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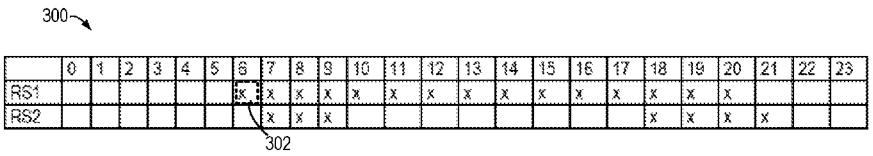


Fig. 3

(57) Abstract: Example embodiments of the present disclosure relate to indication of reference signal presence. A first device receives, from a second device, information indicating presence of at least one reference signal during one or more time windows. The first device determines, based on the information, whether to monitor for the at least one reference signal during at least one of the one or more time windows. In accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first device is in a non-connected state, the first device monitors for the at least one reference signal from the second device during the at least one time window. This solution enables the first device in the non-connected state to monitor for the reference signal to improve time-frequency synchronization and potentially skip reception of the SSB burst (s), which can save energy consumption.

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INDICATION OF REFERENCE SIGNAL PRESENCE

FIELD

[0001] Embodiments of the present disclosure generally relate to the field of telecommunication and in particular, to methods, devices, apparatuses and computer readable storage medium for indication of reference signal presence.

BACKGROUND

[0002] The communication systems has been continuously enhanced due to both an increase in the types of devices using network resources as well as the amount of data and bandwidth being used by various applications, such as video streaming, operating on the terminals. Many terminal devices operating in the communication systems are typically low cost devices that have low power consumption, and thus have smaller batteries. Examples of such terminal devices include sensors (e.g., sensing environmental conditions) or microcontrollers in appliances or vending machines. The number of terminal devices in use is expected to be massive, thus leading to further development as networks attempt to accommodate for the disparate requirements of the different types of terminal devices. Work is ongoing to introduce enhancements to achieve even lower power consumption, to make more efficient use of network resources.

SUMMARY

[0003] The scope of protection sought for various embodiments of the invention is set out by the independent claims. The embodiments/examples and features, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention." Please note that the term "embodiments" or "examples" should be adapted accordingly to the terminology used in the application, i.e. if the term "examples" is used, then the statement should talk of "examples" accordingly, or if the term "embodiments" is used, then the statement should talk of "embodiments" accordingly.

[0004] In general, example embodiments of the present disclosure provide a solution for indicating presence of a reference signal. Embodiments that do not fall under the scope of

the claims, if any, are to be interpreted as examples useful for understanding various embodiments of the disclosure.

[0005] In a first aspect, there is provided a first device. The first device comprises at least one processor; and at least one memory including computer program code; where the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to receive, from a second device, information indicating presence of at least one reference signal during one or more time windows; determine, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first device is in a non-connected state, monitor for the at least one reference signal from the second device during the at least one time window.

[0006] In a second aspect, there is provided a second device. The second device comprises at least one processor; and at least one memory including computer program code; where the at least one memory and the computer program code are configured to, with the at least one processor, cause the second device to transmit, to a first device, information indicating presence of at least one reference signal during one or more time windows for the first device to monitor in a non-connected state; and perform, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

[0007] In a third aspect, there is provided a method. The method comprises receiving, by a first device and from a second device, information indicating presence of at least one reference signal during one or more time windows; determining, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first device is in a non-connected state, monitoring for the at least one reference signal from the second device during the at least one time window.

[0008] In a fourth aspect, there is provided a method. The method comprises transmitting, by a second device and to a first device, information indicating presence of at least one reference signal during one or more time windows for the first device to monitor in a non-connected state; and performing, based on the transmitted information,

transmission of the at least one reference signal during the one or more time windows.

[0009] In a fifth aspect, there is provided a first apparatus. The first apparatus comprises means for receiving, from a second apparatus, information indicating presence of at least one reference signal during one or more time windows; means for determining, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and means for in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first apparatus is in a non-connected state, monitoring for the at least one reference signal from the second apparatus during the at least one time window.

[0010] In a sixth aspect, there is provided a second apparatus. The second apparatus comprises means for transmitting, to a first apparatus, information indicating presence of at least one reference signal during one or more time windows for the first apparatus to monitor in a non-connected state; and means for performing, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

[0011] In a seventh aspect, there is provided a computer readable medium. The computer readable medium comprises program instructions for causing an apparatus to perform at least the method according to the third aspect.

[0012] In an eighth aspect, there is provided a computer readable medium. The computer readable medium comprises program instructions for causing an apparatus to perform at least the method according to the fourth aspect.

[0013] It is to be understood that the Summary section is not intended to identify key or essential features of 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

[0014] Some example embodiments will now be described with reference to the accompanying drawings, where:

[0015] Fig. 1 illustrates an example communication environment in which example embodiments of the present disclosure can be implemented;

[0016] Fig. 2 illustrates a signaling flow for communication according to some example embodiments of the present disclosure;

[0017] Fig. 3 illustrates an example of a timetable for indicating presence of reference signals according to some example embodiments of the present disclosure;

[0018] Fig. 4 illustrates a flowchart of a method implemented at a first device according to some example embodiments of the present disclosure;

[0019] Fig. 5 illustrates a flowchart of a method implemented at a second device according to some example embodiments of the present disclosure;

[0020] Fig. 6 illustrates a simplified block diagram of an apparatus that is suitable for implementing example embodiments of the present disclosure; and

[0021] Fig. 7 illustrates a block diagram of an example computer readable medium in accordance with some example embodiments of the present disclosure.

[0022] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

DETAILED DESCRIPTION

[0023] Principle of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these 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. Embodiments described herein can be implemented in various manners other than the ones described below.

[0024] 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.

[0025] 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 embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an 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 embodiments whether or not explicitly described.

[0026] It shall be understood that although the terms "first," "second" and 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.

[0027] The terminology used herein is for the purpose of describing particular 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, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0028] 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 (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0029] 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.

[0030] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as New Radio (NR), 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 fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. 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.

[0031] 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), an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, an Integrated Access and Backhaul (IAB) node, a low power node such as a femto, a pico, a non-terrestrial network (NTN) or non-ground network device such as a satellite network device, a low earth orbit (LEO) satellite and a geosynchronous earth orbit (GEO) satellite, an aircraft network device, and so forth, depending on the applied terminology and technology. In some example embodiments, radio access network (RAN) split architecture comprises a Centralized Unit (CU) and a Distributed Unit (DU) at an IAB donor node. An IAB node comprises a Mobile Terminal (IAB-MT) part that behaves like

a UE toward the parent node, and a DU part of an IAB node behaves like a base station toward the next-hop IAB node.

[0032] 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), 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 (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., 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. The terminal device may also correspond to a Mobile Termination (MT) part of an IAB node (e.g., a relay node). In the following description, the terms "terminal device", "communication device", "terminal", "user equipment" and "UE" may be used interchangeably.

[0033] As used herein, the term "resource," "transmission resource," "resource block," "physical resource block" (PRB), "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.

[0034] Fig. 1 shows an example communication environment 100 in which example

embodiments of the present disclosure can be implemented. In the communication environment 100, a plurality of communication devices, including one or more first devices 110-1, 110-2, and 110-3 can communicate with a second device 120.

[0035] In the example of Fig. 1, the first devices 110-1, 110-2, and 110-3 are illustrated as terminal devices while the second device 120 is illustrated as a network device serving the terminal device. The serving area of the second device 120 may be called a cell 102. For ease of discussion, the first devices 110-1, 110-2, and 110-3 are collectively or individually referred to as first devices 110.

[0036] It is to be understood that the number of devices and their connections shown in Fig. 1 are only for the purpose of illustration without suggesting any limitation. The environment 100 may include any suitable number of devices adapted for implementing embodiments of the present disclosure. Although not shown, it would be appreciated that one or more additional devices may be located in the cell 102, and one or more additional cells may be deployed in the environment 100. It is noted that although illustrated as a network device, the second device 120 may be other device than a network device. Although illustrated as a terminal device, a first device 110 may be other device than a terminal device.

[0037] In some example embodiments, if the first device 110 is a terminal device and the second device 120 is a network device, a link from the second device 120 to the first device 110 is referred to as a downlink (DL), while a link from the first device 110 to the second device 120 is referred to as an uplink (UL). In DL, the second device 120 is a transmitting (TX) device (or a transmitter) and the first device 110 is a receiving (RX) device (or a receiver). In UL, the first device 110 is a TX device (or a transmitter) and the second device 120 is a RX device (or a receiver).

[0038] 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.

[0039] The second device 120 may transmit signals on multiple beams which are associated with different coverage areas. A beam is generated using an antenna array (including a plurality of antennas) associated with a communication device (e.g., the second device 120 or the first device 110). A beam is the main lobe of the radiation pattern of the antenna or antenna array. A first device 110 may attempt to receive the signals from the second device 120 transmitted on the possible beams or may be configured with the beam(s) on which the signals are to be transmitted.

[0040] During operation, a first device 110 can transition between a connected state and a non-connected state. In the connected state, a connection is established between the first device 110 and the second device 120and thus the first device 110 can perform normal communication with the network device via the connection. The non-connected state may include an idle state, an inactive state, a sleep state, a disconnected state, or a low-power state. In the non-connected state, the first device 110 does not have any dedicated resources (e.g., time and frequency resources) for transmission and/or reception.

[0041] In some cases, the second device 120 may transmit a reference signal to the first device(s) 110. As used herein, a reference signal (RS) is a signal sequence (also referred to as "RS sequence") that is known by both the transmitter and the receiver. Among the various reference signals, one or more of them may be used by the first device 110 to perform time-frequency synchronization with the second device 120. Some examples of such reference signals may include a Tracking Reference Signal (TRS), a Channel State Information-Reference Signal (CSI-RS), and CSI-RS for time-frequency tracking. It should be understood that example embodiments of the present disclosure cover the cases of using all possible reference signals that can be used to perform time-frequency synchronization, such as a Sounding Reference Signal (SRS), a Positioning Reference Signal (PRS), a Demodulation Reference Signal (DM-RS), or the like.

[0042] For a first device in a connected state, the second device may dynamically transmit a configuration of CSI-RS or TRS. In the connected state, the first device may be able to

monitor for CSI-RS or TRS according to the received configuration from the second device.

[0043] For a first device in a non-connected state, it may also need to achieve time-frequency synchronization with the second device before communicating with the second device. For example, the first device can sleep with no receiver processing most of the time, and briefly wake up according to a predefined paging cycle to monitor if there is paging information transmitted from the second device. The first device may need to obtain time-frequency synchronization prior to monitoring for the paging information.

[0044] Conventionally, the first device in the non-connected state is configured to monitor for one or more Synchronization Signal Block (SSB) bursts from the second device. However, as the transmission of the SSB bursts is typically configured with large periodicities, the first device may operate actively for a relatively long time in order to successfully receive sufficient SSB bursts for the purpose of synchronization.

[0045] Although the reference signals other than the SSB bursts can also be used for synchronization, it is currently desired to avoid using the always-on type of reference signals for the first device in the non-connected state. On one hand, from the perspective of the second device, its power consumption will increase if the reference signals are transmitted to the first device(s) in the non-connected state even if there is no connected device operating in the cell 102. On the other hand, a large amount of signaling and resource overhead may be consumed for delivering the dynamic configuration of the reference signals, especially when the configuration is per beam. As an alternative, as the second device may transmit the reference signals to devices in the connected state, the first device in the non-connected state may blindly detect the reference signals. However, the blind detection may require large energy consumption of the devices in the non-connected state, which may not be beneficial.

[0046] According to some example embodiments of the present disclosure, there is provided a solution for indicating presence of a reference signal(s). In this solution, a first device receives information about presence of one or more reference signal(s) in one or more time windows. When the first device operates in a non-connected state, the first device can perform reference signal reception based on the received information, to monitor for one or more reference signals from the second device. The second device performs transmission of the one or more reference signals based on the information provided to the

first device. This solution enables the first device in the non-connected state to monitor for and detect the reference signal to improve time-frequency synchronization and potentially skip reception of the SSB burst(s), which can save energy consumption.

[0047] Example embodiments of the present disclosure will be described in detail below with reference to the accompanying drawings.

[0048] Reference is now made to Fig. 2, which shows a signaling flow 200 for communication according to some example embodiments of the present disclosure. For the purpose of discussion, the signaling flow 200 will be described with reference to Fig. 1. The signaling flow 200 involves the first device 110 and the second device 120 as illustrated in Fig. 1.

[0049] In operation, the second device 120 transmits 205, to the first device 110, information indicating presence or availability of at least one reference signal during one or more time windows.

[0050] A reference signal may be a signal used for time-frequency synchronization. In some example embodiments, the at least one reference signal may include one or more of CSI-RS, CSI-RS for time-frequency tracking, or TRS. In some examples, for each type of reference signal, for example, the CSI-RS or TRS, there may be a number of different signals which may include different signal sequences. For example, there may be a plurality of different TRSs, indexed by TRS1, TRS2, TRS2, or the like.

[0051] In some example embodiments, the information may be provided as a timetable, to indicate in which time window a reference signal is present. In some examples, the timetable may be bitmap-based, with each bit corresponding to one time window and indicating whether the reference signal is present or not in the time window. If the presence of more than one reference signal is to be notified to the first device 110, more than one timetable may be included.

[0052] In some example embodiments, the granularity of the time windows and the number of the time windows may be configurable, for example, by the second device 120. For example, the second device 120 may indicate the presence of one or more reference signals per 15 minutes, per hour, per day, or the like. The number of the time window may be determined according to the field of the timetable. Fig. 3 illustrates an example 300 of a timetable for indicating presence of reference signals according to some example embodiments of the present disclosure. In this example, a timetable includes a 24-bit field

to indicate presence or absence of each of RS1 and RS2 within 24 hours a day. The symbol 302 is corresponding to a single bit in the 24-bit field, used to indicate that the corresponding reference signal is present in the corresponding hour. From the timetable, the first device 110 may determine that RS1 is available from 6 o'clock to 20 o'clock, and RS2 is available during 7 o'clock to 9 o'clock and during 18 o'clock to 21 o'clock. It should be appreciated that the presence of a reference signal within a time window may be indicated in other fashions and Fig. 3 is provided for the purpose of illustration only.

[0053] In addition to the timetable, the information about the presence of the reference signal(s) may be provided in any other ways. For example, the information may indicate a start time and an end time (or the time duration) of presence of a reference signal. For example, to indicate that a reference signal is present from 7:00 am to 1: 00 pm in a day, the information may indicate the start time (7:00 am) and the duration (6 hours) of the presence. The indication of presence or absence of the reference signal for an entire day may be constructed by multiple of such start times and durations. Any indicating approaches may be utilized to create a pattern over the duration of a full day which the first device 110 can utilize to (based on its own understanding of time) determine whether or not the reference signal is available.

[0054] In some example embodiments, there may be different information (for example, different timetables) to indicate presence of a reference signal, for example, for different week days, different months, different areas, or the like. The second device 120 may configure the first device 110 with different timetables to indicate presence of a reference signal within the same or different time windows. For example, the different timetables may indicate the presence of the reference signal within the same hours of several week days, the same week days of several weeks, or the like. The second device 120 may then transmit information indicating one of the pre-configured timetables to the first device 110. In this way, the first device 110 may determine which timetable to be used.

[0055] In some example embodiments, the second device 120 may transmit the information about the presence of the at least one reference signal via system information (SI). The system information may be broadcasted to the first device 110 or may include on-demand system information. For the latter case, the first device 110 may be informed of the existence of the information about the presence of the reference signal(s), for example, from the broadcasted system information. The first device 110 may decide on its own whether to obtain such information and may request the second device 120 to provide

the information if needed. Upon receiving the request from the first device 110, the second device 120 may include the information about the presence of the reference signal(s) in on-demand system information transmitted to the first device 110.

[0056] In some other example embodiments, the information about the presence of the reference signal(s) may be transmitted to the first device 110 via Radio Resource Control (RRC) signaling, downlink control information (DCI), or a paging early indication (PEI). In some examples, the information may be obtained by the first device 110 when the first device 110 enters the cell 102 of the second device 120, or when the first device 110 operates in the connected state, or when the first device 110 transitions into the non-connected state, for example, when or after receiving a RRC release message from the second device 120. The information about the presence of the reference signal(s) may be included as a part of the RRC release message.

[0057] By receiving 210 the information about the presence of the at least one reference signal, the first device 110 can perform reference signal reception according to the information. Specifically, the first device 110 determines 215, based on the received information, whether to monitor for the at least one reference signal during one or more time windows.

[0058] In some example embodiments, the first device 110 may determine to monitor for one or more reference signals when it needs to obtain time-frequency synchronization with the second device 120. In some example embodiments, the first device 110 may decide to monitor for the reference signal(s) for other purposes.

[0059] If the first device 110 determines to monitor for the at least one reference signal at least one time window, the first device 110 monitors 220 for the at least one reference signal from the second device 120 during the at least one time window. The first device 110 is in a non-connected state when it determines whether to monitor for the reference signal(s) based on the information received at 210 or when it monitors for the reference signal(s).

[0060] As the first device 110 is informed of the presence of the reference signal(s) from the second device 120, the possibility of successfully receiving the reference signal(s) in the time window may be relatively higher. For other time windows during which the presence of the reference signal(s) is not specifically indicated, the first device 110 may determine whether not to monitor for the reference signal.

[0061] In some example embodiments, the first device 110 may have additionally received a configuration of the at least one reference signal, which indicates the time and/or frequency resource (for example, one or more transmission occasions) and/or the periodicity of the at least one reference signal. As such, the first device 110 may determine the specific occasions within the at least one time window to monitor for the at least one reference signal.

[0062] At the side of the second device 120, the second device 120 performs 225, based on the information provided to the first device 110, transmission of the at least one reference signal during the one or more time windows. According to the example embodiments of the present disclosure, the second device 120 may have the flexibility to determine whether and when to transmit a reference signal and inform the presence of the reference signal to the first device 110.

[0063] In some example embodiments, the second device 120 may determine during which time window the at least one reference signal is present based on the number of first devices in connected state within its cell 102. Since the at least one reference signal may always be transmitted to the first devices in connected state, the second device 120 may not consume much extra power to transmit it to the first devices in non-connected state. For example, the second device 120 may predict the number of first devices in connected state in different time windows based on historical statistics about the connected first devices. If a larger number of first devices in non-connected state are expected in a certain time window, the second device 120 may determine to indicate to the first device 110 about the presence of the reference signal(s) in that time window.

[0064] In some example embodiments, the information may indicate the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within the cell 102 of the second device 120. The first device 110 may monitor for the at least one reference signal during the at least one time window in the beam, the subset of beams, or the whole set of beams. The second device 120 may also transmit the corresponding reference signal(s) in the indicated beam or beams.

[0065] In some example embodiments, for a type of reference signals, different reference signals of the same type may be configured for different beams. For example, TRS1 is configured for beam 1, TRS2 is configured for beam 2, and so on. Without the indication

of the beam(s), the first device 110 may also determine which reference signal to be detected from the whole set of beams according to the index of the reference signal.

[0066] In some example embodiments, the presence or availability of the at least one reference signal may be conditional for the first device. For example, the condition may be existence of paging. Generally, the first device 110 in the non-connected state may need to perform a paging detection process (also referred to as a paging reception process) in some cases to monitor if there is paging information transmitted from the second device 120. The paging detection process may be initiated periodically in a paging occasion. In some example embodiments, the first device 110 may monitor for the at least one reference signal in one or more transmission occasions during the determined time window(s), and the at least one transmission occasion is prior to a paging occasion for monitoring paging information from the second device 120. The transmission occasions may be configured or determined based on the configuration of the reference signals provided to the first device 110.

[0067] In some example embodiments, if the first device 110 successfully detects the at least one reference signal from the second device 120 during the at least one time window, the first device 110 may skip monitoring of at least one SSB burst. Generally, the SSB burst may be periodically transmitted by the second device 120 prior to the paging occasion, which is generally utilized to achieve synchronization for the first device 110 in the non-connected state such as the inactive or idle state. By skipping the reception of the SSB burst(s), the at least one received reference signal may be utilized to perform time-frequency synchronization with the second device 120.

[0068] In some example embodiments, if the information about the reference signal(s) is not provided by the second device 120, the first device 110 may determine that the at least one reference signal is unavailable. In this case, the first device 110 may monitor for one or more SSB bursts. In some example embodiments, if the first device 110 fails to successfully detect the at least one reference signal, it may also turn to monitor for one or more SSB bursts. As illustrated in the signaling flow 200, the second device 120 transmits 230 the one or more SSB bursts, for example, according the transmission configuration for the SSB bursts. The first device 110 may or may not monitor 235 for the one or more SSB bursts, depending on whether the first device 110 has detected the reference signal(s) for the time-frequency synchronization.

[0069] In some example embodiments, if a configuration for one or more reference signals is provided for the first device 110 but the information about the presence of the one or more reference signals is not received from the second device 120, the first device 110 may assume that the one or more reference signals are available. That is to say, in the case of failing to receiving the information about the presence of the one or more reference signals, the first device 110 may assume that the second device 120 transmits the one or more reference signals constantly. The first device 110 may monitor for the one or more reference signals according to the provided configuration for the one or more reference signals. As an alternative, if the configuration for one or more reference signals is provided for the first device 110 but the information about the presence of the one or more reference signals is not received from the second device 120, the first device 110 may assume that the reference signals are not available.

[0070] In some example embodiments, the information about the presence of the at least one reference signal may further indicate a probability of presence of one or more reference signals during one, some or all of the possible time windows. In some examples, a probability of presence of a reference signal may be indicated with a probability value from 0% to 100%. For example, the second device 120 may indicate to the first device 110 that a reference signal or a type of reference signal is potentially present in a certain time window, with a probability value of 60%. In some examples, the information may indicate one or more activity levels of the reference signal during one or more time windows. The activity of the reference signal may be classified as, for example, low, middle, high, and constant, where a low activity level indicates a relatively small probability of presence of the reference signal in a time window, a high activity level indicates a relatively high probability of presence of the reference signal in a time window, and a constant activity level indicates that the reference signal is constantly present in a time window.

[0071] The first device 110 may determine whether to monitor for the first reference signal during the first time window based on the probability of the presence of the first reference signal during the first time window. Specifically, the first device 110 may compare the probability with a probability threshold. In some example embodiments, the first device 110 may determine to monitor for a reference signal in a certain time window if the probability of presence of such a reference signal in that time window is relatively high (for example, exceeds the probability threshold). Otherwise, the first device 110 may not

monitor for the reference signal due to the high probability of failure detection.

[0072] In some example embodiments, if the first device 110 is informed that a reference signal is potentially present within a time window, with a probability value lower than 100% or a non-constant activity level in a time window, it may determine whether to monitor that reference signal in that time window further based on a channel measurement between the first device 110 and the second device 120. The channel measurement may include a measurement that can be used to indicate the communication or channel quality with the second device 120. In some examples, the channel measurement may include or indicated by a Signal to Interference plus Noise Ratio (SINR) measured on the channel, a received power from the received device 120, or other possible measures.

[0073] The first device 110 may compare the channel measurement with a measurement threshold. If the channel measurement is below the measurement threshold (for example, if the SINR is blow a SINR threshold), the first device 110 may determine to monitor for a reference signal during a certain time window even if the probability of presence of the reference signal is less than 100%, for example, even if the probability is below the probability threshold (for example, 50%). In such case, the channel measurement may indicate that the likelihood of successfully detecting the SSB burst(s) is also relatively low or the first device 110 may need to monitor for a large number of SSB bursts. In order to save energy consumption, the first device 110 may choose to first monitor for the reference signal even if there is a low chance that the reference signal is available in the time window.

[0074] In some cases, if the channel measurement exceeds the measurement threshold (for example, if the SINR is higher than a SINR threshold), the first device 110 may choose to skip the monitoring of the reference signal in the time window with a low probability of presence. The first device 110 may decide to monitor for the SSB burst because a small number of SSB bursts may be needed to monitor in the condition of a relatively high channel measurement with the second device 120.

[0075] In some example embodiments, if the first device 110 determines to monitor for a reference signal in a time window in the case that the probability of the presence is lower than 100%, the first device 110 may still assume that the reference signal may be transmitted from the second device 120 in all the configured transmission occasions during that time window. In some example embodiments, if the first device 110 determines to monitor for a reference signal in a time window in the case that the probability of the

presence is lower than 100%, the first device 110 may attempt to monitor for the reference signal in one or more first transmission occasions of the time window. If no reference signal is detected, the first device 110 may skip monitoring of the reference signal in the following transmission occasions.

[0076] By indicating the probabilities of presence of the reference signal in some time window may provide the flexibility for the second device 120 when performing the transmission of the reference signal. For example, the second device 120 may not always have to transmit a reference signal in a certain time window when it indicates to the first device 110 that the reference signal is available in that time window. If there is no connected device operating in the certain time window, the second device 120 may skip the transmission of the reference signal. This is useful when the second device 120, e.g. provides the time table covering a long time period, for example, a full week, starting Monday. The second device 120 is not sure what will happen at later times. In this case, indicating a probability (lower than 100%) of presence of the reference signal in a later time (e.g., Sunday) may allow high flexibility for the second device 120, and if a TRS transmission is then made Sunday it will be repeated for the entire Sunday.

[0077] In some example embodiments, the first device 110 may be configured that one or more reference signals are constantly available. The second device 120 may specifically indicate to the first device 110 about one or more probabilities lower than 100% of the presence of the one or more reference signals in certain time windows.

[0078] In some example embodiments, the information about the presence of the at least one reference signal may be updated by the second device 120. The second device 120 may transmit an indication of an update to the information. The indication may explicitly how the information is updated or specifically indicates the updated information. For example, the first device 110 may be configured with different information (different timetables) about the presence of one or more reference signals. The second device 120 may transmit an indication (e.g., a flag) to switch between the different timetables. In some example embodiments, the indication of the update to the information may be included via DCI (e.g., a short message of paging DCI) or PEI.

[0079] In some example embodiments, if the first device 110 receives that the indication of the update during a first modification period for system information, it may apply the update to the information during a second modification period following the first

modification period. If the second device 120 updates/changes the information about the presence of one or more reference signals, the second device 120 may indicate the updates/changes via PEI or the paging DCI. In some example embodiments, the updates/changes may not be indicated via the system information (SI). The first device 110 may apply the updated information about the presence of the reference signal(s) in the next modification period similar to a SI update, to ensure all the first devices 110 in the cell 102 have the same understanding about presence of the reference signal(s). In other examples, the update to the information about the presence of the reference signal(s) may also be provided via the system information.

[0080] In some example embodiments, if the update indicates presence of at least one further reference signal during at least one further time window, the first device 110 may apply the update to the information after the reception of the indication, without waiting for the next modification period for the system information. The second device 120 may start the transmission of the further reference signal, which is new to the first device 110, after the update is transmitted to this first device 110. In some examples, if the update is related to removal of previously configured presence of a reference signal, such update is applied at the next modification period for SI or at least the second device 120 can continue on sending the reference signal until all the first devices 110 in the cell 102 are informed, while any first device 110 that has received the update may choose to stop monitoring for the removed reference signal immediately after receiving the update.

[0081] It is expected that the first device 110 can obtain understanding of system time through other means, for example, via Global Navigation Satellite System (GNSS), application layer, or System Information Block 9 (SIB9) containing Universal Time Coordinated (UTC) time information which the first device 110 can apply directly or map to the local time zone. The means to understanding of system time may depend on network and system implementations. However, even if the first device 110 has slightly incorrect understanding of time, it may always fallback to the legacy use of SSB bursts.

[0082] In some example embodiments, if the granularity of the time windows indicated to the first device 110 is large granularity (minutes, hours, or days), the second device 120 may transmit the one or more reference signals in certain time periods before and/or after the time windows during which the reference signals are indicated as available. For example, the second device 120 may start transmitting the one or more reference signals, e.g. 5 minutes before the indicated availability starts and 5 minutes after the indicated

availability ends. It is noted that such a safety margin is implementation specific and is an option in different applications.

[0083] According to the example embodiments of the present disclosure, by informing the first device of presence of one or more reference signals, the first device can use the information to decide on its own to monitor for the reference signal(s) within any time window and to use the reference signal(s) to improve time-frequency synchronization and potentially skip the reception of a SSB burst. As such, the first device can achieve more power saving gain in the non-connected state, with less extra complexity incurred. The monitoring for the reference signal(s) provides more opportunities for the first device to achieve the time-frequency synchronization with the second device. In addition, this solution has a minimal impact on the second device as it can have sufficient flexibility to control, via the information provided to the first device, whether and when to transmit the reference signals. For example, the transmission of the reference signals may still depend on the first device(s) in the connected state in the serving area.

[0084] Fig. 4 shows a flowchart of an example method 400 implemented at a first device 110 in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the method 400 will be described from the perspective of the first device 110 with respect to Fig. 1.

[0085] At block 410, the first device 110 receives, from a second device 120, information indicating presence of at least one reference signal during one or more time windows. At block 420, the first device 110 determines, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows. If it is determined to monitor for the at least one reference signal, at block 430, the first device 110, if it is in a non-connected state, monitors for the at least one reference signal from the second device 120 during the at least one time window.

[0086] In some example embodiments, if the first device 110 determines not to monitor for any reference signal at this time, it may continue to detect and determine whether to monitor for the reference signal in a following paging cycle when it needs to achieve time-frequency synchronization with the second device 120.

[0087] In some example embodiments, the received information further indicates a probability of presence of a first reference signal of the at least one reference signal during a first time window of the one or more time windows. In some example embodiments, the

first device 110 may determine whether to monitor for the at least one reference signal by: determining whether to monitor for the first reference signal during the first time window based on the probability of the presence of the first reference signal during the first time window.

[0088] In some example embodiments, the first device 110 may determine whether to monitor for the first reference signal during the first time window by: in accordance with a determination that the probability is below a probability threshold, comparing a channel measurement between the first device 110 and the second device 120 with a measurement threshold, and in accordance with a determination that the channel measurement is below the measurement threshold, determining to monitor for the first reference signal during the first time window.

[0089] In some example embodiments, the first device 110 may monitor for the at least one reference signal in at least one transmission occasion for the at least one reference signal during the at least one time window. The at least one transmission occasion is prior to a paging occasion for monitoring paging information from the second device 120.

[0090] In some example embodiments, the received information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second device 120. In some example embodiments, the first device 110 may monitor for the at least one reference signal during the at least one time window in the beam, the subset of beams, or the whole set of beams.

[0091] In some example embodiments, the first device 110 may receive the information from the second device 120 via system information, downlink control information, or a paging early indication.

[0092] In some example embodiments, the first device 110 may, in accordance with a determination that the at least one reference signal is detected from the second device 120 during the at least one time window, skip monitoring of at least one synchronization signal block burst.

[0093] In some example embodiments, the first device 110 may receive, from the second device 120, an indication of an update to the information during a first modification period for system information; and apply the update to the information during a second modification period following the first modification period or after the reception of the

indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

[0094] In some example embodiments, the first device 110 may receive the indication from the second device 120 via system information, downlink control information, or a paging early indication.

[0095] In some example embodiments, the first device 110 may in accordance with a determination that the information is failed to be received from the second device 120, determine that the at least one reference signal is unavailable.

[0096] In some example embodiments, the at least one reference signal may comprise at least one of a tracking reference signal and a channel state information-reference signal.

[0097] Fig. 5 shows a flowchart of an example method 500 implemented at a second device 120 in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the method 500 will be described from the perspective of the second device 120with respect to Fig. 1.

[0098] At block 510, the second device 120 transmits, to a first device 110, information indicating presence of at least one reference signal during one or more time windows for the first device 110 to monitor in a non-connected state. At block 520, the second device 120 performs, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

[0099] In some example embodiments, the information further indicates a probability of presence of a first reference signal of the at least one reference signal in a first time window of the one or more time windows. In some example embodiments, the second device 120 may perform the transmission of the at least one reference signal by: performing transmission of the first reference signal during the first time window according to the probability indicated by the information.

[00100] In some example embodiments, the information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second device 120. In some example embodiments, the second device 120 may perform transmission of the at least one reference signal during the one or more time windows in the beam, the subset of beams, or the whole set of beams.

[00101] In some example embodiments, the second device 120 may transmit, to the first device 110, an indication of an update to the information during a first modification period for system information; and perform, based on the update to the information, transmission of the at least one reference signal during a second modification period following the first modification period or after the transmission of the indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

[00102] In some example embodiments, the at least one reference signal may comprise at least one of a tracking reference signal and a channel state information-reference signal.

[00103] In some example embodiments, a first apparatus capable of performing any of the method 400 (for example, the first device 110) may comprise means for performing the respective operations of the method 400. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module. The first apparatus may be implemented as or included in the first device 110.

[00104] In some example embodiments, the first apparatus comprises means for receiving, from a second apparatus (e.g., the second device 120), information indicating presence of at least one reference signal during one or more time windows; means for determining, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and means for in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first apparatus is in a non-connected state, monitoring for the at least one reference signal from the second apparatus during the at least one time window.

[00105] In some example embodiments, the received information further indicates a probability of presence of a first reference signal of the at least one reference signal during a first time window of the one or more time windows, and

[00106] In some example embodiments, the means for determining whether to monitor for the at least one reference signal comprises means for determining whether to monitor for the first reference signal during the first time window based on the probability of the presence of the first reference signal during the first time window.

[00107] In some example embodiments, the means for determining whether to monitor for the first reference signal during the first time window comprises: means for, in accordance with a determination that the probability is below a probability threshold, comparing a

channel measurement between the first apparatus and the second apparatus with a measurement threshold, and means for, in accordance with a determination that the channel measurement is below the measurement threshold, determining to monitor for the first reference signal during the first time window.

[00108] In some example embodiments, the means for monitoring for the at least one reference signal comprises means for monitoring for the at least one reference signal in at least one transmission occasion for the at least one reference signal during the at least one time window. In some example embodiments, the at least one transmission occasion is prior to a paging occasion for monitoring paging information from the second apparatus.

[00109] In some example embodiments, the received information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second apparatus. In some example embodiments, the means for monitoring for the at least one reference signal comprises means for monitoring for the at least one reference signal during the at least one time window in the beam, the subset of beams, or the whole set of beams.

[00110] In some example embodiments, the means for receiving the information comprises means for receiving the information from the second apparatus via system information, downlink control information, or a paging early indication.

[00111] In some example embodiments, the first apparatus further comprises means for, in accordance with a determination that the at least one reference signal is detected from the second apparatus during the at least one time window, skipping monitoring of at least one synchronization signal block burst.

[00112] In some example embodiments, the first apparatus further comprises means for receiving, from the second apparatus, an indication of an update to the information during a first modification period for system information; and means for applying the update to the information during a second modification period following the first modification period or after the reception of the indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

[00113] In some example embodiments, the means for receiving the indication comprises means for receiving the indication from the second apparatus via system information, downlink control information, or a paging early indication.

[00114] In some example embodiments, the first apparatus further comprises means for, in accordance with a determination that the information is failed to be received from the second apparatus, determining that the at least one reference signal is unavailable.

[00115] In some example embodiments, the at least one reference signal comprises at least one of a tracking reference signal and a channel state information-reference signal.

[00116] In some example embodiments, the first apparatus further comprises means for performing other operations in some example embodiments of the method 400 or the first device 110. 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 first apparatus.

[00117] In some example embodiments, a second apparatus capable of performing any of the method 500 (for example, the second device 120) may comprise means for performing the respective operations of the method 500. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module. The second apparatus may be implemented as or included in the second device 120.

[00118] In some example embodiments, the second apparatus comprises means for transmitting, to a first apparatus (e.g., the first device 110), information indicating presence of at least one reference signal during one or more time windows for the first apparatus to monitor in a non-connected state; and means for performing, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

[00119] In some example embodiments, the information further indicates a probability of presence of a first reference signal of the at least one reference signal in a first time window of the one or more time windows. In some example embodiments, the means for performing the transmission of the at least one reference signal comprises means for performing transmission of the first reference signal during the first time window according to the probability indicated by the information.

[00120] In some example embodiments, the information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second apparatus. In some

example embodiments, the means for performing the transmission of the at least one reference signal comprises means for performing the transmission of the at least one reference signal during the one or more time windows in the beam, the subset of beams, or the whole set of beams.

[00121] In some example embodiments, the second apparatus further comprises means for transmitting, to the first apparatus, an indication of an update to the information during a first modification period for system information; and means for performing, based on the update to the information, transmission of the at least one reference signal during a second modification period following the first modification period or after the transmission of the indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

[00122] In some example embodiments, the second apparatus further comprises means for performing other operations in some example embodiments of the method 500 or the second device 120. 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 second apparatus.

[00123] Fig. 6 is a simplified block diagram of a device 600 that is suitable for implementing example embodiments of the present disclosure. The device 600 may be provided to implement a communication device, for example, the first device 110 or the second device 120 as shown in Fig. 1. As shown, the device 600 includes one or more processors 610, one or more memories 620 coupled to the processor 610, and one or more communication modules 640 coupled to the processor 610.

[00124] The communication module 640 is for bidirectional communications. The communication module 640 has one or more communication interfaces to facilitate communication with one or more other modules or devices. The communication interfaces may represent any interface that is necessary for communication with other network elements. In some example embodiments, the communication module 640 may include at least one antenna.

[00125] The processor 610 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 600 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.

[00126] The memory 620 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) 624, an electrically programmable read only memory (EPROM), a flash memory, a hard disk, a compact disc (CD), a digital video disk (DVD), an optical disk, a laser disk, and other magnetic storage and/or optical storage. Examples of the volatile memories include, but are not limited to, a random access memory (RAM) 622 and other volatile memories that will not last in the power-down duration.

[00127] A computer program 630 includes computer executable instructions that are executed by the associated processor 610. The program 630 may be stored in the memory, e.g., ROM 624. The processor 610 may perform any suitable actions and processing by loading the program 630 into the RAM 622.

[00128] The example embodiments of the present disclosure may be implemented by means of the program 630 so that the device 600 may perform any process of the disclosure as discussed with reference to Figs. 2 to 4. The example embodiments of the present disclosure may also be implemented by hardware or by a combination of software and hardware.

[00129] In some example embodiments, the program 630 may be tangibly contained in a computer readable medium which may be included in the device 600 (such as in the memory 620) or other storage devices that are accessible by the device 600. The device 600 may load the program 630 from the computer readable medium to the RAM 622 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. Fig. 7 shows an example of the computer readable medium 700 which may be in form of CD, DVD or other optical storage disk. The computer readable medium has the program 630 stored thereon.

[00130] Generally, various 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 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.

[00131] 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 physical or virtual processor, to carry out any of the methods as described above with reference to Fig. 4 and Fig. 5. 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 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.

[00132] 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.

[00133] In the context of the present disclosure, the computer program code 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, computer readable medium, and the like.

[00134] 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.

[00135] 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 embodiments. Certain features that are described in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment may also be implemented in multiple embodiments separately or in any suitable sub-combination.

[00136] 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 including computer program code;

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to:

receive, from a second device, information indicating presence of at least one reference signal during one or more time windows;

determine, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and

in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first device is in a non-connected state, monitor for the at least one reference signal from the second device during the at least one time window.

2. The first device of claim 1, wherein the received information further indicates a probability of presence of a first reference signal of the at least one reference signal during a first time window of the one or more time windows, and

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to determine whether to monitor for the at least one reference signal by:

determining whether to monitor for the first reference signal during the first time window based on the probability of the presence of the first reference signal during the first time window.

3. The first device of claim 2, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to determine whether to monitor for the first reference signal during the first time window by:

in accordance with a determination that the probability is below a probability threshold,

comparing a channel measurement between the first device and the second device with a measurement threshold, and

in accordance with a determination that the channel measurement is below

the measurement threshold, determining to monitor for the first reference signal during the first time window.

4. The first device of claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to monitor for the at least one reference signal in at least one transmission occasion for the at least one reference signal during the at least one time window, and

wherein the at least one transmission occasion is prior to a paging occasion for monitoring paging information from the second device.

5. The first device of claim 1, wherein the received information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second device; and

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to monitor for the at least one reference signal during the at least one time window in the beam, the subset of beams, or the whole set of beams.

6. The first device of claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to receive the information from the second device via system information, downlink control information, or a paging early indication.

7. The first device of claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, further cause the first device to:

in accordance with a determination that the at least one reference signal is detected from the second device during the at least one time window, skip monitoring of at least one synchronization signal block burst.

8. The first device of claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, further cause the first device to:

receive, from the second device, an indication of an update to the information

during a first modification period for system information; and

apply the update to the information during a second modification period following the first modification period or after the reception of the indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

9. The first device of claim 8, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the first device to receive the indication from the second device via system information, downlink control information, or a paging early indication.

10. The first device of claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, further cause the first device to:

in accordance with a determination that the information is failed to be received from the second device, determine that the at least one reference signal is unavailable.

11. The first device of claim 1, wherein the at least one reference signal comprises at least one of a tracking reference signal and a channel state information-reference signal.

12. A second device comprising:

at least one processor; and

at least one memory including computer program code;

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the second device to:

transmit, to a first device, information indicating presence of at least one reference signal during one or more time windows for the first device to monitor in a non-connected state; and

perform, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

13. The second device of claim 12, wherein the information further indicates a probability of presence of a first reference signal of the at least one reference signal in a first time window of the one or more time windows, and

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the second device to perform the transmission of the at least one reference signal by:

performing transmission of the first reference signal during the first time window according to the probability indicated by the information.

14. The second device of claim 12, wherein the information indicates the presence of the at least one reference signal during the one or more time windows in a beam, a subset of beams, or a whole set of beams within a serving area of the second device; and

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the second device to perform transmission of the at least one reference signal during the one or more time windows in the beam, the subset of beams, or the whole set of beams.

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

transmit, to the first device, an indication of an update to the information during a first modification period for system information; and

perform, based on the update to the information, transmission of the at least one reference signal during a second modification period following the first modification period or after the transmission of the indication in accordance with a determination that the update indicates presence of at least one further reference signal during at least one further time window.

16. A method comprising:

receiving, by a first device and from a second device, information indicating presence of at least one reference signal during one or more time windows;

determining, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and

in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first device is in a non-connected state, monitoring for the at least one reference signal from the second device during the at least one time window.

17. A method comprising:

transmitting, by a second device and to a first device, information indicating presence of at least one reference signal during one or more time windows for the first device to monitor in a non-connected state; and

performing, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

18. A first apparatus comprising:

means for receiving, from a second apparatus, information indicating presence of at least one reference signal during one or more time windows;

means for determining, based on the received information, whether to monitor for the at least one reference signal during at least one of the one or more time windows; and

means for in accordance with a determination to monitor for the at least one reference signal and in accordance with a determination that the first apparatus is in a non-connected state, monitoring for the at least one reference signal from the second apparatus during the at least one time window.

19. A second apparatus comprising:

means for transmitting, to a first apparatus, information indicating presence of at least one reference signal during one or more time windows for the first apparatus to monitor in a non-connected state; and

means for performing, based on the transmitted information, transmission of the at least one reference signal during the one or more time windows.

20. A computer readable medium comprising program instructions for causing an apparatus to perform at least the method of claim 16 or the method of claim 17.

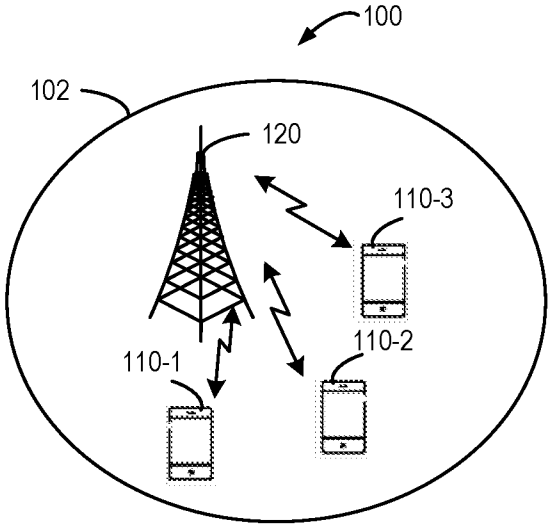

100
102
120
110-3
110-2
110-1

Fig. 1

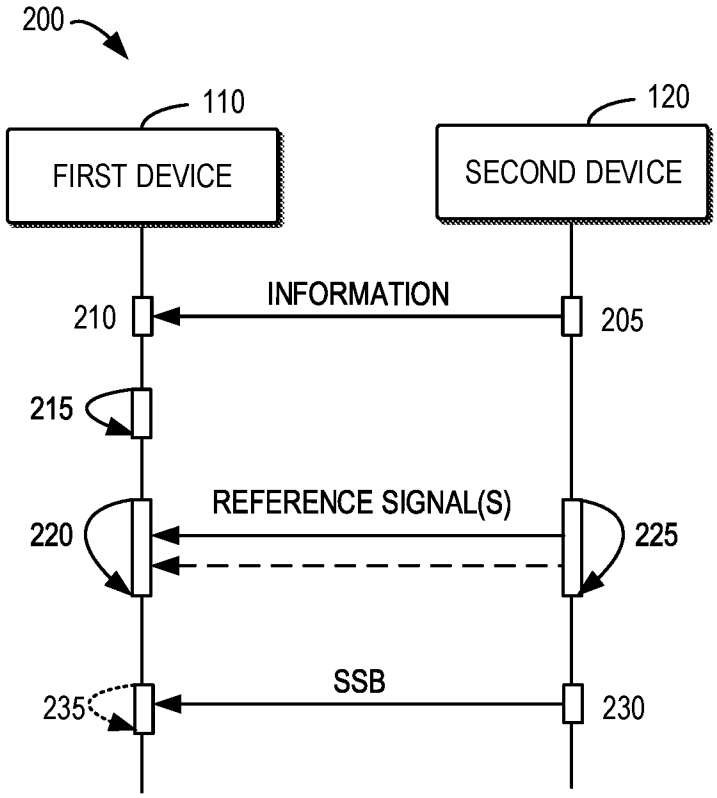

200
110
FIRST DEVICE
120
SECOND DEVICE
INFORMATION
210
205
215
REFERENCE SIGNAL(S)
220
225
SSB
235
230

Fig. 2

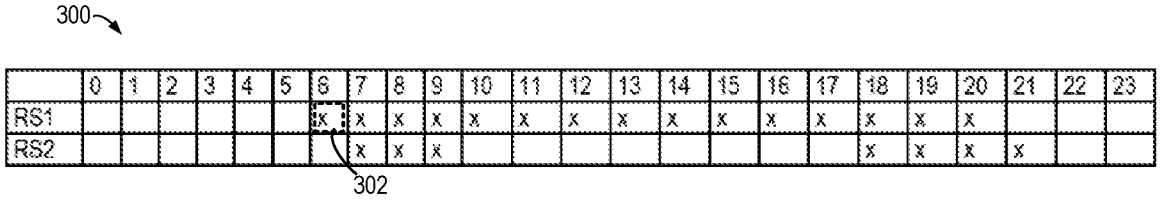


Fig. 3

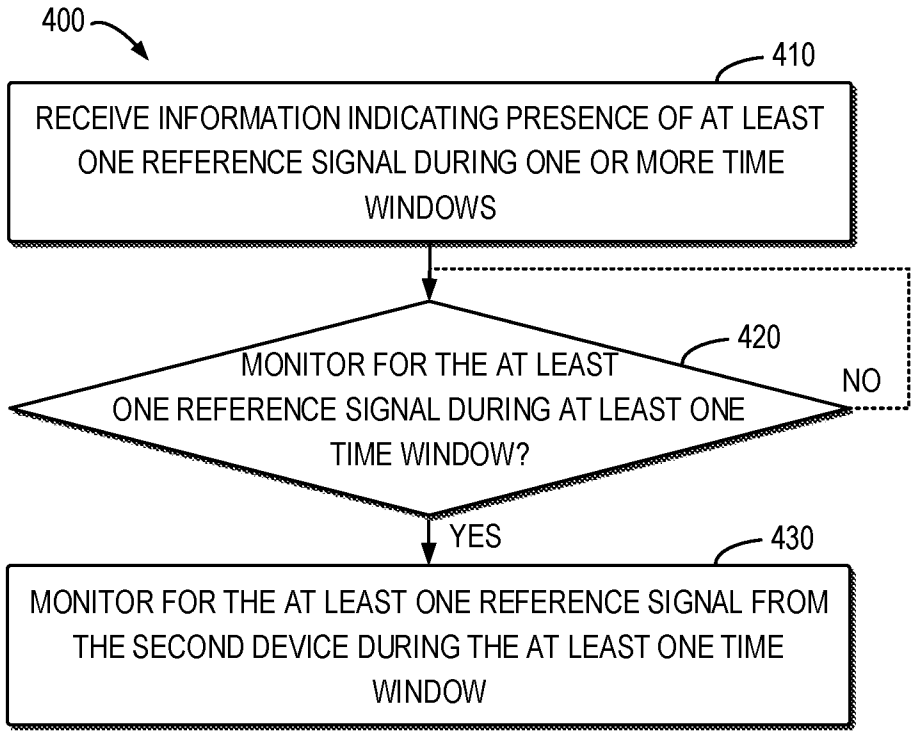


Fig. 4

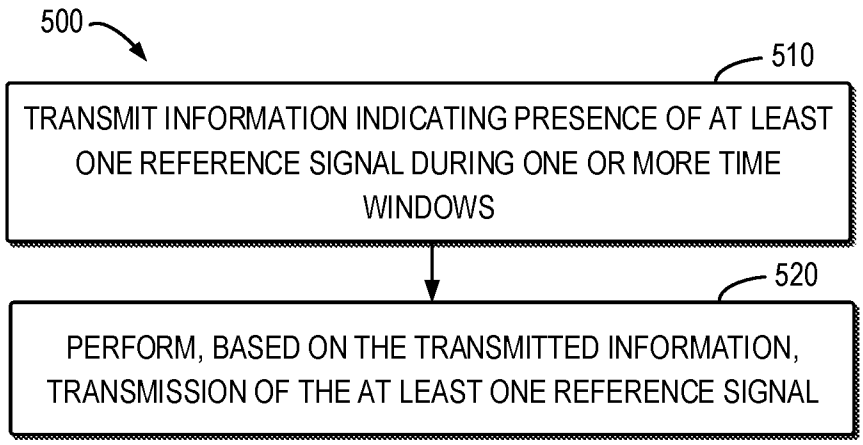


Fig. 5

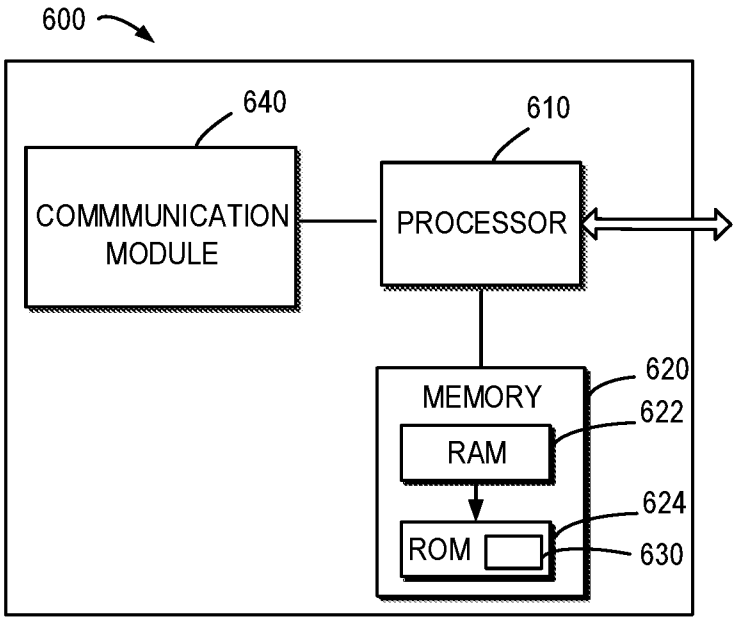

600
640
610
COMMMUNICATION MODULE
PROCESSOR
620
MEMORY
622
RAM
624
ROM
630

Fig. 6

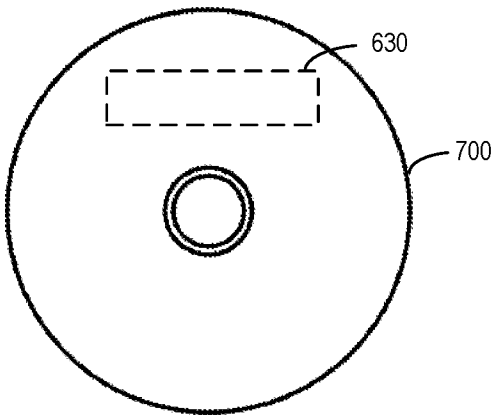

630
700

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/081621

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/08(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; H04L

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)

CNKI;CNPAT;WPI;EPODOC: configure+, information, indicat+, presence, reference signal, time window, received information, during, determination, monitor, non-connected, state, time, window,idle,inactive

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 111052839 A (ZTE CORPORATION) 21 April 2020 (2020-04-21) paragraphs [0051]- [0101] in the description; figures 1-15, claims 1-32	1-20
Y	CN 106165333 A (HUAWEI TECHNOLOGIES CO., LTD.) 23 November 2016 (2016-11-23) paragraphs [0110]- [0154] in the description; figures 1-14, claims 1-52	1-20
A	CN 110572842 A (SPREADTRUM COMMUNICATIONS SHANGHAI INC.) 13 December 2019 (2019-12-13) the whole document	1-20
A	CN 111757438 A (TELECOMMUNICATIONS TECH RES INST CO., LTD.) 09 October 2020 (2020-10-09) the whole document	1-20
A	CN 109315010 A (TELEFONAKTIEBOLAGET LM ERICSSONPUBL) 05 February 2019 (2019-02-05) the whole document	1-20
A	US 2018351611 A1 (QUALCOMM INCORPORATED) 06 December 2018 (2018-12-06) the whole document	1-20

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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
17 November 2021	**25 November 2021**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China** Facsimile No. **(86-10)62019451**	Authorized officer **WANG,Chengmiao** Telephone No. **(86-10)53961686**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/081621

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2020089388 A1 (NOKIA TECHNOLOGIES OY) 07 May 2020 (2020-05-07) the whole document	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/081621

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CN	111052839	A	21 April 2020	WO	2019041244	A1	07 March 2019
				US	2020205219	A1	25 June 2020
CN	106165333	A	23 November 2016	CN	106165333	B	10 May 2019
				WO	2016090567	A1	16 June 2016
CN	110572842	A	13 December 2019	WO	2021052057	A1	25 March 2021
CN	111757438	A	09 October 2020	WO	2020200003	A1	08 October 2020
CN	109315010	A	05 February 2019	US	10548181	B2	28 January 2020
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				JP	2019507550	A	14 March 2019
				PH	12018501634	A1	27 May 2019
				EP	3412113	A1	12 December 2018
				JP	6757414	B2	16 September 2020
				WO	2017134561	A1	10 August 2017
				EP	3412113	B1	10 June 2020
				US	2019313475	A1	10 October 2019
				KR	102103761	B1	23 April 2020
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				TW	201904317	A	16 January 2019
				US	2019288750	A1	19 September 2019
				EP	3632162	A1	08 April 2020
				US	10868588	B2	15 December 2020
				CN	110679182	A	10 January 2020
WO	2020089388	A1	07 May 2020	CN	113273254	A	17 August 2021