

[0127] Referring to FIG. **7**, in some designs, the FoV determination is further based at least in part on visual information (e.g., captured by camera sensor(s) of the UE or the target device or both). For example, the visual information may be used to verify the height of the UE or the target device or both, to verify the height differential, to verify the distance, etc.

[0128] Referring to FIG. **7**, in some designs, the FoV determination determines that the target device is inside of the FoV. In an aspect, the at least one action comprises pairing the target device with the UE.

[0129] Referring to FIG. **7**, in some designs, the FoV determination determines that the target device is not inside of the FoV. In an aspect, the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.

[0130] Referring to FIG. **7**, in some designs, the FoV determination is further based on an FoV uncertainty parameter.

[0131] Referring to FIG. **7**, in some designs, the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or the second information associated with the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or the second information associated with the second height of the target device is based on computer vision analysis, or the second information associated with the second height of the target device is fixed or pre-determined based on device type or device location, or any combination thereof.

[0132] Referring to FIG. **7**, in some designs, the first information comprises the first height or a first pressure measurement, or the second information comprises the second height or a second pressure measurement, or a combination thereof.

[0133] Referring to FIG. **7**, in some designs, the communications device corresponds to the UE, or the communications device corresponds to the target device, or the communications device corresponds to a network device.

[0134] Referring to FIG. **7**, in a specific example, another device may be selected for pairing with a phone (to push or pull content) if it is inferred to be within a certain field-of-view (FoV) of the phone. Say that this FOV threshold is pre-configured to a value f.sub.1. However, due to the impact of an elevation angle that cannot be estimated, the true azimuthal AoA may be larger (and the FoV more uncertain) than f.sub.1. In other words, a device may be erroneously paired despite being outside the FoV. In an aspect, the elevation angle may be inferred as a function of a height differential between the devices, as follows:

[00004] $= \sin^{-1}\left(\frac{h_p - h_d}{r}\right)$

where θ denotes the elevation angle, h.sub.p denotes the height of the phone, h.sub.d denotes the height of the target device for pairing, and r denotes a distance between the phone and the target device for pairing.

[0135] FIG. **8** illustrates an example implementation **800** of the process **700** of FIG. **7**, in accordance with aspects of the disclosure. Referring to FIG. **8**, a height for the phone (h.sub.p) and for the target/smart device (h.sub.d) may be inferred via any of a variety of ways (discussed in more detail below). Given a range estimate (r) (e.g., using UWB, WiFi, Bluetooth, or NR-SL, etc.), the elevation AoA (θ) may be estimated. The true or corrected azimuth AoA (ϕ′) may in turn be estimated (as discussed above). If |ϕ′|<f.sub.1, then the device may be paired with the phone and content may be pulled or pushed. Additionally (and optionally), an FoV uncertainty may be reported, which is linearly proportional to θ, r, and the uncertainty in the estimate of r. The pairing process may be performed if the reported FOV uncertainty is below a certain threshold.

[0136] Referring to FIG. **8**, in a specific example, the following methodology may be utilized for calibrating and inferring a height for the phone. Note that the calibration process may be performed initially for a single time.

[0137] First, a user may be guided to hold the phone with certain poses (e.g., while standing, sitting down, etc.) during which barometer readings may be gathered and stored in memory. User height information may be stored as well to estimate h.sub.p and map it to the recorded barometer readings. In an aspect, this procedure would be a part of the training phase, involving manual calibration by the user, and may be characterized as a manual calibration procedure. The user may also be provided with a prompt (such as a push notification or button press) to confirm that the current pose is valid and can be used for training.

[0138] Second, after the above training phase, barometer readings may be compared with the stored values/mapping to infer a current height for the phone. For example, the comparison may involve a mathematical relationship between barometer readings and relative height. Here, the inferred height is used for improving azimuth AoA estimation accuracy.

[0139] The above training data (e.g., barometer readings, user height, user pose) obtained during training may be stored either directly on the user device (e.g., for future inferences, the device would refer to previously recorded and stored values from its own memory), or on the smart device or target device (e.g., a smart bulb may gather calibration data from multiple phones and store it locally or on the server. When a new phone attempts to pair with the device, the phone's data may be compared with the stored training data to perform inference. This would require signaling of the phone's data (such as barometer readings) to the smart device, or to a server associated with the smart device.). In other designs, the training data may be stored remotely (e.g., on a network device).

[0140] Referring to FIG. **8**, in another specific example, the following methodology may be utilized for calibrating and inferring a height for the phone. Note that the calibration process may be performed initially for a single time.

[0141] First, a manual calibration procedure is performed as already described above.

[0142] Second, following the manual calibration procedure, a user may be guided to hold the phone at the same level or height as the target device (h.sub.p=h.sub.d). Barometer readings may be stored in memory for inference later.

[0143] Third, a user may be guided to switch on the back camera and point towards the target device. In an aspect, the height of the device from the ground (h.sub.d) may be directly estimated using computer vision techniques (such as visual ruler feature. In another aspect, following the above manual calibration, barometer readings in combination with computer vision techniques (that can estimate the difference in height (Δh) between the phone and the device) can be used to estimate h.sub.d=h.sub.p−Δh. In yet another aspect, the nature of the device can be mapped to a default or standard value for h.sub.d. For instance, smart bulbs in floor lamps may be considered to be 5 feet off the ground. In the event the device is not a smart device (no wireless connectivity for positioning), a prompt may be provided to the user suggesting that the user is not pointing to a valid device. This may be detected when no smart device is seen to be within the user's FoV (may be expanded further). Furthermore, a prompt may be provided to the user with suggestions of other devices in the vicinity (location not known), such as “Did you mean—Bose Soundlink?”.

[0144] FIG. **9** illustrates an exemplary process **900** of communications according to an aspect of the disclosure. The process **900** of FIG. **9** is performed by a communications device. In some designs, the communications device may correspond to a network component (e.g., gNB/BS **304** or O-RAN component or a remote location server such as network entity **306**, etc.). In other designs, the communications device may correspond to a UE (e.g., a device trying to pair another device or a target device for pairing, etc.).

[0145] Referring to FIG. **9**, at **910**, the communications device (e.g., user interface **346**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, etc.) prompts a user of a user equipment (UE) to achieve a target orientation relative to a target device. In some designs, the prompt is delivered directly to the user via the user interface **346**. In other designs, the prompt is remotely triggered at **910** (i.e., a prompt instruction is signaled to the UE via some communication mechanism). In some designs, a means for performing the prompt of **910** includes user interface **346**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, etc., of FIGS. **3**A-**3**C.

[0146] Referring to FIG. **9**, at **920**, the communications device (e.g., receiver **312** or **322** or **352** or **362**, network transceiver(s) **380** or **390**, sensor(s) **344**, etc.) obtains pitch measurement information associated with the UE while the UE is configured with the target

orientation. In some designs, a means for obtaining the pitch measurement information at **920** includes receiver **312** or **322** or **352** or **362**, network transceiver(s) **380** or **390**, sensor(s) **344**, etc., of FIGS. **3**A-**3**C.
[0147] Referring to FIG. **9**, at **930**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines an elevation angle between the UE and the target device based on the pitch measurement information. In some designs, a means for performing the determination of **930** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.
[0148] Referring to FIG. **9**, at **940**, the communications device (e.g., processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) determines whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle. In some designs, a means for performing the determination of **940** includes processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.
[0149] Referring to FIG. **9**, at **950**, the communications device (e.g., receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc.) performs at least one action based on the FoV determination. In some designs, a means for performing the at least one action of **950** includes receiver **312** or **322** or **352** or **362**, transmitter **314** or **324** or **354** or **364**, network transceiver(s) **380** or **390**, processor(s) **342** or **384** or **394**, FoV determination component **348** or **388** or **398**, etc., of FIGS. **3**A-**3**C.
[0150] Referring to FIG. **9**, in some designs, the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0151] Referring to FIG. **9**, in some designs, the FoV determination determines that the target device is inside of the FoV. In some designs, the at least one action comprises pairing the target device with the UE.
[0152] Referring to FIG. **9**, in some designs, the FoV determination determines that the target device is not inside of the FoV. In some designs, the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0153] Referring to FIG. **9**, in some designs, the FoV determination is further based on an FoV uncertainty parameter.
[0154] Referring to FIG. **9**, in some designs, the communications device corresponds to the UE, or the communications device corresponds to the target device, or the communications device corresponds to a network device.
[0155] Referring to FIG. **9**, in some designs, the FoV determination is further based at least in part on visual information (e.g., captured by camera sensor(s) of the UE or the target device or both). For example, the visual information may be used to verify the target orientation is correct (e.g., within some tolerance).
[0156] FIG. **10** illustrates an example implementation **1000** of the process **900** of FIG. **9**, in accordance with aspects of the disclosure. In FIG. **10**, an orientation of the UE is depicted at **1010**. In a specific example, a user of the phone (UE) is guided to directly calibrate for the elevation angle between the phone and device. The user may be guided to tilt the phone (as shown in FIG. **10** with respect to orientation **1010**) such that the phone faces the target directly (the line joining the device and the center of the phone is perpendicular to the screen). The pitch value (reported by Android sensors) would then be nearly equal to the value of the elevation angle, depending on the accuracy of calibration.
[0157] In the detailed description above it can be seen that different features are grouped together in examples. This manner of disclosure should not be understood as an intention that the example clauses have more features than are explicitly mentioned in each clause. Rather, the various aspects of the disclosure may include fewer than all features of an individual example clause disclosed. Therefore, the following clauses should hereby be deemed to be incorporated in the description, wherein each clause by itself can stand as a separate example. Although each dependent clause can refer in the clauses to a specific combination with one of the other clauses, the aspect(s) of that dependent clause are not limited to the specific combination. It will be appreciated that other example clauses can also include a combination of the dependent clause aspect(s) with the subject matter of any other dependent clause or independent clause or a combination of any feature with other dependent and independent clauses. The various aspects disclosed herein expressly include these combinations, unless it is explicitly expressed or can be readily inferred that a specific combination is not intended (e.g., contradictory aspects, such as defining an element as both an electrical insulator and an electrical conductor). Furthermore, it is also intended that aspects of a clause can be included in any other independent clause, even if the clause is not directly dependent on the independent clause.
[0158] Implementation examples are described in the following numbered clauses:
[0159] Clause 1. A method of operating a communications device, comprising: determining first information associated with a first height of a user equipment (UE); determining second information associated with a second height of a target device; determining a distance between the UE and the target device; determining an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.
[0160] Clause 2. The method of clause 1, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0161] Clause 3. The method of any of clauses 1 to 2, wherein the FoV determination determines that the target device is inside of the FoV.
[0162] Clause 4. The method of clause 3, wherein the at least one action comprises pairing the target device with the UE.
[0163] Clause 5. The method of any of clauses 1 to 4, wherein the FoV determination determines that the target device is not inside of the FoV.
[0164] Clause 6. The method of clause 5, wherein the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0165] Clause 7. The method of any of clauses 1 to 6, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0166] Clause 8. The method of any of clauses 1 to 7, wherein the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or wherein the second information associated with

the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or wherein the second information associated with the second height of the target device is based on computer vision analysis, or wherein the second information associated with the second height of the target device is fixed or pre-determined based on device type or device location, or any combination thereof.
[0167] Clause 9. The method of any of clauses 1 to 8, wherein the first information comprises the first height or a first pressure measurement, or wherein the second information comprises the second height or a second pressure measurement, or a combination thereof.
[0168] Clause 10. The method of any of clauses 1 to 9, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0169] Clause 11. A method of operating a communications device, comprising: prompting a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtaining pitch measurement information associated with the UE while the UE is configured with the target orientation; determining an elevation angle between the UE and the target device based on the pitch measurement information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.
[0170] Clause 12. The method of clause 11, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0171] Clause 13. The method of any of clauses 11 to 12, wherein the FoV determination determines that the target device is inside of the FoV.
[0172] Clause 14. The method of clause 13, wherein the at least one action comprises pairing the target device with the UE.
[0173] Clause 15. The method of any of clauses 11 to 14, wherein the FoV determination determines that the target device is not inside of the FoV.
[0174] Clause 16. The method of clause 15, wherein the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0175] Clause 17. The method of any of clauses 11 to 16, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0176] Clause 18. The method of any of clauses 11 to 17, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0177] Clause 19. A communications device, comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: determine first information associated with a first height of a user equipment (UE); determine second information associated with a second height of a target device; determine a distance between the UE and the target device; determine an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.
[0178] Clause 20. The communications device of clause 19, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0179] Clause 21. The communications device of any of clauses 19 to 20, wherein the FoV determination determines that the target device is inside of the FoV.
[0180] Clause 22. The communications device of clause 21, wherein the at least one action comprises pairing the target device with the UE.
[0181] Clause 23. The communications device of any of clauses 19 to 22, wherein the FoV determination determines that the target device is not inside of the FoV.
[0182] Clause 24. The communications device of clause 23, wherein the at least one action comprises: prohibit the UE from pairing with the target device, or prompt the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0183] Clause 25. The communications device of any of clauses 19 to 24, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0184] Clause 26. The communications device of any of clauses 19 to 25, wherein the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or wherein the second information associated with the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or wherein the second information associated with the second height of the target device is based on computer vision analysis, or wherein the second information associated with the second height of the target device is fixed or pre-determined based on device type or device location, or any combination thereof.
[0185] Clause 27. The communications device of any of clauses 19 to 26, wherein the first information comprises the first height or a first pressure measurement, or wherein the second information comprises the second height or a second pressure measurement, or a combination thereof.
[0186] Clause 28. The communications device of any of clauses 19 to 27, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0187] Clause 29. A communications device, comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: prompt a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtain pitch measurement information associated with the UE while the UE is configured with the target orientation; determine an elevation angle between the UE and the target device based on the pitch measurement information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.

[0188] Clause 30. The communications device of clause 29, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0189] Clause 31. The communications device of any of clauses 29 to 30, wherein the FoV determination determines that the target device is inside of the FoV.
[0190] Clause 32. The communications device of clause 31, wherein the at least one action comprises pairing the target device with the UE.
[0191] Clause 33. The communications device of any of clauses 29 to 32, wherein the FoV determination determines that the target device is not inside of the FoV.
[0192] Clause 34. The communications device of clause 33, wherein the at least one action comprises: prohibit the UE from pairing with the target device, or prompt the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0193] Clause 35. The communications device of any of clauses 29 to 34, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0194] Clause 36. The communications device of any of clauses 29 to 35, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0195] Clause 37. A communications device, comprising: means for determining first information associated with a first height of a user equipment (UE); means for determining second information associated with a second height of a target device; means for determining a distance between the UE and the target device; means for determining an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; means for determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and means for performing at least one action based on the FoV determination.
[0196] Clause 38. The communications device of clause 37, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0197] Clause 39. The communications device of any of clauses 37 to 38, wherein the FoV determination determines that the target device is inside of the FoV.
[0198] Clause 40. The communications device of clause 39, wherein the at least one action comprises pairing the target device with the UE.
[0199] Clause 41. The communications device of any of clauses 37 to 40, wherein the FoV determination determines that the target device is not inside of the FoV.
[0200] Clause 42. The communications device of clause 41, wherein the at least one action comprises: means for prohibiting the UE from pairing with the target device, or means for prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0201] Clause 43. The communications device of any of clauses 37 to 42, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0202] Clause 44. The communications device of any of clauses 37 to 43, wherein the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or wherein the second information associated with the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or wherein the second information associated with the second height of the target device is based on computer vision analysis, or wherein the second information associated with the second height of the target device is fixed or pre-determined based on device type or device location, or any combination thereof.
[0203] Clause 45. The communications device of any of clauses 37 to 44, wherein the first information comprises the first height or a first pressure measurement, or wherein the second information comprises the second height or a second pressure measurement, or a combination thereof.
[0204] Clause 46. The communications device of any of clauses 37 to 45, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0205] Clause 47. A communications device, comprising: means for prompting a user of a user equipment (UE) to achieve a target orientation relative to a target device; means for obtaining pitch measurement information associated with the UE while the UE is configured with the target orientation; means for determining an elevation angle between the UE and the target device based on the pitch measurement information; means for determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and means for performing at least one action based on the FoV determination.
[0206] Clause 48. The communications device of clause 47, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0207] Clause 49. The communications device of any of clauses 47 to 48, wherein the FoV determination determines that the target device is inside of the FoV.
[0208] Clause 50. The communications device of clause 49, wherein the at least one action comprises pairing the target device with the UE.
[0209] Clause 51. The communications device of any of clauses 47 to 50, wherein the FoV determination determines that the target device is not inside of the FoV.
[0210] Clause 52. The communications device of clause 51, wherein the at least one action comprises: means for prohibiting the UE from pairing with the target device, or means for prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0211] Clause 53. The communications device of any of clauses 47 to 52, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0212] Clause 54. The communications device of any of clauses 47 to 53, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a

network device.
[0213] Clause 55. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a communications device, cause the communications device to: determine first information associated with a first height of a user equipment (UE); determine second information associated with a second height of a target device; determine a distance between the UE and the target device; determine an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.
[0214] Clause 56. The non-transitory computer-readable medium of clause 55, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0215] Clause 57. The non-transitory computer-readable medium of any of clauses 55 to 56, wherein the FoV determination determines that the target device is inside of the FoV.
[0216] Clause 58. The non-transitory computer-readable medium of clause 57, wherein the at least one action comprises pairing the target device with the UE.
[0217] Clause 59. The non-transitory computer-readable medium of any of clauses 55 to 58, wherein the FoV determination determines that the target device is not inside of the FoV.
[0218] Clause 60. The non-transitory computer-readable medium of clause 59, wherein the at least one action comprises: prohibit the UE from pairing with the target device, or prompt the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0219] Clause 61. The non-transitory computer-readable medium of any of clauses 55 to 60, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0220] Clause 62. The non-transitory computer-readable medium of any of clauses 55 to 61, wherein the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or wherein the second information associated with the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or wherein the second information associated with the second height of the target device is based on computer vision analysis, or wherein the second information associated with the second height of the target device is fixed or pre-determined based on device type or device location, or any combination thereof.
[0221] Clause 63. The non-transitory computer-readable medium of any of clauses 55 to 62, wherein the first information comprises the first height or a first pressure measurement, or wherein the second information comprises the second height or a second pressure measurement, or a combination thereof.
[0222] Clause 64. The non-transitory computer-readable medium of any of clauses 55 to 63, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0223] Clause 65. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a communications device, cause the communications device to: prompt a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtain pitch measurement information associated with the UE while the UE is configured with the target orientation; determine an elevation angle between the UE and the target device based on the pitch measurement information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.
[0224] Clause 66. The non-transitory computer-readable medium of clause 65, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
[0225] Clause 67. The non-transitory computer-readable medium of any of clauses 65 to 66, wherein the FoV determination determines that the target device is inside of the FoV.
[0226] Clause 68. The non-transitory computer-readable medium of clause 67, wherein the at least one action comprises pairing the target device with the UE.
[0227] Clause 69. The non-transitory computer-readable medium of any of clauses 65 to 68, wherein the FoV determination determines that the target device is not inside of the FoV.
[0228] Clause 70. The non-transitory computer-readable medium of clause 69, wherein the at least one action comprises: prohibit the UE from pairing with the target device, or prompt the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
[0229] Clause 71. The non-transitory computer-readable medium of any of clauses 65 to 70, wherein the FoV determination is further based on an FoV uncertainty parameter.
[0230] Clause 72. The non-transitory computer-readable medium of any of clauses 65 to 71, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
[0231] 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.
[0232] 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.
[0233] The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an ASIC, a field-programable gate

array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.
[0234] 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.
[0235] 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.
[0236] While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. For example, the functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Further, no component, function, action, or instruction described or claimed herein should be construed as critical or essential unless explicitly described as such. Furthermore, as used herein, the terms “set,” “group,” and the like are intended to include one or more of the stated elements. Also, as used herein, the terms “has,” “have,” “having,” “comprises,” “comprising,” “includes,” “including,” and the like does not preclude the presence of one or more additional elements (e.g., an element “having” A may also have B). Further, the phrase “based on” is intended to mean “based, at least in part, on” unless explicitly stated otherwise. Also, as used herein, the term “or” is intended to be inclusive when used in a series and may be used interchangeably with “and/or,” unless explicitly stated otherwise (e.g., if used in combination with “either” or “only one of”) or the alternatives are mutually exclusive (e.g., “one or more” should not be interpreted as “one and more”). Furthermore, although components, functions, actions, and instructions may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Accordingly, as used herein, the articles “a,” “an,” “the,” and “said” are intended to include one or more of the stated elements. Additionally, as used herein, the terms “at least one” and “one or more” encompass “one” component, function, action, or instruction performing or capable of performing a described or claimed functionality and also “two or more” components, functions, actions, or instructions performing or capable of performing a described or claimed functionality in combination.

Claims

1. A method of operating a communications device, comprising: determining first information associated with a first height of a user equipment (UE); determining second information associated with a second height of a target device; determining a distance between the UE and the target device; determining an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.
2. The method of claim 1, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
3. The method of claim 1, wherein the FoV determination determines that the target device is inside of the FoV.
4. The method of claim 3, wherein the at least one action comprises pairing the target device with the UE.
5. The method of claim 1, wherein the FoV determination determines that the target device is not inside of the FoV.
6. The method of claim 5, wherein the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
7. The method of claim 1, wherein the FoV determination is further based on an FoV uncertainty parameter.
8. The method of claim 1, wherein the first information associated with the first height of the UE is based on a first height estimation calibration procedure performed by a user of the UE, or wherein the second information associated with the second height of the target device is based on a second height estimation calibration procedure performed by a user of the target device, or wherein the second information associated with the second height of the target device is based on computer vision analysis, or wherein the second information associated with the second height of the target device is fixed or pre-determined based on device type or device

location, or any combination thereof.
9. The method of claim 1, wherein the first information comprises the first height or a first pressure measurement, or wherein the second information comprises the second height or a second pressure measurement, or a combination thereof.
10. The method of claim 1, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
11. A method of operating a communications device, comprising: prompting a user of a user equipment (UE) to achieve a target orientation relative to a target device; obtaining pitch measurement information associated with the UE while the UE is configured with the target orientation; determining an elevation angle between the UE and the target device based on the pitch measurement information; determining whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and performing at least one action based on the FoV determination.
12. The method of claim 11, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.
13. The method of claim 11, wherein the FoV determination determines that the target device is inside of the FoV.
14. The method of claim 13, wherein the at least one action comprises pairing the target device with the UE.
15. The method of claim 11, wherein the FoV determination determines that the target device is not inside of the FoV.
16. The method of claim 15, wherein the at least one action comprises: prohibiting the UE from pairing with the target device, or prompting the user of the UE to adjust an orientation of the UE, or prompting the user of the UE with one or more alternative target device pairing suggestions, or any combination thereof.
17. The method of claim 11, wherein the FoV determination is further based on an FoV uncertainty parameter.
18. The method of claim 11, wherein the communications device corresponds to the UE, or wherein the communications device corresponds to the target device, or wherein the communications device corresponds to a network device.
19. A communications device, comprising: one or more memories; one or more transceivers; and one or more processors communicatively coupled to the one or more memories and the one or more transceivers, the one or more processors, either alone or in combination, configured to: determine first information associated with a first height of a user equipment (UE); determine second information associated with a second height of a target device; determine a distance between the UE and the target device; determine an elevation angle between the UE and the target device based on the distance and a differential between the first information and the second information; determine whether the target device is inside of a field of view (FoV) of the UE based on the elevation angle; and perform at least one action based on the FoV determination.
20. The communications device of claim 19, wherein the FoV determination is further based on an Azimuth angle of arrival (AoA) associated with one or more signals communicated between the UE and the target device.