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FREQUENCY DOMAIN SEARCH WINDOW FOR NON-TERRESTRIAL NETWORK POSITIONING REFERENCE SIGNALS

Abstract

Disclosed are techniques for wireless positioning. In an aspect, a network entity may determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session. The network entity may measure the at least one PRS resource in the frequency domain search window during the positioning session.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present Application for Patent claims priority under 35 U.S.C. § 371 to International Patent Application No. PCT/US2023/016663, entitled "FREQUENCY DOMAIN SEARCH WINDOW FOR NON-TERRESTRIAL NETWORK POSITIONING REFERENCE SIGNALS," filed Mar. 29, 2023, and to Greek Patent Application No. 20220100399, entitled "FREQUENCY DOMAIN SEARCH WINDOW FOR NON-TERRESTRIAL NETWORK POSITIONING REFERENCE SIGNALS," filed May 16, 2022, each of which is assigned to the assignee hereof and expressly incorporated herein by reference in their entirety.

BACKGROUND OF THE DISCLOSURE
1. Field of the Disclosure
[0002] Aspects of the disclosure relate generally to wireless communications.
2. Description of the Related Art
[0003] 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.
[0004] 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
[0005] 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.

[0006] In an aspect, a method of wireless communication performed by a network entity includes determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measuring the at least one PRS resource in the frequency domain search window during the positioning session.
[0007] In an aspect, a method of wireless communication performed by a first network entity includes sending information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receiving a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.
[0008] In an aspect, a network entity includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measure the at least one PRS resource in the frequency domain search window during the positioning session.
[0009] In an aspect, a first network entity includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: send, via the at least one transceiver, information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receive, via the at least one transceiver, a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.
[0010] In an aspect, a network entity includes means for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and means for measuring the at least one PRS resource in the frequency domain search window during the positioning session.
[0011] In an aspect, a first network entity includes means for sending information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and means for receiving a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.
[0012] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a network entity, cause the network entity to: determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measure the at least one PRS resource in the frequency domain

search window during the positioning session.

[0013] In an aspect, a non-transitory computer-readable medium stores computer-executable instructions that, when executed by a first network entity, cause the first network entity to: send information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receive a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.

[0014] 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

[0015] 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.

[0016] FIG. **1** illustrates an example wireless communications system, according to aspects of the disclosure.

[0017] FIGS. **2**A, **2**B, and **2**C illustrate example wireless network structures, according to aspects of the disclosure.

[0018] 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.

[0019] FIG. **4** illustrates examples of various positioning methods supported in New Radio (NR), according to aspects of the disclosure.

[0020] FIG. **5** is a diagram illustrating an example frame structure, according to aspects of the disclosure.

[0021] FIG. **6** depicts an example non-terrestrial network (NTN) environment that may be used with transparent payloads and in NTN positioning operations, according to aspects of the disclosure.

[0022] FIG. **7** depicts an example NTN environment that may be used with regenerative payloads and in NTN positioning operations, according to aspects of the disclosure.

[0023] FIG. **8** is a table showing examples of satellite platforms that may be used as a non-terrestrial transmission-reception points (NT-TRPs), according to aspects of the disclosure.

[0024] FIG. **9** depicts an example scenario in which positioning determinations based on a Global Navigation Satellite System (GNSS) positioning method are cross-checked with positioning determinations based on an NTN positioning method, according to aspects of the disclosure.

[0025] FIG. **10** depicts an example of a time-based positioning reference signal (PRS) search window, according to aspects of the disclosure.

[0026] FIG. **11** shows an example procedure for exchanging information between a base station and a location server in an uplink positioning reference signal (UL-PRS) positioning procedure, according to aspects of the disclosure.

[0027] FIG. **12** is a table showing an example of the information elements (IEs) used to determine the parameters of time-based search windows, according to aspects of the disclosure.

[0028] FIG. **13** is a diagram illustrating system geometry for Doppler shift computation for a non-geostationary satellite system, according to aspects of the disclosure.

[0029] FIG. **14** is a graph illustrating an example Doppler shift scenario with a two gigahertz

(GHz) signal at 600 kilometers (km) on the downlink and uplink, according to aspects of the disclosure.

[0030] FIG. **15** is a graph illustrating an example Doppler shift scenario with a two GHz signal at 1500 km on the downlink and uplink, according to aspects of the disclosure.

[0031] FIG. **16** shows examples of auto-correlation responses for PRS received under different Doppler shift conditions.

[0032] FIG. **17** depicts examples of configurations for frequency domain search windows using the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty, according to aspects of the disclosure.

[0033] FIG. **18** illustrates an example method of wireless communication performed by a network entity, according to aspects of the disclosure.

[0034] FIG. **19** illustrates an example method of wireless communication performed by a first network entity, according to aspects of the disclosure.

DETAILED DESCRIPTION

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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).

[0043] 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.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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**.

[0048] 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).

[0049] 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).

[0050] 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 gigahertz (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.

[0051] 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.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR two initial operating bands have been identified as frequency range designations FR1 (410 MHz-7.125 GHZ) and FR2 (24.25 GHz-52.6 GHz). It

should be understood that although a portion of FR1 is greater than 6 GHz, FR1 is often referred to (interchangeably) as a “Sub-6 GHz” band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a “millimeter wave” band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHz-300 GHz) which is identified by the International Telecommunications Union (ITU) as a “millimeter wave” band.
[0059] 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.
[0060] 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.
[0061] 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.
[0062] 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.
[0063] 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**.

[0064] 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**.

[0065] 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.

[0066] 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**.

[0067] In the example of FIG. **1**, any of the illustrated UEs (shown in FIG. **1** as UEs **114** and **116** 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 the UEs **114** and/or **116** (or any other UE) 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 **114** and/or **116**) 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 (e.g., UEs **114** and/or **116**) may include one or more dedicated receivers specifically designed to receive signals **124** for deriving geo location information from the SVs **112**.

[0068] 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.

[0069] 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(ES) **118** (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 (e.g., core network **170**). 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 **114** and/or **116** may receive communication signals (e.g., signals **124**) from an SV **112** instead of, or in addition to, communication signals from a terrestrial base station **102**. The radio link between a UE (e.g., UE **114**, **116**) and an SV **112** is referred to as a “service link” (e.g., service links **124**). The radio link between an SV **112** and the earth station **118** is referred to as a “feeder link” (e.g., feeder link **126**).

[0070] NTNs may also be used to reinforce 5G service reliability by providing service continuity for machine-to-machine (M2M) and/or IoT devices, or for passengers on board moving platforms (e.g., passenger vehicles such as aircraft, ships, high speed trains, buses, etc.), or ensuring service availability anywhere, especially for critical communications. NTNs can also enable 5G network scalability by providing efficient multicast/broadcast resources for data delivery towards the network edges or even the UE (e.g., UEs **114** and/or **116**).

[0071] In the example of FIG. **1**, an SV **112** is in communication with a UE **114** outside the coverage area of a base station **102** (representing a UE in an area that is not served by a terrestrial 5G network) and with a UE **116** inside the coverage area of a base station **102** (representing a UE that is under-served by the terrestrial 5G network). Thus, SV **112** may act as a serving base station to UE **114** and as a primary cell or a secondary cell to UE **116**, depending on the service provided to UE **116** by base station **102**.

[0072] Note that although FIG. **1** only illustrates a single SV **112** and a single earth station **118**, as will be appreciated, this is merely an example, and there may be any number of SVs **112** connected to any number of earth stations **118**.

[0073] 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

[0074] AP **150** (through which UE **190** may indirectly obtain WLAN-based Internet connectivity). In an example, the D2D P2P links **192** and **194** may be supported with any well-known D2D RAT, such as LTE Direct (LTE-D), WiFi Direct (WiFi-D), Bluetooth®, and so on.

[0075] 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).

[0076] 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).

[0077] 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.

[0078] 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**.

[0079] 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.

[0080] 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).

[0081] 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.

[0082] User plane interface **263** and control plane interface **265** connect the 5GC **260**, and specifically the UPF **262** and AMF **264**, respectively, to one or more gNBs **222** and/or ng-eNBs **224** in the NG-RAN **220**. The interface between gNB(s) **222** and/or ng-eNB(s) **224** and the AMF **264** is referred to as the “N2” interface, and the interface between gNB(s) **222** and/or ng-eNB(s) **224** and the UPF **262** is referred to as the “N3” interface. The gNB(s) **222** and/or ng-eNB(s) **224** of the NG-RAN **220** may communicate directly with each other via backhaul connections **223**, referred to as the “Xn-C” interface. One or more of gNBs **222** and/or ng-eNBs **224** may communicate with one or more UEs **204** over a wireless interface, referred to as the “Uu” interface.

[0083] 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.

[0084] 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, access point (AP), a transmit receive point (TRP), or a 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.

[0085] 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).

[0086] 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.

[0087] 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 distributed units (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**.

[0088] 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 radio frequency (RF) transceiver), configured to receive or transmit signals, or both, over a wireless transmission medium to one or more of the other units.
[0089] In some aspects, the CU **280** may host one or more higher layer control functions. Such control functions can include radio resource control (RRC), packet data convergence protocol (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.
[0090] 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 radio link control (RLC) layer, a medium access control (MAC) layer, and one or more high physical (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**.
[0091] 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.
[0092] 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 **02** interface). Such virtualized network elements can include, but are not limited to, CUs **280**, DUs **285**, RUs **287** and Near-RT RICs **259**. In some implementations, the SMO Framework **255** can communicate with

a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) **261**, via an O1 interface. Additionally, in some implementations, the SMO Framework **255** can communicate directly with one or more RUs **287** via an O1 interface. The SMO Framework **255** also may include a Non-RT RIC **257** configured to support functionality of the SMO Framework **255**.

[0093] 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**.

[0094] 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 **01**) or via creation of RAN management policies (such as A1 policies).

[0095] 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.

[0096] The UE **302** and the base station **304** each include one or more wireless wide area network (WWAN) transceivers **310** and **350**, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) via one or more wireless communication networks (not shown), such as an NR network, an LTE network, a GSM network, and/or the like. The WWAN transceivers **310** and **350** may each be connected to one or more antennas **316** and **356**, respectively, for communicating with other network nodes, such as other UEs, access points, base stations (e.g., eNBs, gNBs), etc., via at least one designated RAT (e.g., NR, LTE, GSM, etc.) over a wireless communication medium of interest (e.g., some set of time/frequency resources in a particular frequency spectrum). The WWAN transceivers **310** and **350** may be variously configured for transmitting and encoding signals **318** and **358** (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals **318** and **358** (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the WWAN transceivers **310** and **350** include one or more transmitters **314** and **354**, respectively, for transmitting and encoding signals **318** and **358**, respectively, and one or more receivers **312** and **352**, respectively, for receiving and decoding signals **318** and **358**, respectively.

[0097] The UE **302** and the base station **304** each also include, at least in some cases, one or more short-range wireless transceivers **320** and **360**, respectively. The short-range wireless transceivers **320** and **360** may be connected to one or more antennas **326** and **366**, respectively, and provide means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) with other network nodes, such as other UEs, access points, base stations, etc., via at least one designated RAT (e.g., WiFi, LTE-D, Bluetooth®, Zigbee®, Z-Wave®, PC5, dedicated short-range communications (DSRC), wireless access for vehicular environments (WAVE), near-field communication (NFC), 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 WiFi transceivers, Bluetooth® transceivers, Zigbee® and/or Z-Wave® transceivers, NFC transceivers, UWB transceivers, or vehicle-to-vehicle (V2V) and/or vehicle-to-everything (V2X) transceivers.

[0098] The UE **302** and the base station **304** also include, at least in some cases, satellite signal receivers **330** and **370**. The satellite signal receivers **330** and **370** may be connected to one or more antennas **336** and **376**, respectively, and may provide means for receiving and/or measuring satellite positioning/communication signals **338** and **378**, respectively. Where the satellite signal receivers **330** and **370** are satellite positioning system receivers, the satellite positioning/communication signals **338** and **378** may be global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC), Quasi-Zenith Satellite System (QZSS), etc. Where the satellite signal receivers **330** and **370** are non-terrestrial network (NTN) receivers, the satellite positioning/communication signals **338** and **378** may be communication signals (e.g., carrying control and/or user data) originating from a 5G network. The satellite signal receivers **330** and **370** may comprise any suitable hardware and/or software for receiving and processing satellite positioning/communication signals **338** and **378**, respectively. The satellite signal receivers **330** and **370** may request information and operations as appropriate from the other systems, and, at least in some cases, perform calculations to determine locations of the UE **302** and the base station **304**, respectively, using measurements obtained by any suitable satellite positioning system algorithm.

[0099] 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.

[0100] 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.

[0101] 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.

[0102] The UE **302**, the base station **304**, and the network entity **306** also include other components that may be used in conjunction with the operations as disclosed herein. The UE **302**, the base station **304**, and the network entity **306** include one or more processors **332**, **384**, and **394**, respectively, for providing functionality relating to, for example, wireless communication, and for providing other processing functionality. The processors **332**, **384**, and **394** may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processors **332**, **384**, and **394** may include, for example, one or more general purpose processors, multi-core processors, central processing units (CPUs), ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGAs), other programmable logic devices or processing circuitry, or various combinations thereof.

[0103] The UE **302**, the base station **304**, and the network entity **306** include memory circuitry implementing memories **340**, **386**, and **396** (e.g., each including a memory device), respectively, for maintaining information (e.g., information indicative of reserved resources, thresholds, parameters, and so on). The memories **340**, **386**, and **396** may therefore provide means for storing, means for retrieving, means for maintaining, etc. In some cases, the UE **302**, the base station **304**, and the network entity **306** may include positioning component **342**, **388**, and **398**, respectively. The positioning component **342**, **388**, and **398** may be hardware circuits that are part of or coupled to the processors **332**, **384**, and **394**, respectively, that, when executed, cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. In other aspects, the positioning component **342**, **388**, and **398** may be external to the processors **332**, **384**, and **394** (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the positioning component **342**, **388**, and **398** may be memory modules stored in the memories **340**, **386**, and **396**, respectively, that, when executed by the processors **332**, **384**, and **394** (or a modem processing system, another processing system, etc.), cause the UE **302**, the base station **304**, and the network entity **306** to perform the functionality described herein. FIG. **3**A illustrates possible locations of the positioning component **342**, which may be, for example, part of the one or more WWAN transceivers **310**, the memory **340**, the one or more processors **332**, or any combination thereof, or may be a standalone component. FIG. **3**B illustrates possible locations of the positioning component **388**, which may be, for example, part of the one or more WWAN transceivers **350**, the memory **386**, the one or more processors **384**, or any combination thereof, or may be a standalone component. FIG. **3**C illustrates possible locations of the positioning component **398**, which may be, for example, part of the one or more network transceivers **390**, the memory **396**, the one or more processors **394**, or any combination thereof, or may be a standalone component.

[0104] The UE **302** may include one or more sensors **344** coupled to the one or more processors **332** to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the one or more WWAN transceivers **310**, the one or more short-range wireless transceivers **320**, and/or the satellite signal receiver **330**. By way of example, the sensor(s) **344** may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor. Moreover, the sensor(s) **344** may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s) **344** may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in two-dimensional (2D) and/or three-dimensional (3D) coordinate systems.

[0105] 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.

[0106] 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.

[0107] 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.

[0108] At the UE **302**, the receiver **312** receives a signal through its respective antenna(s) **316**. The receiver **312** recovers information modulated onto an RF carrier and provides the information to the one or more processors **332**. The transmitter **314** and the receiver **312** implement Layer-1 functionality associated with various signal processing functions. The receiver **312** may perform spatial processing on the information to recover any spatial streams destined for the UE **302**. If multiple spatial streams are destined for the UE **302**, they may be combined by the receiver **312** into a single OFDM symbol stream. The receiver **312** then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **304**. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to recover the data and control signals that were originally transmitted by the base station **304** on the physical channel. The data and control signals are then provided to the one or more processors **332**, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

[0109] In the uplink, the one or more processors **332** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The one or more processors **332** are also responsible for error detection.

[0110] Similar to the functionality described in connection with the downlink transmission by the base station **304**, the one or more processors **332** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.

[0111] 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.

[0112] 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**.

[0113] 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.

[0114] For convenience, the UE **302**, the base station **304**, and/or the network entity **306** are shown in FIGS. **3**A, **3**B, and **3**C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated components may have different functionality in different designs. In particular, various components in FIGS. **3**A to **3**C are optional in alternative configurations and the various aspects include configurations that may vary due to design choice, costs, use of the device, or other considerations. For example, in case of FIG. **3**A, a particular implementation of UE **302** may omit the WWAN transceiver(s) **310** (e.g., a wearable device or tablet computer or PC or laptop may have Wi-Fi and/or Bluetooth capability without cellular capability), or may omit the short-range wireless transceiver(s) **320** (e.g., cellular-only, etc.), or may omit the satellite signal receiver **330**, or may omit the sensor(s) **344**, and so on. In another example, in case of FIG. **3**B, a particular implementation of the base station **304** may omit the WWAN transceiver(s) **350** (e.g., a Wi-Fi "hotspot" access point without cellular capability), or may omit the short-range wireless transceiver(s) **360** (e.g., cellular-only, etc.), or may omit the satellite receiver **370**, and so on. For brevity, illustration of the various alternative configurations is not provided herein, but would be readily understandable to one skilled in the art.

[0115] The various components of the UE **302**, the base station **304**, and the network entity **306** may be communicatively coupled to each other over data buses **334**, **382**, and **392**, respectively. In an aspect, the data buses **334**, **382**, and **392** may form, or be part of, a communication interface of the UE **302**, the base station **304**, and the network entity **306**, respectively. For example, where different logical entities are embodied in the same device (e.g., gNB and location server functionality incorporated into the same base station **304**), the data buses **334**, **382**, and **392** may provide communication between them.

[0116] The components of FIGS. **3**A, **3**B, and **3**C may be implemented in various ways. In some implementations, the components of FIGS. **3**A, **3**B, and **3**C may be implemented in one or more circuits such as, for example, one or more processors and/or one or more ASICs (which may include one or more processors). Here, each circuit may use and/or incorporate at least one memory component for storing information or executable code used by the circuit to provide this functionality. For example, some or all of the functionality represented by blocks **310** to **346** may be implemented by processor and memory component(s) of the UE **302** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Similarly, some or all of the functionality represented by blocks **350** to **388** may be implemented by processor and memory component(s) of the base station **304** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Also, some or all of the functionality represented by blocks **390** to **398** may be implemented by processor and memory component(s) of the network entity **306** (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). For simplicity, various operations, acts, and/or functions are described herein as being performed "by a UE," "by a base station," "by a network entity," etc. However, as will be appreciated, such operations, acts, and/or functions may actually be performed by specific components or combinations of components of the UE **302**, base station **304**, network entity **306**, etc., such as the processors **332**, **384**, **394**, the transceivers **310**, **320**, **350**, and **360**, the memories **340**, **386**, and **396**, the positioning component **342**, **388**, and **398**, etc.

[0117] In some designs, the network entity **306** may be implemented as a core network component. In other designs, the network entity **306** may be distinct from a network operator or operation of the cellular network infrastructure (e.g., NG RAN **220** and/or 5GC **210**/**260**). For example, the network entity **306** may be a component of a private network that may be configured to communicate with the UE **302** via the base station **304** or independently from the base station **304** (e.g., over a non-cellular communication link, such as WiFi).

[0118] NR supports a number of cellular network-based positioning technologies, including downlink-based, uplink-based, and downlink-and-uplink-based positioning methods. Downlink-based positioning methods include observed time difference of arrival (OTDOA) in LTE, downlink time difference of arrival (DL-TDOA) in NR, and downlink angle-of-departure (DL-AoD) in NR. FIG. **4** illustrates examples of various positioning methods, according to aspects of the disclosure. In an OTDOA or DL-TDOA positioning procedure, illustrated by scenario **410**, a UE measures the differences between the times of arrival (ToAs) of reference signals (e.g., positioning reference signals (PRS)) received from pairs of base stations, referred to as reference signal time difference (RSTD) or time difference of arrival (TDOA) measurements, and reports them to a positioning entity. More specifically, the UE receives the identifiers (IDs) of a reference base station (e.g., a serving base station) and multiple non-reference base stations in assistance data. The UE then measures the RSTD between the reference base station and each of the non-reference base stations. Based on the known locations of the involved base stations and the RSTD measurements, the positioning entity (e.g., the UE for UE-based positioning or a location server for UE-assisted positioning) can estimate the UE's location.

[0119] For DL-AoD positioning, illustrated by scenario **420**, the positioning entity uses a measurement report from the UE of received signal strength measurements of multiple downlink transmit beams to determine the angle(s) between the UE and the transmitting base station(s). The positioning entity can then estimate the location of the UE based on the determined angle(s) and the known location(s) of the transmitting base station(s).

[0120] Uplink-based positioning methods include uplink time difference of arrival (UL-TDOA) and uplink angle-of-arrival (UL-AoA). UL-TDOA is similar to DL-TDOA, but is based on uplink reference signals (e.g., sounding reference signals (SRS)) transmitted by the UE to multiple base stations. Specifically, a UE transmits one or more uplink reference signals that are measured by a reference base station and a plurality of non-reference base stations. Each base station then reports the reception time (referred to as the relative time of arrival (RTOA)) of the reference signal(s) to a positioning entity (e.g., a location server) that knows the locations and relative timing of the involved base stations. Based on the reception-to-reception (Rx-Rx) time difference between the reported RTOA of the reference base station and the reported RTOA of each non-reference base station, the known locations of the base stations, and their known timing offsets, the positioning entity can estimate the location of the UE using TDOA.

[0121] For UL-AoA positioning, one or more base stations measure the received signal strength of one or more uplink reference signals (e.g., SRS) received from a UE on one or more uplink receive beams. The positioning entity uses the signal strength measurements and the angle(s) of the receive beam(s) to determine the angle(s) between the UE and the base station(s). Based on the determined angle(s) and the known location(s) of the base station(s), the positioning entity can then estimate the location of the UE.

[0122] Downlink-and-uplink-based positioning methods include enhanced cell-ID (E-CID) positioning and multi-round-trip-time (RTT) positioning (also referred to as “multi-cell RTT” and “multi-RTT”). In an RTT procedure, a first entity (e.g., a base station or a UE) transmits a first RTT-related signal (e.g., a PRS or SRS) to a second entity (e.g., a UE or base station), which transmits a second RTT-related signal (e.g., an SRS or PRS) back to the first entity. Each entity measures the time difference between the time of arrival (ToA) of the received RTT-related signal and the transmission time of the transmitted RTT-related signal. This time difference is referred to as a reception-to-transmission (Rx-Tx) time difference. The Rx-Tx time difference measurement may be made, or may be adjusted, to include only a time difference between nearest slot boundaries for the received and transmitted signals. Both entities may then send their Rx-Tx time difference measurement to a location server (e.g., an LMF **270**), which calculates the round trip propagation time (i.e., RTT) between the two entities from the two Rx-Tx time difference measurements (e.g., as the sum of the two Rx-Tx time difference measurements). Alternatively, one entity may send its Rx-Tx time difference measurement to the other entity, which then calculates the RTT. The distance between the two entities can be determined from the RTT and the known signal speed (e.g., the speed of light). For multi-RTT positioning, illustrated by scenario **430**, a first entity (e.g., a UE or base station) performs an RTT positioning procedure with multiple second entities (e.g., multiple base stations or UEs) to enable the location of the first entity to be determined (e.g., using multilateration) based on distances to, and the known locations of, the second entities. RTT and multi-RTT methods can be combined with other positioning techniques, such as UL-AoA and DL-AoD, to improve location accuracy, as illustrated by scenario **440**.

[0123] The E-CID positioning method is based on radio resource management (RRM) measurements. In E-CID, the UE reports the serving cell ID, the timing advance (TA), and the identifiers, estimated timing, and signal strength of detected neighbor base stations. The location of the UE is then estimated based on this information and the known locations of the base station(s).

[0124] To assist positioning operations, a location server (e.g., location server **230**, LMF **270**, SLP **272**) may provide assistance data to the UE. For example, the assistance data may include identifiers of the base stations (or the cells/TRPs of the base stations) from which to measure reference signals, the reference signal configuration parameters (e.g., the number of consecutive slots including PRS, periodicity of the consecutive slots including PRS, muting sequence, frequency hopping sequence, reference signal identifier, reference signal bandwidth, etc.), and/or other parameters applicable to the particular positioning method. Alternatively, the assistance data may originate directly from the base stations themselves (e.g., in periodically broadcasted overhead messages, etc.). In some cases, the UE may be able to detect neighbor network nodes itself without the use of assistance data.

[0125] In the case of an OTDOA or DL-TDOA positioning procedure, the assistance data may further include an expected RSTD value and an associated uncertainty, or search window, around the expected RSTD. In some cases, the value range of the expected RSTD may be +/−500 microseconds (μs). In some cases, when any of the resources used for the positioning measurement are in FR1, the value range for the uncertainty of the expected RSTD may be +/−32 μs. In other cases, when all of the resources used for the positioning measurement(s) are in FR2, the value range for the uncertainty of the expected RSTD may be +/−8 μs.

[0126] A location estimate may be referred to by other names, such as a position estimate, location, position, position fix, fix, or the like. A location estimate may be geodetic and comprise coordinates (e.g., latitude, longitude, and possibly altitude) or may be civic and comprise a street address, postal address, or some other verbal description of a location. A location estimate may further be defined relative to some other known location or defined in absolute terms (e.g., using latitude, longitude, and possibly altitude). A location estimate may include an expected error or uncertainty (e.g., by including an area or volume within which the location is expected to be included with some specified or default level of confidence).

[0127] Various frame structures may be used to support downlink and uplink transmissions between network nodes (e.g., base stations and UEs). FIG. **5** is a diagram **500** illustrating an example frame structure, according to aspects of the disclosure. The frame structure may be a downlink or uplink frame structure. Other wireless communications technologies may have different frame structures and/or different channels.

[0128] LTE, and in some cases NR, utilizes orthogonal frequency-division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. Unlike LTE, however, NR has an option to use OFDM on the uplink as well. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kilohertz (kHz) and the minimum resource allocation (resource block) may be 12 subcarriers (or 180 kHz). Consequently, the nominal fast Fourier transform (FFT) size may be equal to 128, 256, 512, 1024, or 2048 for system bandwidth of 1.25, 2.5, 5, 10, or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., 6 resource blocks), and there may be 1, 2, 4, 8, or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10, or 20 MHz, respectively.

[0129] LTE supports a single numerology (subcarrier spacing (SCS), symbol length, etc.). In contrast, NR may support multiple numerologies (μ), for example, subcarrier spacings of 15 kHz (μ=0), 30 kHz (μ=1), 60 kHz (μ=2), 120 kHz (μ=3), and 240 kHz (μ=4) or greater may be available. In each subcarrier spacing, there are 14 symbols per slot. For 15 kHz SCS (μ=0), there is one slot per subframe, 10 slots per frame, the slot duration is 1 millisecond (ms), the symbol duration is 66.7 microseconds (μs), and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 50. For 30 kHz SCS (μ=1), there are two slots per subframe, 20 slots per frame, the slot duration is 0.5 ms, the symbol duration is 33.3 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 100. For 60 kHz SCS (μ=2), there are four slots per subframe, 40 slots per frame, the slot duration is 0.25 ms, the symbol duration is 16.7 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 200. For 120 kHz SCS (μ=3), there are eight slots per subframe, 80 slots per frame, the slot duration is 0.125 ms, the symbol duration is 8.33 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 400. For 240 kHz SCS (μ=4), there are 16 slots per subframe, 160 slots per frame, the slot duration is 0.0625 ms, the symbol duration is 4.17 μs, and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 800.

[0130] In the example of FIG. **5**, a numerology of 15 kHz is used. Thus, in the time domain, a 10 ms frame is divided into 10 equally sized subframes of 1 ms each, and each subframe includes one time slot. In FIG. **5**, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top.

[0131] A resource grid may be used to represent time slots, each time slot including one or more time-concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)) in the frequency domain. The resource grid is further divided into multiple resource elements (REs). An RE may correspond to one symbol length in the time domain and one subcarrier in the frequency domain. In the numerology of FIG. **5**, for a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and seven consecutive symbols in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and six consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

[0132] Some of the REs may carry reference (pilot) signals (RS). The reference signals may include positioning reference signals (PRS), tracking reference signals (TRS), phase tracking reference signals (PTRS), cell-specific reference signals (CRS), channel state information reference signals (CSI-RS), demodulation reference signals (DMRS), primary synchronization signals (PSS), secondary synchronization signals (SSS), synchronization signal blocks (SSBs), sounding reference signals (SRS), etc., depending on whether the illustrated frame structure is used for uplink or downlink communication. FIG. **5** illustrates example locations of REs carrying a reference signal (labeled “R”).

[0133] A collection of resource elements (REs) that are used for transmission of PRS is referred to as a “PRS resource.” The collection of resource elements can span multiple PRBs in the frequency domain and ‘N’ (such as 1 or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol in the time domain, a PRS resource occupies consecutive PRBs in the frequency domain.

[0134] The transmission of a PRS resource within a given PRB has a particular comb size (also referred to as the “comb density”). A comb size ‘N’ represents the subcarrier spacing (or frequency/tone spacing) within each symbol of a PRS resource configuration. Specifically, for a comb size ‘N,’ PRS are transmitted in every Nth subcarrier of a symbol of a PRB. For example, for comb-4, for each symbol of the PRS resource configuration, REs corresponding to every fourth subcarrier (such as subcarriers 0, 4, 8) are used to transmit PRS of the PRS resource. Currently, comb sizes of comb-2, comb-4, comb-6, and comb-12 are supported for DL-PRS. FIG. **5** illustrates an example PRS resource configuration for comb-4 (which spans four symbols). That is, the locations of the shaded REs (labeled “R”) indicate a comb-4 PRS resource configuration.

[0135] Currently, a DL-PRS resource may span 2, 4, 6, or 12 consecutive symbols within a slot with a fully frequency-domain staggered pattern. A DL-PRS resource can be configured in any higher layer configured downlink or flexible (FL) symbol of a slot. There may be a constant energy per resource element (EPRE) for all REs of a given DL-PRS resource. The following are the frequency offsets from symbol to symbol for comb sizes 2, 4, 6, and 12 over 2, 4, 6, and 12 symbols. 2-symbol comb-2: {0, 1}; 4-symbol comb-2: {0, 1, 0, 1}; 6-symbol comb-2: {0, 1, 0, 1, 0, 1}; 12-symbol comb-2: {0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3} (as in the example of FIG. **5**); 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 6-symbol comb-6: {0, 3, 1, 4, 2, 5}; 12-symbol comb-6: {0, 3, 1, 4, 2, 5, 0, 3, 1, 4, 2, 5}; and 12-symbol comb-12: {0, 6, 3, 9, 1, 7, 4, 10, 2, 8, 5, 11}.

[0136] A “PRS resource set” is a set of PRS resources used for the transmission of PRS signals, where each PRS resource has a PRS resource ID. In addition, the PRS resources in a PRS resource set are associated with the same TRP. A PRS resource set is identified by a PRS resource set ID and is associated with a particular TRP (identified by a TRP ID). In addition, the PRS resources in a PRS resource set have the same periodicity, a common muting pattern configuration, and the same repetition factor (such as “PRS-ResourceRepetitionFactor”) across slots. The periodicity is the time from the first repetition of the first PRS resource of a first PRS instance to the same first repetition of the same first PRS resource of the next PRS instance. The periodicity may have a length selected from 2∧μ*{4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 160, 320, 640, 1280, 2560, 5120, 10240} slots, with μ=0, 1, 2, 3. The repetition factor may have a length selected from {1, 2, 4, 6, 8, 16, 32} slots.

[0137] A PRS resource ID in a PRS resource set is associated with a single beam (or beam ID) transmitted from a single TRP (where a TRP may transmit one or more beams). That is, each PRS resource of a PRS resource set may be transmitted on a different beam, and as such, a “PRS resource,” or simply “resource,” also can be referred to as a “beam.” Note that this does not have any implications on whether the TRPs and the beams on which PRS are transmitted are known to the UE.

[0138] A “PRS instance” or “PRS occasion” is one instance of a periodically repeated time window (such as a group of one or more consecutive slots) where PRS are expected to be transmitted. A PRS occasion also may be referred to as a “PRS positioning occasion,” a “PRS positioning instance, a “positioning occasion,” “a positioning instance,” a “positioning repetition,” or simply an “occasion,” an “instance,” or a “repetition.”

[0139] A “positioning frequency layer” (also referred to simply as a “frequency layer”) is a collection of one or more PRS resource sets across one or more TRPs that have the same values for certain parameters. Specifically, the collection of PRS resource sets has the same subcarrier spacing and cyclic prefix (CP) type (meaning all numerologies supported for the physical downlink shared channel (PDSCH) are also supported for PRS), the same Point A, the same value of the downlink PRS bandwidth, the same start PRB (and center frequency), and the same comb-size. The Point A parameter takes the value of the parameter “ARFCN-ValueNR” (where “ARFCN” stands for “absolute radio-frequency channel number”) and is an identifier/code that specifies a pair of physical radio channel used for transmission and reception. The downlink PRS bandwidth may have a granularity of four PRBs, with a minimum of 24 PRBs and a maximum of 272 PRBs. Currently, up to four frequency layers have been defined, and up to two PRS resource sets may be configured per TRP per frequency layer.

[0140] The concept of a frequency layer is somewhat like the concept of component carriers and bandwidth parts (BWPs), but different in that component carriers and BWPs are used by one base station (or a macro cell base station and a small cell base station) to transmit data channels, while frequency layers are used by several (usually three or more) base stations to transmit PRS. A UE may indicate the number of frequency layers it can support when it sends the network its positioning capabilities, such as during an LTE positioning protocol (LPP) session. For example, a UE may indicate whether it can support one or four positioning frequency layers.

[0141] Note that the terms “positioning reference signal” and “PRS” generally refer to specific reference signals that are used for positioning in NR and LTE systems. However, as used herein, the terms “positioning reference signal” and “PRS” may also refer to any type of reference signal that can be used for positioning, such as but not limited to, PRS as defined in LTE and NR, TRS, PTRS, CRS, CSI-RS, DMRS, PSS, SSS, SSB, SRS, UL-PRS, etc. In addition, the terms “positioning reference signal” and “PRS” may refer to downlink, uplink, or sidelink positioning reference signals, unless otherwise indicated by the context. If needed to further distinguish the type of PRS, a downlink positioning reference signal may be referred to as a “DL-PRS,” an uplink positioning reference signal (e.g., an SRS-for-positioning, PTRS) may be referred to as an “UL-PRS,” and a sidelink positioning reference signal may be referred to as an “SL-PRS.” In addition, for signals that may be transmitted in the downlink, uplink, and/or sidelink (e.g., DMRS), the signals may be prepended with “DL,” “UL,” or “SL” to distinguish the direction. For example, “UL-DMRS” is different from “DL-DMRS.”

[0142] In an aspect, the reference signal carried on the REs labeled “R” in FIG. **5** may be SRS. SRS transmitted by a UE may be used by a base station to obtain the channel state information (CSI) for the transmitting UE. CSI describes how an RF signal propagates from the UE to the base station and represents the combined effect of scattering, fading, and power decay with distance. The system uses the SRS for resource scheduling, link adaptation, massive MIMO, beam management, etc.

[0143] A collection of REs that are used for transmission of SRS is referred to as an “SRS resource,” and may be identified by the parameter “SRS-ResourceId.” The collection of resource elements can span multiple PRBs in the frequency domain and ‘N’ (e.g., one or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol, an SRS resource occupies one or more consecutive PRBs. An “SRS resource set” is a set of SRS resources used for the transmission of SRS signals, and is identified by an SRS resource set ID (“SRS-ResourceSetId”).

[0144] The transmission of SRS resources within a given PRB has a particular comb size (also referred to as the “comb density”). A comb size ‘N’ represents the subcarrier spacing (or frequency/tone spacing) within each symbol of an SRS resource configuration. Specifically, for a comb size ‘N,’ SRS are transmitted in every Nth subcarrier of a symbol of a PRB. For example, for comb-4, for each symbol of the SRS resource configuration, REs corresponding to every fourth subcarrier (such as subcarriers 0, 4, 8) are used to transmit SRS of the SRS resource. In the example of FIG. **5**, the illustrated SRS is comb-4 over four symbols. That is, the locations of the shaded SRS REs indicate a comb-4 SRS resource configuration.

[0145] Currently, an SRS resource may span 1, 2, 4, 8, or 12 consecutive symbols within a slot with a comb size of comb-2, comb-4, or comb-8. The following are the frequency offsets from symbol to symbol for the SRS comb patterns that are currently supported. 1-symbol comb-2: {0}; 2-symbol comb-2: {0, 1}; 2-symbol comb-4: {0, 2}; 4-symbol comb-2: {0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3} (as in the example of FIG. **5**); 8-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3}; 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 4-symbol comb-8: {0, 4, 2, 6}; 8-symbol comb-8:

{0, 4, 2, 6, 1, 5, 3, 7}; and 12-symbol comb-8: {0, 4, 2, 6, 1, 5, 3, 7, 0, 4, 2, 6}.

[0146] Generally, as noted above, a UE transmits SRS to enable the receiving base station (either the serving base station or a neighboring base station) to measure the channel quality (i.e., CSI) between the UE and the base station. However, SRS can also be specifically configured as uplink positioning reference signals for uplink-based positioning procedures, such as uplink time difference of arrival (UL-TDOA), round-trip-time (RTT), uplink angle-of-arrival (UL-AoA), etc. As used herein, the term “SRS” may refer to SRS configured for channel quality measurements or SRS configured for positioning purposes. The former may be referred to herein as “SRS-for-communication” and/or the latter may be referred to as “SRS-for-positioning” or “positioning SRS” when needed to distinguish the two types of SRS.

[0147] Several enhancements over the previous definition of SRS have been proposed for SRS-for-positioning (also referred to as “UL-PRS”), such as a new staggered pattern within an SRS resource (except for single-symbol/comb-2), a new comb type for SRS, new sequences for SRS, a higher number of SRS resource sets per component carrier, and a higher number of SRS resources per component carrier. In addition, the parameters “SpatialRelationInfo” and “PathLossReference” are to be configured based on a downlink reference signal or SSB from a neighboring TRP. Further still, one SRS resource may be transmitted outside the active BWP, and one SRS resource may span across multiple component carriers. Also, SRS may be configured in RRC connected state and only transmitted within an active BWP. Further, there may be no frequency hopping, no repetition factor, a single antenna port, and new lengths for SRS (e.g., 8 and 12 symbols). There also may be open-loop power control and not closed-loop power control, and comb-8 (i.e., an SRS transmitted every eighth subcarrier in the same symbol) may be used. Lastly, the UE may transmit through the same transmit beam from multiple SRS resources for UL-AoA. All of these are features that are additional to the current SRS framework, which is configured through RRC higher layer signaling (and potentially triggered or activated through a MAC control element (MAC-CE) or downlink control information (DCI)).

[0148] As described above, an NTN is a network or segment of a network using RF resources on board a satellite or unmanned aircraft system (UAS) platform. In accordance with the aspects of the disclosure, one or more of the satellite and/or UAS platforms may be non-terrestrial transmission-reception points (NT-TRPs) that transmit and/or measure PRS that are used in positioning determinations. Examples of NTN environments providing access to one or more UEs are depicted in FIG. **6** and FIG. **7**.

[0149] FIG. **6** depicts an example NTN environment **600** that may be used with transparent payloads and in NTN positioning operations, according to aspects of the disclosure. In the case of transparent payloads, the NT-TRP **602** performs RF filtering, frequency conversion, and amplification on the waveform signal received from a gateway **604** over a feeder link **606**. As such, the original waveform signal received from the gateway **604** is repeated by the NT-TRP **602** and transmitted to one or more UEs **608** over one or more service links **610**. Additionally, or in the alternative, the NT-TRP **602** may be configured to transmit DL-PRS on one or more DL-PRS resources and/or receive UL-PRS (e.g., SRS) on one or more UL-PRS resources pursuant to engaging in positioning determinations with the UEs **608**. In certain aspects, the UEs **608** may be configured for positioning determinations through communications with the NT-TRP **602** over the service link **610**, communications with one or more terrestrial network entities (e.g., base station, location server, UE, etc.), or any combination thereof.

[0150] As shown in FIG. **6**, the NT-TRP **602** generates one or more beams over a given service area bounded by the field of view **612** of the NT-TRP **602**. In certain aspects, beams are used to transmit DL-PRS from the NT-TRP **602** to the UEs **608** or receive UL-PRS transmitted by the UEs **608**. Each of the beams has a beam footprint **614**, which typically has a corresponding elliptic shape. In certain aspects, the field of view **612** depends on the design of the onboard antenna of the NT-TRP **602** and the minimum elevation angle of the NT-TRP **602** (e.g., the minimum angle under which

the NT-TRP **602** can be seen by a UE).
[0151] FIG. **7** depicts an example NTN environment **700** that may be used with regenerative payloads and in NTN positioning operations, according to aspects of the disclosure. In the case of regenerative payloads, the NT-TRP **702** performs RF filtering, frequency conversion, and amplification, as well as demodulation/decoding, switch and/or routing, and coding/modulation on payloads that it receives before sending the payloads to one or more UEs **704** over one or more service links **706**. In certain aspects, the NT-TRP **702** communicates directly with a gateway **722** over a feeder link **708**. Additionally, or in the alternative, the NT-TRP **702** communicates with another satellite or UAS platform **710** over an inter-satellite link (ISL) **712**. In certain aspects, the satellite or UAS platform **710** may communicate directly with the gateway **722** over a further feeder link **714**.
[0152] Additionally, or in the alternative, the NT-TRP **702** may be configured to transmit DL-PRS on one or more DL-PRS resources and/or receive UL-PRS (e.g., SRS) on one or more UL-PRS resources pursuant to engaging in positioning determinations with the UEs **704**. In certain aspects, the UEs **704** may be configured for positioning determinations through communications with the NT-TRP **702** over the service link **706**, communications with one or more terrestrial network entities (e.g., base station, location server, UE, etc.), or any combination thereof.
[0153] As shown in FIG. **7**, the NT-TRP **702** generates one or more beams over a given service area bounded by the field of view **716** of the NT-TRP **702**. The beams may be used to transmit DL-PRS from the NT-TRP **702** to the UEs **704** or receive UL-PRS transmitted by the UEs **10704**. Each of the beams has a beam footprint **718**, which typically has a corresponding elliptic shape. In certain aspects, the field of view **716** depends on the design of the onboard antenna of the NT-TRP **702** and the minimum elevation angle of the NT-TRP **702** (e.g., the minimum angle under which the NT-TRP **702** can be seen by a UE).
[0154] In the example NTN environments, the beam footprints may move over the earth as the corresponding NT-TRP moves over the earth (e.g., as the corresponding NT-TRP orbits the earth). Alternatively, the beam footprints may be stationary in a service area that is located at a fixed position on the earth. In the latter instance, the NT-TRP may implement beam pointing mechanisms (e.g., mechanical or electronic steering features) to compensate for the motion of the NT-TRP.
[0155] FIG. **8** is a table 800 showing examples of satellite platforms that may be used as NT-TRPs, according to aspects of the disclosure. Table 800 provides the name of each platform, the altitude range associated with each platform, the orbit associated with each platform, and the typical beam footprint size for each platform.
[0156] NTN positioning methods may be used alone or in conjunction with other positioning, methods to determine the position of a UE. In certain instances, NTN positioning methods may be used to verify positioning determinations that are made using other positioning methods. In this regard, a network operator may find it necessary to cross-check the location reported by the UE in order to fulfill the regulatory requirements (e.g., lawful intercept, emergency call, Public Warning System, etc.). In such instances, the location reported by the UE using one positioning method may be cross-checked with the location of the UE as determined using an NTN positioning method.
[0157] FIG. **9** depicts an example scenario **900** in which positioning determinations based on a Global Navigation Satellite System (GNSS) positioning method are cross-checked with positioning determinations based on an NTN positioning method, according to aspects of the disclosure. In this example, a network entity **902** engages in positioning operations with a UE **904** to determine the position of the UE **904**. To this end, the UE **904** engages in a GNSS positioning method and reports the location of the UE **904** based on the GNSS positioning method to the network entity **902** in a GNSS report **906**. A further determination of the position of the UE **904** is made based on an exchange of NTN positioning information associated with the execution of an NTN positioning method. The network entity **902** may refine and/or verify the location of the UE **904** as reported in the GNSS report **906** using the results of the NTN positioning operations. It is assumed that the UE

904 has both GNSS location and NTN positioning capabilities to execute the positioning operations shown in FIG. **9**.

[0158] An entity engaging in positioning operations in which the entity measures a PRS is typically configured with a time-based search window indicating the time during which the entity can expect to receive the PRS from a reference TRP or neighbor TRP. During a positioning session in which a UE is designated as a target device to measure the PRS, the UE is configured by a location server (e.g., LMF) with the time-based search window during which the UE searches for the PRS. The time-based search window configuration may be sent to the UE as positioning assistance data (AD) in an LPP message.

[0159] FIG. **10** depicts an example of a time-based PRS search window, according to aspects of the disclosure. In this example, the target device may assume that the beginning of the subframe for the PRS of the TRP is received within a time-based search window spanning from -(nr-DL-PRS-ExpectedRSTD)-Uncertainty×R) to +(nr-DL-PRS-ExpectedRSTD)-Uncertainty×R) centered at an expected RSTD time corresponding to ((T_REF+N milliseconds)+(nr-DL-PRS-ExpectedRSTD)×4 Ts, where T_REF is the reception time of the beginning of the subframe for the PRS of the assistance data reference TRP at the target device antenna connector, and N can be calculated based on information in an nr-DL-PRS-SFNO-Offset information element (IE), a dl-PRS-Periodicity-and-ResourceSetSlotOffset IE, and a dl-PRS-ResourceSlotOffset IE. The value of resolution R is equal to Ts if all PRS resources are in FR2. Otherwise, resolution R is equal to 4 Ts, with Ts=1/(15000*2048) seconds.

[0160] FIG. **11** shows an example procedure **1100** for exchanging information between a base station **1102** (e.g., an NG-RAN node) and a location server **1104** (e.g., an LMF) in a UL-PRS (e.g., SRS) positioning procedure, according to aspects of the disclosure. In this example, the location server **1104** initiates the procedure by sending a Measurement Request Message **1106** to the base station **1102**, indicating the TRPs for which PRS measurements are requested in a TRP Measurement Request List IE. The base station **1102** uses the information included in the Measurement Request Message to configure PRS resource measurements for the indicated TRPs. If at least one of the requested measurements has been successfully measured by the base station **1102** for at least one of the TRPs, the base station **1102** replies with a Measurement Response Message **1108**, including PRS measurements of the successfully measured TRPs in a TRP Measurement Response List IE.

[0161] The SRS may be used in the uplink positioning determinations. To this end, the SRS is designed to cover the full bandwidth of resource elements spread across different symbols so as to cover all subcarriers. Similar to the PRS, the SRS is also designed with a comb-based pattern. As such, UEs can be multiplexed over the same transmitted symbol by assigning different comb patterns.

[0162] The exchange of SRS configuration parameters between the base station **1102** and location server **1104** is conducted using the NR positioning protocol A (NRPPa). The configuration information includes parameters that are used by the base station **1102** to set time-based search windows during which the base station **1102** can expect to receive SRS from UEs indicated in the TRP Measurement Request List IE. FIG. **12** shows an example of the IEs used to determine the parameters of such time-based search windows, according to aspects of the disclosure.

[0163] An issue that arises with using NT-TRPs for positioning is that there is a significant Doppler shift (and thus frequency offset) in the signals transmitted by the NT-TRPs, particularly when the NT-TRPS are satellites that orbit the earth. Table 1 provides a summary of Doppler shifts and shift variations for different altitudes of such satellites.

TABLE-US-00001 TABLE 1 Max. Doppler Frequency Relative Shift (GHz) Max. Doppler Doppler Variation 2 +/−48 kHz 0.0024% −544 Hz/s Low-Earth 20 +/−480 kHz 0.0024% −5.44 kHz/s orbit (LEO) at 30 +/−720 kHz 0.0024% −8.16 kHz/s 600 kilometers (km) altitude 2 +/−40 kHz 0.002% −180 Hz/s LEO at 1,500 20 +/−400 kHz 0.002% −1.8 kHz/s km altitude 30 +/−600 kHz 0.002% −2.7 kHz/s 2 +/−15 kHz 0.00075% −6 Hz/s Medium Earth 20 +/−150 kHz 0.00075% −60 Hz/s orbit (MEO) at 30 +/−225 kHz 0.00075% −90 Hz/s 10,000 km altitude

[0164] FIG. **13** is a diagram **1300** illustrating system geometry for Doppler shift computation for a non-geostationary satellite system, according to aspects of the disclosure. The scenario illustrated in FIG. **13** assumes a Cartesian coordinate system such that the moving satellite and the receiver (e.g., a UE, terrestrial base station) are on the y-z plane. The Doppler shift experienced by a stationary receiver can be computed as a function of time as follows:

[00001] $f_d(t) = \frac{f_0}{c} \frac{d(t)}{.Math.\ d(t)\ .Math.} \frac{\partial x_{SAT} t()}{\partial t}$

where f.sub.0 is the carrier frequency, d(t) is the distance vector between the satellite and the receiver, and x.sub.SAT(t) is the vector of the satellite position. These vectors can be expressed as:

[00002]
$$d(t) = [0 (R_E + h)\sin(\ _{SAT} t)\ (R_E + h)\cos(\ _{SAT} t) - R_E]^T$$
$$x_{SAT}(t) = [0 (R_E + h)\sin(\ _{SAT} t)\ (R_E + h)\cos(\ _{SAT} t)]^T$$

where R.sub.E is the Earth radius, h is the satellite altitude, and ω.sub.SATt is the satellite angular velocity.

[0165] After some mathematical manipulation, the Doppler shift as a function of the elevation angle can be computed in a closed-form expression as follows:

[00003] $f_d(t) = \frac{f_0}{c}\ _{SAT} R_E \cos[\ (t)]$

where the angular velocity is

[00004] $\ _{SAT} = \sqrt{\frac{GM_E}{(R_E + h)^3}},$

with G the gravitational constant and ME the Earth's mass.

[0166] If the receiver (e.g., a UE) is placed on board an aircraft or a high-speed train, there will be an additional term of Doppler shift resulting from its own velocity. In the case of non-geostationary satellites, the Doppler shift due to satellite movement is much higher than the Doppler shift caused by the receiver's movement. For geostationary earth orbiting (GEO) satellites and high-altitude platform station (HAPS), however, the Doppler shift component is mainly caused by the receiver's movement.

[0167] FIG. **14** is a graph **1400** illustrating an example Doppler shift scenario with a two GHz signal at 600 km on the downlink and uplink, according to aspects of the disclosure. Graph **1400** illustrates plots for both a fixed UE and UEs in motion (both moving in the same direction as the satellite and in the opposite direction as the satellite).

[0168] FIG. **15** is a graph **1500** illustrating an example Doppler shift scenario with a two GHz signal at 1500 km on the downlink and uplink, according to aspects of the disclosure. Graph **1500** illustrates plots for both a fixed UE and UEs in motion (both moving in the same direction as the satellite and in the opposite direction as the satellite).

[0169] Graphs **1400** and **1500** illustrate the worst-case impact for a UE moving at 1000 km/h and moving in the same direction as the satellite (which is a non-geostationary satellite). The bounds of the graphs can be defined by adding the Doppler shift due to the satellite motion and the Doppler shift due to the UE motion. Graphs **1400** and **1500** clearly show the boundaries of the Doppler shift depending on the sense of motion between the satellite and the UE.

[0170] The times of arrival of the PRS (e.g., DL-PRS, UL-PRS, SRS) are determined at the receiving entity through a time correlation of the received PRS with a locally generated copy of the PRS. FIG. **16** shows examples of such auto-correlation responses for PRS received under different Doppler shift conditions. Graph **1602** shows that a clearly defined time-correlation peak **1604** may be obtained under zero Doppler conditions. However, as shown in graph **1606**, peak detection of the same PRS becomes ambiguous under high Doppler shift conditions because of the appearance of sidelobes **1608** and **1610**. Such ambiguities are particularly problematic under the high Doppler shift conditions associated with NT-TRPs used in NTN positioning.

[0171] To address the ambiguities that occur with PRS detection under such high Doppler shift conditions, certain aspects of the disclosure are directed to the use of a frequency domain search window for PRS detection. A network entity may limit its PRS detection to PRS occurring in the frequency range determined from the frequency domain search window. As such, peaks of the PRS received under high Doppler shift conditions may be detected without the corresponding peak detection ambiguities typically associated with such high Doppler shift conditions. According to aspects of the disclosure, the frequency domain search window may be used with a time-based search window to provide a two-dimensional search window for PRS detection.

[0172] Certain aspects of the disclosure are directed to wireless communication performed by a network entity in which a frequency domain search window is determined for at least one PRS resource associated with at least one NT-TRP for use during an NTN positioning session. In certain aspects, the frequency domain search window corresponds to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty. In certain aspects, the values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are provided to the network entity in positioning AD from a location server (e.g., LMF). In certain aspects, the values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are determined by the network entity based on ephemeris information associated with the NT-TRP. The ephemeris information may be pre-programmed in the network entity, received from another network entity (e.g., UE, location server, NT-TRP, etc.), or any combination thereof. In an aspect, the PRS resource is measured in the frequency domain search window during the positioning session.

[0173] In accordance with certain aspects of the disclosure, the PRS may be re-sampled based on the expected Doppler frequency shift offset. Multiple hypotheses for detecting the peak of the at least one PRS within the frequency domain search window may be constructed based on the re-sampling of the at least one PRS.

[0174] Different frequency ranges and resolutions for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty may be used depending on the orbit of the NT-TRP. In accordance with certain aspects of the disclosure, the NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geo-stationary earth orbit (GEO). The expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on the orbit of the earth-orbiting satellite. In certain aspects, the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on 1) an altitude of the at least one NT-TRP, 2) a frequency of the PRS resource, or 3) any combination thereof.

[0175] Other types of vehicles may be used for the NT-TRP. In certain aspects, the NT-TRP may be an unmanned aerial vehicle, a manned aerial vehicle, or a lighter than air vehicle.

[0176] The expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty can be specified using various measurement units. In certain aspects, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty can be specified as absolute frequency values. Additionally, or in the alternative, the measurement units may be specified as parts per million (ppm). When specified as ppm, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty can be signaled for each NT-TRP that is to be measured. From the perspective of a UE, the UE may read the ppm units value indicated in the DL-PRS assistance data and use the value to compute a band-specific search window in units of frequency (e.g., hertz (Hz), kilohertz (kHz), megahertz (MHz), gigahertz (GHz), etc.). From the perspective of a base station (e.g., NG-RAN), the base station may read the ppm units value indicated in the SRS measurement request and compute the band-specific search window in units of frequency. In an aspect, the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a part-per-million (PPM) value with respect to the expected

Doppler frequency shift offset.
[0177] Additionally, or in the alternative, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty can be specified as directional units indicating the position of the NT-TRP relative to the network entity (e.g., azimuth and elevation angles with respect to the coordinate system local to the NT-TRP). In an aspect, a reference direction may be specified as the direction of the center of a beam serving the network entity with respect to the NT-TRP and a standard deviation (or uncertainty) of directions. The network entity can determine the expected Doppler frequency shift offset from the reference direction and ephemeris information associated with the NT-TRP. Further, the network can determine the expected Doppler frequency shift offset uncertainty from the direction uncertainty.
[0178] The expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty may be used to form various configurations of the frequency domain search window. FIG. **17** depicts examples of configurations for frequency domain search windows using the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty, according to aspects of the disclosure. In configuration **1702**, the frequency domain search window **1704** is a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty **1706** around the expected Doppler frequency shift offset **1708**. In configuration **1710**, the frequency domain search window **1712** is an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty **1706** around the expected Doppler frequency shift offset **1708**, where the lower edge of the frequency domain search window **1712** is offset from the expected frequency shift offset **1708** by an amount Δf. Similarly, in configuration **1714**, the frequency domain search window **1716** is an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty **1706** around the expected Doppler frequency shift offset **1708**, where the upper edge of the frequency domain search window **1716** is offset from the expected frequency shift offset **1708** by an amount Δf. In configuration **1718**, the lower edge of the frequency domain search window **1720** is adjacent to and includes the expected Doppler frequency shift offset **1708**. In configuration **1722**, the upper edge of the frequency domain search window **1724** is adjacent to and includes the expected Doppler frequency shift offset **1708**.
[0179] Certain aspects of the disclosure consider secondary aspects of the Doppler shift conditions. Such secondary aspects include how the Doppler shift conditions change over time. For example, the expected Doppler frequency offset value may drift over the duration of the positioning session. In certain aspects, the expected Doppler frequency offset drift and/or the expected Doppler frequency offset drift rate is determined from indications in the positioning AD (e.g., in the case of a UE) or measurement request message (e.g., in the case of a base station). In certain aspects, the expected Doppler frequency shift drift and the expected Doppler frequency shift drift rate may be used as parameters to dynamically shift the position of the frequency domain search window in the frequency domain during the positioning session and/or to determine new values for the expected Doppler frequency shift during subsequent positioning sessions.
[0180] In certain aspects, the network entity may determine a validity duration corresponding to a duration of time during which the frequency domain search window is valid. The validity duration may correspond to the maximum time up to which the network entity can propagate the expected Doppler frequency shift offset without significant deviation from the current value of the expected Doppler frequency shift offset. The validity duration may be 1) indicated in positioning AD received by the network entity, 2) determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or 3) any combination thereof. In certain aspects, the network entity 1) sends a request for new positioning AD based on an expiration of the validity duration, 2) sends an error message indicating a positioning error cause corresponding to the expiration of the validity duration, or 3) any combination thereof. In certain aspects, the request for new positioning AD may include a request for new values for the expected Doppler frequency offset and/or the expected Doppler frequency offset uncertainty. In certain aspects, the positioning

error cause may be indicated by an ExpectedFrequencyOffsetValidityExpired parameter in a TargetDeviceErrorCauses IE.

[0181] FIG. **18** illustrates an example method **1800** of wireless communication performed by a network entity, according to aspects of the disclosure. At operation **1802**, the network entity determines a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session. In an aspect, operation **1802** may be performed by the one or more WWAN transceivers **310**, the one or more processors **332**, memory **340**, and/or positioning component **342**, any or all of which may be considered means for performing this operation. In an aspect, operation **1802** may be performed by the one or more WWAN transceivers **350**, the one or more processors **384**, memory **386**, and/or positioning component **388**, any or all of which may be considered means for performing this operation.

[0182] At operation **1804**, the network entity measures the at least one PRS resource in the frequency domain search window during the positioning session. In an aspect, operation **1804** may be performed by the one or more WWAN transceivers **310**, the one or more processors **332**, memory **340**, and/or positioning component **342**, any or all of which may be considered means for performing this operation.

[0183] As will be appreciated, a technical advantage of the method **1800** is the addition of a frequency domain search window to conduct NTN positioning operations in high Doppler frequency shift conditions. By using the frequency domain search window, the ambiguities associated with detecting the peak of PRS received under such conditions are minimized, thereby improving the accuracy of the NTN positioning determinations.

[0184] FIG. **19** illustrates an example method **1900** of wireless communication performed by a first network entity, according to aspects of the disclosure. At operation **1902**, the first network entity sends information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session. In an aspect, operation **1902** may be performed by the one or more WWAN transceivers **310**, the one or more processors **332**, memory **340**, and/or positioning component **342**, any or all of which may be considered means for performing this operation. In an aspect, operation **1902** may be performed by the one or more WWAN transceivers **350**, the one or more processors **384**, memory **386**, and/or positioning component **388**, any or all of which may be considered means for performing this operation. In an aspect, operation **1902** may be performed by the one or more network transceivers **390**, the one or more processors **394**, memory **396**, and/or positioning component **398**, any or all of which may be considered means for performing this operation.

[0185] At operation **1904**, the first network entity receives a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity. In an aspect, operation **1904** may be performed by the one or more WWAN transceivers **310**, the one or more processors **332**, memory **340**, and/or positioning component **342**, any or all of which may be considered means for performing this operation. In an aspect, operation **1904** may be performed by the one or more WWAN transceivers **350**, the one or more processors **384**, memory **386**, and/or positioning component **388**, any or all of which may be considered means for performing this operation. In an aspect, operation **1904** may be performed by the one or more network transceivers **390**, the one or more processors **394**, memory **396**, and/or positioning component **398**, any or all of which may be considered means for performing this operation.

[0186] As will be appreciated, a technical advantage of the method **1900** is the addition of a frequency domain search window to conduct NTN positioning operations in high Doppler frequency shift conditions. By using the frequency domain search window, the ambiguities associated with detecting the peak of PRS received under such conditions are minimized, thereby improving the accuracy of the NTN positioning determinations.

[0187] 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.

[0188] Implementation examples are described in the following numbered clauses:

[0189] Clause 1. A method of wireless communication performed by a network entity, comprising: determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measuring the at least one PRS resource in the frequency domain search window during the positioning session.

[0190] Clause 2. The method of clause 1, further comprising: re-sampling the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.

[0191] Clause 3. The method of clause 2, further comprising: constructing multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at least one PRS resource.

[0192] Clause 4. The method of any of clauses 1 to 3, further comprising: transmitting a measurement report including information corresponding to one or more measurements made of the at least one PRS resource.

[0193] Clause 5. The method of any of clauses 1 to 4, wherein the frequency domain search window is determined as: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0194] Clause 6. The method of any of clauses 1 to 5, wherein determining the frequency domain search window comprises: receiving positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; receiving ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift

offset uncertainty; or any combination thereof.
[0195] Clause 7. The method of clause 6, wherein the ephemeris information associated with the at least one NT-TRP is received, and the method further comprises: receiving directional information for the at least one NT-TRP; and determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.
[0196] Clause 8. The method of any of clauses 6 to 7, wherein: the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.
[0197] Clause 9. The method of any of clauses 1 to 8, further comprising: determining an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; determining an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.
[0198] Clause 10. The method of clause 9, wherein: the expected Doppler frequency offset drift is determined from indications in positioning AD; the expected Doppler frequency offset drift rate is determined from indications in the positioning AD; or any combination thereof.
[0199] Clause 11. The method of any of clauses 1 to 10, further comprising: determining a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.
[0200] Clause 12. The method of clause 11, further comprising: sending a request for new positioning AD based on an expiration of the validity duration; sending an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.
[0201] Clause 13. The method of any of clauses 1 to 12, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.
[0202] Clause 14. The method of any of clauses 1 to 12, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.
[0203] Clause 15. The method of any of clauses 1 to 14, wherein: the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.
[0204] Clause 16. The method of any of clauses 1 to 15, further comprising: receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.
[0205] Clause 17. The method of any of clauses 1 to 16, further comprising: measuring one or more signals of a global navigation satellite system (GNSS), wherein the measuring of the at least one PRS resource in the frequency domain search window is proximate in time to the measuring of the one or more signals of the GNSS; and reporting measurement data associated with the measurements of the one or more signals of the GNSS and the measurements of the at least one PRS resource.
[0206] Clause 18. The method of any of clauses 1 to 17, wherein: the network entity is a base station; determining the frequency domain search window comprises receiving positioning AD

indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; and the at least one PRS resource is an uplink PRS (UL-PRS) resource.

[0207] Clause 19. A method of wireless communication performed by a first network entity, comprising: sending information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receiving a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.

[0208] Clause 20. The method of clause 19, wherein the frequency domain search window is based on: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0209] Clause 21. The method of any of clauses 19 to 20, wherein sending the information to the second network entity comprises: sending positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; sending ephemeris information associated with the at least one NT-TRP for determining, by the second network entity, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; sending directional information associated with the at least one NT-TRP for determining, by the second network entity, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

[0210] Clause 22. The method of clause 21, wherein: the positioning AD sent to the second network entity indicates the expected Doppler frequency shift offset uncertainty as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0211] Clause 23. The method of any of clauses 19 to 22, wherein sending the information to the second network entity comprises: sending positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0212] Clause 24. The method of any of clauses 19 to 23, wherein sending the information to the second network entity further comprises: sending positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.

[0213] Clause 25. The method of clause 24, further comprising: receiving a request for new positioning AD based on an expiration of the validity duration; receiving an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0214] Clause 26. The method of any of clauses 19 to 25, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0215] Clause 27. The method of any of clauses 19 to 25, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0216] Clause 28. The method of any of clauses 19 to 27, wherein the expected Doppler frequency shift offset is based on: an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0217] Clause 29. The method of any of clauses 19 to 28, further comprising: receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0218] Clause 30. A network entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measure the at least one PRS resource in the frequency domain search window during the positioning session.

[0219] Clause 31. The network entity of clause 30, wherein the at least one processor is further configured to: re-sample the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.

[0220] Clause 32. The network entity of clause 31, wherein the at least one processor is further configured to: construct multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at least one PRS resource.

[0221] Clause 33. The network entity of any of clauses 30 to 32, wherein the at least one processor is further configured to: transmit, via the at least one transceiver, a measurement report including information corresponding to one or more measurements made of the at least one PRS resource.

[0222] Clause 34. The network entity of any of clauses 30 to 33, wherein the frequency domain search window is determined as: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0223] Clause 35. The network entity of any of clauses 30 to 34, wherein the at least one processor configured to determine the frequency domain search window comprises the at least one processor configured to: receive, via the at least one transceiver, positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; receive, via the at least one transceiver, ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

[0224] Clause 36. The network entity of clause 35, wherein the ephemeris information associated with the at least one NT-TRP is received, and the at least one processor is further configured to: receive, via the at least one transceiver, directional information for the at least one NT-TRP; and determine the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.

[0225] Clause 37. The network entity of any of clauses 35 to 36, wherein: the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0226] Clause 38. The network entity of any of clauses 30 to 37, wherein the at least one processor is further configured to: determine an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; determine an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0227] Clause 39. The network entity of clause 38, wherein: the expected Doppler frequency offset drift is determined from indications in positioning AD; the expected Doppler frequency offset drift rate is determined from indications in the positioning AD; or any combination thereof.

[0228] Clause 40. The network entity of any of clauses 30 to 39, wherein the at least one processor is further configured to: determine a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.

[0229] Clause 41. The network entity of clause 40, wherein the at least one processor is further configured to: send, via the at least one transceiver, a request for new positioning AD based on an expiration of the validity duration; send, via the at least one transceiver, an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0230] Clause 42. The network entity of any of clauses 30 to 41, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0231] Clause 43. The network entity of any of clauses 30 to 41, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0232] Clause 44. The network entity of any of clauses 30 to 43, wherein: the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0233] Clause 45. The network entity of any of clauses 30 to 44, wherein the at least one processor is further configured to: receive, via the at least one transceiver, positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0234] Clause 46. The network entity of any of clauses 30 to 45, wherein the at least one processor is further configured to: measure one or more signals of a global navigation satellite system (GNSS), wherein the measuring of the at least one PRS resource in the frequency domain search window is proximate in time to the measuring of the one or more signals of the GNSS; and report, via the at least one transceiver, measurement data associated with the measurements of the one or more signals of the GNSS and the measurements of the at least one PRS resource.

[0235] Clause 47. The network entity of any of clauses 30 to 46, wherein: the network entity is a base station; determining the frequency domain search window comprises receiving positioning AD indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; and the at least one PRS resource is an uplink PRS (UL-PRS) resource.

[0236] Clause 48. A first network entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: send, via the at least one transceiver, information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receive, via the at least one transceiver, a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.

[0237] Clause 49. The first network entity of clause 48, wherein the frequency domain search window is based on: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0238] Clause 50. The first network entity of any of clauses 48 to 49, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send, via the at least one transceiver, positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send, via the at least one transceiver, ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send, via the at least one transceiver, directional information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

[0239] Clause 51. The first network entity of clause 50, wherein: the positioning AD sent to the second network entity indicates the expected Doppler frequency shift offset uncertainty as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0240] Clause 52. The first network entity of any of clauses 48 to 51, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0241] Clause 53. The first network entity of any of clauses 48 to 52, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send, via the at least one transceiver, positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.

[0242] Clause 54. The first network entity of clause 53, wherein the at least one processor is further configured to: receive, via the at least one transceiver, a request for new positioning AD based on an expiration of the validity duration; receive, via the at least one transceiver, an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0243] Clause 55. The first network entity of any of clauses 48 to 54, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0244] Clause 56. The first network entity of any of clauses 48 to 54, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0245] Clause 57. The first network entity of any of clauses 48 to 56, wherein the expected Doppler frequency shift offset is based on: an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0246] Clause 58. The first network entity of any of clauses 48 to 57, wherein the at least one processor is further configured to: receive, via the at least one transceiver, positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0247] Clause 59. A network entity, comprising: means for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and means for measuring the at least one PRS resource in the frequency domain search window during the positioning session.

[0248] Clause 60. The network entity of clause 59, further comprising: means for re-sampling the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.

[0249] Clause 61. The network entity of clause 60, further comprising: means for constructing multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at least one PRS resource.

[0250] Clause 62. The network entity of any of clauses 59 to 61, further comprising: means for transmitting a measurement report including information corresponding to one or more measurements made of the at least one PRS resource.

[0251] Clause 63. The network entity of any of clauses 59 to 62, wherein the frequency domain search window is determined as: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0252] Clause 64. The network entity of any of clauses 59 to 63, wherein the means for determining the frequency domain search window comprises: means for receiving positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; means for receiving ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

[0253] Clause 65. The network entity of clause 64, wherein the ephemeris information associated with the at least one NT-TRP is received, and the network entity further comprises: means for receiving directional information for the at least one NT-TRP; and means for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.

[0254] Clause 66. The network entity of any of clauses 64 to 65, wherein: the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0255] Clause 67. The network entity of any of clauses 59 to 66, further comprising: means for determining an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; means for determining an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0256] Clause 68. The network entity of clause 67, wherein: the expected Doppler frequency offset drift is determined from indications in positioning AD; the expected Doppler frequency offset drift rate is determined from indications in the positioning AD; or any combination thereof.

[0257] Clause 69. The network entity of any of clauses 59 to 68, further comprising: means for determining a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.

[0258] Clause 70. The network entity of clause 69, further comprising: means for sending a request for new positioning AD based on an expiration of the validity duration; means for sending an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0259] Clause 71. The network entity of any of clauses 59 to 70, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0260] Clause 72. The network entity of any of clauses 59 to 70, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0261] Clause 73. The network entity of any of clauses 59 to 72, wherein: the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0262] Clause 74. The network entity of any of clauses 59 to 73, further comprising: means for receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0263] Clause 75. The network entity of any of clauses 59 to 74, further comprising: means for measuring one or more signals of a global navigation satellite system (GNSS), wherein the measuring of the at least one PRS resource in the frequency domain search window is proximate in time to the measuring of the one or more signals of the GNSS; and means for reporting measurement data associated with the measurements of the one or more signals of the GNSS and the measurements of the at least one PRS resource.

[0264] Clause 76. The network entity of any of clauses 59 to 75, wherein: the network entity is a base station; determining the frequency domain search window comprises receiving positioning AD indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; and the at least one PRS resource is an uplink PRS (UL-PRS) resource.

[0265] Clause 77. A first network entity, comprising: means for sending information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial

transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and means for receiving a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.
[0266] Clause 78. The first network entity of clause 77, wherein the frequency domain search window is based on: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.
[0267] Clause 79. The first network entity of any of clauses 77 to 78, wherein the means for sending the information to the second network entity comprises: means for sending positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; means for sending ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; means for sending directional information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.
[0268] Clause 80. The first network entity of clause 79, wherein: the positioning AD sent to the second network entity indicates the expected Doppler frequency shift offset uncertainty as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.
[0269] Clause 81. The first network entity of any of clauses 77 to 80, wherein the means for sending the information to the second network entity comprises: means for sending positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; means for sending an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.
[0270] Clause 82. The first network entity of any of clauses 77 to 81, wherein the means for sending the information to the second network entity further comprises: means for sending positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.
[0271] Clause 83. The first network entity of clause 82, further comprising: means for receiving a request for new positioning AD based on an expiration of the validity duration; means for receiving an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.
[0272] Clause 84. The first network entity of any of clauses 77 to 83, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.
[0273] Clause 85. The first network entity of any of clauses 77 to 83, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.
[0274] Clause 86. The first network entity of any of clauses 77 to 85, wherein the expected Doppler frequency shift offset is based on: an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0275] Clause 87. The first network entity of any of clauses 77 to 86, further comprising: means for receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.
[0276] Clause 88. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a network entity, cause the network entity to: determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measure the at least one PRS resource in the frequency domain search window during the positioning session.
[0277] Clause 89. The non-transitory computer-readable medium of clause 88, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: re-sample the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.
[0278] Clause 90. The non-transitory computer-readable medium of clause 89, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: construct multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at least one PRS resource.
[0279] Clause 91. The non-transitory computer-readable medium of any of clauses 88 to 90, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: transmit a measurement report including information corresponding to one or more measurements made of the at least one PRS resource.
[0280] Clause 92. The non-transitory computer-readable medium of any of clauses 88 to 91, wherein the frequency domain search window is determined as: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.
[0281] Clause 93. The non-transitory computer-readable medium of any of clauses 88 to 92, wherein the computer-executable instructions that, when executed by the network entity, cause the network entity to determine the frequency domain search window comprise computer-executable instructions that, when executed by the network entity, cause the network entity to: receive positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; receive ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.
[0282] Clause 94. The non-transitory computer-readable medium of clause 93, wherein the ephemeris information associated with the at least one NT-TRP is received, and the computer-executable instructions further comprise computer-executable instructions that, when executed by the network entity, cause the network entity to: receive directional information for the at least one NT-TRP; and determine the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.
[0283] Clause 95. The non-transitory computer-readable medium of any of clauses 93 to 94, wherein: the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0284] Clause 96. The non-transitory computer-readable medium of any of clauses 88 to 95, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: determine an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; determine an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0285] Clause 97. The non-transitory computer-readable medium of clause 96, wherein: the expected Doppler frequency offset drift is determined from indications in positioning AD; the expected Doppler frequency offset drift rate is determined from indications in the positioning AD; or any combination thereof.

[0286] Clause 98. The non-transitory computer-readable medium of any of clauses 88 to 97, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: determine a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.

[0287] Clause 99. The non-transitory computer-readable medium of clause 98, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: send a request for new positioning AD based on an expiration of the validity duration; send an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0288] Clause 100. The non-transitory computer-readable medium of any of clauses 88 to 99, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0289] Clause 101. The non-transitory computer-readable medium of any of clauses 88 to 99, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0290] Clause 102. The non-transitory computer-readable medium of any of clauses 88 to 101, wherein: the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0291] Clause 103. The non-transitory computer-readable medium of any of clauses 88 to 102, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: receive positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0292] Clause 104. The non-transitory computer-readable medium of any of clauses 88 to 103, further comprising computer-executable instructions that, when executed by the network entity, cause the network entity to: measure one or more signals of a global navigation satellite system (GNSS), wherein the measuring of the at least one PRS resource in the frequency domain search window is proximate in time to the measuring of the one or more signals of the GNSS; and report measurement data associated with the measurements of the one or more signals of the GNSS and the measurements of the at least one PRS resource.

[0293] Clause 105. The non-transitory computer-readable medium of any of clauses 88 to 104, wherein: the network entity is a base station; determining the frequency domain search window comprises receiving positioning AD indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; and the at least one PRS resource is an uplink PRS (UL-PRS) resource.

[0294] Clause 106. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a first network entity, cause the first network entity to: send information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receive a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.

[0295] Clause 107. The non-transitory computer-readable medium of clause 106, wherein the frequency domain search window is based on: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

[0296] Clause 108. The non-transitory computer-readable medium of any of clauses 106 to 107, wherein the computer-executable instructions that, when executed by the first network entity, cause the first network entity to send the information to the second network entity comprise computer-executable instructions that, when executed by the first network entity, cause the first network entity to: send positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send directional information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

[0297] Clause 109. The non-transitory computer-readable medium of clause 108, wherein: the positioning AD sent to the second network entity indicates the expected Doppler frequency shift offset uncertainty as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

[0298] Clause 110. The non-transitory computer-readable medium of any of clauses 106 to 109, wherein the computer-executable instructions that, when executed by the first network entity, cause the first network entity to send the information to the second network entity comprise computer-executable instructions that, when executed by the first network entity, cause the first network entity to: send positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

[0299] Clause 111. The non-transitory computer-readable medium of any of clauses 106 to 110, wherein the computer-executable instructions that, when executed by the first network entity, cause the first network entity to send the information to the second network entity comprise computer-executable instructions that, when executed by the first network entity, cause the first network entity to: send positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.

[0300] Clause 112. The non-transitory computer-readable medium of clause 111, further comprising computer-executable instructions that, when executed by the first network entity, cause the first network entity to: receive a request for new positioning AD based on an expiration of the validity duration; receive an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

[0301] Clause 113. The non-transitory computer-readable medium of any of clauses 106 to 112, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

[0302] Clause 114. The non-transitory computer-readable medium of any of clauses 106 to 112, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

[0303] Clause 115. The non-transitory computer-readable medium of any of clauses 106 to 114, wherein the expected Doppler frequency shift offset is based on: an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.

[0304] Clause 116. The non-transitory computer-readable medium of any of clauses 106 to 115, further comprising computer-executable instructions that, when executed by the first network entity, cause the first network entity to: receive positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.

[0305] 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.

[0306] 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.

[0307] The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an ASIC, a field-programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0308] 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.
[0309] 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.
[0310] While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. The functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Furthermore, although elements of the disclosure may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated.

Claims

1. A method of wireless communication performed by a network entity, comprising: determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measuring the at least one PRS resource in the frequency domain search window during the positioning session.
2. The method of claim 1, further comprising: re-sampling the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.
3. The method of claim 2, further comprising: constructing multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at

least one PRS resource.

4. The method of claim 1, further comprising: transmitting a measurement report including information corresponding to one or more measurements made of the at least one PRS resource.

5. The method of claim 1, wherein the frequency domain search window is determined as: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.

6. The method of claim 1, wherein determining the frequency domain search window comprises: receiving positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; receiving ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

7. The method of claim 6, wherein the ephemeris information associated with the at least one NT-TRP is received, and the method further comprises: receiving directional information for the at least one NT-TRP; and determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.

8. The method of claim 6, wherein: the expected Doppler frequency shift offset uncertainty is indicated by the positioning AD as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.

9. The method of claim 1, further comprising: determining an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; determining an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

10. The method of claim 9, wherein: the expected Doppler frequency offset drift is determined from indications in positioning AD; the expected Doppler frequency offset drift rate is determined from indications in the positioning AD; or any combination thereof.

11. The method of claim 1, further comprising: determining a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.

12. The method of claim 11, further comprising: sending a request for new positioning AD based on an expiration of the validity duration; sending an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.

13. The method of claim 1, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.

14. The method of claim 1, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.

15. The method of claim 1, wherein: the expected Doppler frequency shift offset, the expected

Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.
16. The method of claim 1, further comprising: receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.
17. The method of claim 1, further comprising: measuring one or more signals of a global navigation satellite system (GNSS), wherein the measuring of the at least one PRS resource in the frequency domain search window is proximate in time to the measuring of the one or more signals of the GNSS; and reporting measurement data associated with the measurements of the one or more signals of the GNSS and the measurements of the at least one PRS resource.
18. The method of claim 1, wherein: the network entity is a base station; determining the frequency domain search window comprises receiving positioning AD indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; and the at least one PRS resource is an uplink PRS (UL-PRS) resource.
19. A method of wireless communication performed by a first network entity, comprising: sending information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receiving a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.
20. The method of claim 19, wherein the frequency domain search window is based on: a symmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an asymmetrical arrangement of the expected Doppler frequency shift offset uncertainty around the expected Doppler frequency shift offset; an arrangement of the expected Doppler frequency shift offset uncertainty in which a lowest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset; or an arrangement of the expected Doppler frequency shift offset uncertainty in which a highest offset of the expected Doppler frequency shift offset uncertainty is adjacent to the expected Doppler frequency shift offset.
21. The method of claim 19, wherein sending the information to the second network entity comprises: sending positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; sending ephemeris information associated with the at least one NT-TRP for determining, by the second network entity, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; sending directional information associated with the at least one NT-TRP for determining, by the second network entity, the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.
22. The method of claim 21, wherein: the positioning AD sent to the second network entity indicates the expected Doppler frequency shift offset uncertainty as a parts-per-million (ppm) value with respect to the expected Doppler frequency shift offset.
23. The method of claim 19, wherein sending the information to the second network entity comprises: sending positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.
24. The method of claim 19, wherein sending the information to the second network entity further

comprises: sending positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.
25. The method of claim 24, further comprising: receiving a request for new positioning AD based on an expiration of the validity duration; receiving an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.
26. The method of claim 19, wherein: the at least one NT-TRP is an earth-orbiting satellite having a low-earth orbit (LEO), a medium-earth orbit (MEO), or a geostationary earth orbit (GEO), and the expected Doppler frequency shift offset, the expected Doppler frequency shift offset uncertainty, or both the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty are based on an orbit of the earth-orbiting satellite.
27. The method of claim 19, wherein the at least one NT-TRP comprises: an unmanned aerial vehicle; a manned aerial vehicle; or a lighter than air vehicle.
28. The method of claim 19, wherein the expected Doppler frequency shift offset is based on: an altitude of the at least one NT-TRP; a frequency of the at least one PRS resource; or any combination thereof.
29. The method of claim 19, further comprising: receiving positioning AD indicating a time search window corresponding to an expected time for receiving the at least one PRS resource and an expected time uncertainty.
30. A network entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) for a positioning session; and measure the at least one PRS resource in the frequency domain search window during the positioning session.
31. The network entity of claim 30, wherein the at least one processor is further configured to: re-sample the at least one PRS resource based on the expected Doppler frequency shift offset to detect a peak of the at least one PRS resource in the frequency domain search window.
32. The network entity of claim 31, wherein the at least one processor is further configured to: construct multiple hypotheses to detect the peak of the at least one PRS in the frequency domain search window based on the re-sampling of the at least one PRS resource.
33. The network entity of claim 30, wherein the at least one processor configured to determine the frequency domain search window comprises the at least one processor configured to: receive, via the at least one transceiver, positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; receive, via the at least one transceiver, ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.
34. The network entity of claim 33, wherein the ephemeris information associated with the at least one NT-TRP is received, and the at least one processor is further configured to: receive, via the at least one transceiver, directional information for the at least one NT-TRP; and determine the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty based on the directional information and the ephemeris information.
35. The network entity of claim 30, wherein the at least one processor is further configured to: determine an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; determine an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.
36. The network entity of claim 30, wherein the at least one processor is further configured to:

determine a validity duration corresponding to a duration of time during which the frequency domain search window is valid, wherein the validity duration is indicated in positioning AD received by the network entity, the validity duration is determined by the network entity from ephemeris information corresponding to the at least one NT-TRP, or any combination thereof.

37. A first network entity, comprising: a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: send, via the at least one transceiver, information to a second network entity for determining a frequency domain search window corresponding to an expected Doppler frequency shift offset and an expected Doppler frequency shift offset uncertainty for at least one positioning reference signal (PRS) resource associated with at least one non-terrestrial transmission-reception point (NT-TRP) measured by the second network entity during a positioning session; and receive, via the at least one transceiver, a measurement report including information corresponding to one or more measurements made of the at least one PRS resource by the second network entity.

38. The first network entity of claim 37, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send, via the at least one transceiver, positioning assistance data (AD) indicating values for the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send, via the at least one transceiver, ephemeris information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; send, via the at least one transceiver, directional information associated with the at least one NT-TRP for determining the expected Doppler frequency shift offset and the expected Doppler frequency shift offset uncertainty; or any combination thereof.

39. The first network entity of claim 37, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send positioning AD indicating an expected Doppler frequency offset drift corresponding to an expected Doppler frequency drift of the expected Doppler frequency shift offset during the positioning session; an expected Doppler frequency offset drift rate corresponding to an expected Doppler frequency drift rate of the expected Doppler frequency shift offset during the positioning session; or any combination thereof.

40. The first network entity of claim 37, wherein the at least one processor configured to send the information to the second network entity comprises the at least one processor configured to: send, via the at least one transceiver, positioning AD indicating a validity duration corresponding to a duration of time during which the information for determining the frequency domain search window is valid.

41. The first network entity of claim 40, wherein the at least one processor is further configured to: receive, via the at least one transceiver, a request for new positioning AD based on an expiration of the validity duration; receive, via the at least one transceiver, an error message indicating a positioning error cause corresponding to the expiration of the validity duration; or any combination thereof.