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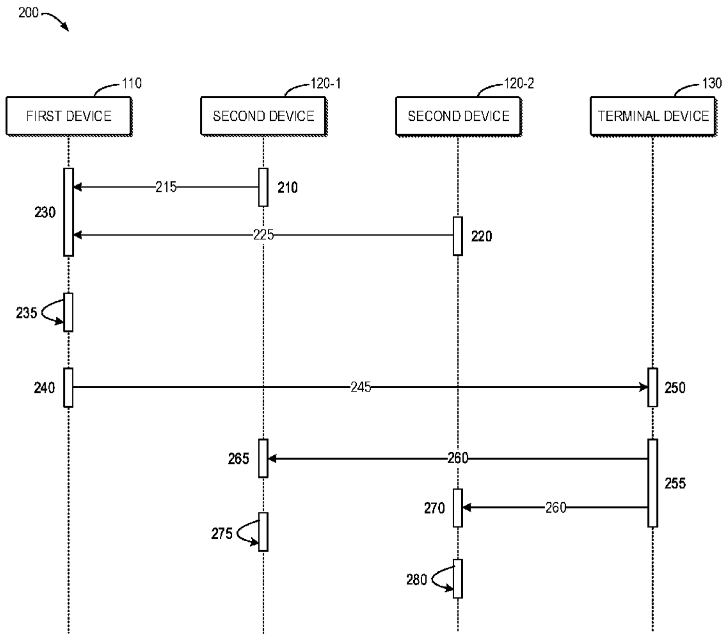

FIG. 2

(57) **Abstract:** Example embodiments of the present disclosure relate to a solution for controlling transmission power of a reference signal. In an aspect, a first device receives, from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device. The first device determines, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices. The first device provides the at least one set of power control parameters to the terminal device. Example embodiments of the present disclosure can improve positioning performance of positioning a terminal device based on a reference signal.

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POWER CONTROL OF POSITIONING REFERENCE SIGNAL

FIELD

[0001] Example embodiments of the present disclosure generally relate to the field of communication, and in particular to devices, methods, apparatuses and a computer readable medium for configuring transmission power of a reference signal.

BACKGROUND

[0002] A work item was conducted in the third Generation Partnership Project (3GPP) for native positioning support in the New Radio (NR) during Release 16 (Rel-16). As a result of that work, the following positioning solutions are specified for Rel-16 NR positioning, for example, Downlink Time Difference of Arrival (DL-TDOA), Uplink Time Difference of Arrival (UL-TDOA), Downlink Angle of Departure (DL-AoD), Uplink Angle of Arrival (UL-AoA), and Multi-cell Round Trip Time (Multi-RTT).

[0003] In particular, the work is to specify solutions to enable radio access technology (RAT) dependent (for both of the frequency range 1, FR1, and the FR2) and RAT independent NR positioning techniques. In the downlink (DL), a new positioning reference signal (DL PRS) was introduced and in the uplink (UL) a new sounding reference signal (SRS) for positioning was introduced. In release 17, there will be further work on NR positioning with most focusing on Industrial Internet of Things (IIoT), and improving accuracy and reducing latency for Rel-16 NR positioning.

SUMMARY

[0004] In general, example embodiments of the present disclosure provide a solution for controlling transmission power of a reference signal.

[0005] In a first aspect, there is provided a first device. The first device comprises at least one processor and at least one memory storing computer program codes. The at least one memory and the computer program codes are configured, with the at least one processor, to cause the first device to receive, from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device. The at least one memory and the computer program codes are also configured, with the at least one processor, to cause the first device to determine, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices. The at least one memory and the computer program codes are further configured, with the at least one processor, to cause the first device to provide the at least one set of power control parameters to the terminal device.

[0006] In a second aspect, there is provided a second device. The second device comprises at least one processor and at least one memory storing computer program codes. The at least one memory and the computer program codes are configured, with the at least one processor, to cause the second device to transmit, to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device. The at least one memory and the computer program codes are also configured, with the at least one processor, to cause the second device to receive, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information. The at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to perform at least one positioning measurement based on the received reference signal from the terminal device.

[0007] In a third aspect, there is provided a method. The method comprises receiving, at a first device from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device. The method also comprises determining, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices. The method further comprises providing the at least one set of power control parameters to the terminal device.

[0008] In a fourth aspect, there is provided a method. The method comprises transmitting, at a second device to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device. The method also comprises receiving, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information. The method further comprises performing at least one positioning measurement based on the received reference signal from the terminal device.

[0009] In a fifth aspect, there is provided an apparatus. The apparatus comprises means for receiving, at a first device from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device. The apparatus also comprises means for determining, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices. The apparatus further comprises means for providing the at least one set of power control parameters to the terminal device.

[0010] In an sixth aspect, there is provided an apparatus. The apparatus comprises means for transmitting, at a second device to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device. The apparatus also comprises means for receiving, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information. The apparatus further comprises means for performing at least one positioning measurement based on the received reference signal from the terminal device.

[0011] In a seventh aspect, there is provided a non-transitory computer readable medium storing program instructions for causing an apparatus to perform at least the method according to the third or fourth aspect.

[0012] It is to be understood that the summary section is not intended to identify key or essential features of example embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Some example embodiments will now be described with reference to the accompanying drawings, in which:

[0014] Fig. 1 illustrates a schematic diagram of a communication environment in which some example embodiments of the present disclosure can be implemented;

[0015] Fig. 2 illustrates an example communication process between a first device, a set of second devices, and a terminal device in accordance with some example embodiments of the present disclosure;

[0016] Fig. 3 illustrates another example communication process between a first device, a set of second devices, and a terminal device in accordance with some example embodiments of the present disclosure;

[0017] Fig. 4 illustrates an example communication process between a first device, a serving device of a terminal device, and the terminal device in accordance with some example embodiments of the present disclosure;

[0018] Fig. 5 illustrates another example communication process between a first device, a serving device of a terminal device, and the terminal device in accordance with some example embodiments of the present disclosure;

[0019] Fig. 6 illustrates a further example communication process between a first device, a serving device of a terminal device, and the terminal device in accordance with some example embodiments of the present disclosure;

[0020] Fig. 7 illustrates an example of grouping of a set of second devices in accordance with some example embodiments of the present disclosure;

[0021] Fig. 8 illustrates another example of grouping of a set of second devices in accordance with some example embodiments of the present disclosure;

[0022] Fig. 9 illustrates a flowchart of an example method in accordance with some example embodiments of the present disclosure;

[0023] Fig. 10 illustrates a flowchart of another example method in accordance with some example embodiments of the present disclosure;

[0024] Fig. 11 illustrates a simplified block diagram of a device that is suitable for implementing example embodiments of the present disclosure; and

[0025] Fig. 12 illustrates a block diagram of an example computer readable medium in accordance with some example embodiments of the present disclosure.

[0026] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0027] Principles of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these example embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0028] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0029] References in the present disclosure to "one embodiment," "an embodiment," "an example embodiment," and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every example embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same example embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an example embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other example embodiments whether or not explicitly described.

[0030] It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0031] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "has," "having," "includes" and/or "including," when used herein, specify the presence of stated features, elements, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0032] As used in this application, the term "circuitry" may refer to one or more or all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) combinations of hardware circuits and software, such as (as applicable):

(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and

(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (for example, firmware) for operation, but the software may not be present when it is not needed for operation.

[0033] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0034] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT) and so on. Furthermore, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. Example embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will of course also be future type communication technologies and systems with which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned system.

[0035] As used herein, the term “network device” refers to a node in a communication network via which a terminal device accesses the network and receives services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), a radio access network (RAN) node, an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), an infrastructure device for a V2X (vehicle-to-everything) communication, a Transmission/Reception Point (TRP), a Reception Point (RP), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth, depending on the applied terminology and technology.

[0036] The term “terminal device” refers to any end device that may be capable of wireless communication. By way of example rather than limitation, a terminal device may also be referred to as a communication device, user equipment (UE), a Subscriber Station (SS), an unmanned aerial vehicle (UAV), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a smart phone, voice over IP (VoIP) phones, wireless local loop phones, a tablet, a wearable terminal device, a personal digital assistant (PDA), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, vehicle-mounted wireless terminal devices, wireless endpoints, mobile stations, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), USB dongles, smart devices, wireless customer-premises equipment (CPE), an Internet of Things (loT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (for example, remote surgery), an industrial device and applications (for example, a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms “terminal device,” “communication device,” “terminal,” "user equipment" and "UE" may be used interchangeably.

[0037] As used herein, the term "resource," "transmission resource," "resource block," "physical resource block," "uplink resource," or "downlink resource" may refer to any resource for performing a communication, for example, a communication between a terminal device and a network device, such as a resource in time domain, a resource in frequency domain, a resource in space domain, a resource in code domain, or any other resource enabling a communication, and the like. In the following, a resource in both frequency domain and time domain will be used as an example of a transmission resource for describing some example embodiments of the present disclosure. It is noted that example embodiments of the present disclosure are equally applicable to other resources in other domains.

[0038] During the Rel-16 work, SRS enhancements were made to transmit SRS for positioning to neighbour cells. One enhancement was to allow a UE to be configured with "spatialRelationInfo" and "pathlossRS" reference RS from a neighbour cell. However, for the issues as listed below, this enhancement was not sufficient and further work needs to be addressed in Rel-17.

[0039] The first issue may be misalignment between the power control procedure defined in the standard and the actual operation. In particular, the power control equation originally intended to be composed by two parts. One part is the target received power P0, and the other part is UE's pathloss compensation according to its pathloss measurement. When the reception point (TRP/gNb) is aligned with the transmission point (TRP/gNb) of the pathloss RS, UE is able to properly compensate the pathloss, but if those two points are not aligned, then the required received power P0 would not be satisfied at the intended receiver.

[0040] In NR positioning, SRS for positioning needs to reach multiple of neighbour cells for positioning purpose. But according to the discussion of 3GPP RAN1 Rel-15 and Rel-16, UE is tightly limited at the number of pathloss RSs that it can measure, so the number of pathloss RSs should be smaller than the number of receivers for positioning SRS transmission. As a result, the misalignment between transmitter of the pathloss RS and the receiver of the positioning SRS is not avoidable.

[0041] The second issue may be that the gNB determines power control parameters. As described above, in NR positioning, SRS (as UL positioning reference signal) may be expected at the neighbour cells for positioning purpose, while UE cannot always compensate the pathloss. As an alternative solution, as shown in power control equation, the gNb may adjust such misalignment by SRS resource set specific configuration of P0. With this approach, for example, when SRS received at certain reception points continuously show 3 dB less power than required, then the gNb may configure 3dB higher value of P0 for an SRS resource set configured for the transmission toward that reception points.

[0042] In this approach, it is obvious that the SRS transmission power would be better to be adjusted according to a neighbour cell's expectation when the SRS is transmitted towards the neighbour cell. However, in the current standard, the power control parameters for SRS are configured by serving gNB via RRC signalling. Without any knowledge of SRS's target gNB/TRP, the serving gNB is not able to assign suitable power control parameters. Arbitrary UL transmission power adjustment may result in lack of coverage (not able to reach target cell) or exceeding interference.

[0043] The third issue may be that power control parameters are common for a SRS resource set. In the NR, power control parameters (including P0, alpha, pathloss RS) may be configured per SRS resource set. Right now, Rel-16 NR positioning allows "SpatialRelationInfo" to be configured per SRS-resource. Thus, within one SRS resource set, a UE can sweep across beams for multiple cells. But, controlling the power to multiple neighbour cells in different SRS resources is not allowed, as power control parameters are common per SRS resource set.

[0044] Right now, there is no feasible solution directly addressing the above problems. One potential approach for solving the third issue may be that the serving gNB can configure a SRS resource set for each cell that the UE is targeting with SRS for positioning. Thus, multiple SRS resource sets can be used for SRS transmission towards multiple cells. However, the number of supported SRS resource sets depends on UE capability. Accordingly, even though the maximum number defined in the 3GPP specifications is 16, a given UE may only support even just one resource set for positioning. In that case, the UE has no way to control the power to neighbour cells. Further, more UE capability values between 1 and 16 may still be agreed during the UE feature discussions. Therefore, multiple UE capability values of the maximum number of SRS resource sets for positioning may be not sufficient to solve the above issues. Furthermore, the first and second issues as mentioned above are still there with this potential approach.

[0045] In view of the above problems and other potential problems in the traditional solutions, example embodiments of the present disclosure provide a solution for controlling transmission power of a reference signal, so as to address the above issues of power control toward neighbour cells for NR positioning, thereby improving positioning performance of positioning a terminal device based on a reference signal. In some example embodiments, there is proposed a centralized UL power control for UL positioning signaling transmitting to multiple cells (or gNBs, TPRs, or the like).

[0046] An advantage of example embodiments of the present disclosure is to allow the transmission power of the reference signal for positioning (such as, the SRS) on a resource set to be controlled taking into account the neighbour cell/TRP reception. Without the signalling proposed in example embodiments of the present disclosure to allow a location server (such as, a location management function, LMF) to make an informed decision about the transmission power control, the UE will not be able to accurately control its transmission power for neighbour cells. A significant benefit may be that more neighbour cells are able to hear the reference signal for positioning (for example, SRS), therefore making more measurements and improving the achievable positioning accuracy. Principles and implementations of example embodiments of the present disclosure will be described in detail below with reference to the figures.

[0047] Fig. 1 illustrates a schematic diagram of a communication environment 100 in which some example embodiments of the present disclosure can be implemented. As shown in Fig. 1, the communication environment (also referred to as a communication network) 100 includes a first device 110, which may be used for determining and managing a location of a terminal device, such as the terminal device 130. For example, in order to determine the location of the terminal device 130, the first device 110 can communicate with a set of second devices 120 related to the terminal device 130. In particular, the first device 110 may communicate with a second device 120-1 via a communication link 115, communicate with a second device 120-2 via a communication link 125, and communicate with a third device 120-3 via a communication link 135.

[0048] In some example embodiments, the first device 110 may be a location server for determining or managing locations of devices. For example, the first device 110 may be a location management function (LMF) in a core network. Alternatively, the first device 110 may be at a network device of an access network. For instance, the first device 110 can be a component of one or more of the set of second devices 120. In some example embodiments, the set of second devices 120 may include a plurality of network devices, in which the second device 120-1 can be a serving device of the terminal device 130 located in a cell 122 of the second device 120-1.

[0049] In particular, the terminal device 130 may communicate with the second device 120-1 via a communication link 145. For transmissions from the second device 120-1 to the terminal device 130, the communication link 145 may be referred to as a downlink channel, whereas for transmissions from the terminal device 130 to the second device 120-1, the communication link 145 may alternatively be referred to as an uplink channel. For the terminal device 130 served by the second device 120-1, other second devices including the second device 120-2, 120-3, and so on may be referred to as non-serving devices of the terminal device 130.

[0050] In communications with the terminal device 130, the second device 120-1 (for example, a gNB) may transmit downlink reference signals (RSs) such as Positioning Reference Signal (PRS), Demodulation Reference Signal (DM-RS), Channel State Information-Reference Signal (CSI-RS), Phase Tracking Reference Signal (PT-RS), fine time and frequency Tracking Reference Signal (TRS), and the like. The terminal device 130 (for example, user equipment) in the communication network 100 may receive the downlink RSs on allocated resources.

[0051] In addition, the terminal device 130 may also transmit uplink RSs (such as DM-RS, PT-RS, SRS) to the second device 120-1 on corresponding allocated resources. For indicating the allocated resources and/or other necessary information for the RSs, the second device 120-1 may transmit RS configurations to the terminal device 130 prior to the transmissions of the RSs. In some example embodiments, the uplink reference signals (for example, a reference signal for positioning) transmitted by the terminal device 130 can also be received by the non-serving devices of the terminal device 130, for example, the second devices 120-2 and 120-3. In other words, the terminal device 130 may also transmit a reference signal to the second device 120-2 via a communication link 155, and to the second device 120-3 via a communication link 165.

[0052] As used herein, a reference signal (RS) is a signal sequence (also referred to as "RS sequence") that is known by both the second device 120-1 (or other second devices) and the terminal device 130. For example, a RS sequence may be generated and transmitted by the second device 120-1 (or other second devices) based on a certain rule and the terminal device 130 may deduce the RS sequence based on the same rule. In transmission of downlink and uplink RSs, the second device 120-1 may allocate corresponding resources (also referred to as "RS resources") for the transmission and/or specify which RS sequence is to be transmitted.

[0053] Among these various reference signals, some reference signals (for example, the PRS in downlink and the SRS in uplink) may be used for positioning the terminal device 130. In particular, the terminal device 130 can transmit the reference signal for positioning to the set of second devices 120, including the serving device 120-1 as well as the non-serving devices 120-2, 120-3, and so on. Accordingly, the set of second devices 120 may receive the reference signal for positioning from the terminal device 130, and then perform positioning measurements on the terminal device 130 based on the received reference signal. For example, the set of second devices 120 can measure the distances between the terminal device 130 and the set of second devices 120, or any other suitable positioning parameters that can be used for positioning the terminal device 130. Afterwards, the set of second devices 120 may transmit the measurement results of the positioning measurements to the first device 110, which can determine the location of the terminal device 130 based on the measurement results.

[0054] In some example embodiments, the reference signal for positioning the terminal device 130 may be an uplink reference signal, such as, the sounding reference signals. Alternatively or in addition, the reference signal for positioning the terminal device 130 may be a downlink reference signal, such as, the positioning reference signals. More generally, it should be understood that example embodiments of the present disclosure cover the case of using all possible existing or future reference signals (such as CSI-RSs in DL, DM-RSs in UL, or the like) for positioning the terminal device 130.

[0055] Although the first device 110, the set of second devices 120, and the terminal device 130 are described in the communication environment 100 of Fig. 1, example embodiments of the present disclosure may be equally applicable to any other suitable communication devices in communication with one another. That is, example embodiments of the present disclosure are not limited to the example scenario of Fig. 1. In this regard, it is noted that although the set of second devices 120 and the terminal device 130 are schematically depicted as base stations and a mobile phone in Fig. 1, it is understood that this depiction is only for example without suggesting any limitation. In other example embodiments, the first device 110, the set of second devices 120, and the terminal device 130 may be any other communication devices, for example, wireless communication devices.

[0056] It is to be understood that the number of communication devices, the number of communication links, and the number of other elements as shown in Fig. 1 are only for the purpose of illustration without suggesting any limitations. The communication environment 100 may include any suitable number of communication devices, any suitable number of communication links, and any suitable number of other elements adapted for implementing example embodiments of the present disclosure. In addition, it would be appreciated that there may be various wireless communications as well as wireline communications (if needed) among all the communication devices.

[0057] Communications in the communication environment 100 may be implemented according to any proper communication protocol(s), comprising, but not limited to, cellular communication protocols of the first generation (1G), the second generation (2G), the third generation (3G), the fourth generation (4G) and the fifth generation (5G) and on the like, wireless local network communication protocols such as Institute for Electrical and Electronics Engineers (IEEE) 802.11 and the like, and/or any other protocols currently known or to be developed in the future. Moreover, the communication may utilize any proper wireless communication technology, comprising but not limited to: Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Frequency Division Duplex (FDD), Time Division Duplex (TDD), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiple (OFDM), Discrete Fourier Transform spread OFDM (DFT-s-OFDM) and/or any other technologies currently known or to be developed in the future.

[0058] Reference is now made to Fig. 2, which illustrates an example communication process 200 between the first device 110, the set of second devices 120, and the terminal device 130 in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the communication process 200 will be described with reference to Fig. 1. However, it would be appreciated that the communication process 200 may be equally applicable to other communication scenarios where a plurality of devices communicate with one another.

[0059] As shown in Fig. 2, the set of second devices 120 may transmit power control information to the first device 110. For example, the set of second devices 120 may include the network devices that may participate in positioning the terminal device 130 based on a reference signal 260 to be transmitted 255 by the terminal device 130 to the set of second devices 120. Thus, the power control information may be determined by respective second devices of the set of second devices 120, and may be intended for controlling transmission power of the reference signal 260.

[0060] In some example embodiments, the power control information can be transmitted to the first device 110 via the NR Positioning Protocol A (NRPPa) as defined in the 3GPP specifications. However, it is appreciated that the power control information may be transmitted using any other existing or future protocols in other example embodiments. In some example embodiments, the set of second devices 120 may transmit the power control information to the first device 110 in response to a request for the power control information from the first device 110. In other word, the first device 110 may transmit a request to the set of second devices 120 for the power control information of the set of second devices 120. Upon receiving the request from the first device 110, the set of second devices 120 can transmit power control information to the first device 110.

[0061] More specifically, as the serving device of the terminal device 130, the second device 120-1 can transmit 210 power control information 215 to the first device 110 via the communication link 115. The power control information 215 may be intended for controlling the transmission power of the reference signal 260 to be transmitted 255 by the terminal device 130 to the second device 120-1. In a similar way, as a non-serving device of the terminal device 130, the second device 120-2 may transmit 220 power control information 225 to the first device 110 via the communication link 125. The power control information 225 may be intended for controlling the transmission power of the reference signal 260 to be transmitted 255 by the terminal device 130 to the second device 120-2. Although not shown, other non-serving devices of the terminal device 130 (for example, the second device 120-3 and so on) can also transmit power control information to the first device 110, which power control information may be intended for controlling the transmission power of the reference signal 260 to be transmitted 255 by the terminal device 130 to the respective second devices.

[0062] In some example embodiments, the power control information 215, 225, and so on may include received power of the reference signal 260 expected by a respective second device of the set of second devices 120, for example, expected received power of the reference signal 260 at a gNB/TRP/RP, namely, the parameter *p0* as defined in the 3GPP specifications. In particular, the power control information 215 can include received power of the reference signal 260 expected by the second device 120-1, the power control information 225 can include received power of the reference signal 260 expected by the second device 120-2, and so forth.

[0063] There may be various ways for the second device 120-1 (or other second devices) to determine the expected received power of the reference signal 260. As an example, the second device 120-1 (or other second devices) can determine the expected received power as a cell normalized power for data reception. For instance, the transmission powers of a plurality of terminal devices in the cell can be normalized to obtain the cell normalized power. As another example, the expected received power of the reference signal 260 may refer to power of the reference signal 260 sufficient for the reference signal 260 to be detectable by the second device 120-1 (or other second devices). In other words, the reference signal 260 is strong enough such that the second device 120-1 (or other second devices) can perform a positioning measurement based on the received reference signal 260. For instance, the expected received power may be a minimum power with which SRS transmission from a UE can be detected or measured by a gNB.

[0064] As a further example, the expected received power of the reference signal 260 may correspond to power of the reference signal 260 sufficient for achieving a predefined positioning measurement quality using the reference signal 260. For instance, the expected received power can be a minimum power to achieve predefined positioning measurement accuracy, for example in a received time of arrival (RTOA) measurement. With these various types of expected received power, the second device 120-1 (or other second devices) can achieve more flexibility in the measurement accuracy of the positioning measurement on the reference signal 260.

[0065] In addition or as an alternative to the expected received power, the power control information 215, 225, and so on may include other parameters related to the transmission power control of the reference signal 260. For example, these other parameters can include, but not limited to: an offset from the expected received power of the reference signal 260, a fractional power control factor (namely, the parameter *alpha* as defined in the 3GPP specifications) associated with the second device 120-1 (or other second devices), information on a pathloss reference signal (namely, *pathlossReferenceRS*) to be transmitted by the second device 120-1 (or other second devices) for determining pathloss between the second device 120-1 (or other second devices) and the terminal device 130, or information on a beam of the second device 120-1 (or other second devices) to be used during reception of the reference signal 260.

[0066] With these various types of power control information associated with the set of second devices 120 for controlling transmission power of the reference signal 260, the first device 110 can know various requirements or expectations of the set of second devices 120 on the transmission power of the reference signal 260, and thus can determine more suitable power control parameters for the terminal device 130 to transmit the reference signal 260, so as to implement a more comprehensive control of the transmission of the reference signal 260, thereby improving the positioning performance of positioning the terminal device 130 based on the reference signal 260.

[0067] Continuing with reference to Fig. 2, the first device 110 receives 230 power control information 215, 225, and so on from the set of second devices 120 related to the terminal device 130. For example, the first device 110 can collect such power control information from second devices that may participate in the positioning service for the terminal device 130. Then, based at least on the received power control information 215, 225, and so on, the first device 110 can determine 235 at least one set of power control parameters 245 for the terminal device 130 to transmit the reference signal 260 to the set of second devices 120. In other words, the first device 110 may determine one or more sets of power control parameters 245 available for the terminal device 130, based on the requirements or expectations of the set of second devices 120.

[0068] As an example embodiment, when determining at least one set of power control parameters 245, the first device 110 may also consider spatial directions of receiving beams to be used by the set of second devices 120. For example, if a plurality of second devices are to use receiving beams with similar spatial directions to receive the reference signal 260, the first device 110 can determine a set of power control parameters for the plurality of second devices, such that the terminal device 130 can transmit the reference signal 260 using a transmitting beam corresponding to the receiving beams with similar spatial directions. As another example, the first device 110 may determine a plurality of groups of second devices from the set of second devices 120, and second devices in each of the plurality of groups are located in a small region with a predefined size. Then, when determining a set of power control parameters for each group of second devices, the first device 110 may consider a respective spatial direction of a receiving beam for the group of second devices. Such an example will be further described with reference to Figs. 6 and 8.

[0069] In some example embodiments, the at least one set of power control parameters 245 may include received power of the reference signal 260 expected by the set of second devices 120. In other words, the expected received power of the reference signal 260 determined by the first device 110 may be the one to be used by the terminal device 130 to determine the actual transmission power of the reference signal 260, and which is common to all the second devices 120.

[0070] In addition to the expected received power (P0), the at least one set of power control parameters 245 may also include an offset from the expected received power of the reference signal 260, a fractional power control factor (namely, the *alpha* as defined in the 3GPP specifications) for transmitting the reference signal 260, or configurations of pathloss reference signals (namely, *pathlossReferenceRS*) to be transmitted by the set of second devices 120.

[0071] Additionally or alternatively, the at least one set of power control parameters 245 may contain other parameters in the transmission power equation of a reference signal as specified in the existing or future specifications. With these various power control parameters, the first device 110 can control the transmission power of the reference signal 260 by the terminal device 130 in a more effective, efficiency, and flexible manner.

[0072] In some example embodiments, in determining 235 the at least one set of power control parameters 245, the first device 110 may determine 235 one set of power control parameters 245 for all the second devices in the set of second devices 120. Alternatively, the first device 110 can select part of the set of second devices 120 to perform the positioning of the terminal device 130, and then determine the one set of power control parameters 245 for the selected second devices. In this way, the computing, storing, or communicating resource overhead of the first device 110 for positioning the terminal device 130 may be reduced.

[0073] In particular, depending on a positioning performance requirement, for example, the first device 110 can first determine a subset of the set of second devices 120 to perform the positioning of the terminal device 130 and to provide the positioning measurements. Then, the first device 110 can determine the one set of power control parameters 245 for the subset of second devices, such that the reference signal 260 transmitted by the terminal device 130 is detectable by the subset of second devices. For example, the first device 110 may determine suitable power control parameters 245 to ensure that the reference signal

260 transmitted from the terminal device 130 can be detected by sufficient number of second devices in the set of second devices 120.

[0074] In some other example embodiments, instead of determining 235 one set of power control parameters 245 for part or all of the set of second devices 120, the first device 110 can determine 235 a plurality of sets of power control parameters 245 available for the terminal device 130 to transmit the reference signal 260. These example embodiments will be described in detail below with reference to Figs. 4 and 5.

[0075] Continuing with reference to Fig. 2, after determining 235 the at least one set of power control parameters 245, the first device 110 may provide 240 the at least one set of power control parameters 245 to the terminal device 130 for transmitting the reference signal 260. There are various possible manners for providing the least one set of power control parameters 245 from the first device 110 to the terminal device 130. For example, the first device 110 can directly transmit the least one set of power control parameters 245 to the terminal device 130, if there are direct communication links between them.

[0076] In other example embodiments, the first device 110 can transmit the at least one set of power control parameters 245 to the terminal device 130 through the serving device 120-1 of the terminal device 130, for example, via the NRPPa. In this way, the direct communication links between the first device 110 and terminal device 130 can be omitted, thereby saving communication resources and avoiding potential interference due to the direct communications between the first device 110 and terminal device 130. Such example embodiments will be described in detail below with reference to Fig. 3.

[0077] After receiving 250 (for example, through the second device 120-1) the at least one set of power control parameters 245 provided by the first device 110, the terminal device 130 can transmit 255 the reference signal 260 to the set of second devices 120 using the at least one set of power control parameters 245. For example, the terminal device 130 can transmit 255 the reference signal 260 to the set of second devices 120 using the at least one set of power control parameters 245.

[0078] In particular, the terminal device 130 may transmit 255 the reference signal 260 using the at least one set of power control parameters 245 to the second device 120-1 via the communication link 145, to the second device 120-2 via the communication link 155, to the second device 120-3 via the communication link 165, and so on. Since the at least one set of power control parameters 245 of the reference signal 260 is determined based on the requirements or expectations of the set of second devices 120, respective second devices of the set of second devices 120 can successfully and correctly receive the reference signal 260 from the terminal device 130.

[0079] Accordingly, the set of second devices 120 can respectively receive the reference signal 260 from the terminal device 130 transmitted using the set of power control parameters 245. For example, the second device 120-1 may receive 265 the reference signal 260 from the terminal device 130 via the communication link 145, the second device 120-2 may receive 270 the reference signal 260 from the terminal device 130 via the communication link 155, and the second device 120-3 may receive the reference signal 260 from the terminal device 130 via the communication link 165, and so on.

[0080] After receiving the reference signal 260, the set of second devices 120 can respectively perform positioning measurements on the reference signal 260. For example, the set of second devices 120 may calculate the distances between the terminal device 130 and the set of second devices 120, respectively. In some other example embodiments, the positioning measurements may include measuring any existing or future positioning parameters which can be used for positioning a terminal device.

[0081] In particular, the second device 120-1 can perform 275 at least one positioning measurement based on the received reference signal 260 from the terminal device 130. In a similar way, the second device 120-2 may perform 280 at least one positioning measurement based on the received reference signal 260 from the terminal device 130. Although not shown in Fig. 2, other non-serving devices of the terminal device 130 (for example, the second device 120-3 and so on) can also perform at least one positioning measurements on the reference signal 260.

[0082] In some example embodiments, after performing the positioning measurements, the set of second devices 120 can transmit the measurement results of the positioning measurements to the first device 110, respectively. For example, the second device 120-1 may transmit its measurement results to the first device 110 via the communication link 115, the second device 120-2 may transmit its measurement results to the first device 110 via the communication link 125, and second device 120-3 may transmit its measurement results to the first device 110 via the communication link 135, and so on. Based on the measurement results from the set of second devices 120, the first device 110 can determine a position of the terminal device 130.

[0083] Through the communication process 200, various technical advantages can be achieved. For example, in contrast to traditional solutions, power control of a reference signal for positioning (such as, a SRS) toward neighbor cells can be enabled. As indicated above, the traditional solutions do not fully allow for power control of a reference signal toward neighbor cells. In addition, positioning accuracy based on the reference signal can be improved. In particular, by allowing more second devices (such as, gNBs) to receive the reference signal for positioning (such as, the SRS), the overall positioning performance can be enhanced. Further, network flexibility or control of interference due to the transmission of the reference signal may also be improved. For example, by allowing the first device (such as, an LMF) to acquire power control information for many cells, the network can make an informed decision about the interference levels that may be generated.

[0084] As indicated in describing the providing operation 240 of the communication process 200, in some example embodiments, the first device 110 can transmit the at least one set of power control parameters 245 to the terminal device 130 through the serving device 120-1 of the terminal device 130. Such example embodiments will be detailed now with reference to Fig. 3.

[0085] Fig. 3 illustrates another example communication process 300 between the first device 110, the set of second devices 120, and the terminal device 130 in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the communication process 300 will be described with reference to Fig. 1. However, it would be appreciated that the communication process 300 may be equally applicable to other communication scenarios where a plurality of devices communicate with one another.

[0086] Referring to both Figs. 2 and 3, in order to provide 240 the at least one set of power control parameters 245 to the terminal device 130, the first device 110 can transmit 310 the at least one set of power control parameters 245 to the second device 120-1, which is the serving device of the terminal device 130. Accordingly, the second device 120-1 may receive 320 the at least one set of power control parameters 245 from the first device 110. Then, the second device 120-1 may transmit 330 the at least one set of power control parameters 245 to the terminal device 130.

[0087] As such, the at least one set of power control parameters 245 is provided to the terminal device 130 through the serving device 120-1 of the terminal device 130, thereby saving potential communication resources for direct communications between the first device 110 and terminal device 130, and avoiding potential interference due to the direct communications. After receiving 340 the at least one set of power control parameters 245 from the second device 120-1, the terminal device 130 can transmit 255 the reference signal 260 using the at least one set of power control parameters 245 to the set of second devices 120.

[0088] In some example embodiments, before transmitting 330 the at least one set of power control parameters 245 to the terminal device 130, the second device 120-1 can estimate interference to be caused by the transmission of the reference signal 260 using the set of power control parameters 245. If the second device 120-1 determines that the estimated interference exceeds a predefined threshold, the second device 120-1 can adjust 350 the at least one set of power control parameters 245 prior to transmitting 330 the at least one set of power control parameters 245, so as to reduce the potential interference due to the transmission of the reference signal 260.

[0089] More specifically, if the terminal device 130 is requested by the first device 110 to transmit with large transmission power to neighbor cells (for example, the non-serving devices) and if the serving device 120-1 knows that the additional interference is too high, then the serving device 120-1 may adapt the power control parameters 245 provided by the first device 110 accordingly. In this event, the transmission of these power control parameters 245 may be in the form of a request from the first device 110 to the second device 120-1.

[0090] In some example embodiments, after receiving 320 the at least one set of power control parameters 245 from the first device 110, the second device 120-1 can update 360, based on the at least one set of power control parameters 245, a measurement configuration for performing 275 the at least one positioning measurement, since the power control parameters 245 determined by the first device 110 may be different from the initially intended power control information 215 determined by the second device 120-1. As such, the positioning measurement to be performed 275 by the second device 120-1 on the reference signal 260 can be optimized.

[0091] In some example embodiments, the first device 110 can also transmit the at least one set of power control parameters 245 to the non-serving devices of the terminal device 130, so that the non-serving devices can update, based on the at least one set of power control parameters 245, their respective measurement configurations for performing the positioning measurements on the reference signal 260 transmitted by the terminal device 130. For example, the first device 110 may transmit 370 the at least one set of power control parameters 245 to the second device 120-2.

[0092] Therefore, the second device 120-2 may receive 380 the at least one set of power control parameters 245 from the first device 110. Then, similar to the updating 360 performed by the second device 120-1, the second device 120-2 may update 390, based on the set of power control parameters 245, a measurement configuration for performing 280 the at least one positioning measurement. Since the power control parameters 245 determined by the first device 110 may be different from the initially intended power control information 225 determined by the second device 120-2, through the updating 390, the positioning measurement to be performed 280 by the second device 120-2 on the reference signal 260 can be optimized.

[0093] As mentioned in describing the determining operation 235 of the communication process 200, in some example embodiments, the first device 110 can determine 235 a plurality of sets of power control parameters 245 available for the terminal device 130 to transmit the reference signal 260, and may transmit the plurality of sets of power control parameters 245 to the serving device 120-1. In this event, the second device 120-1 may have various options to configure the transmission of the reference signal 260 by the terminal device 130. These example embodiments will be detailed now with reference to Figs. 4 and 5.

[0094] Fig. 4 illustrates an example communication process 400 between the first device 110, the serving device 120-1 of the terminal device 130, and the terminal device 130, in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the communication process 400 will be described with reference to Fig. 1. However, it would be appreciated that the communication process 400 may be equally applicable to other communication scenarios where three devices communicate with one another.

[0095] Referring to both Figs. 3 and 4, in transmitting 310 the at least one set of power control parameters 245 to the second device 120-1, the first device 110 can transmit 410 a plurality of sets of power control parameters 405 to the second device 120-1. In other words, the first device 110 determines that the plurality of sets of power control parameters

405 are available for the terminal device 130 to transmit the reference signal 260 to the set of second devices 120, and send them to the serving device 120-1 for providing to the terminal device 130. In some example embodiments, the plurality of sets of power control parameters 405 may be determined based on grouping the set of second devices 120 into a plurality of groups. Such example embodiments will be further described in detail with reference to Figs. 6 to 8.

[0096] Continuing with reference to Fig. 4, the second device 120-1 may receive 420 the plurality of sets of power control parameters 405 from the first device 110. Then, the second device 120-1 can select 430 a target set of power control parameters 415 from the plurality of sets of power control parameters 405, as the set of power control parameters used by the terminal device 130 to transmit the reference signal 260. For example, the second device 120-1 may select 430 the target set of power control parameters 415 corresponding to the greatest transmission power values of the reference signal 260, so as to ensure that a non-serving device with the farthest distance from the terminal device can receive the reference signal 260.

[0097] As another example, the selection of the target set of power control parameters 415 by the second device 120-1 may be based on the estimated interferences to neighbor cells (for example, the cells of the non-serving devices) and its own cell 122, due to the transmissions of the reference signal 260 using the plurality of sets of power control parameters 405, respectively. By selecting only one set of power control parameters 415, the second device 120-1 can simplify the configuring of terminal device 130 to transmit the reference signal 260, and reduce the potential interferences.

[0098] Afterwards, the second device 120-1 may transmit 440 the target set of power control parameters 415 to the terminal device 130. Referring to both Figs. 2 and 4, after receiving 450 the target set of power control parameters 415 from the serving device 120-1, the terminal device 130 can transmit 255 the reference signal 260 to the set of second devices 120 using the target set of power control parameters 415.

[0099] Fig. 5 illustrates another example communication process 500 between the first device 110, the serving device 120-1 of the terminal device 130, and the terminal device 130, in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the communication process 500 will be described with reference to Fig. 1. However, it would be appreciated that the communication process 500 may be equally applicable to other communication scenarios where three devices communicate with each other.

[00100] As shown in Fig. 5, similar to the communication process 400, the first device 110 can transmit 410 a plurality of sets of power control parameters 405 to the second device 120-1. In other words, the first device 110 determines that the plurality of sets of power control parameters 405 are available for the terminal device 130 to transmit the reference signal 260 to the set of second devices 120, and send them to the serving device 120-1 for providing to the terminal device 130. Accordingly, the second device 120-1 receives 420 the plurality of sets of power control parameters 405 from the first device 110.

[00101] Different from the communication process 400, the second device 120-1 may then determine 510 respective sets of resources associated with the plurality of sets of power control parameters 405. In other words, for each set of power control parameters, the second device 120-1 can determine a corresponding set of resources to be used by the terminal device 130 to transmit the reference signal 260. As such, second devices in the set of second devices 120 with different requirements or expectations on the transmission power of the reference signal 260 can receive the reference signal 260 transmitted using different sets of power control parameters in respective sets of resources, thereby improving the effectiveness and efficiency of the reference signal 260 for the positioning of the terminal device 130.

[00102] As an example, the serving device 120-1 may configure the reference signal 260 for a first subset of the set of second devices 120 in a first resource set. Then, the first set of power control parameters (informed from the first device 110) may be further configured for the first resource set. Similarly, the serving device 120-1 may configure the reference signal 260 for a second subset of the set of second devices 120 in a second resource set. Then, the second set of power control parameters (informed from the first device 110) may be configured for the second resource set.

[00103] In other words, the second device 120-1 can configure the terminal device 130 to transmit the reference signal 260 using the plurality sets of power control parameters 405 and the respective sets of resources. For example, the second device 120-1 may transmit 520 configuration information 505 to the terminal device 130. The configuration information 505 may indicate the plurality sets of power control parameters 405 and the respective sets of resources. Referring to both Figs. 2 and 5, after receiving 530 the configuration information 505 from the serving device 120-1, the terminal device 130 can transmit 255 the reference signal 260 to the set of second devices 120, using the plurality sets of power control parameters 405 and the respective sets of resources.

[00104] As mentioned above in describing Fig. 4, in some example embodiments, when determining 235 the plurality of power control parameters 405, the first device 110 may group (namely, dividing) the set of second devices 120 into different groups of second devices. Then, the first device 110 may determine a set of power control parameters for each group of second devices. In this way, the power control parameters can be determined for a group of second devices with analogous characteristics, thereby enhancing the effectiveness and efficiency of the reference signal 260 for the positioning of the terminal device 130. These example embodiments will be detailed now with reference to Figs. 6 to 8.

[00105] Fig. 6 illustrates a further example communication process 600 between the first device 110, the serving device 120-1 of the terminal device 130, and the terminal device 130, in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the communication process 600 will be described with reference to Fig. 1. However, it would be appreciated that the communication process 600 may be equally applicable to other communication scenarios where three devices communicate with one another.

[00106] Referring both Figs. 2 and 6, in order to determine 235 the at least one set of power control parameters 245, the first device 110 may first divide 610 the set of second devices 120 into a plurality of groups. It is to be appreciated that the first device 110 may divide the set of second devices 120 into groups based on any suitable factors or characteristics of the set of second devices 120, for example, depending on specific design requirements or technical environments for the positioning of the terminal device 130.

[00107] As an option, the set of second devices 120 may be divided into the plurality of groups based on their geographical locations. For example, the first device 110 may determine the plurality of groups of second devices based on distances between the serving device 120-1 and other second devices (for example, second device 120-2, 120-3, and so on) of the set of second devices 120. That is, second devices in each of the plurality of groups can have substantially identical distance from the serving device 120-1. In other words, distances from second devices in each of the plurality of groups to the serving device 120-1 may be within a predefined distance range. In this way, the transmission power of the reference signal 260 can be configured to be substantially identical for second devices in a same group, thereby improving the effectiveness and efficiency of the reference signal 260 for the positioning of the terminal device 130. A specific example will be further described in detail below with reference to Fig. 7.

[00108] Fig. 7 illustrates an example 700 of grouping of the set of second devices 120 in accordance with some example embodiments of the present disclosure. As shown in Fig. 7, it is assumed that there are twelve (12) second devices anticipating in the positioning of the terminal device 130. These second devices include the second device 120-1 as the serving device of the terminal device 130 and second devices 720-1 to 720-11 as non-serving devices of the terminal device 130. In the example scenario of Fig. 7, there are depicted a first circle 705 and a second circle 715, both centered on the serving device 120-1. It is to be understood that the number of second devices, the number of circles, and the sizes of the circles as shown in Fig. 7 are only for the purpose of illustration without suggesting any limitations. Example embodiments of the present disclosure may equally applicable to any suitable number of second devices, any suitable number of circles, and any suitable sizes of the circles. In addition, it should be noted that Fig. 7 is not drawn to scale.

[00109] As can be seen from Fig. 7, the second devices 720-1 to 720-5 are located substantially along the first circle 705, and thus have an approximately same first distance 725 from the serving device 120-1. Similarly, the second devices 720-6 to 720-11 are located substantially along the second circle 715, and thus have an approximately same second distance 735 from the serving device 120-1. In the example of Fig. 7, the second distance 735 is greater than the first distance 725. In this event, the first device 110 can determine the second devices 720-1 to 720-5 as a first group of second devices, and determine the second devices 720-6 to 720-11 as a second group of second devices.

[00110] In particular, the first device 110 may assign suitable power control parameters to make the transmission power of the reference signal 260 for the second group to be higher than that for the first group. In some example embodiments, different sets of power control parameters may be configured for the first and second groups of second devices, and meanwhile associated with different sets of resources for transmitting the reference signal 260. For example, the terminal device 130 can be configure to transmit the reference signal 260 to the first group of second devices using a first set of resources and a first set of power control parameters, transmit the reference signal 260 to the second group of second devices using a second set of resources and a second set of power control parameters, and so on.

[00111] As another example of grouping based on the geographical locations of the set of second devices 120, the first device 110 may determine the plurality of groups of second devices such that second devices in each of the plurality of groups are located in a region with a predefined size. For example, the first device 110 may assign second devices 120 located in a small region into one group. In this way, both the transmission power and transmission beam of the reference signal 260 can be configured to be substantially identical for second devices in a same group, thereby improving the effectiveness and efficiency of the reference signal 260 for the positioning of the terminal device 130. A specific example will be further described in detail below with reference to Fig. 8.

[00112] Fig. 8 illustrates another example 800 of grouping of the set of second devices 120 in accordance with some example embodiments of the present disclosure. As shown in Fig. 8, it is assumed that there are twelve (12) second devices anticipating in the positioning of the terminal device 130. These second devices include the second device 120-1 as the serving device of the terminal device 130 and second devices 820-1 to 820-11 as non-serving devices of the terminal device 130.

[00113] In the example scenario of Fig. 8, there are depicted a first region 805, a second region 815, a third region 825, and a fourth region 835. In some example embodiments, the four regions may have a substantially same predefined size. In some other example embodiments, the four regions can have respective predefined sizes. In some further example embodiments, some of the four regions can have a substantially same predefined size. It is to be understood that the number of second devices, the number of regions, and the sizes of the regions as shown in Fig. 8 are only for the purpose of illustration without suggesting any limitations. Example embodiments of the present disclosure may equally applicable to any suitable number of second devices, any suitable number of regions, and any suitable sizes of the regions. In addition, it should be noted that Fig. 8 is not drawn to scale.

[00114] As can be seen from Fig. 8, the second devices 820-1 to 820-3 are located in the first region 805, the second devices 820-4 to 820-6 are located in the second region 815, the second devices 820-7 to 820-9 are located in the third region 825, and the second devices

820-10 and 820-11 are located in the fourth region 835. In this event, the first device 110 can determine the second devices 820-1 to 820-3 as a first group of second devices, the second devices 820-4 to 820-6 as a second group of second devices, the second devices 820-7 to 820-9 as a third group of second devices, and the second devices 820-10 and 820-11 as a forth group of second devices.

[00115] In such a grouping case, each group of second devices may experience similar path loss (from the terminal device 130 to the second devices). Hence, the first device 110 can assign a common pathloss reference signal for one group accordingly. Such a grouping case may further be used when the terminal device 130 is beamforming its transmission of the reference signal 260 and therefore spatially similar second devices may receive the same transmissions of the reference signal 260. For example, as mentioned above in describing the determining operation 235 of Fig. 2, if the second devices participating in the positioning of the terminal device 130 are divided into a plurality of groups in a way shown in Fig. 8, the first device 110 may consider a respective spatial direction of a receiving beam for each group of second devices, when determining a respective set of power control parameters for each group of second devices.

[00116] In particular, for the example of Fig. 8, the first device 110 may consider a first spatial direction of a receiving beam directed from the terminal device 130 to the first region 805 when determining a first set of power control parameters for the first group of second devices 820-1 to 802-3, consider a second spatial direction of a receiving beam directed from the terminal device 130 to the second region 815 when determining a second set of power control parameters for the second group of second devices 820-4 to 802-6, consider a third spatial direction of a receiving beam directed from the terminal device 130 to the third region 825 when determining a third set of power control parameters for the third group of second devices 820-7 to 802-9, and consider a fourth spatial direction of a receiving beam directed from the terminal device 130 to the fourth region 835 when determining a fourth set of power control parameters for the fourth group of second devices 820-10 and 802-11.

[00117] In addition or as an alternative to the grouping based on the geographical locations, the first device 110 can determine the plurality of groups based on received powers at the terminal device 130 associated with reference signals transmitted by the set of second devices 120. In this way, the transmission power of the reference signal 260 can be configured to be substantially identical for second devices in a same group, thereby improving the effectiveness and efficiency of the reference signal 260 for the positioning of the terminal device 130. As an example, for the case of multi-cell RTT positioning, the first device 110 may assign second devices with similar Reference Signal Received Power (RSRP) values (for example, measured based on DL PRS) at the terminal device 130 to the same group. Especially, in the case of periodic RTT measurements, the configuration of resources sets for transmitting the reference signal 260 can be updated accordingly.

[00118] Additionally or alternatively, the first device 110 can determine the plurality of groups based on a mobility measurement report of the terminal device 130. For example, the first device 110 may use prior mobility measurement reports (such as, based on TRS), which may include RSRP, Reference Signal Receiving Quality (RSRQ), and other measurement results, to help determine the groups of second devices.

[00119] Referring back to Fig. 6, after dividing 610 the set of second devices 120 into the plurality of groups, the first device 110 may determine 620 a plurality of sets of power control parameters for the plurality of groups, respectively. For example, if the set of second devices 120 are divided based on the distances between the serving device 120-1 and other second devices, the first device 110 may determine 620 the plurality of sets of power control parameters such that different transmission power values of the reference signal 260 are used for different groups.

[00120] If the set of second devices 120 are divided such that second devices in each of the plurality of groups are located in a region with a predefined size, the first device 110 may determine 620 the plurality of sets of power control parameters such that a common pathloss reference signal and a common transmission beam of the reference signal 260 are used for each of different groups. Similarly, if the set of second devices 120 are divided based on received powers at the terminal device 130 associated with reference signals transmitted by the set of second devices 120, the first device 110 may determine 620 the plurality of sets of power control parameters such that a common RSRP value is used for each of different groups.

[00121] Then, the first device 110 may transmit 630 information 605 to the serving device 120-1. The information 605 may be about the grouping of the set of second devices 120. For example, the information 605 can indicate how the set of second devices 120 are grouped into the plurality of groups. In addition, the first device 110 can also transmit 650 the respective sets of power control parameters 615 for the plurality of groups of second devices to the serving device 120-1. In other words, the first device 110 can not only inform the second device 120-1 of the grouping of the set of second devices 120, but also indicate the respective sets of power control parameters 615 to the second device 120-1.

[00122] In some example embodiments, the respective sets of power control parameters 615 may alternatively be included in the information 605. In other words, the information 605 on the grouping may be transmitted together with the respective sets of power control parameters 615. As such, the second device 120-1 can associate the respective sets of power control parameters 615 with respective groups of second devices, and thus can accordingly configure the terminal device 130 to transmit the reference signal 260 to various groups of second devices, thereby improving the effectiveness and efficiency of the positioning of the terminal device 130. In some other example embodiments, the first device 110 may only inform the second device 120-1 of the sets of power control parameters 615, without transmitting the information 605. Such example embodiments may be examples that the first device 110 transmits a plurality of power control parameters 405 to the second device 120-1, as described above with reference to Figs. 4 and 5.

[00123] Continuing with reference to Fig. 6, after receiving 640 the information 605 and receiving 660 the respective sets of power control parameters 615 from the first device 110, the second device 120-1 may be aware that the sets of power control parameters 615 are used for the plurality of groups of second devices. Then, the second device 120-1 can configure the terminal device 130 to transmit the reference signal 260 to the plurality of groups using the respective sets of power control parameters, respectively.

[00124] For example, the second device 120-1 can transmit 670 configuration information 625 to the terminal device 130. The configuration information 625 may indicate such a configuration for the terminal device 130 to transmit the reference signal 260 to the plurality of groups of second devices 120. After receiving 680 the configuration information 625 from the second device 120-1, the terminal device 130 may transmit the reference signal 260 to the various groups of second devices using the respective sets of power control parameters, respectively.

[00125] Fig. 9 illustrates a flowchart of an example method 900 in accordance with some example embodiments of the present disclosure. In some example embodiments, the method 900 can be implemented at a device in a communication network, such as the first device 110 as shown in Fig. 1. Additionally or alternatively, the method 900 can also be implemented at other devices shown in Fig. 1. In some other example embodiments, the method 900 may be implemented at devices not shown in Fig. 1.

[00126] At block 910, the first device 110 receives, from a set of second devices 120 related to a terminal device 130, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device 130 to the set of second devices 120 for positioning the terminal device 130. At block 920, the first device 110 determines, based at least on the received power control information, at least one set of power control parameters for the terminal device 130 to transmit the reference signal to the set of second devices 120. At block 930, the first device 110 provides the at least one set of power control parameters to the terminal device 130.

[00127] In some example embodiments, the power control information comprises at least one of the following: received power of the reference signal expected by a second device of the set of second devices 120, an offset from the expected received power of the reference signal, a fractional power control factor associated with the second device, information on a pathloss reference signal to be transmitted by the second device to the terminal device 130 for determining pathloss between the second device and the terminal device 130, or information on a beam of the second device to be used during reception of the reference signal.

[00128] In some example embodiments, the expected received power of the reference signal comprises at least one of the following: power of the reference signal sufficient for the reference signal to be detectable by the second device, or power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

[00129] In some example embodiments, determining the at least one set of power control parameters comprises: determining a subset of the set of second devices 120 to perform positioning of the terminal device 130; and determining one set of power control parameters such that the reference signal transmitted by the terminal device 130 is detectable by the subset of second devices.

[00130] In some example embodiments, determining the at least one set of power control parameters comprises: dividing the set of second devices 120 into a plurality of groups; and determining a plurality of sets of power control parameters for the plurality of groups, respectively.

[00131] In some example embodiments, the set of second devices 120 includes a serving device 120-1 of the terminal device 130, and dividing the set of second devices 120 into the plurality of groups comprises at least one of the following: determining the plurality of groups based on distances between the serving device 120-1 and other second devices of the set of second devices 120; determining the plurality of groups such that second devices in each of the plurality of groups are located in a region with a predefined size; determining the plurality of groups based on received powers at the terminal device 130 associated with reference signals transmitted by the set of second devices 120; and determining the plurality of groups based on a mobility measurement report of the terminal device 130.

[00132] In some example embodiments, the set of second devices 120 includes a serving device 120-1 of the terminal device 130, and the method 900 further comprises: transmitting, to the serving device 120-1, information on the grouping of the set of second devices 120.

[00133] In some example embodiments, the set of power control parameters comprises at least one of the following: received power of the reference signal expected by the set of second devices 120, an offset from the expected received power of the reference signal, a fractional power control factor for transmitting the reference signal, or configurations of pathloss reference signals to be transmitted by the set of second devices 120.

[00134] In some example embodiments, the set of second devices 120 includes a serving device 120-1 of the terminal device 130, and providing the at least one set of power control parameters to the terminal device 130 comprises: transmitting the at least one set of power control parameters to the terminal device 130 through the serving device 120-1.

[00135] In some example embodiments, the set of second devices 120 includes a serving device 120-1 and a non-serving device 120-2 of the terminal device 130, and the method 900 further comprises: transmitting the at least one set of power control parameters to the non-serving device 120-2.

[00136] In some example embodiments, the first device 110 comprises a location server, and the set of second devices 120 comprises network devices.

[00137] Fig. 10 illustrates a flowchart of another example method 1000 in accordance with some example embodiments of the present disclosure. In some example embodiments, the method 1000 can be implemented at a device in a communication network, such as the second device 120-1 (or other second devices) as shown in Fig. 1. Additionally or alternatively, the method 1000 can also be implemented at other devices shown in Fig. 1. In some other example embodiments, the method 1000 may be implemented at devices not shown in Fig. 1.

[00138] At block 1010, the second device 120-1 (or 120-2, 120-3, and so on) transmits, to a first device 110, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device 130 to the second device (or 120-2, 120-3, and so on) for positioning the terminal device 130. At block 1020, the second device 120-1 (or 120-2, 120-3, and so on) receives, from the terminal device 130, the reference signal transmitted using a set of power control parameters determined by the first device 110 based on the power control information. At block 1030, the second device 120-1 (or 120-2, 120-3, and so on) performs at least one positioning measurement based on the received reference signal from the terminal device 130.

[00139] In some example embodiments, the power control information comprises at least one of the following: received power of the reference signal expected by the second device (or 120-2, 120-3, and so on), an offset from the expected received power of the reference signal, a fractional power control factor associated with the second device (or 120-2, 120-3, and so on), information on a pathloss reference signal to be transmitted by the second device (or 120-2, 120-3, and so on) to the terminal device 130 for determining pathloss between the second device (or 120-2, 120-3, and so on) and the terminal device 130, or information on a beam of the second device (or 120-2, 120-3, and so on) to be used during reception of the reference signal.

[00140] In some example embodiments, the expected received power of the reference signal comprises at least one of the following: power of the reference signal sufficient for the reference signal to be detectable by the second device (or 120-2, 120-3, and so on), or power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

[00141] In some example embodiments, the second device 120-1 is a serving device of the terminal device 130, and the method 1000 further comprises: receiving the set of power control parameters from the first device 110; and transmitting the set of power control parameters to the terminal device 130.

[00142] In some example embodiments, the method 1000 further comprises: in accordance with a determination that estimated interference, to be caused by the transmission of the reference signal using the set of power control parameters, exceeds a predefined threshold, adjusting the set of power control parameters prior to transmitting the set of power control parameters to the terminal device 130.

[00143] In some example embodiments, the second device 120-1 is a serving device of the terminal device 130, and the method 1000 further comprises: receiving, from the first device 110, a plurality of sets of power control parameters for the terminal device 130 to transmit the reference signal; selecting, from the plurality of sets of power control parameters, a target set of power control parameters as the set of power control parameters used by the terminal device 130 to transmit the reference signal; and transmitting the target set of power control parameters to the terminal device 130.

[00144] In some example embodiments, the second device 120-1 is a serving device of the terminal device 130, and the method 1000 further comprises: receiving, from the first device 110, a plurality of sets of power control parameters including the set of power control parameters; determining respective sets of resources associated with the plurality of sets of power control parameters; and configuring the terminal device 130 to transmit the reference signal using the plurality sets of power control parameters and the respective sets of resources.

[00145] In some example embodiments, the second device 120-1 is a serving device of the terminal device 130, and the method 1000 further comprises: receiving, from the first device 110, information on grouping of a set of second devices 120 including the second device (or 120-2, 120-3, and so on) into a plurality of groups; receiving, from the first device 110, respective sets of power control parameters for the plurality of groups; and configuring the terminal device 130 to transmit the reference signal to the plurality of groups using the respective sets of power control parameters.

[00146] In some example embodiments, the method 1000 further comprises: receiving the set of power control parameters from the first device 110; and updating, based on the set of power control parameters, a measurement configuration for performing the at least one positioning measurement.

[00147] In some example embodiments, the set of power control parameters comprises at least one of the following: received power of the reference signal expected by a set of second devices 120 including the second device (or 120-2, 120-3, and so on), an offset from the expected received power of the reference signal, a fractional power control factor for transmitting the reference signal, or configurations of pathloss reference signals to be transmitted by the set of second devices 120.

[00148] In some example embodiments, the first device 110 comprises a location server, and the second device (or 120-2, 120-3, and so on) comprises a network device.

[00149] In some example embodiments, an apparatus capable of performing the method 900 (for example, the first device 110) may comprise means for performing the respective steps of the method 900. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[00150] In some example embodiments, the apparatus comprises means for receiving, at a first device from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device; means for determining, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices; and means for providing the at least one set of power control parameters to the terminal device.

[00151] In some example embodiments, the power control information comprises at least one of the following: received power of the reference signal expected by a second device of the set of second devices, an offset from the expected received power of the reference signal, a fractional power control factor associated with the second device, information on a pathloss reference signal to be transmitted by the second device to the terminal device for determining pathloss between the second device and the terminal device, or information on a beam of the second device to be used during reception of the reference signal.

[00152] In some example embodiments, the expected received power of the reference signal comprises at least one of the following: power of the reference signal sufficient for the reference signal to be detectable by the second device, or power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

[00153] In some example embodiments, the means for determining the at least one set of power control parameters comprises: means for determining a subset of the set of second devices to perform positioning of the terminal device; and means for determining one set of power control parameters such that the reference signal transmitted by the terminal device is detectable by the subset of second devices.

[00154] In some example embodiments, the means for determining the at least one set of power control parameters comprises: means for dividing the set of second devices into a plurality of groups; and means for determining a plurality of sets of power control parameters for the plurality of groups, respectively.

[00155] In some example embodiments, the set of second devices includes a serving device of the terminal device, and the means for dividing the set of second devices into the plurality of groups comprises at least one of the following: means for determining the plurality of groups based on distances between the serving device and other second devices of the set of second devices; means for determining the plurality of groups such that second devices in each of the plurality of groups are located in a region with a predefined size; means for determining the plurality of groups based on received powers at the terminal device associated with reference signals transmitted by the set of second devices; and means for determining the plurality of groups based on a mobility measurement report of the terminal device.

[00156] In some example embodiments, the set of second devices includes a serving device of the terminal device, and the apparatus further comprises: means for transmitting, to the serving device, information on the grouping of the set of second devices.

[00157] In some example embodiments, the set of power control parameters comprises at least one of the following: received power of the reference signal expected by the set of second devices, an offset from the expected received power of the reference signal, a fractional power control factor for transmitting the reference signal, or configurations of pathloss reference signals to be transmitted by the set of second devices.

[00158] In some example embodiments, the set of second devices includes a serving device of the terminal device, and the means for providing the at least one set of power control parameters to the terminal device comprises: means for transmitting the at least one set of power control parameters to the terminal device through the serving device.

[00159] In some example embodiments, the set of second devices includes a serving device and a non-serving device of the terminal device, and the apparatus further comprises: means for transmitting the at least one set of power control parameters to the non-serving device.

[00160] In some example embodiments, the first device comprises a location server, and the set of second devices comprises network devices.

[00161] In some example embodiments, the apparatus further comprises means for performing other steps in some example embodiments of the method 900. In some example embodiments, the means comprises at least one processor; and at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

[00162] In some example embodiments, an apparatus capable of performing the method 1000 (for example, the second device 120-1, 120-2, or 120-3, and so on) may comprise means for performing the respective steps of the method 1000. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[00163] In some example embodiments, the apparatus comprises means for transmitting, at a second device to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device; means for receiving, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information; and means for performing at least one positioning measurement based on the received reference signal from the terminal device.

[00164] In some example embodiments, the power control information comprises at least one of the following: received power of the reference signal expected by the second device, an offset from the expected received power of the reference signal, a fractional power control factor associated with the second device, information on a pathloss reference signal to be transmitted by the second device to the terminal device for determining pathloss between the second device and the terminal device, or information on a beam of the second device to be used during reception of the reference signal.

[00165] In some example embodiments, the expected received power of the reference signal comprises at least one of the following: power of the reference signal sufficient for the reference signal to be detectable by the second device, or power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

[00166] In some example embodiments, the second device is a serving device of the terminal device, and the apparatus further comprises: means for receiving the set of power control parameters from the first device; and means for transmitting the set of power control parameters to the terminal device.

[00167] In some example embodiments, the apparatus further comprises: in accordance with a determination that estimated interference, to be caused by the transmission of the reference signal using the set of power control parameters, exceeds a predefined threshold, means for adjusting the set of power control parameters prior to transmitting the set of power control parameters to the terminal device.

[00168] In some example embodiments, the second device is a serving device of the terminal device, and the apparatus further comprises: means for receiving, from the first device, a plurality of sets of power control parameters for the terminal device to transmit the reference signal; means for selecting, from the plurality of sets of power control parameters, a target set of power control parameters as the set of power control parameters used by the terminal device to transmit the reference signal; and means for transmitting the target set of power control parameters to the terminal device.

[00169] In some example embodiments, the second device is a serving device of the terminal device, and the apparatus further comprises: means for receiving, from the first device, a plurality of sets of power control parameters including the set of power control parameters; means for determining respective sets of resources associated with the plurality of sets of power control parameters; and means for configuring the terminal device to transmit the reference signal using the plurality sets of power control parameters and the respective sets of resources.

[00170] In some example embodiments, the second device is a serving device of the terminal device, and the apparatus further comprises: means for receiving, from the first device, information on grouping of a set of second devices including the second device into a plurality of groups; means for receiving, from the first device, respective sets of power control parameters for the plurality of groups; and means for configuring the terminal device to transmit the reference signal to the plurality of groups using the respective sets of power control parameters.

[00171] In some example embodiments, the apparatus further comprises: means for receiving the set of power control parameters from the first device; and means for updating, based on the set of power control parameters, a measurement configuration for performing the at least one positioning measurement.

[00172] In some example embodiments, the set of power control parameters comprises at least one of the following: received power of the reference signal expected by a set of second devices including the second device, an offset from the expected received power of the reference signal, a fractional power control factor for transmitting the reference signal, or configurations of pathloss reference signals to be transmitted by the set of second devices.

[00173] In some example embodiments, the first device comprises a location server, and the second device comprises a network device.

[00174] In some example embodiments, the apparatus further comprises means for performing other steps in some example embodiments of the method 1000. In some example embodiments, the means comprises at least one processor; and at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

[00175] Fig. 11 illustrates a simplified block diagram of a device 1100 that is suitable for implementing example embodiments of the present disclosure. The device 1100 may be provided to implement a communication device, for example the first device 110, the set of second devices 120, and the terminal device 130 as shown in Fig. 1. As shown, the device 1100 includes one or more processors 1110, one or more memories 1120 coupled to the processor 1110, and one or more communication modules 1140 coupled to the processor 1110.

[00176] The communication module 1140 is for bidirectional communications. The communication module 1140 has at least one antenna to facilitate communications. The communication interface may represent any interface that is necessary for communications with other network elements.

[00177] The processor 1110 may be of any type suitable to the local technical network and may include one or more of the following: general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 1100 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time to a clock which synchronizes the main processor.

[00178] The memory 1120 may include one or more non-volatile memories and one or more volatile memories. Examples of the non-volatile memories include, but are not limited to, a Read Only Memory (ROM) 1124, an electrically programmable read only memory (EPROM), a flash memory, a hard disk, a compact disc (CD), a digital video disk (DVD), and other magnetic storage and/or optical storage. Examples of the volatile memories include, but are not limited to, a random access memory (RAM) 1122 and other volatile memories that will not last in the power-down duration.

[00179] A computer program 1130 includes computer executable instructions that are executed by the associated processor 1110. The computer program 1130 may be stored in the ROM 1124. The processor 1110 may perform any suitable actions and processing by loading the computer program 1130 into the RAM 1122.

[00180] The example embodiments of the present disclosure may be implemented by means of the computer program 1130 so that the device 1100 may perform any process of the disclosure as discussed with reference to Fig. 9 or 10. The example embodiments of the present disclosure may also be implemented by hardware or by a combination of software and hardware.

[00181] In some example embodiments, the computer program 1130 may be tangibly contained in a computer readable medium which may be included in the device 1100 (such as in the memory 1120) or other storage devices that are accessible by the device 1100. The device 1100 may load the computer program 1130 from the computer readable medium to the RAM 1122 for execution. The computer readable medium may include any types of tangible non-volatile storage, such as ROM, EPROM, a flash memory, a hard disk, CD, DVD, and the like.

[00182] Fig. 12 illustrates a block diagram of an example computer readable medium 1200 in accordance with some example embodiments of the present disclosure. In the example of Fig. 12, the computer readable medium 1200 is in form of CD or DVD. The computer readable medium 1200 has the computer program 1130 stored thereon.

[00183] Generally, various example embodiments of the present disclosure may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device. While various aspects of example embodiments of the present disclosure are illustrated and described as block diagrams, flowcharts, or using some other pictorial representations, it is to be understood that the block, apparatus, system, technique or method described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[00184] The present disclosure also provides at least one computer program product tangibly stored on a non-transitory computer readable storage medium. The computer program product includes computer-executable instructions, such as those included in program modules, being executed in a device on a target real or virtual processor, to carry out the method 900 or 1000 as described above with reference to Fig. 9 or 10. Generally, program modules include routines, programs, libraries, objects, classes, components, data structures, or the like that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or split between program modules as desired in various example embodiments. Machine-executable instructions for program modules may be executed within a local or distributed device. In a distributed device, program modules may be located in both local and remote storage media.

[00185] Program code for carrying out methods of the present disclosure may be written in any combination of one or more programming languages. These program codes may be provided to a processor or controller of a general purpose computer, special purpose computer, or other programmable data processing apparatus, such that the program codes, when executed by the processor or controller, cause the functions/operations specified in the flowcharts and/or block diagrams to be implemented. The program code may execute entirely on a machine, partly on the machine, as a stand-alone software package, partly on the machine and partly on a remote machine or entirely on the remote machine or server.

[00186] In the context of the present disclosure, the computer program codes or related data may be carried by any suitable carrier to enable the device, apparatus or processor to perform various processes and operations as described above. Examples of the carrier include a signal, a computer readable medium, and the like.

[00187] The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable medium may include but not limited to an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium would include an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[00188] Further, while operations are depicted in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the present disclosure, but rather as descriptions of features that may be specific to particular example embodiments. Certain features that are described in the context of separate example embodiments may also be implemented in combination in a single example embodiment. Conversely, various features that are described in the context of a single example embodiment may also be implemented in multiple example embodiments separately or in any suitable sub-combination.

[00189] Although the present disclosure has been described in languages specific to structural features and/or methodological acts, it is to be understood that the present disclosure defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

WHAT IS CLAIMED IS:

1. A first device comprising:

at least one processor; and

at least one memory storing computer program codes;

the at least one memory and the computer program codes being configured, with the at least one processor, to cause the first device to:

receive, from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device;

determine, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices; and

provide the at least one set of power control parameters to the terminal device.

2. The first device of claim 1, wherein the power control information comprises at least one of the following:

received power of the reference signal expected by a second device of the set of second devices,

an offset from the expected received power of the reference signal,

a fractional power control factor associated with the second device,

information on a pathloss reference signal to be transmitted by the second device to the terminal device for determining pathloss between the second device and the terminal device, or

information on a beam of the second device to be used during reception of the reference signal.

3. The first device of claim 2, wherein the expected received power of the reference signal comprises at least one of the following:

power of the reference signal sufficient for the reference signal to be detectable by the second device, or

power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

4. The first device of claim 1, wherein the first device is caused to determine the at least one set of power control parameters by:

determining a subset of the set of second devices to perform positioning of the terminal device; and

determining one set of power control parameters such that the reference signal transmitted by the terminal device is detectable by the subset of second devices.

5. The first device of claim 1, wherein the first device is caused to determine the at least one set of power control parameters by:

dividing the set of second devices into a plurality of groups; and

determining a plurality of sets of power control parameters for the plurality of groups, respectively.

6. The first device of claim 5, wherein the set of second devices includes a serving device of the terminal device, and wherein the first device is caused to divide the set of second devices into the plurality of groups by at least one of the following:

determining the plurality of groups based on distances between the serving device and other second devices of the set of second devices;

determining the plurality of groups such that second devices in each of the plurality of groups are located in a region with a predefined size;

determining the plurality of groups based on received powers at the terminal device associated with reference signals transmitted by the set of second devices; and

determining the plurality of groups based on a mobility measurement report of the terminal device.

7. The first device of claim 5, wherein the set of second devices includes a serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the first device to:

transmit, to the serving device, information on the grouping of the set of second devices.

8. The first device of claim 1, wherein the set of power control parameters comprises at least one of the following:

received power of the reference signal expected by the set of second devices,

an offset from the expected received power of the reference signal,

a fractional power control factor for transmitting the reference signal, or

configurations of pathloss reference signals to be transmitted by the set of second devices.

9. The first device of claim 1, wherein the set of second devices includes a serving device of the terminal device, and wherein the first device is caused to provide the at least one set of power control parameters to the terminal device by:

transmitting the at least one set of power control parameters to the terminal device through the serving device.

10. The first device of claim 1, wherein the set of second devices includes a serving device and a non-serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the first device to:

transmit the at least one set of power control parameters to the non-serving device.

11. The first device of claim 1, wherein the first device comprises a location server, and the set of second devices comprises network devices.

12. A second device comprising:

at least one processor; and

at least one memory storing computer program codes;

the at least one memory and the computer program codes being configured, with the at least one processor, to cause the second device to:

transmit, to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device;

receive, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information; and perform at least one positioning measurement based on the received reference signal from the terminal device.

13. The second device of claim 12, wherein the power control information comprises at least one of the following:

received power of the reference signal expected by the second device,

an offset from the expected received power of the reference signal,

a fractional power control factor associated with the second device,

information on a pathloss reference signal to be transmitted by the second device to the terminal device for determining pathloss between the second device and the terminal device, or

information on a beam of the second device to be used during reception of the reference signal.

14. The second device of claim 13, wherein the expected received power of the reference signal comprises at least one of the following:

power of the reference signal sufficient for the reference signal to be detectable by the second device, or

power of the reference signal sufficient for achieving a predefined positioning measurement quality using the reference signal.

15. The second device of claim 12, wherein the second device is a serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

receive the set of power control parameters from the first device; and

transmit the set of power control parameters to the terminal device.

16. The second device of claim 15, wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

in accordance with a determination that estimated interference, to be caused by the transmission of the reference signal using the set of power control parameters, exceeds a predefined threshold, adjust the set of power control parameters prior to transmitting the set of power control parameters to the terminal device.

17. The second device of claim 12, wherein the second device is a serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

receive, from the first device, a plurality of sets of power control parameters for the terminal device to transmit the reference signal;

select, from the plurality of sets of power control parameters, a target set of power control parameters as the set of power control parameters used by the terminal device to transmit the reference signal; and

transmit the target set of power control parameters to the terminal device.

18. The second device of claim 12, wherein the second device is a serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

receive, from the first device, a plurality of sets of power control parameters including the set of power control parameters;

determine respective sets of resources associated with the plurality of sets of power control parameters; and

configure the terminal device to transmit the reference signal using the plurality sets of power control parameters and the respective sets of resources.

19. The second device of claim 12, wherein the second device is a serving device of the terminal device, and wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

receive, from the first device, information on grouping of a set of second devices including the second device into a plurality of groups;

receive, from the first device, respective sets of power control parameters for the plurality of groups; and

configure the terminal device to transmit the reference signal to the plurality of groups using the respective sets of power control parameters.

20. The second device of claim 12, wherein the at least one memory and the computer program codes are further configured, with the at least one processor, to cause the second device to:

receive the set of power control parameters from the first device; and

update, based on the set of power control parameters, a measurement configuration for performing the at least one positioning measurement.

21. The second device of claim 12, wherein the set of power control parameters comprises at least one of the following:

received power of the reference signal expected by a set of second devices including the second device,

an offset from the expected received power of the reference signal,

a fractional power control factor for transmitting the reference signal, or

configurations of pathloss reference signals to be transmitted by the set of second devices.

22. The second device of claim 12, wherein the first device comprises a location server, and the second device comprises a network device.

23. A method comprising:

receiving, at a first device from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device;

determining, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices; and

providing the at least one set of power control parameters to the terminal device.

24. A method comprising:

transmitting, at a second device to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device;

receiving, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information; and

performing at least one positioning measurement based on the received reference signal from the terminal device.

25. An apparatus comprising:

means for receiving, at a first device from a set of second devices related to a terminal device, power control information for controlling transmission power of a reference signal to be transmitted by the terminal device to the set of second devices for positioning the terminal device;

means for determining, based at least on the received power control information, at least one set of power control parameters for the terminal device to transmit the reference signal to the set of second devices; and

means for providing the at least one set of power control parameters to the terminal device.

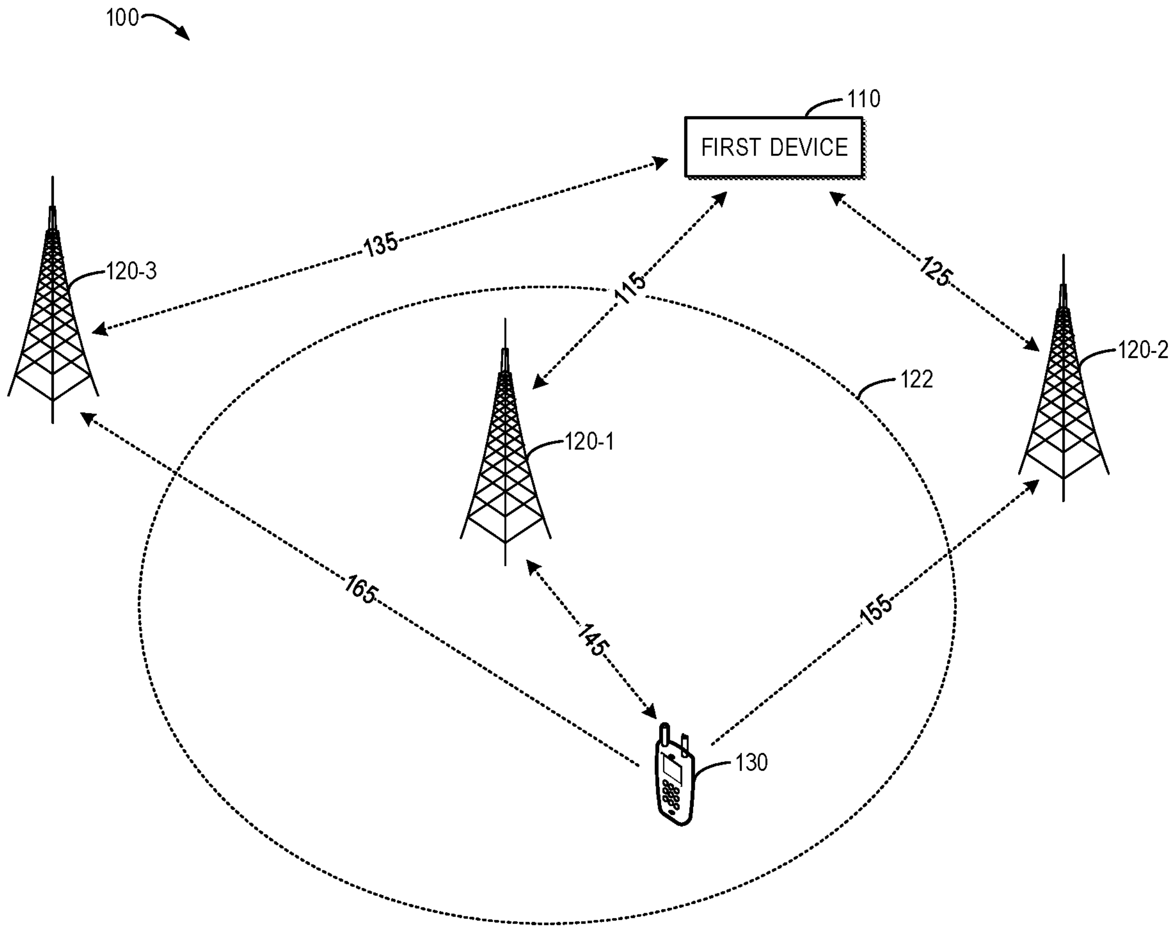
26. An apparatus comprising:

means for transmitting, at a second device to a first device, power control information for controlling transmission power of a reference signal to be transmitted by a terminal device to the second device for positioning the terminal device;

means for receiving, from the terminal device, the reference signal transmitted using a set of power control parameters determined by the first device based on the power control information; and

means for performing at least one positioning measurement based on the received reference signal from the terminal device.

27. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method of claim 23 or 24.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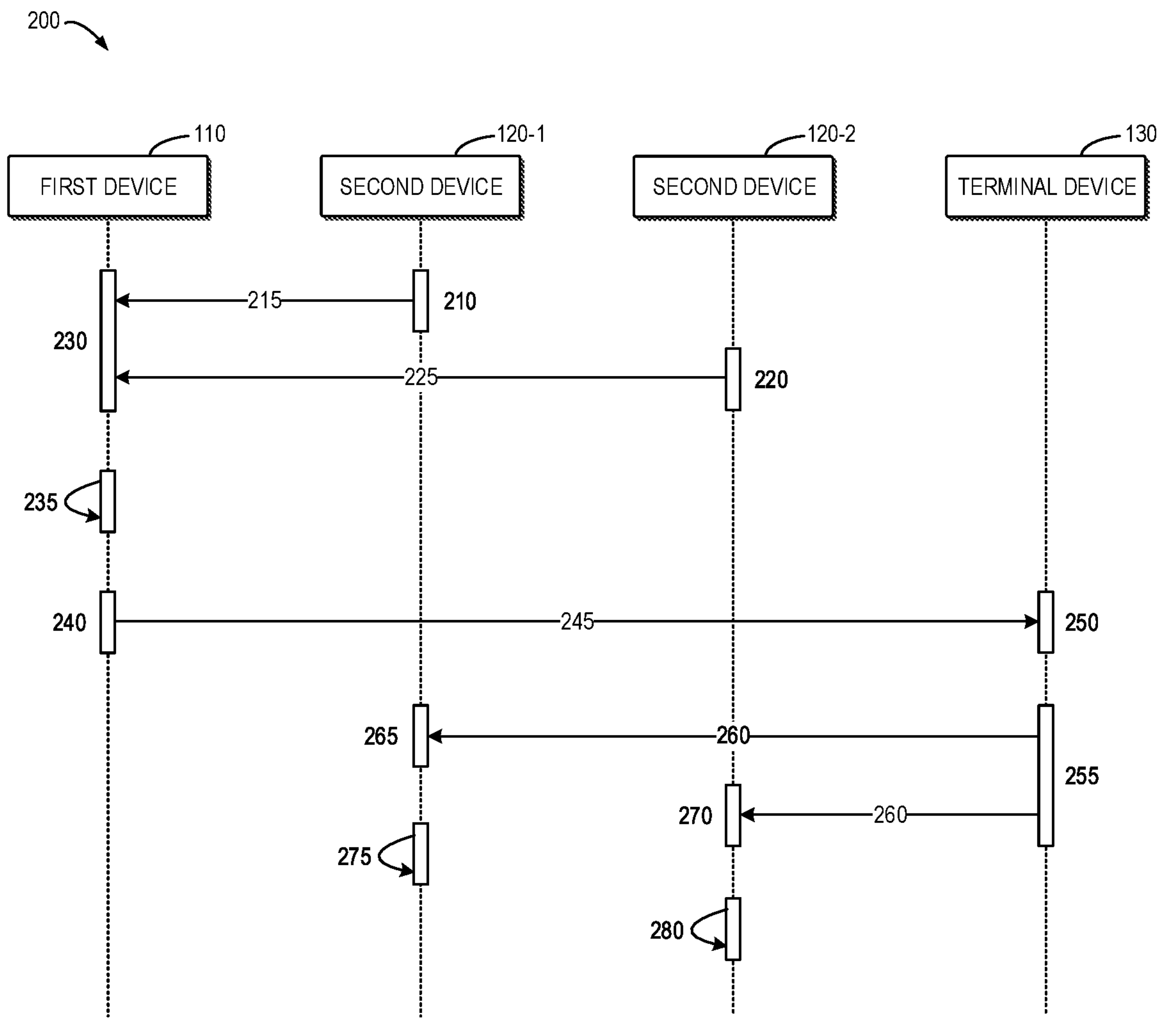
130

FIG. 1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SECOND DEVICE
SECOND DEVICE
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FIG. 2

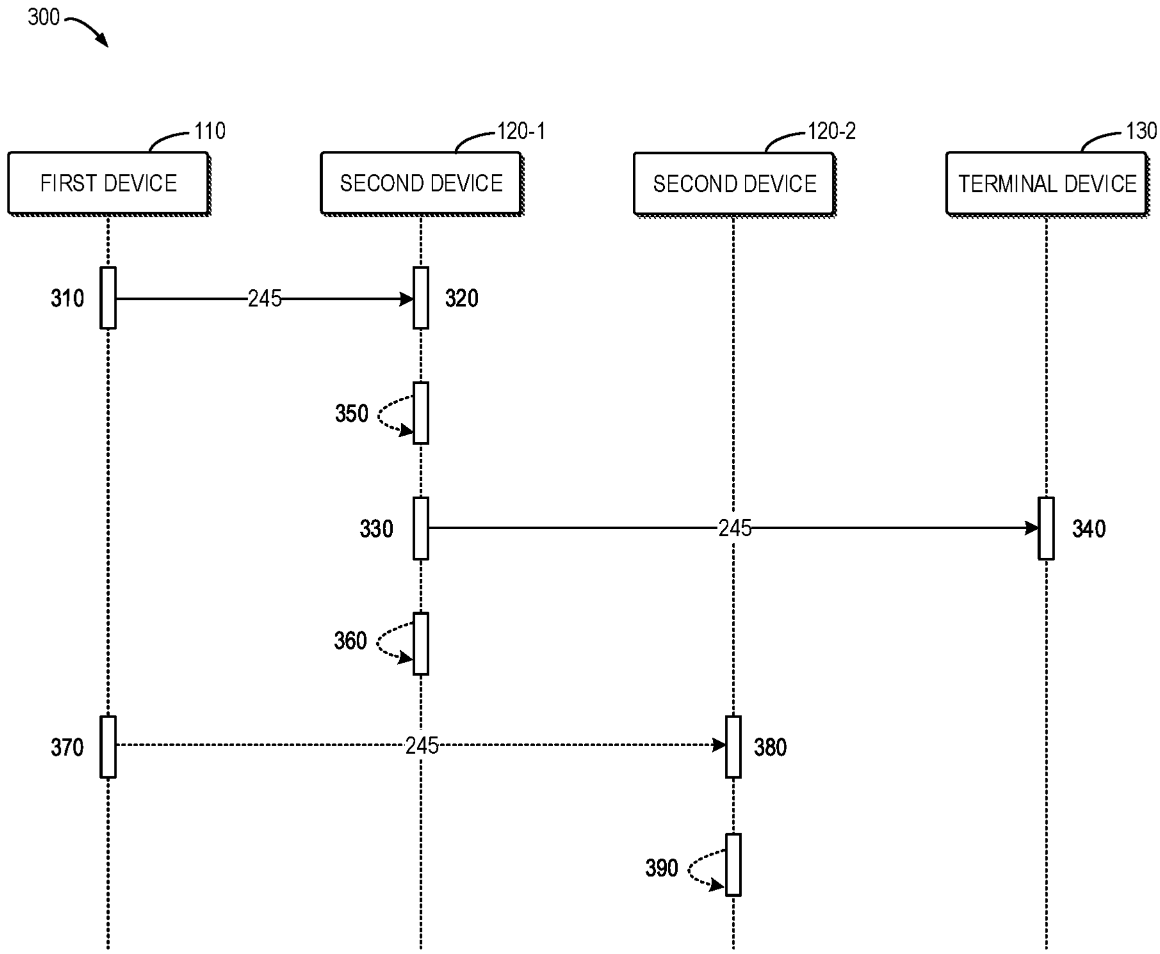
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FIG. 3

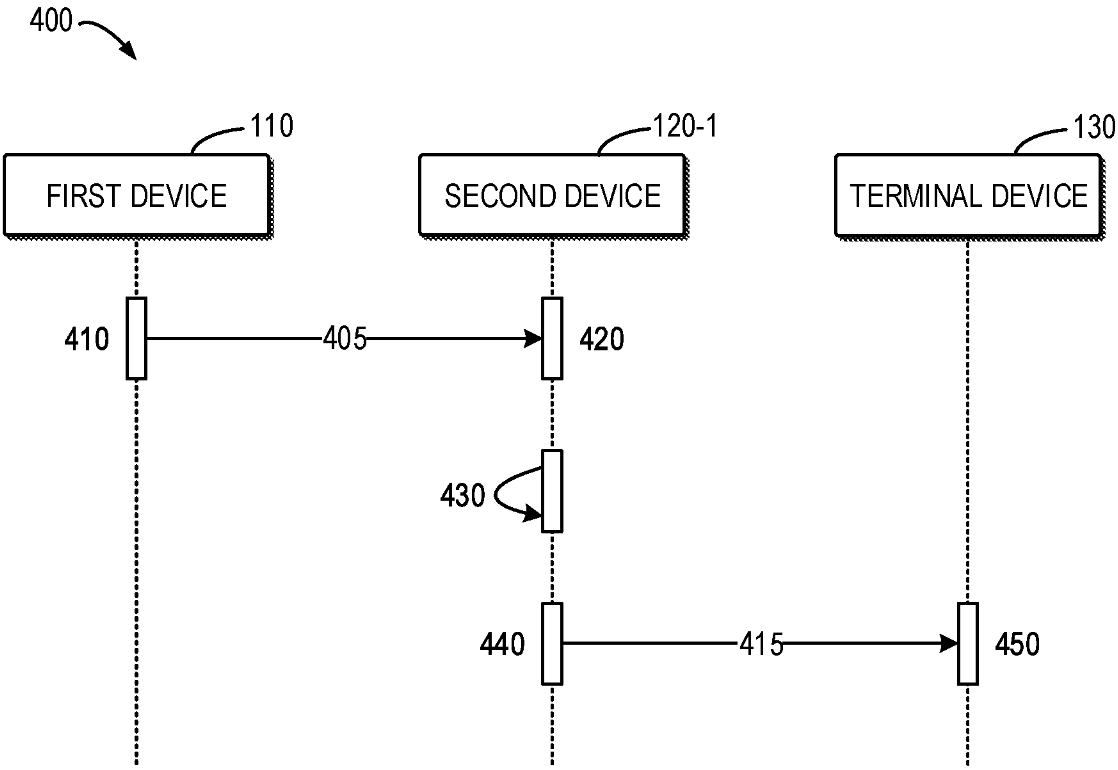
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FIG. 4

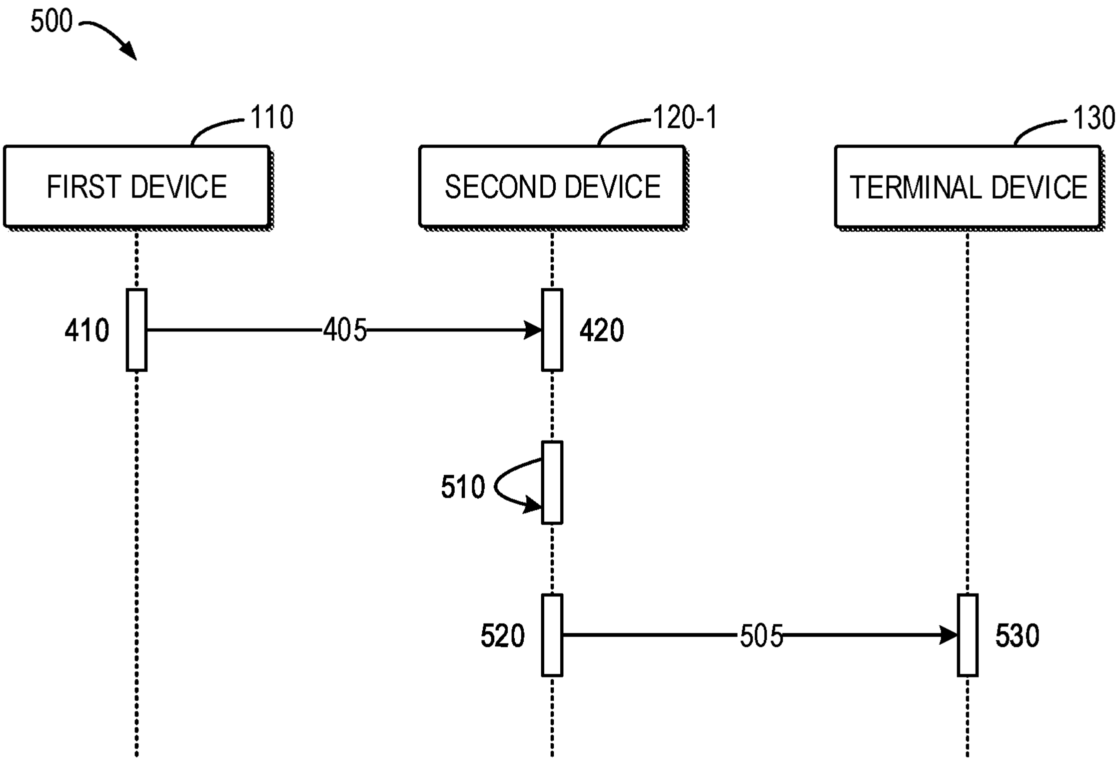
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FIG. 5

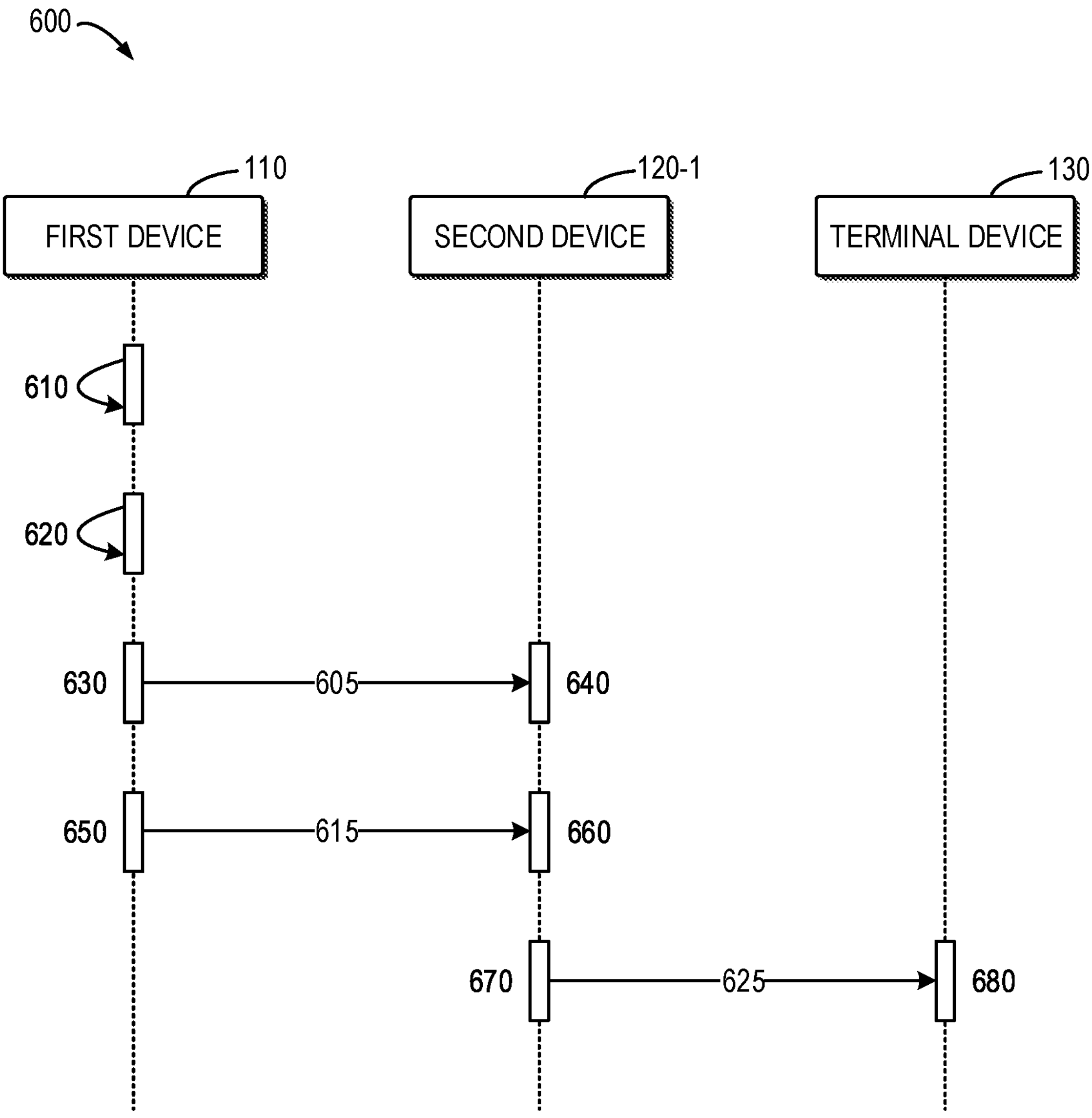
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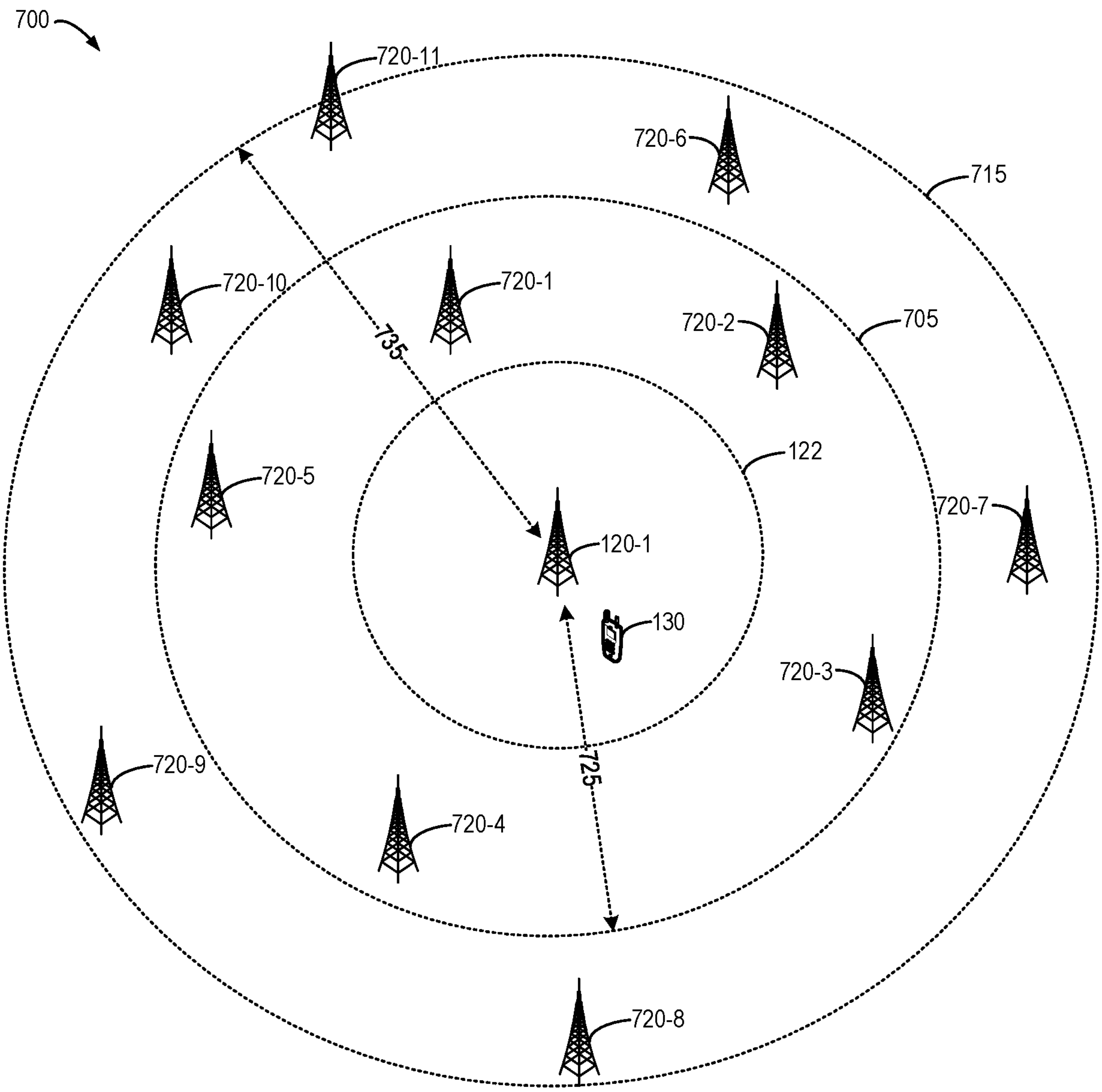
FIG. 6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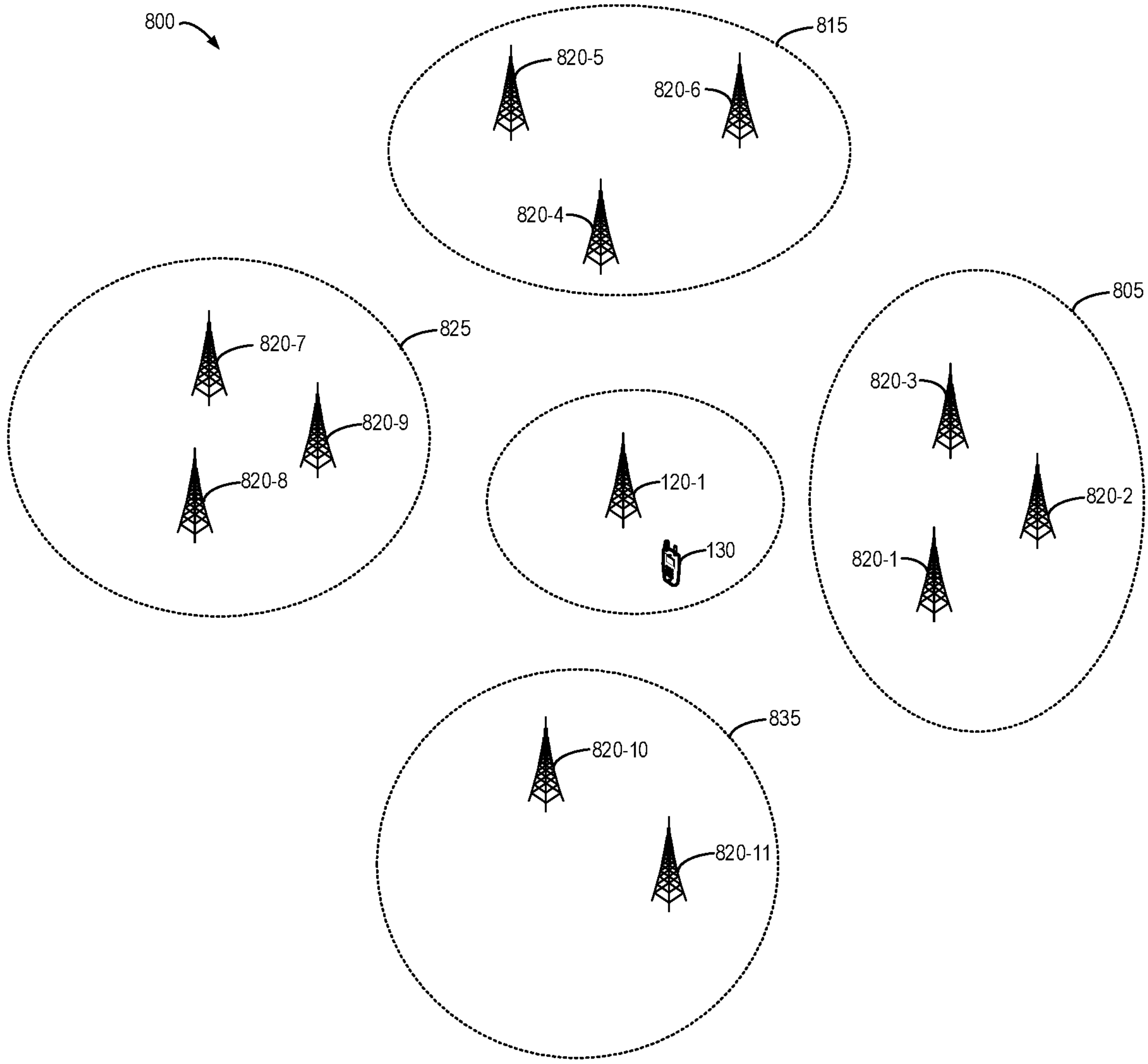
720-8

FIG. 7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820-11

FIG. 8

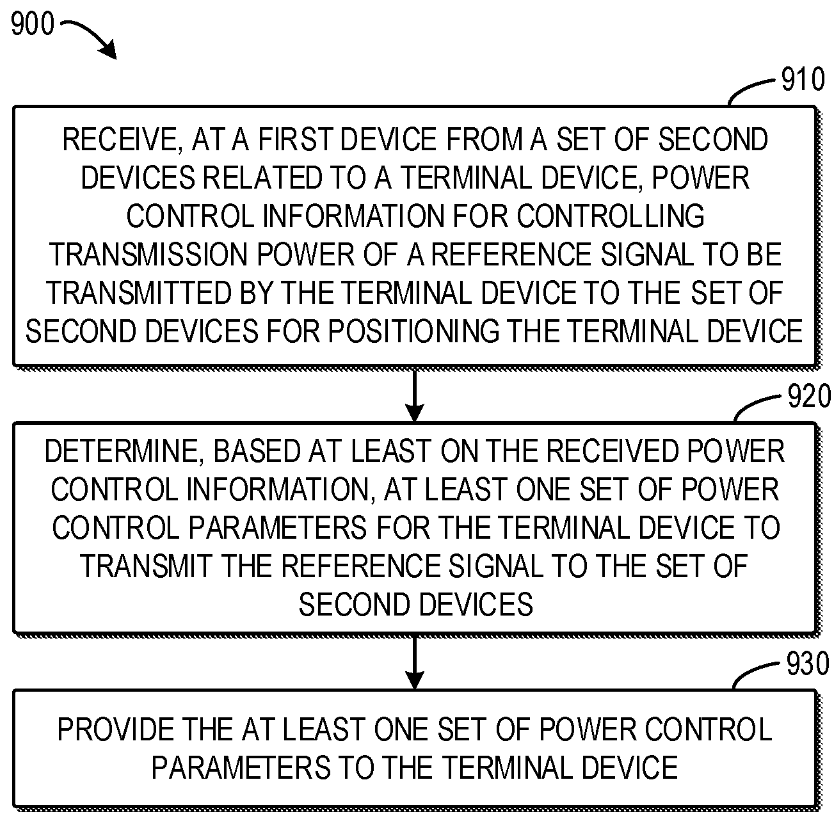

900
910
RECEIVE, AT A FIRST DEVICE FROM A SET OF SECOND DEVICES RELATED TO A TERMINAL DEVICE, POWER CONTROL INFORMATION FOR CONTROLLING TRANSMISSION POWER OF A REFERENCE SIGNAL TO BE TRANSMITTED BY THE TERMINAL DEVICE TO THE SET OF SECOND DEVICES FOR POSITIONING THE TERMINAL DEVICE
920
DETERMINE, BASED AT LEAST ON THE RECEIVED POWER CONTROL INFORMATION, AT LEAST ONE SET OF POWER CONTROL PARAMETERS FOR THE TERMINAL DEVICE TO TRANSMIT THE REFERENCE SIGNAL TO THE SET OF SECOND DEVICES
930
PROVIDE THE AT LEAST ONE SET OF POWER CONTROL PARAMETERS TO THE TERMINAL DEVICE

FIG. 9

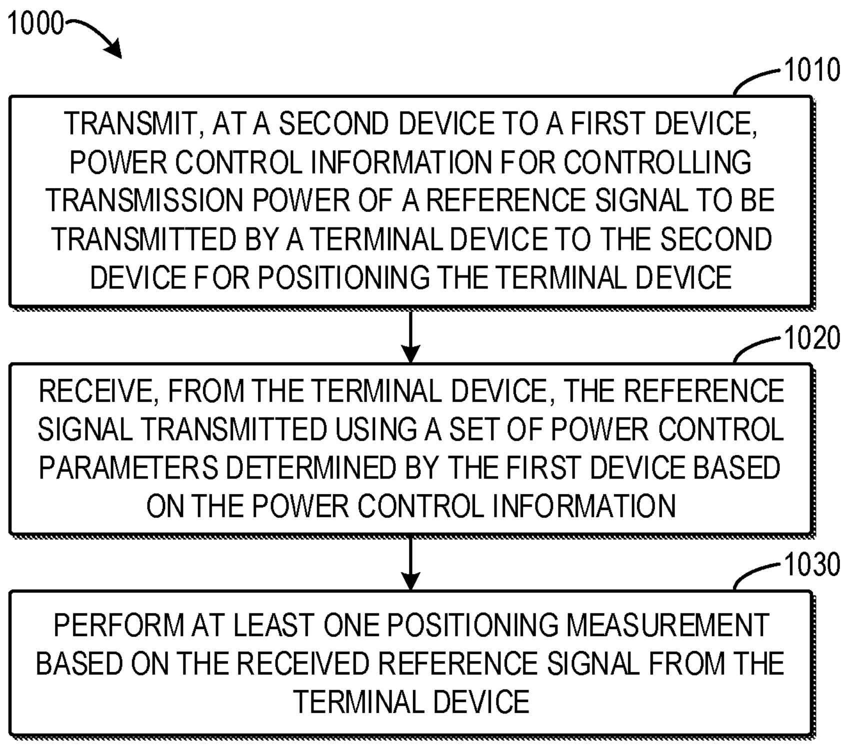
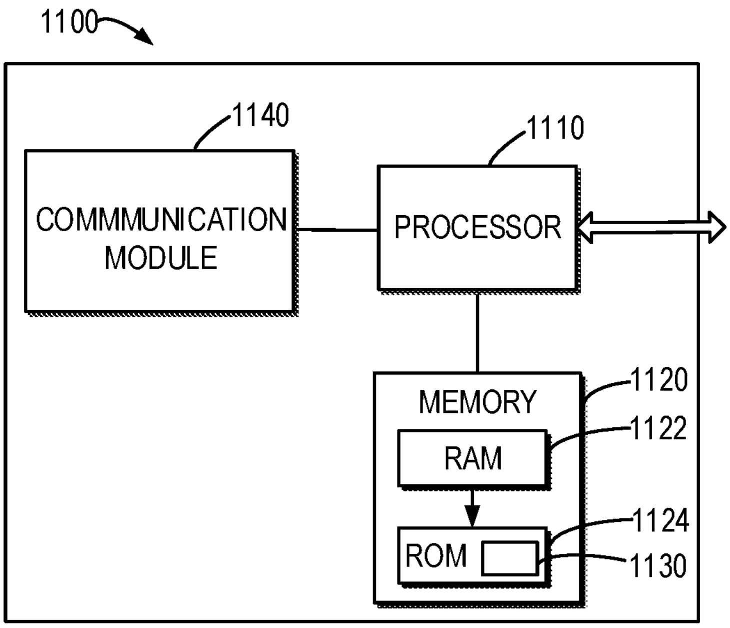

1000
1010
TRANSMIT, AT A SECOND DEVICE TO A FIRST DEVICE, POWER CONTROL INFORMATION FOR CONTROLLING TRANSMISSION POWER OF A REFERENCE SIGNAL TO BE TRANSMITTED BY A TERMINAL DEVICE TO THE SECOND DEVICE FOR POSITIONING THE TERMINAL DEVICE
1020
RECEIVE, FROM THE TERMINAL DEVICE, THE REFERENCE SIGNAL TRANSMITTED USING A SET OF POWER CONTROL PARAMETERS DETERMINED BY THE FIRST DEVICE BASED ON THE POWER CONTROL INFORMATION
1030
PERFORM AT LEAST ONE POSITIONING MEASUREMENT BASED ON THE RECEIVED REFERENCE SIGNAL FROM THE TERMINAL DEVICE

FIG. 10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MODULE
PROCESSOR
MEMORY
1120
RAM
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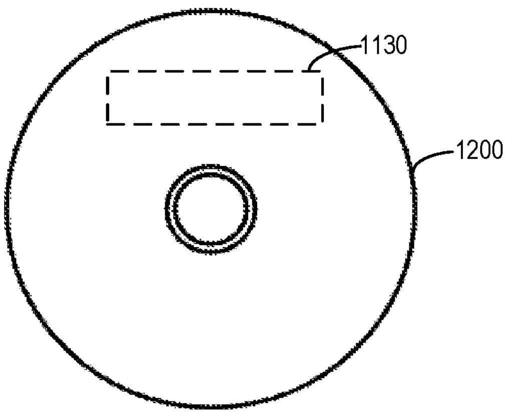
ROM
1124
1130

FIG. 11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1200

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/075350

A. CLASSIFICATION OF SUBJECT MATTER

H04W 52/14(2009.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,CNKI,WPI,EPODOC,3GPP:power control, reference signal, terminal, UE, position, location, power, parameter, base station, AP, access point, transmission

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2019127462 A1 (GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORP., LTD.) 04 July 2019 (2019-07-04) description, page 7 to page 10	1-27
A	CN 103379603 A (CHINA ACADEMIC OF TELECOMMUCATION TECHNOLOGY) 30 October 2013 (2013-10-30) the whole document	1-27
A	CN 103535096 A (FUJITSU LTD.) 22 January 2014 (2014-01-22) the whole document	1-27
A	CN 101584132 A (NTT DOCOMO INC.) 18 November 2009 (2009-11-18) the whole document	1-27
A	US 2019261281 A1 (LENOVO SINGAPORE PTE. LTD.) 22 August 2019 (2019-08-22) the whole document	1-27

☐ Further documents are listed in the continuation of Box C.

☑ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 November 2020	**24 November 2020**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**YU,Feng**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(010)-53961793**

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2019127462	A1	04 July 2019	AU	2017445532	A1	06 August 2020
				CN	111543108	A	14 August 2020
CN	103379603	A	30 October 2013	WO	2013155914	A1	24 October 2013
CN	103535096	A	22 January 2014	US	2014119321	A1	01 May 2014
				KR	20140034278	A	19 March 2014
				WO	2013010307	A1	24 January 2013
				EP	2733999	A1	21 May 2014
				JP	2014521258	A	25 August 2014
CN	101584132	A	18 November 2009	US	2010103867	A1	29 April 2010
				EP	2120370	A1	18 November 2009
				WO	2008084700	A1	17 July 2008
				JP	2008193439	A	21 August 2008
				CN	102932890	A	13 February 2013
				RU	2009129217	A	20 February 2011
				KR	20090107029	A	12 October 2009
				CA	2673383	A1	17 July 2008
				BR	PI0720894	A2	10 June 2014
				MX	2009007187	A	15 July 2009
				PT	2120370	T	27 April 2018
US	2019261281	A1	22 August 2019	WO	2019159002	A1	22 August 2019
				US	2019261280	A1	22 August 2019
				WO	2019159008	A1	22 August 2019