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(71) **Applicant: LENOVO (BEIJING) LIMITED** [CN/CN]; 6 Shangdi West Road, Haidian District, Beijing 100085 (CN).

(72) **Inventors: YAN, Zhi**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **LEI, Haipeng**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **YU, Xiaodong**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **SUN, Zhennian**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN).

(74) **Agent: KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Centre, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

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(54) **Title:** WUS CONFIGURATON

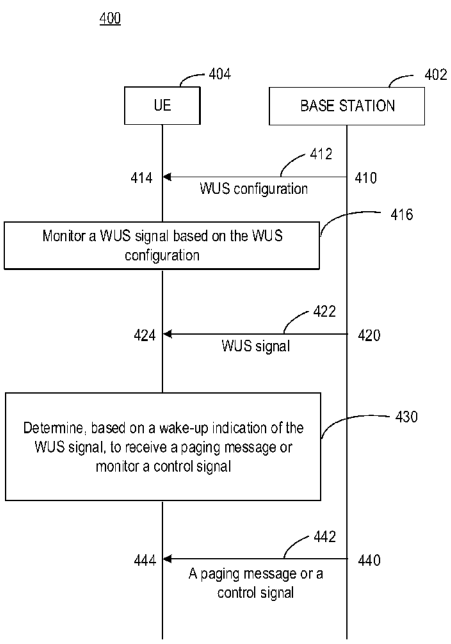

FIG. 4

(57) **Abstract:** Various aspects of the present disclosure relate to a user equipment, a base station, processors, and methods for a wake up signal (WUS) configuration. In an aspect, a user equipment (UE) receives, from a base station, a wake-up signal (WUS) configuration. The UE monitors a WUS signal based on the WUS configuration. The UE determines, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

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WUS CONFIGURATON

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment, a base station, processors, and methods for a wake up signal (WUS) configuration.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] Power consumption could be dramatically reduced by using a wake-up signal (WUS) to trigger the wake up of the main radio and a separate receiver (e.g., low power receiver) which has the ability to monitor wake-up signal with ultra-low power consumption. Main radio works for data and/or signaling transmission and reception (e.g., control signal monitoring and paging message receiving), which can be turned off or set to deep sleep unless it is turned on. However, there are still some open problems that need to be studied.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support a wake up signal (WUS) configuration, especially for a user equipment (UE) in idle/inactive states.

[0005] In a first aspect of the solution, a user equipment (UE) comprises: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive a wake-up signal (WUS) configuration; monitor a WUS signal based on the WUS configuration; and determine, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

[0006] In some implementations of the user equipment described herein, the UE is further caused to receive a low power synchronization signal (LP-SS), the LP-SS is determined based on a period of the LP-SS and a start time of the LP-SS, and wherein the start time of the LP-SS is determined based on a first time offset to a first reference time, and the first time offset is included in the WUS configuration or determined based on a cell identity (ID) of a cell.

[0007] In some implementations of the user equipment described herein, the UE is further caused to receive a synchronization signal block (SSB), and the period of the LP-SS is determined based on one or more periods of the SSB.

[0008] In some implementations of the user equipment described herein, the first reference time is an absolute time, and the first time offset is a frame-level offset or a subframe-level offset.

[0009] In some implementations of the user equipment described herein, the first time offset further comprises an additional time offset, and the additional time offset is one of the following: a first half frame of a frame; a second half frame of a frame; a time offset within a frame; or a time offset within a subframe.

[0010] Additionally, in some implementations of the user equipment described herein, the first time offset is a frame-level offset or a subframe-level offset, the start time of the LP-SS is further determined based on a second time offset included in the WUS configuration, and the second time offset is a time offset between a main radio and a low power radio.

[0011] In some implementations of the user equipment described herein, the second time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0012] Alternatively, in some implementations of the user equipment described herein, the first reference time is a start of a first SSB within the period of the LP-SS, and the first time offset is included in the WUS configuration.

[0013] In some implementations of the user equipment described herein, the first time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0014] In some implementations of the user equipment described herein, wherein the main radio is associated with a first frequency band where a SSB or the paging message or the control signal is transmitted, and the low power radio is associated with a second frequency band where the LP-SS or the WUS signal is transmitted.

[0015] In some implementations of the user equipment described herein, LP-SS in each period of the LP-SS is transmitted in a LP-SS block set with one or more LP-SS beams and one or more repetitions.

[0016] In some implementations of the user equipment described herein, the one or more LP-SS beams are associated with one or more SSB beams, and a pattern of the one or more LP-SS beams is indicated by a pattern of the one or more SSB beams.

[0017] Alternatively, in some implementations of the user equipment described herein, a pattern of the one or more LP-SS beams is configured by the WUS configuration.

[0018] In some implementations of the user equipment described herein, the UE is further caused to determine, based on an indication of a higher layer, that the one or more LP-SS beams is the same as the one or more SSB beams.

[0019] Alternatively, in some implementations of the user equipment described herein, the one or more LP-SS beams have an association with one or more SSB beams, and the association is configured by the WUS configuration.

[0020] In some implementations of the user equipment described herein, the one or more LP-SS beams are transmitted in consecutive slots or subframes, or the one or more LP-SS beams are transmitted with at least one interval of multiple slots or subframes.

[0021] In some implementations of the user equipment described herein, an order of the one or more LP-SS beams is cyclically shifted among one or more periods of the LP-SS.

[0022] In some implementations of the user equipment described herein, the WUS signal is transmitted in WUS resource, the WUS resource is determined based on a period of the WUS resource and a start or end time of the WUS resource, and the start or end time of the WUS resource is determined based on a third time offset to a third reference time.

[0023] In some implementations of the user equipment described herein, the period of the WUS resource is determined based on a paging period.

[0024] In some implementations of the user equipment described herein, the third reference time is an absolute time, and the third time offset is a frame-level offset or a subframe-level offset, and wherein the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0025] In some implementations of the user equipment described herein, the third reference time is a start slot or start frame of a first paging occasion within a paging period, and the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0026] In some implementations of the user equipment described herein, WUS signal transmitted in at least one WUS resource is associated with one or more WUS beams and one or more repetitions.

[0027] In some implementations of the user equipment described herein, the WUS signal is transmitted in at least one WUS resource with a transmission manner based on an order of the one or more WUS beams and the one or more repetitions.

[0028] In some implementations of the user equipment described herein, the transmission manner comprises one of the following: beams sweeping first and repetition second; or repetition for one beam first and beams sweeping second.

[0029] In some implementations of the user equipment described herein, the one or more WUS beams have an association with one or more LP-SS beams or one or more SSB beams, and the association is configured by the WUS configuration.

[0030] In some implementations of the user equipment described herein, the WUS signal is transmitted in consecutive WUS resources or interleaved WUS resources.

[0031] In some implementations of the user equipment described herein, the UE is configured with a WUS window for a paging occasion, and the WUS window is determined based on a start or end time and a window length, and wherein the UE is caused to monitor the WUS signal in the WUS window for the paging occasion.

[0032] In some implementations of the user equipment described herein, the end time is a start of a paging occasion minus a gap offset configured by a higher layer, and the window length is determined based on a higher layer with one or more periods of the WUS resource or configured by the WUS configuration.

[0033] In a second aspect of the solution, a base station comprises: a processor; and a transceiver coupled to the processor, wherein the processor is configured to: transmit, via the transceiver and to a user equipment (UE), a wake-up signal (WUS) configuration; transmit, based on the WUS configuration and via the transceiver, a WUS signal to the UE; and transmit, via the transceiver and to the UE, a paging message or a control signal.

[0034] In some implementations of the base station described herein, the base station is further caused to transmit a low power synchronization signal (LP-SS), the LP-SS is determined based on a period of the LP-SS and a start time of the LP-SS, and wherein the start time of the LP-SS is determined based on a first time offset to a first reference time, and the first time offset is included in the WUS configuration or determined based on a cell identity (ID) of a cell.

[0035] In some implementations of the base station described herein, the base station is further caused to transmit a synchronization signal block (SSB), and the period of the LP-SS is determined based on one or more periods of the SSB.

[0036] In some implementations of the base station described herein, the first reference time is an absolute time, and the first time offset is a frame-level offset or a subframe-level offset.

[0037] In some implementations of the base station described herein, the first time offset further comprises an additional time offset, and the additional time offset is one of the following: a first half frame of a frame; a second half frame of a frame; a time offset within a frame; or a time offset within a subframe.

[0038] Additionally, in some implementations of the base station described herein, the first time offset is a frame-level offset or a subframe-level offset, the start time of the LP-SS is further determined based on a second time offset included in the WUS configuration, and the second time offset is a time offset between a main radio and a low power radio.

[0039] In some implementations of the base station described herein, the second time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0040] Alternatively, in some implementations of the base station described herein, the first reference time is a start of a first SSB within the period of the LP-SS, and the first time offset is included in the WUS configuration.

[0041] In some implementations of the base station described herein, the first time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0042] In some implementations of the base station described herein, the main radio is associated with a first frequency band where the SSB or the paging message or the control signal is transmitted, and the low power radio is associated with a second frequency band where the LP-SS or the WUS signal is transmitted.

[0043] In some implementations of the base station described herein, LP-SS in each period of the LP-SS is transmitted in a LP-SS block set with one or more LP-SS beams and one or more repetitions.

[0044] In some implementations of the base station described herein, the one or more LP-SS beams are associated with one or more SSB beams, and a pattern of the one or more LP-SS beams is indicated by a pattern of the one or more SSB beams.

[0045] Alternatively, in some implementations of the base station described herein, a pattern of the one or more LP-SS beams is configured by the WUS configuration.

[0046] In some implementations of the base station described herein, the base station is further caused to transmit an indication for indicating that the one or more LP-SS beams is the same as the one or more SSB beams.

[0047] Alternatively, in some implementations of the base station described herein, the one or more LP-SS beams have an association with one or more SSB beams, and the association is configured by the WUS configuration.

[0048] In some implementations of the base station described herein, the one or more LP-SS beams are transmitted in consecutive slots or subframes, or the one or more LP-SS beams are transmitted with at least one interval of multiple slots or subframes.

[0049] In some implementations of the base station described herein, an order of the one or more LP-SS beams is cyclically shifted among one or more periods of the LP-SS.

[0050] In some implementations of the base station described herein, the WUS signal is transmitted in WUS resource, the WUS resource is determined based on a period of the WUS resource and a start or end time of the WUS resource, and the start or end time of the WUS resource is determined based on a third time offset to a third reference time.

[0051] In some implementations of the base station described herein, the period of the WUS resource is determined based on a paging period.

[0052] In some implementations of the base station described herein, the third reference time is an absolute time, and the third time offset is a frame-level offset or a subframe-level offset, and wherein the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0053] In some implementations of the base station described herein, the third reference time is a start slot or start frame of a first paging occasion within a paging period, and the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0054] In some implementations of the base station described herein, WUS signal transmitted in at least one WUS resource is associated with one or more WUS beams and one or more repetitions.

[0055] In some implementations of the base station described herein, the WUS signal is transmitted in at least one WUS resource with a transmission manner based on an order of the one or more WUS beams and the one or more repetitions.

[0056] In some implementations of the base station described herein, the transmission manner comprises one of the following: beams sweeping first and repetition second; or repetition for one beam first and beams sweeping second.

[0057] In some implementations of the base station described herein, the one or more WUS beams have an association with one or more LP-SS beams or one or more SSB beams, and the association is configured by the WUS configuration.

[0058] In some implementations of the base station described herein, the WUS signal is transmitted in consecutive WUS resources or interleaved WUS resources.

[0059] In some implementations of the base station described herein, a WUS window is configured for a paging occasion, and the WUS window is determined based on a start or end time and a window length, and wherein the processor is further configured to transmit the WUS signal in the WUS window for the paging occasion.

[0060] In some implementations of the base station described herein, the end time is a start of a paging occasion minus a gap offset configured by a higher layer, and the window length is determined based on a higher layer with one or more periods of the WUS resource or configured by the WUS configuration.

[0061] In a third aspect of the solution, a processor for wireless communication comprises: at least one memory; and a controller coupled with the at least one memory and configured to cause the controller to: receive, from a base station, a wake-up signal (WUS) configuration; monitor a WUS signal based on the WUS configuration; and determine, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

[0062] In a fourth aspect of the solution, a processor for wireless communication comprises: at least one memory; and a controller coupled with the at least one memory and configured to cause the controller to: transmit, to a user equipment (UE), a wake-up signal (WUS) configuration; transmit, based on the WUS configuration, a WUS signal to the UE; and transmit, to the UE, a paging message or a control signal.

[0063] In a fifth aspect of the solution, a method performed by a user equipment, the method comprises: receiving, from a base station, a wake-up signal (WUS) configuration; monitoring a WUS signal based on the WUS configuration; and determining, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

[0064] In a sixth aspect of the solution, a method performed by a base station, the method comprises: transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration; transmitting, based on the WUS configuration, a WUS signal to the UE; and transmitting, to the UE, a paging message or a control signal.

[0065] 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

[0066] FIG. 1A illustrates an example of a wireless communications system that supports WUS configuration in accordance with aspects of the present disclosure.

[0067] FIG. 1B illustrates an example interaction between a main radio and a separate ultra-low power wake-up receiver within a UE.

[0068] FIG. 2A illustrates an example of synchronization signal blocks (SSBs) mechanism.

[0069] FIG. 2B illustrates an example of SSB configuration.

[0070] FIG. 3A illustrates an example of narrowband internet-of-things (NB-IoT) WUS configuration.

[0071] FIG. 3B illustrates an example of enhanced machine type communication (eMTC) WUS configuration.

[0072] FIG. 4 illustrates an example signaling procedure for WUS configuration in accordance with aspects of the present disclosure.

[0073] FIG. 5A illustrates a first example of LP-SS transmissions in accordance with aspects of the present disclosure.

[0074] FIG. 5B illustrates a second example of LP-SS transmissions in accordance with aspects of the present disclosure.

[0075] FIG. 5C illustrates a third example of LP-SS transmissions in accordance with aspects of the present disclosure.

[0076] FIG. 5D illustrates a fourth example of LP-SS transmissions in accordance with aspects of the present disclosure.

[0077] FIG. 6A illustrates a first example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0078] FIG. 6B illustrates a second example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0079] FIG. 6C illustrates a third example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0080] FIG. 6D illustrates a fourth example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0081] FIG. 6E illustrates a fifth example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0082] FIG. 6F illustrates a sixth example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0083] FIG. 6G illustrates a seventh example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0084] FIG. 6H illustrates an eighth example of LP-WUS transmissions in accordance with aspects of the present disclosure.

[0085] FIG. 7 illustrates an example of device that support WUS configuration in accordance with aspects of the present disclosure.

[0086] FIG. 8 illustrates an example of processor that support WUS configuration in accordance with aspects of the present disclosure.

[0087] FIG. 9 illustrates a flowchart of a method that support WUS configuration in accordance with aspects of the present disclosure.

[0088] FIG. 10 illustrates a flowchart of a method that support WUS configuration in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0089] Principles of the present disclosure will now be described with reference to some 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. The disclosure described herein may be implemented in various manners other than the ones described below.

[0090] 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.

[0091] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) 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 do not necessarily refer to the same embodiment(s). 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.

[0092] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0093] 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.

[0094] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as, 5G 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. Further, 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 also be future type communication technologies and systems in which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned systems.

[0095] As used herein, the term "network device" generally refers to a node in a communication network via which a terminal device can access the communication network and receive services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), a radio access network (RAN) node, an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a remote radio unit (RRU), a radio header (RH), an infrastructure device for a V2X (vehicle-to-everything) communication, a transmission and reception point (TRP), a reception point (RP), a remote radio head (RRH), a relay, an integrated access and backhaul (IAB) node, a low power node such as a femto BS, a pico BS, and so forth, depending on the applied terminology and technology.

[0096] As used herein, the term "terminal device" generally refers to any end device that may be capable of wireless communications. By way of example rather than a limitation, a terminal device may also be referred to as a communication device, a user equipment (UE), an end user device, a subscriber station (SS), an unmanned aerial vehicle (UAV), a portable subscriber station, a mobile station (MS), or an access terminal (AT). The terminal device may include, but is not limited to, a mobile phone, a cellular phone, a smart phone, a voice over IP (VoIP) phone, a wireless local loop phone, a tablet, a wearable terminal device, a personal digital assistant (PDA), a portable computer, a desktop computer, an image capture terminal device such as a digital camera, a gaming terminal device, a music storage and playback appliance, a vehicle-mounted wireless terminal device, a wireless endpoint, a mobile station, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), a USB dongle, a smart device, wireless customer-premises equipment (CPE), an internet of things (loT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device (for example, a remote surgery device), an industrial device (for example, a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms: "terminal device," "communication device," "terminal," "user equipment" and "UE," may be used interchangeably.

[0097] Aspects of the present disclosure are described in the context of a wireless communications system.

[0098] FIG. 1A illustrates an example of a wireless communications system 100A that supports WUS configuration in accordance with aspects of the present disclosure. The wireless communications system 100A may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100A may support various radio access technologies. In some implementations, the wireless communications system 100A may be a 4G network, such as an LTE network or an LTE-advanced (LTE-A) network. In some other implementations, the wireless communications system 100A may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100A may be a combination of a 4G network and a 5G network, or other suitable radio access technology including institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100A may support radio access technologies beyond 5G. Additionally, the wireless communications system 100A may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0099] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100A. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0100] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0101] The one or more UEs 104 (such as UE 104-1 or UE 104-2) may be dispersed throughout a geographic region of the wireless communications system 100A. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100A. In some other implementations, a UE 104 may be mobile in the wireless communications system 100A.

[0102] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1A. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1A. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100A.

[0103] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0104] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0105] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open radio access network (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a CU, a DU, a radio unit (RU), a RAN intelligent controller (RIC) (e.g., a near-real time RIC (Near-RT RIC), a non-real time RIC (Non-RT RIC)), a service management and orchestration (SMO) system, or any combination thereof.

[0106] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0107] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., radio resource control (RRC), service data adaption protocol (SDAP), packet data convergence protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0108] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0109] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0110] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a packet data network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0111] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0112] In the wireless communications system 100A, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100A (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0113] One or more numerologies may be supported in the wireless communications system 100A, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0114] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0115] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100A. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0116] In the wireless communications system 100A, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100A may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0117] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0118] FIG. 1B illustrates an example interaction 100B between a main radio 130 and a separate ultra-low power wake-up receiver (e.g., LP-WUR) 140 within a UE 104. As discussed above, the UE 104 needs to periodically wake up once per DRX cycle, which dominates the power consumption in periods with no signaling or data traffic. If the UE 104 are able to wake up only when they are triggered (e.g., triggered by paging), power consumption could be dramatically reduced. This can be achieved by using a wake-up signal to trigger the wake up of the main radio 130 and a separate receiver 140 which has the ability to monitor wake-up signal with ultra-low power consumption. Main radio 130 works for data and/or signaling transmission and reception (e.g., control signal monitoring and paging message receiving), which can be turned off or set to deep sleep unless it is turned on. It should be noted that, in the following description, the terms of “MR” and “main radio” may be used interchangeably, the terms of “LP” and “low power receiver/radio” may be used interchangeably, and the terms of “WUS” and “wake-up signal” may be used interchangeably.

[0119] The LP-WUS associated parameters are configured by higher layer. The LP-WUS configuration is transmitted to the UE by being included in the system information or being included in a UE specific RRC signaling. The UE monitors the WUS in a first frequency band (e.g., a first carrier, or a first BWP in the first carrier). Based on the WUS indication (e.g., WUS ON indication), the UE switches to receive paging message (e.g., in IDLE/INACTIVE states) in a second frequency band (in MR) or switches to DRX ON duration (if DRX configured) or allow UE monitoring control signal (e.g., CONNECTED states) in a second frequency band (in MR).

[0120] UE is further configured with transmission bits or segments for each OFDM symbol. The transmission bits for each OFDM symbol implicitly determine the waveform of WUS. For example, if the transmission bits (i.e., transmission segments) for each OFDM are 1, the waveform of WUS may be a first waveform that transmits a single bit in one OFDM symbol. An example of the first waveform is OOK-1. If the transmission bits for each OFDM symbol are larger than 1, the waveform of WUS may be a second waveform that transmits M (M>1) bits in one OFDM symbol. An example of the second waveform is OOK-4. OOK stands for On-Off Keying.

[0121] With regard to WUS generation and structure, WUS can be generated by various methods, e.g., multi-carrier (MC)-OOK. For example, a first waveform (e.g., OOK-1) can be used to generate WUS, where each OFDM symbol carries one-bit information of WUS. For another example, a second waveform (e.g., OOK-4) can be used to generate WUS, where each OFDM symbol carries multiple-bits information of WUS. For example, the OOK-4 may need DFT precoder before mapping the signal to frequency domain.

[0122] The sequence of WUS (e.g., OOK-1 or OOK-4) can be generated with random QPSK sequence or ZC sequence. For OOK-1, one bit (e.g., the information bit) is transmitted in each OFDM symbol. It means that two different states, one of which modulates ‘on’ chip and the other of which modulates ‘off’ chip, are mapped to REs. For example, the random QPSK sequence or ZC sequence is mapped to REs to modulate ‘on’ chip in time domain, and zeros are mapped to the REs to modulate ‘off’ chip.

[0123] FIG. 2A illustrates an example of synchronization signal blocks (SSBs) mechanism, and FIG. 2B illustrates an example of SSB configuration.

[0124] As illustrated in FIG. 2A, the transmission of synchronization signal/physical broadcast channels (SS/PBCHs) within an SS/PBCH set is confined to a 5ms window. The maximum number of SS/PBCHs within an SS/PBCH set (i.e., within 5ms period) is specified to be 4 for frequency ranges up to 3 GHz, 8 for frequency ranges from 3 to 6 GHz, or 64 for frequency ranges from 6 to 52.6 GHz in order to achieve a trade-off between coverage and resource overhead.

[0125] Moreover, as illustrated in FIG. 2B, the first symbol of SS/PBCH within 5ms half radio frame is determined by the subcarrier spacing of SS/PBCHs. The periods of

SSB transmission include the following ranges: {ms5, ms10, ms20, ms40, ms80, ms160}. Generally, ms20 (i.e., 20ms interval) is most common.

[0126] FIG. 3A illustrates an example of narrowband internet-of-things (NB-IoT) WUS configuration, and FIG. 3B illustrates an example of enhanced machine type communication (eMTC) WUS configuration.

[0127] In some scenarios, a UE supporting group WUS (GWUS) may be configured to monitor a WUS group and a common WUS. Upon detecting either of them, the UE shall monitor POs. As illustrated in FIG. 3A, for NB-IoT, the E-UTRAN may configure up to 2 WUS resources (e.g., numbered as WUS 0 and WUS 1). The *timeoffset*, $g0$, from the end of WUS resource numbered as WUS 0 to the start of corresponding PO is determined or configured.

[0128] Moreover, when both *wus-Config* and *gwus-Config* are present, the WUS resource numbered as WUS 0 may share radio resources with *wus-Config*. As illustrated in FIG. 3A, the *timeoffset* from the end of WUS resource numbered as WUS 1 to the start of corresponding PO is a sum of the *timeoffset* $g0$ and the maximum WUS duration T_{max}.

[0129] Furthermore, as illustrated in FIG. 3B, for eMTC, the E-UTRAN may configure up to 4 WUS resources (numbered as 0, 1, 2, 3).

[0130] In view of the above discussions, some embodiments of the present disclosure propose a solution of WUS configuration, especially for a UE in idle/inactive states. In some embodiments of the proposed solution, at the UE, a wake-up signal (WUS) configuration is received from a base station, a WUS signal is monitored based on the WUS configuration, and based on a wake-up indication of the WUS signal, it is determined to receive a paging message (e.g., in IDLE/INACTIVE states) or monitor a control signal (e.g., in CONNECTED states). By implementing the example embodiments of the present disclosure, a WUS configuration is provided to trigger one or more UEs to receive a paging message or monitor a control signal.

[0131] The example embodiments of the present disclosure at least relate to two aspects. The first aspect mainly relates to low power synchronization signal (LP-SS) transmissions; and the second aspect mainly relates to WUS transmissions, especially relates to low power WUS (LP-WUS) transmissions.

[0132] FIG. 4 illustrates an example signaling procedure 400 for WUS configuration in accordance with aspects of the present disclosure. At 410, a base station 402 may transmit, to a UE 404, a WUS configuration 412, where the base station 402 may be an example of network entity 102 in FIG. 1, and the UE 404 may be an example of UE 104 in FIG. 1. Accordingly, at 414, the UE 404 may receive the WUS configuration 412. At 416, the UE 404 may monitor a WUS signal based on the WUS configuration.

[0133] At 420, the base station 402 may transmit, based on the WUS configuration, a WUS signal 422 to the UE 404. Accordingly, at 424, the WUS signal 422 may be received by the UE 404 based on the WUS configuration. At 430, the UE 404 may determine, based on a wake-up indication of the WUS signal 422, to receive a paging message or monitor a control signal. At 440, the base station 402 may transmit, to the UE 404, a paging message 442 or a control signal 442. It should be noted that, the operation 430 may be carried out before the operation 440 or at the same time with the operation 440.

[0134] For the first aspect as mentioned above, in some implementations, the UE may further receive a low power synchronization signal (LP-SS), the LP-SS is determined based on a period of the LP-SS and a start time of the LP-SS, and the start time of the LP-SS is determined based on a first time offset to a first reference time, and the first time offset is included in the WUS configuration or determined based on a cell identity (ID) of a cell. In some implementations, the UE may further receive a synchronization signal block (SSB), and the period of the LP-SS is determined based on one or more periods of the SSB.

[0135] In some implementations, the first reference time is an absolute time (e.g. frame #0 and slot #0, or slot #0 of each period of the LP-SS), and the first time offset is a frame-level offset or a subframe-level offset. In some implementations, the first time offset further comprises an additional time offset, and the additional time offset is one of the following: a first half frame of a frame; a second half frame of a frame; a time offset within a frame; or a time offset within a subframe, which is indicated to avoid the potential collision with existing SSB in time domain.

[0136] Additionally, in some implementations, the first time offset is a frame-level offset or a subframe-level offset, the start time of the LP-SS is further determined based on a second time offset included in the WUS configuration, and the second time offset is a time offset between a main radio and a low power radio, the second time offset may be the time offset of the two radios or two frequency bands or two BWPs (e.g., 3ms time offset for the slot #0, frame #0 of the two). In some implementations, the second time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0137] Alternatively, in some implementations, the first reference time is a start of a first SSB within the period of the LP-SS, and the first time offset is included in the WUS configuration. In some implementations, the first time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

[0138] In some implementations, the main radio is associated with a first frequency band where a SSB or the paging message or the control signal is transmitted, and the low power radio is associated with a second frequency band where the LP-SS or the WUS signal is transmitted.

[0139] FIG. 5A illustrates a first example of LP-SS transmissions in accordance with aspects of the present disclosure, and FIG. 5B illustrates a second example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIGS. 5A and 5B, the LP-SS transmissions in a low power wake-up receiver (LP-WUR) and the SSB transmissions in a main radio (MR) may be within the same frequency range 1 (FR1) band or within different bands. The LP-SS is transmitted with a period of $T_{LP\text{-}SS}$ and the start of LP-SS is configured with a first time offset to a reference time.

[0140] In some cases, for example, as illustrated in FIG. 5A, the period of LP-SS (e.g., $T_{LP\text{-}SS}$) may be configured as a multiple of the period of SSB, e.g., $T_{LP\text{-}SS} = KT_{SSB}$, where T_{SSB} is the period of associated SSB (e.g., cell defined SSB in MR), and K is the scaling factor, e.g., $K = \{2, 4, 6, 8\}$.

[0141] In some cases, the reference time may be an absolute time (e.g., frame #0, subframe #0), and the first time offset to the absolute time may include a frame offset. The start of LP-SS should meet some requirement. For example, the frame number of the start of LP-SS should meet the requirement of $n_f \ mod \ (T_{LP\text{-}SS}/10) = O_{LP\text{-}SS}$, where n_f is the frame number of the start of LP-SS, and $O_{LP\text{-}SS}$ is an offset value (e.g., frame number offset) configured by higher layer or determined by cell ID.

[0142] The first time offset may further include an indication of the first or second 5ms half radio frame to avoid the potential collision with SSB transmission or include additional time offset within a frame and even within a subframe.

[0143] In some other cases, for example, as illustrated in FIG. 5B, in order to facilitate for the UE to switch to LP to monitor the LP-SS quickly and facilitate for the UE with SSB synchronization to switch to LP to monitor LP-WUS without further LP-SS synchronization, a second time offset between MR (e.g., slot #0, bwp #0, cell #0) and LP (e.g., slot #0, bwp #1, cell #1) is indicated in SIB (in MR) with default value of 0, since LP doesn't include the PBCH and frame number indication. As such, the start of LP-SS may be configured based on the second time offset and the first time offset.

[0144] In these cases, the second time offset may be associated with the smaller or higher subcarrier spacing between that in MR and LP, or associated with one subcarrier spacing of that in MR and LP.

[0145] It should be noted that, for the second time offset between MR and LP as mentioned above, MR may be associated with a first frequency band where a SSB or a paging message or a control signal is transmitted, and LP may be associated with a second frequency band where the LP-SS or the LP-WUS is transmitted.

[0146] In other words, for the second time offset between MR and LP as mentioned above, the second time offset may be considered as a time offset between an absolute time associated with MR and an absolute time associated with LP, where the absolute time may be slot #0 of frame #0.

[0147] FIG. 5C illustrates a third example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIG. 5C, the LP-SS transmissions in the LP-WUR and the SSB transmissions in the MR may be within the same FR1 band or within different bands. The LP-SS is transmitted with a period of $T_{LP\text{-}SS}$ and the start of LP-SS is configured with a time offset to a reference time.

[0148] In some cases, in order to facilitate for the UE to switch to LP to monitor the LP-SS quickly and facilitate for the UE with SSB synchronization to switch to LP to monitor LP-WUS without further LP-SS synchronization, the reference time may be the start of first SSB in period of $T_{LP\text{-}SS}$, and the time offset is configured in SIB (in MR). In these cases, the time offset is associated with the smaller or higher subcarrier spacing between that in MR and LP, or associated with one subcarrier spacing of that in MR and LP.

[0149] Referring back to FIG. 4, in some implementations, LP-SS in each period of the LP-SS is transmitted in a LP-SS block set with one or more LP-SS beams and one or more repetitions. In some implementations, the one or more LP-SS beams are associated with one or more SSB beams, and a pattern (including the order of the pattern) of the one or more LP-SS beams is indicated by a pattern of the one or more SSB beams.

[0150] Alternatively, in some implementations, a pattern of the one or more LP-SS beams is configured by the WUS configuration. In some implementations, the UE may further determine, based on an indication of a higher layer, that the one or more LP-SS beams is the same as the one or more SSB beams. Alternatively, in some implementations, the one or more LP-SS beams have an association with one or more SSB beams, and the association is configured by the WUS configuration. Particularly, the association that the one or more LP-SS beams is the same as the one or more SSB beams (e.g., both in pattern and order) can be one special case of association between the two.

[0151] In some implementations, the one or more LP-SS beams are transmitted in consecutive slots or subframes or frames. Alternatively, in some other implementations, the one or more LP-SS beams are transmitted with at least one interval of multiple slots or subframes or frames. In some embodiments, an order of the one or more LP-SS beams is cyclically shifted among one or more periods of the LP-SS.

[0152] FIG. 5D illustrates a fourth example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIG. 5D, the LP-SS transmissions in each period (e.g., $T_{LP\text{-}SS}$) is transmitted in LP-SS block set with one or more LP-SS beams with one or more repetitions.

[0153] In some cases, for example, as illustrated in FIG. 5D, the one or more LP-SS beams are the same as SSB beams (e.g., as indicated by *ssb-PositionsInBurst* in SIB, which may be "11110000" as illustrated in FIG. 5D). In some other cases, for example, as illustrated in FIG. 5D, the one or more LP-SS beams are indicated by higher layer parameter with a separate bitmap from that for SSB beams (e.g., *ssb-PositionsInBurst2*, which may be "11110000" as illustrated in FIG. 5D), and the UE may assume that the LP-SS beams are the same as corresponding SSB beams as indicated in higher parameter (e.g., *ssb-PositionsInBurst*) for each bit of the bitmap interpreting.

[0154] In some further cases, for example, as illustrated in FIG. 5D, the one or more LP-SS beams are associated with the SSB beams (e.g., a subset of the SSB beams or an extension of the SSB beams), and the association is configured in higher layer. For example, as illustrated in FIG. 5D, the association includes that LP-SS beam #n is associated with SSB beams #2n-1 and beam #2n, and *ssb-PositionsInBurst2* which may be "11000000".

[0155] For example, as illustrated in FIG. 5D, the LP-SS beams may be transmitted in consecutive slots or subframes, or the LP-SS beams may be transmitted with the interval of $N_{interval}$ slots.

[0156] In some cases, to make the UE fairness, the order of LP-SS beams is cyclically shifted among one or more periods of LP-SS (e.g., $T_{LP\text{-}SS}$). For example, as illustrated in FIG. 5D, for beams {#1, #2, #3, #4} with original beams order in the first LP-SS period, after beam shifting, there are beams {#2, #3, #4, #1} with updated beams order in the second LP-SS period.

[0157] Moreover, for example, as illustrated in FIG. 5D, the one or multiple LP-SS beams may be in the same symbols as the symbols of corresponding SSB beams (e.g., in the same BWP with same subcarrier spacing).

[0158] Referring back to FIG. 4, for the second aspect as mentioned above, in some implementations, the WUS signal is transmitted in WUS resource, the WUS resource is determined based on a period of the WUS resource and a start or end time of the WUS resource, and the start or end time of the WUS resource is determined based on a third time offset to a third reference time.

[0159] In some implementations, the period of the WUS resource is determined based on a paging period. In some examples, the third reference time is an absolute time, and the third time offset is a frame-level offset or a subframe-level offset. For instance, the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0160] In some implementations, the third reference time is a start slot or start frame of a first paging occasion within a paging period, and the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

[0161] FIG. 6A illustrates a first example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIG. 6A, the LP-WUS may be transmitted in LP-WUS resource, the LP-WUS resource is configured with a period of $T_{LP\text{-}WUS}$ and the start or end time of LP-WUS resource is configured with a time offset to a reference time. The period of LP-WUS resource (e.g., $T_{LP\text{-}WUS}$) is configured as a scaling factor of paging cycle, e.g., $T_{LP\text{-}WUS} = KT_{Page}$, where T_{Page} is paging cycle, and K is the scaling factor, e.g., K={1/32, 1/128, 1/256}.

[0162] In some cases, for example, as illustrated in FIG. 6A, the reference time may be an absolute time (e.g., frame #0, subframe #0, slot #0), the time offset to the absolute time (e.g., frame #0, subframe #0, slot #0) may include a frame offset or subframe offset or slot offset or symbol offset. The start of LP-WUS should meet some requirement. For example, the frame number of the start of LP-WUS should meet the requirement of n_f mod $(T_{LP\text{-}WUS}/10) = O_{LP\text{-}WUS}$, where n_f is the frame number of the start of LP-WUS, and $O_{LP\text{-}WUS}$ is frame offset value configured by higher layer or determined by PO index within a paging frame. For example, $n_{po} = 1$, time offset $O_{LP\text{-}WUS} = 1/4\ T_{LP\text{-}WUS}$; $n_{po} = 2$, and time offset $O_{LP\text{-}WUS} = 1/2\ T_{LP\text{-}WUS}$.

[0163] In some other cases, for example, as illustrated in FIG. 6A, the reference time may be the start subframe or frame of paging occasion (PO) in period of T_{page}, and the time offset is configured in SIB (in MR) or the time offset is determined by PO index within a paging frame. For example, n_{po} =1, and time offset = 1/4 $T_{LP\text{-}WUS}$; or n_{po} = 2, and time offset = 1/2 $T_{LP\text{-}WUS}$.

[0164] It should be noted that, as illustrated in FIG. 6A, although the time offset is indicated as an offset from the last LP-WUS (e.g., end of the last LP-WUS) as counted in time to the start frame of corresponding PO, the time offset may also be indicated as an offset from the first LP-WUS (e.g., start of the first LP-WUS) as counted in time to the start frame of corresponding PO. Alternatively, the time offset may also be indicated as an offset from any other LP-WUS to the start frame of corresponding PO.

[0165] Referring back to FIG. 4, in some implementations, WUS signal transmitted in at least one WUS resource is associated with one or more WUS beams and one or more repetitions. In some implementations, the WUS signal is transmitted in at least one WUS resource with a transmission manner based on an order of the one or more WUS beams and the one or more repetitions. In some implementations, the transmission manner comprises one of the following: beams sweeping first and repetition second; or repetition for one beam first and beams sweeping second.

[0166] In some implementations, the one or more WUS beams have an association with one or more LP-SS beams or one or more SSB beams, and the association is configured by the WUS configuration. In some implementations, the WUS signal is transmitted in consecutive WUS resources or interleaved WUS resources.

[0167] FIG. 6B illustrates a second example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIG. 6B, the LP-WUS in multiple LP-WUS resources may be associated with one or more LP-WUS beams with one or more repetitions. The LP-WUS may be transmitted in LP-WUS resources with manners in order of LP-WUS beams and repetitions.

[0168] In some cases, for example, as illustrated in FIG. 6B, with the manner of beams sweeping first and repetition second, LP-WUS associated with multiple LP-WUS beams may be transmitted in consecutive LP-WUS resources and LP-WUS associated with multiple LP-WUS beams may be repeated in LP-WUS resources.

[0169] In some other cases, for example, as illustrated in FIG. 6B, with the manner of repetition for one beam first and beams sweeping second, LP-WUS associated with the same LP-WUS beams may be repeated in consecutive LP-WUS resources X times and LP-WUS associated with multiple LP-WUS beams may be transmitted in following LP-WUS resources. The repetition number X may be configured by higher layer parameters.

[0170] It should be noted that, as illustrated in FIG. 6B, some LP-WUS resources, which may conflict with LP-SSs in time domain and depicted with dotted boxes correspondingly, may be indicated as invalid LP-WUS resources. Thus, LP-WUS may not be transmitted in such LP-WUS resources. Alternatively, such LP-WUS resources may not be indicated as invalid, and LP-WUS may also be transmitted in such LP-WUS resources.

[0171] FIG. 6C illustrates a third example of LP-SS transmissions in accordance with aspects of the present disclosure, FIG. 6D illustrates a fourth example of LP-SS transmissions in accordance with aspects of the present disclosure, FIG. 6E illustrates a fifth example of LP-SS transmissions in accordance with aspects of the present disclosure, and FIG. 6F illustrates a sixth example of LP-SS transmissions in accordance with aspects of the present disclosure.

[0172] For example, as illustrated in FIGS. 6C-6F, the LP-WUS transmissions in multiple LP-WUS resources may be associated with one or more LP-WUS beams. In some cases, for example, as illustrated in FIGS. 6C and 6D, the LP-WUS beams may be associated with beams of LP-SS, which may be indicated by higher layer parameter. In some other cases, for example, as illustrated in FIGS. 6E-6F, the LP-WUS beams may be associated with beams of SSB, which may be indicated by higher layer parameter.

[0173] FIG. 6G illustrates a seventh example of LP-SS transmissions in accordance with aspects of the present disclosure. In some cases, for example, as illustrated in FIG. 6G, the LP-WUS associated with one or more beams may be transmitted in consecutive LP-WUS resources for particular UE subgroup. The start of the LP-WUS resource for particular UE group is determined by the UE subgroup index or configured by higher layer parameter.

[0174] In some other cases, for example, as illustrated in FIG. 6G, the LP-WUS associated with one or more beams may be transmitted in interleaved LP-WUS resources for particular UE subgroup. The interval of the LP-WUS resource for the LP-WUS is determined by the total group number or configured by higher layer parameter.

[0175] Generally, the LP-WUS associated with one or more beams transmission manner may be configured by higher layer parameter or determined by LP-WUS resource configuration (e.g., number of consecutive WUS resource for one beams).

[0176] Referring back to FIG. 4, in some implementations, the UE may be configured with a WUS window for a paging occasion, and the WUS window is determined based on a start or end time and a window length, and the UE may monitor the WUS signal in the WUS window for the paging occasion. In some implementations, the end time is a start of a paging occasion minus a gap offset configured by a higher layer, and the window length is determined based on a higher layer with one or more periods of the WUS resource or configured by the WUS configuration.

[0177] FIG. 6H illustrates an eighth example of LP-SS transmissions in accordance with aspects of the present disclosure. For example, as illustrated in FIG. 6H, a WUS window with a start or end time and a window length may be configured for particular

PO. The end time may be the start of PO minus a gap offset, and the gap offset may be configured by higher layer. Moreover, the window length may be configured by higher layer with the unit of the period of WUS resource (e.g., 16 periods of WUS resource) or further determined by the LP-WUS beams number (e.g., LP-WUS beams number =5, and the window length is 4 times of all LP-WUS beams duration).

[0178] FIG. 7 illustrates an example of a device 700 that supports WUS configuration in accordance with aspects of the present disclosure. The device 700 may be an example of a UE 104-1 as described herein. The device 700 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 700 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 702, a memory 704, a transceiver 706, and, optionally, an I/O controller 708. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0179] The processor 702, the memory 704, the transceiver 706, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0180] In some implementations, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704).

[0181] For example, the processor 702 may support wireless communication at the device 700 in accordance with examples as disclosed herein. The processor 702 may be configured to operable to support means for receiving, from a base station, a wake-up signal (WUS) configuration; means for monitoring a WUS signal based on the WUS configuration; and means for determining, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

[0182] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 702 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 704) to cause the device 700 to perform various functions of the present disclosure.

[0183] The memory 704 may include random access memory (RAM) and read-only memory (ROM). The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 702 cause the device 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 702 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 704 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0184] The I/O controller 708 may manage input and output signals for the device 700. The I/O controller 708 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 708 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 708 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 708 may be implemented as part of a processor, such as the processor 706. In some implementations, a user may interact with the device 700 via the I/O controller 708 or via hardware components controlled by the I/O controller 708.

[0185] In some implementations, the device 700 may include a single antenna 710. However, in some other implementations, the device 700 may have more than one antenna 710 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 706 may communicate bi-directionally, via the one or more antennas 710, wired, or wireless links as described herein. For example, the transceiver 706 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 706 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 710 for transmission, and to demodulate packets received from the one or more antennas 710. The transceiver 706 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0186] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 710 for transmitting the amplified signal into the air or wireless medium.

[0187] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 710 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0188] FIG. 8 illustrates an example of a processor 800 that supports WUS configuration in accordance with aspects of the present disclosure. The processor 800 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 800 may include a controller 802 configured to perform various operations in accordance with examples as described herein. The processor 800 may optionally include at least one memory 804, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 800 may optionally include one or more arithmetic-logic units (ALUs) 800. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0189] The processor 800 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 800) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0190] The controller 802 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 800 to cause the processor 800 to support various operations of a base station in accordance with examples as described herein. For example, the controller 802 may operate as a control unit of the processor 800, generating control signals that manage the operation of various components of the processor 800. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0191] The controller 802 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 804 and determine subsequent instruction(s) to be executed to cause the processor 800 to support various operations in accordance with examples as described herein. The controller 802 may be configured to track memory address of instructions associated with the memory 804. The controller 802 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 802 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 802 may be configured to manage flow of data within the processor 800. The controller 802 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 800.

[0192] The memory 804 may include one or more caches (e.g., memory local to or included in the processor 800 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 804 may reside within or on a processor chipset (e.g., local to the processor 800). In some other implementations, the memory 804 may reside external to the processor chipset (e.g., remote to the processor 800).

[0193] The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 800, cause the processor 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 802 and/or the processor 800 may be configured to execute computer-readable instructions stored in the memory 804 to cause the processor 800 to perform various functions. For example, the processor 800 and/or the controller 802 may be coupled with or to the memory 804, and the processor 800, the controller 802, and the memory 804 may be configured to perform various functions described herein. In some examples, the processor 800 may include multiple processors and the memory 804 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0194] The one or more ALUs 800 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 800 may reside within or on a processor chipset (e.g., the processor 800). In some other implementations, the one or more ALUs 800 may reside external to the processor chipset (e.g., the processor 800). One or more ALUs 800 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 800 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 800 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 800 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 800 to handle conditional operations, comparisons, and bitwise operations.

[0195] The processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to or operable to support means for transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration; means for transmitting, based on the WUS configuration, a WUS signal to the UE; and means for transmitting, to the UE, a paging message or a control signal.

[0196] FIG. 9 illustrates a flowchart of a method 900 that supports WUS configuration in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a device or its components as described herein. For example, the operations of the method 900 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0197] At 910, the method may include receiving, from a base station, a wake-up signal (WUS) configuration. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910 may be performed by a device as described with reference to FIG. 1A.

[0198] At 920, the method may include monitoring a WUS signal based on the WUS configuration. The operations of 920 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 920 may be performed by a device as described with reference to FIG. 1A.

[0199] At 930, the method may include determining, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal. The operations of 930 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 930 may be performed by a device as described with reference to FIG. 1A.

[0200] FIG. 10 illustrates a flowchart of a method 1000 that supports WUS configuration in accordance with aspects of the present disclosure. The operations of the method 1000 may be implemented by a device or its components as described herein. For example, the operations of the method 1000 may be performed by a base station as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0201] At 1010, the method may include transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration. The operations of 1010 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1010 may be performed by a device as described with reference to FIG. 1A.

[0202] At 1020, the method may include transmitting, based on the WUS configuration, a WUS signal to the UE. The operations of 1020 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1020 may be performed by a device as described with reference to FIG. 1A.

[0203] At 1030, the method may include transmitting, to the UE, a paging message or a control signal. The operations of 1030 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1030 may be performed by a device as described with reference to FIG. 1A.

[0204] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0205] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0206] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0207] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0208] As used herein, including in the claims, an article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

[0209] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A user equipment (UE), comprising:

at least one memory; and

at least one processor coupled with the at least one memory and configured to cause the UE to:

receive a wake-up signal (WUS) configuration;

monitor a WUS signal based on the WUS configuration; and

determine, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

2. The UE of claim 1, wherein the UE is further caused to receive a low power synchronization signal (LP-SS), the LP-SS is determined based on a period of the LP-SS and a start time of the LP-SS, and

wherein the start time of the LP-SS is determined based on a first time offset to a first reference time, and the first time offset is included in the WUS configuration or determined based on a cell identity (ID) of a cell.

3. The UE of claim 2, wherein the UE is further caused to receive a synchronization signal block (SSB), and the period of the LP-SS is determined based on one or more periods of the SSB.

4. The UE of claim 2, wherein the first reference time is an absolute time, and the first time offset is a frame-level offset or a subframe-level offset.

5. The UE of claim 4, wherein the first time offset further comprises an additional time offset, and the additional time offset is one of the following:

a first half frame of a frame;

a second half frame of a frame;

a time offset within a frame; or

a time offset within a subframe.

6. The UE of claim 2, wherein the first time offset is a frame-level offset or a subframe-level offset, the start time of the LP-SS is further determined based on a second time offset included in the WUS configuration, and the second time offset is a time offset between a main radio and a low power radio.

7. The UE of claim 6, wherein the second time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

8. The UE of claim 2, wherein the first reference time is a start of a first SSB within the period of the LP-SS, and the first time offset is included in the WUS configuration.

9. The UE of claim 8, wherein the first time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

10. The UE of any of claims 6, 7, and 9, wherein the main radio is associated with a first frequency band where a SSB or the paging message or the control signal is transmitted, and the low power radio is associated with a second frequency band where the LP-SS or the WUS signal is transmitted.

11. The UE of claim 2, wherein LP-SS in each period of the LP-SS is transmitted in a LP-SS block set with one or more LP-SS beams and one or more repetitions.

12. The UE of claim 11, wherein the one or more LP-SS beams are associated with one or more SSB beams, and a pattern of the one or more LP-SS beams is indicated by a pattern of the one or more SSB beams.

13. The UE of claim 11, wherein a pattern of the one or more LP-SS beams is configured by the WUS configuration.

14. The UE of claim 13, wherein the UE is further caused to determine, based on an indication of a higher layer, that the one or more LP-SS beams is the same as the one

or more SSB beams.

15. The UE of claim 11, the one or more LP-SS beams have an association with one or more SSB beams, and the association is configured by the WUS configuration.

16. The UE of claim 11, wherein the one or more LP-SS beams are transmitted in consecutive slots or subframes, or the one or more LP-SS beams are transmitted with at least one interval of multiple slots or subframes.

17. The UE of claim 11, wherein an order of the one or more LP-SS beams is cyclically shifted among one or more periods of the LP-SS.

18. The UE of claim 1, wherein the WUS signal is transmitted in WUS resource, the WUS resource is determined based on a period of the WUS resource and a start or end time of the WUS resource, and the start or end time of the WUS resource is determined based on a third time offset to a third reference time.

19. The UE of claim 18, wherein the period of the WUS resource is determined based on a paging period.

20. The UE of claim 18, wherein the third reference time is an absolute time, and the third time offset is a frame-level offset or a subframe-level offset, and wherein the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

21. The UE of claim 18, wherein the third reference time is a start slot or start frame of a first paging occasion within a paging period, and the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

22. The UE of claim 18, wherein WUS signal transmitted in at least one WUS resource is associated with one or more WUS beams and one or more repetitions.

23. The UE of claim 22, wherein the WUS signal is transmitted in at least one

WUS resource with a transmission manner based on an order of the one or more WUS beams and the one or more repetitions.

24. The UE of claim 23, wherein the transmission manner comprises one of the following:

beams sweeping first and repetition second; or

repetition for one beam first and beams sweeping second.

25. The UE of claim 22, wherein the one or more WUS beams have an association with one or more LP-SS beams or one or more SSB beams, and the association is configured by the WUS configuration.

26. The UE of claim 22, wherein the WUS signal is transmitted in consecutive WUS resources or interleaved WUS resources.

27. The UE of claim 18, wherein the UE is configured with a WUS window for a paging occasion, and the WUS window is determined based on a start or end time and a window length, and wherein the UE is caused to monitor the WUS signal in the WUS window for the paging occasion.

28. The UE of claim 27, wherein the end time is a start of a paging occasion minus a gap offset configured by a higher layer, and the window length is determined based on a higher layer with one or more periods of the WUS resource or configured by the WUS configuration.

29. A base station, comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, via the transceiver and to a user equipment (UE), a wake-up signal (WUS) configuration;

transmit, based on the WUS configuration and via the transceiver, a WUS signal to the UE; and

transmit, via the transceiver and to the UE, a paging message or a control signal.

30. The base station of claim 29, wherein the base station is further caused to transmit a low power synchronization signal (LP-SS), the LP-SS is determined based on a period of the LP-SS and a start time of the LP-SS, and

wherein the start time of the LP-SS is determined based on a first time offset to a first reference time, and the first time offset is included in the WUS configuration or determined based on a cell identity (ID) of a cell.

31. The base station of claim 30, wherein the base station is further caused to transmit a synchronization signal block (SSB), and the period of the LP-SS is determined based on one or more periods of the SSB.

32. The base station of claim 30, wherein the first reference time is an absolute time, and the first time offset is a frame-level offset or a subframe-level offset.

33. The base station of claim 32, wherein the first time offset further comprises an additional time offset, and the additional time offset is one of the following:

a first half frame of a frame;

a second half frame of a frame;

a time offset within a frame; or

a time offset within a subframe.

34. The base station of claim 30, wherein the first time offset is a frame-level offset or a subframe-level offset, the start time of the LP-SS is further determined based on a second time offset included in the WUS configuration, and the second time offset is a time offset between a main radio and a low power radio.

35. The base station of claim 34, wherein the second time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

36. The base station of claim 30, wherein the first reference time is a start of a first SSB within the period of the LP-SS, and the first time offset is included in the WUS

configuration.

37. The base station of claim 36, wherein the first time offset is associated with a smaller one or a greater one between a subcarrier spacing in a main radio and a subcarrier spacing in a low power radio.

38. The base station of any of claims 34, 35, and 37, wherein the main radio is associated with a first frequency band where the SSB or the paging message or the control signal is transmitted, and the low power radio is associated with a second frequency band where the LP-SS or the WUS signal is transmitted.

39. The base station of claim 30, wherein LP-SS in each period of the LP-SS is transmitted in a LP-SS block set with one or more LP-SS beams and one or more repetitions.

40. The base station of claim 39, wherein the one or more LP-SS beams are associated with one or more SSB beams, and a pattern of the one or more LP-SS beams is indicated by a pattern of the one or more SSB beams.

41. The base station of claim 39, wherein a pattern of the one or more LP-SS beams is configured by the WUS configuration.

42. The base station of claim 41, wherein the base station is further caused to transmit an indication for indicating that the one or more LP-SS beams is the same as the one or more SSB beams.

43. The base station of claim 39, the one or more LP-SS beams have an association with one or more SSB beams, and the association is configured by the WUS configuration.

44. The base station of claim 39, wherein the one or more LP-SS beams are transmitted in consecutive slots or subframes, or the one or more LP-SS beams are transmitted with at least one interval of multiple slots or subframes.

45. The base station of claim 39, wherein an order of the one or more LP-SS beams

is cyclically shifted among one or more periods of the LP-SS.

46. The base station of claim 29, wherein the WUS signal is transmitted in WUS resource, the WUS resource is determined based on a period of the WUS resource and a start or end time of the WUS resource, and the start or end time of the WUS resource is determined based on a third time offset to a third reference time.

47. The base station of claim 46, wherein the period of the WUS resource is determined based on a paging period.

48. The base station of claim 46, wherein the third reference time is an absolute time, and the third time offset is a frame-level offset or a subframe-level offset, and wherein the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

49. The base station of claim 46, wherein the third reference time is a start slot or start frame of a first paging occasion within a paging period, and the third time offset is included in the WUS configuration or determined based on an index of a paging occasion within a paging frame or paging period.

50. The base station of claim 46, wherein WUS signal transmitted in at least one WUS resource is associated with one or more WUS beams and one or more repetitions.

51. The base station of claim 50, wherein the WUS signal is transmitted in at least one WUS resource with a transmission manner based on an order of the one or more WUS beams and the one or more repetitions.

52. The base station of claim 51, wherein the transmission manner comprises one of the following:

beams sweeping first and repetition second; or

repetition for one beam first and beams sweeping second.

53. The base station of claim 50, wherein the one or more WUS beams have an association with one or more LP-SS beams or one or more SSB beams, and the association

is configured by the WUS configuration.

54. The base station of claim 50, wherein the WUS signal is transmitted in consecutive WUS resources or interleaved WUS resources.

55. The base station of claim 46, wherein a WUS window is configured for a paging occasion, and the WUS window is determined based on a start or end time and a window length, and wherein the processor is further configured to transmit the WUS signal in the WUS window for the paging occasion.

56. The base station of claim 55, wherein the end time is a start of a paging occasion minus a gap offset configured by a higher layer, and the window length is determined based on a higher layer with one or more periods of the WUS resource or configured by the WUS configuration.

57. A processor for wireless communication, comprising:

at least one memory; and

a controller coupled with the at least one memory and configured to cause the controller to:

receive, from a base station, a wake-up signal (WUS) configuration;

monitor a WUS signal based on the WUS configuration; and

determine, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

58. A processor for wireless communication, comprising:

at least one memory; and

a controller coupled with the at least one memory and configured to cause the controller to:

transmit, to a user equipment (UE), a wake-up signal (WUS) configuration;

transmit, based on the WUS configuration, a WUS signal to the UE; and

transmit, to the UE, a paging message or a control signal.

59. A method performed by a user equipment, the method comprising:

receiving, from a base station, a wake-up signal (WUS) configuration;

monitoring a WUS signal based on the WUS configuration; and

determining, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal.

60. A method performed by a base station, the method comprising:

transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration;

transmitting, based on the WUS configuration, a WUS signal to the UE; and

transmitting, to the UE, a paging message or a control signal.

DRAWINGS

100A

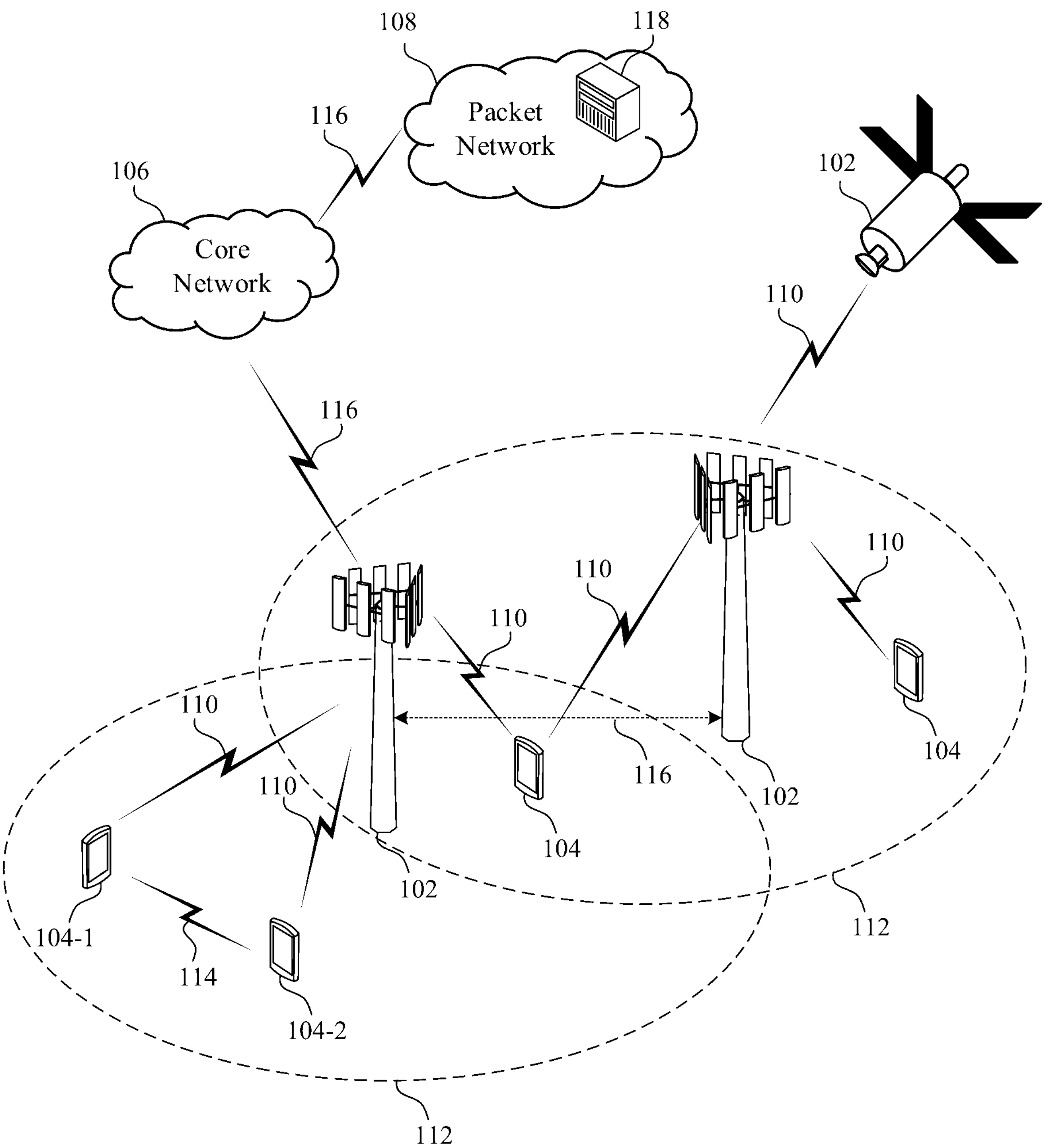


FIG. 1A

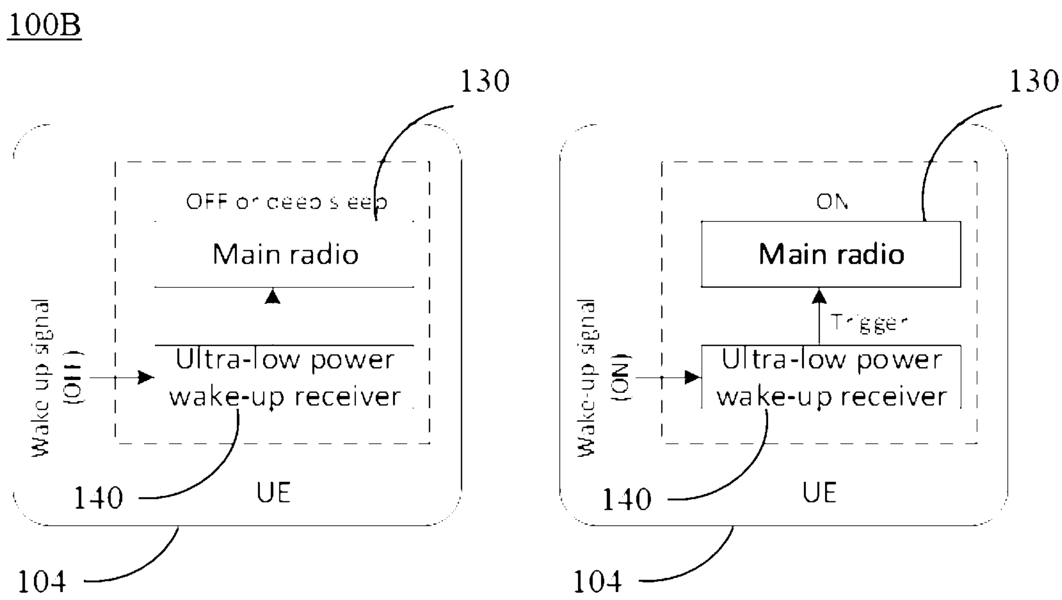

100B
130
OFF or deep sleep
Main radio
Wake up signal (OFF)
Ultra-low power wake-up receiver
140
UE
104
130
ON
Main radio
Trigger
Wake-up signal (ON)
Ultra-low power wake-up receiver
140
UE
104

FIG. 1B

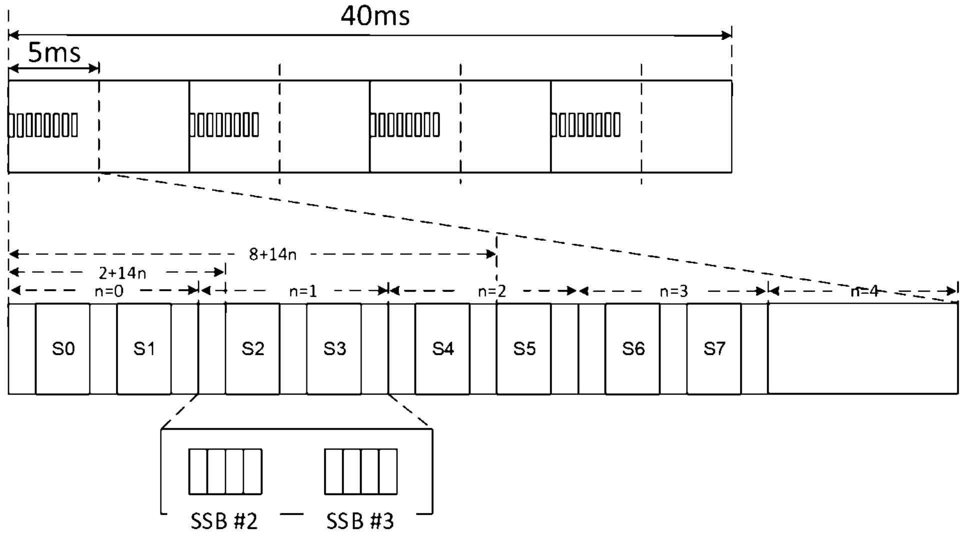


FIG. 2A

Type	SSB SCS(kHz)	SSB first symbol index in half radio frame(5ms)
A	15	{2,8}+14n
B	30	{4,8,16,20}+28n
C	30	{2,8}+14n

FIG. 2B

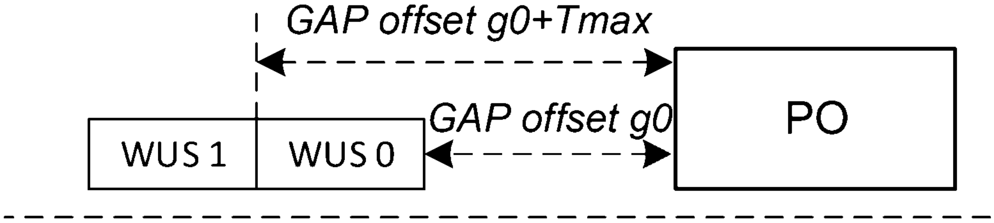

GAP offset g0+Tmax
GAP offset g0
WUS 1
WUS 0
PO

FIG. 3A

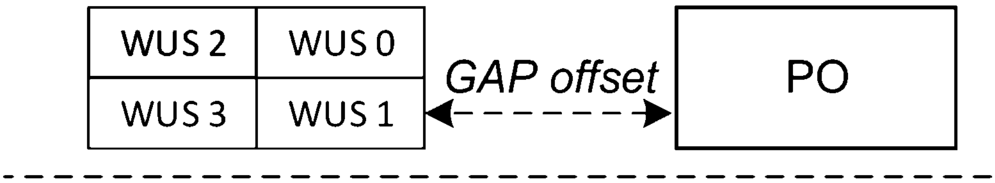

WUS 2
WUS 0
WUS 3
WUS 1
GAP offset
PO

FIG. 3B

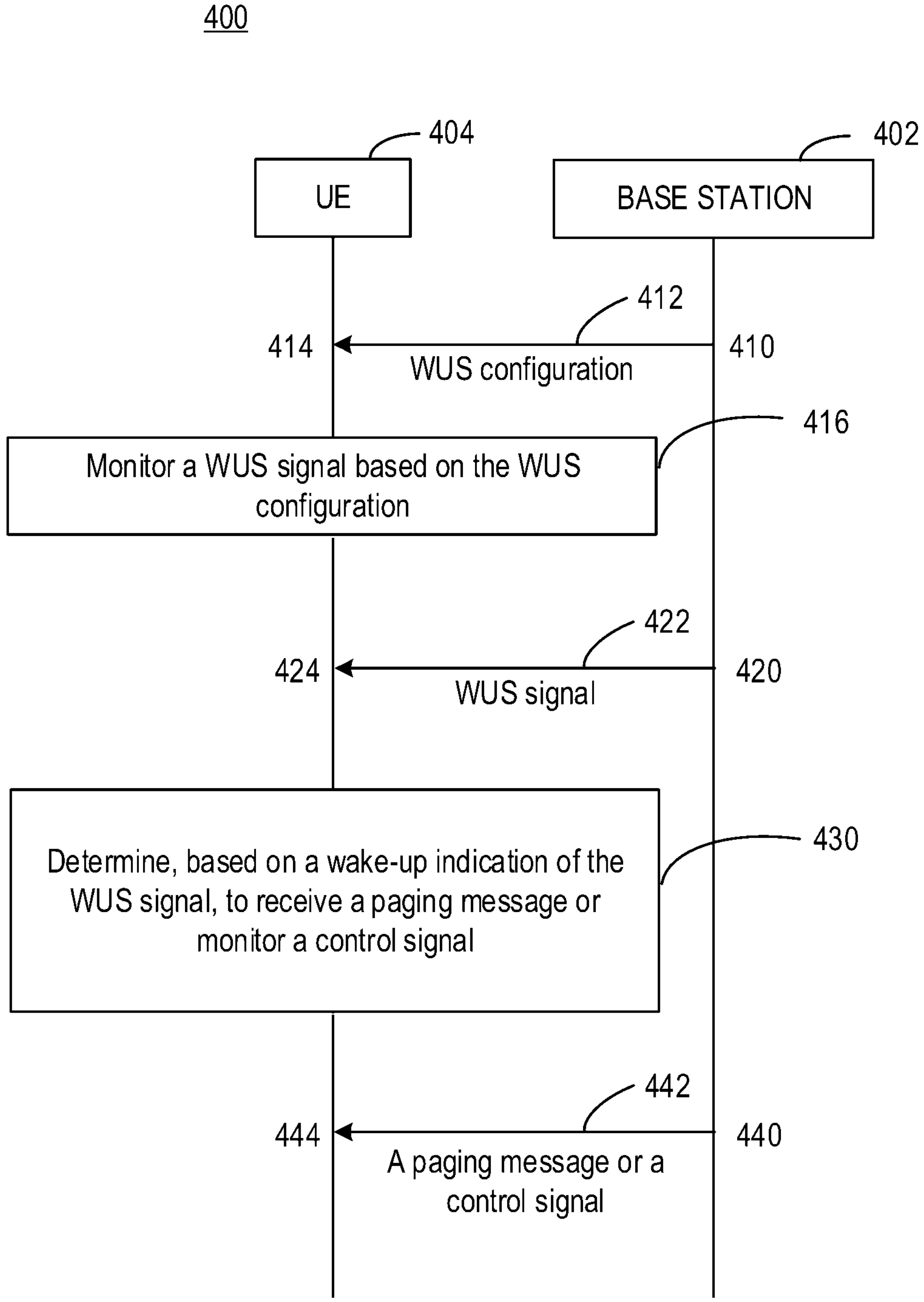

400
404
402
UE
BASE STATION
412
414
410
WUS configuration
416
Monitor a WUS signal based on the WUS configuration
422
424
420
WUS signal
430
Determine, based on a wake-up indication of the WUS signal, to receive a paging message or monitor a control signal
442
444
440
A paging message or a control signal

FIG. 4

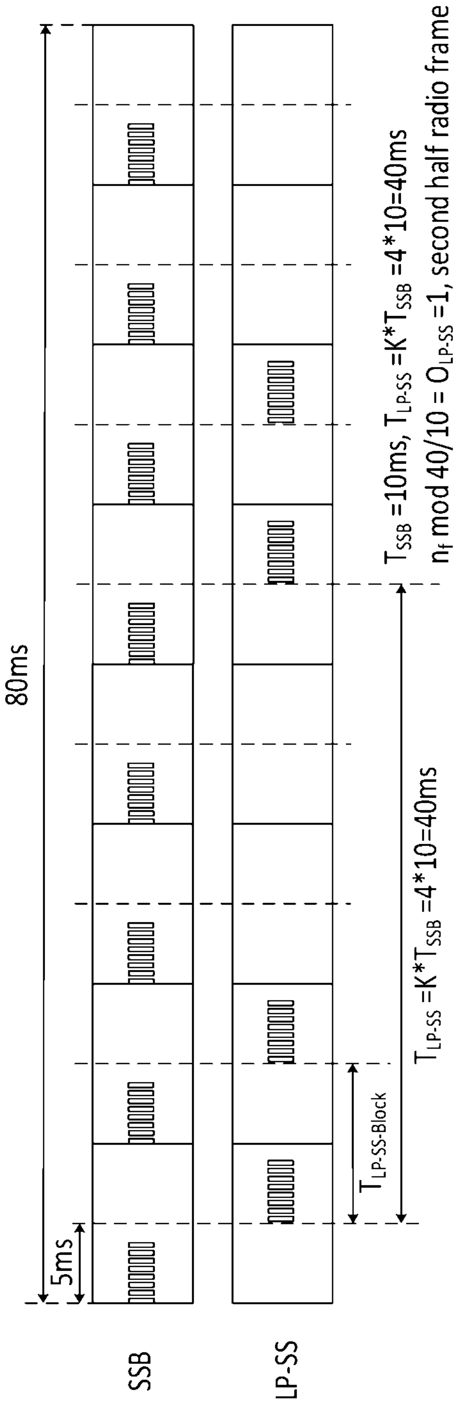
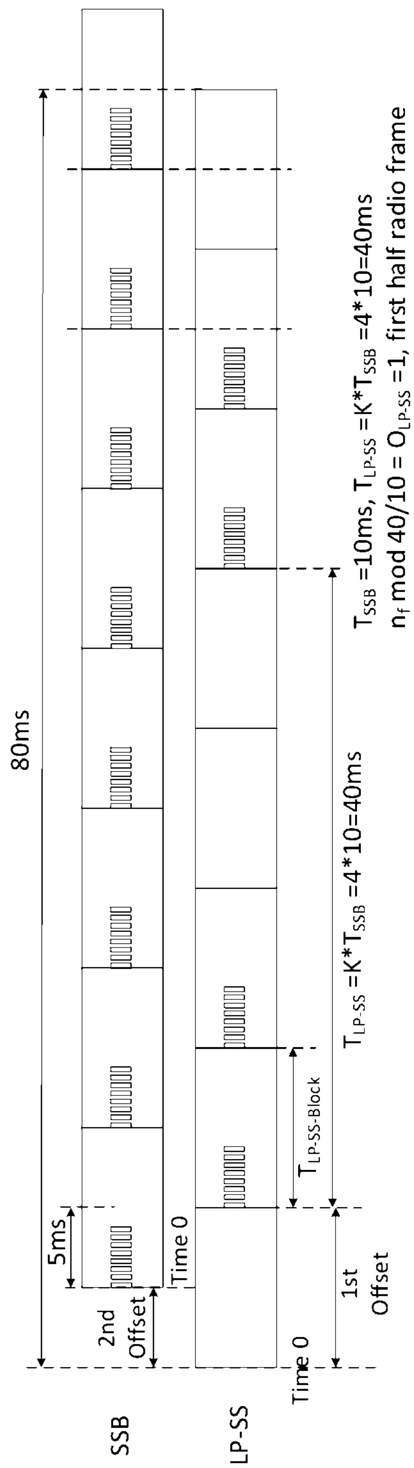

80ms
5ms
SSB
LP-SS
$T_{LP\text{-}SS\text{-}Block}$
$T_{LP\text{-}SS} = K*T_{SSB} = 4*10=40ms$
$T_{SSB} = 10ms$, $T_{LP\text{-}SS} = K*T_{SSB} = 4*10=40ms$
n_f mod 40/10 = $O_{LP\text{-}SS}$ =1, second half radio frame

FIG. 5A



SSB
LP-SS
80ms
5ms
Time 0
2nd Offset
Time 0
1st Offset
$T_{LP\text{-}SS\text{-}Block}$
$T_{LP\text{-}SS}$ =K*T_{SSB} =4*10=40ms
T_{SSB} =10ms, $T_{LP\text{-}SS}$ =K*T_{SSB} =4*10=40ms
n_f mod 40/10 = $O_{LP\text{-}SS}$ =1, first half radio frame

FIG. 5B

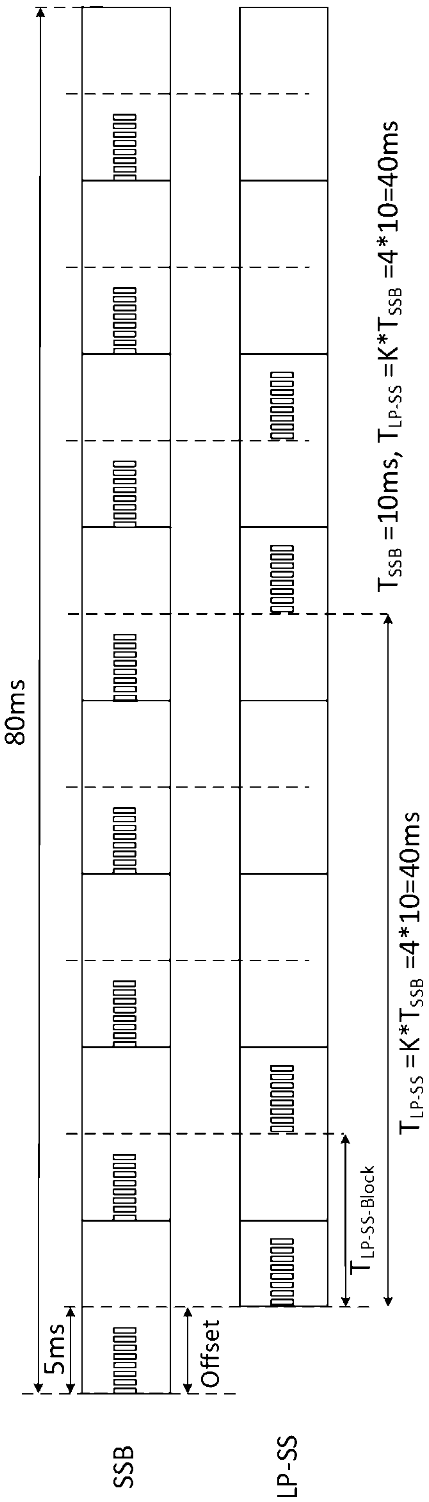

80ms
5ms
Offset
SSB
LP-SS
T_{SSB} =10ms, $T_{LP\text{-}SS}$ =K*T_{SSB} =4*10=40ms
$T_{LP\text{-}SS\text{-}Block}$
$T_{LP\text{-}SS}$ =K*T_{SSB} =4*10=40ms

FIG. 5C

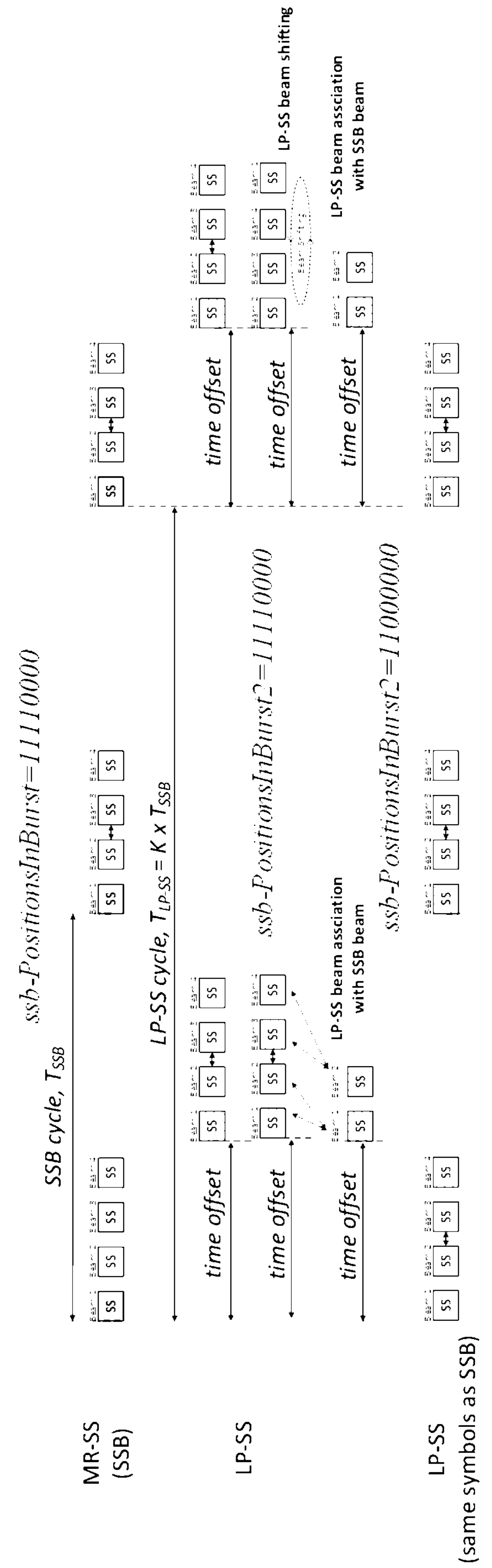

MR-SS
(SSB)
LP-SS
LP-SS
(same symbols as SSB)
SSB cycle, T_{SSB}
ssb-PositionsInBurst=11110000
LP-SS cycle, $T_{LP-SS} = K \times T_{SSB}$
ssb-PositionsInBurst2=11110000
ssb-PositionsInBurst2=11000000
time offset
time offset
time offset
time offset
time offset
time offset
LP-SS beam assciation with SSB beam
LP-SS beam assciation with SSB beam
LP-SS beam shifting
SS

FIG. 5D

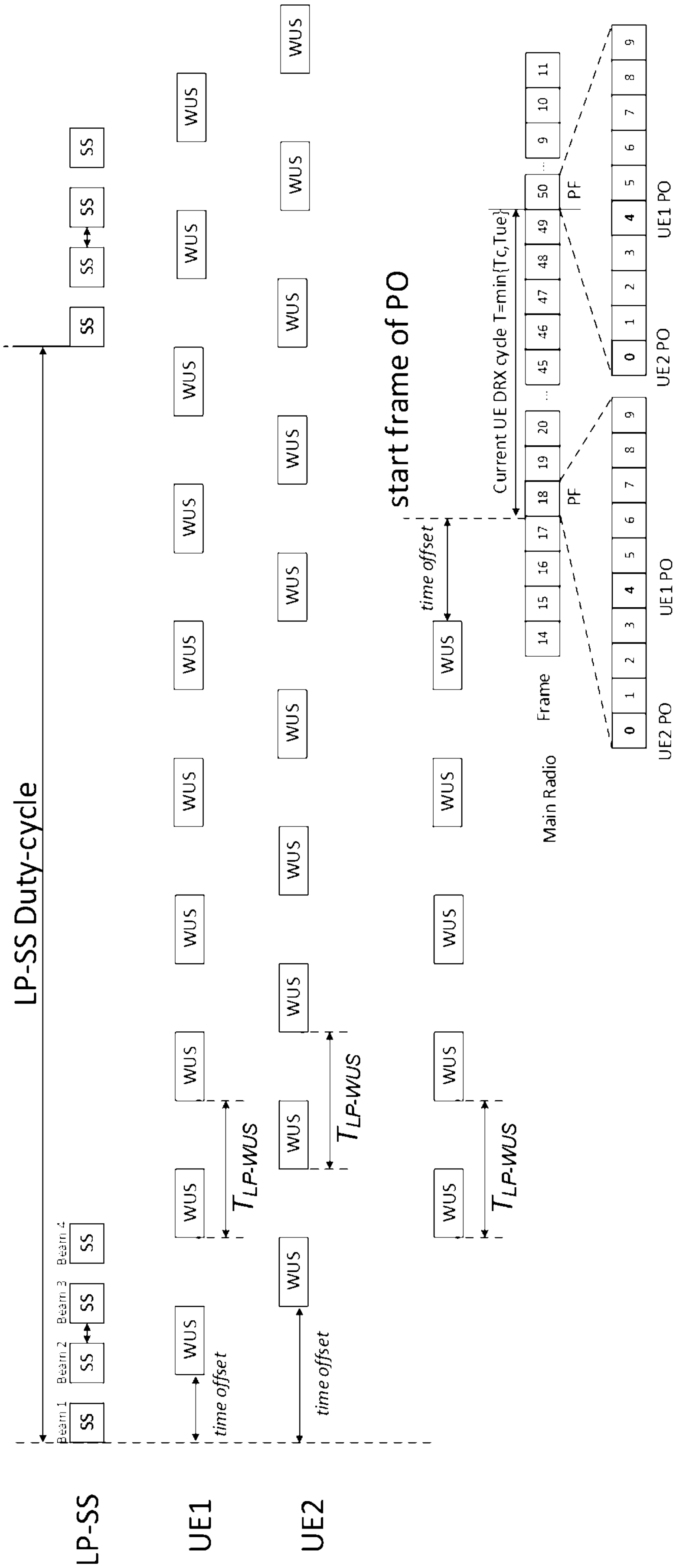

LP-SS
UE1
UE2
LP-SS Duty-cycle
Beam 1
Beam 2
Beam 3
Beam 4
SS
WUS
time offset
$T_{LP\text{-}WUS}$
start frame of PO
Current UE DRX cycle T=min{Tc,Tue}
Main Radio
Frame
14 15 16 17 18 19 20 ... 45 46 47 48 49 50 ... 9 10 11
PF
0 1 2 3 4 5 6 7 8 9
UE2 PO
UE1 PO

FIG. 6A

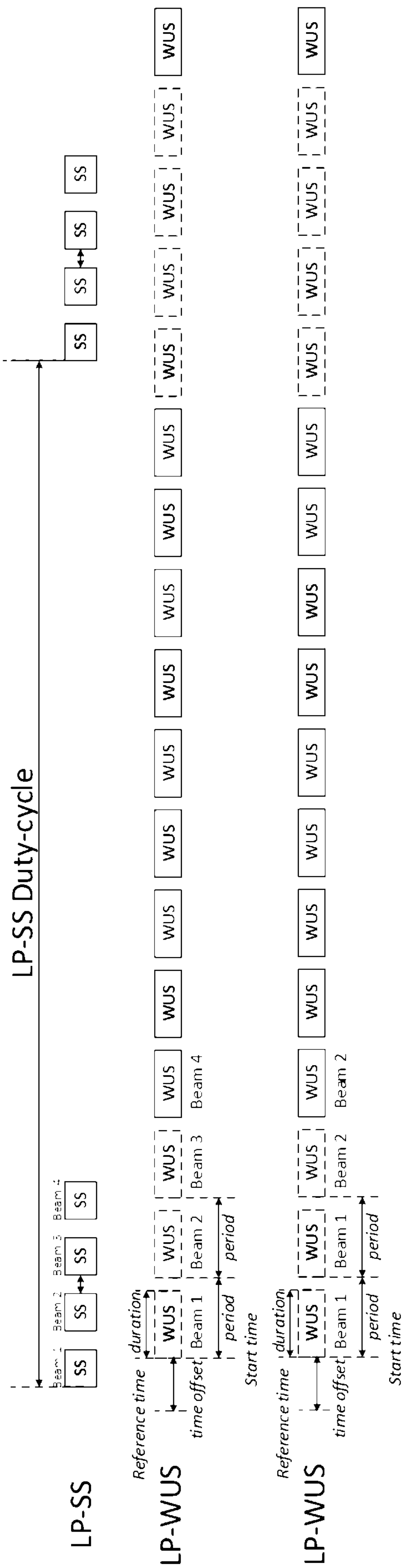

LP-SS Duty-cycle
LP-SS
LP-WUS
LP-WUS
SS
WUS
Beam 1
Beam 2
Beam 3
Beam 4
Reference time
time offset
duration
period
Start time

FIG. 6B

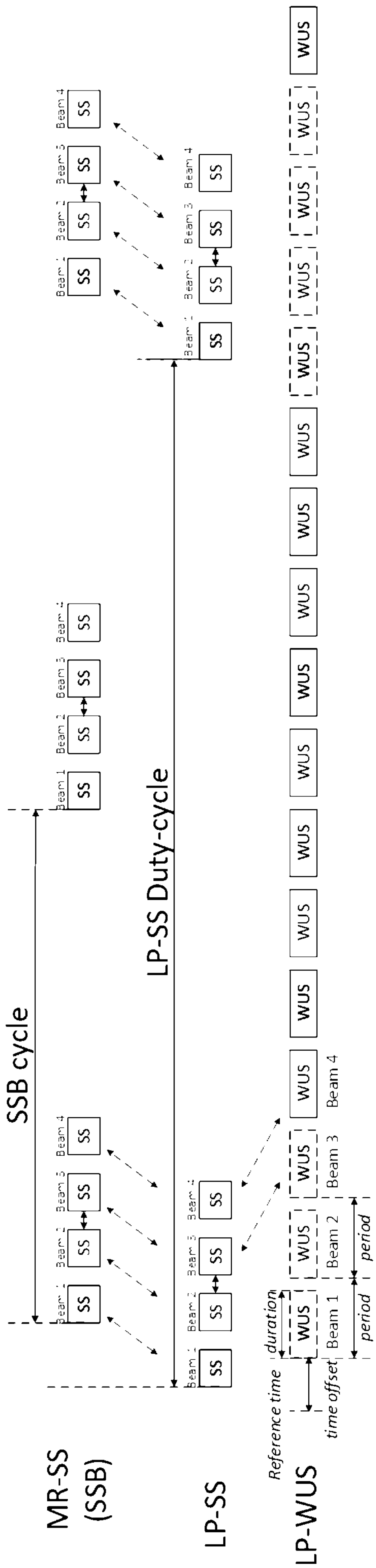

MR-SS
(SSB)
LP-SS
LP-WUS
SSB cycle
LP-SS Duty-cycle
SS
Beam 1
Beam 2
Beam 3
Beam 4
WUS
Reference time
time offset
duration
period

FIG. 6C

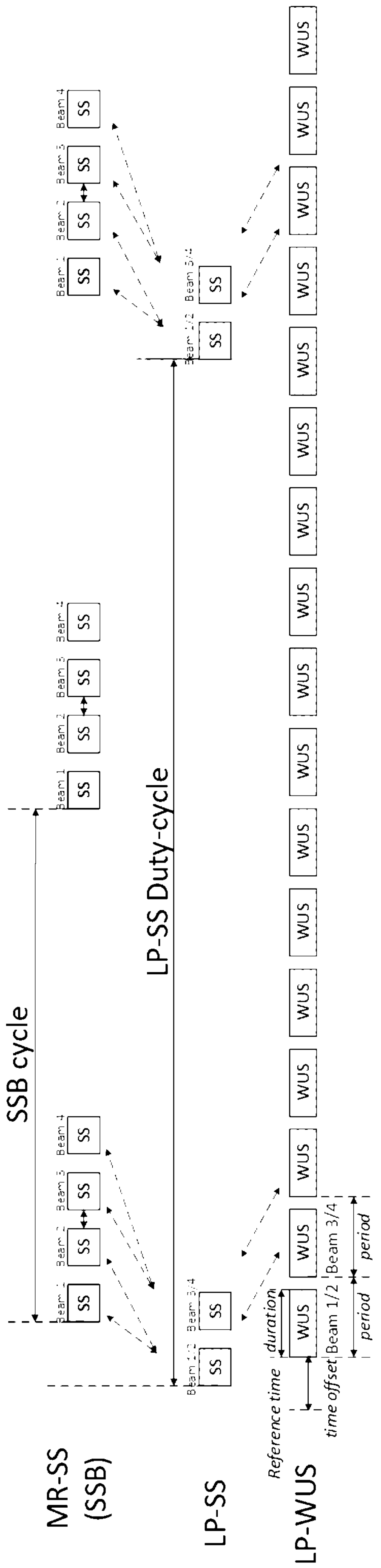

MR-SS
(SSB)
LP-SS
LP-WUS
SSB cycle
LP-SS Duty-cycle
Beam 1
Beam 2
Beam 3
Beam 4
SS
Beam 1/2
Beam 3/4
WUS
Reference time
time offset
duration
period
period

FIG. 6D

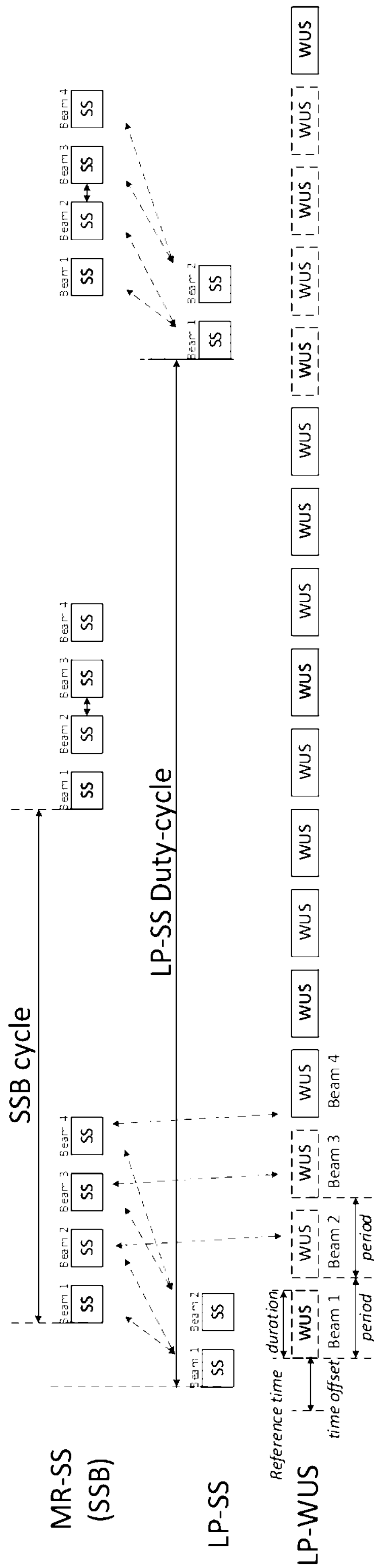

MR-SS
(SSB)
LP-SS
LP-WUS
SSB cycle
LP-SS Duty-cycle
Reference time
time offset
duration
period
period
Beam 1
Beam 2
Beam 3
Beam 4
SS
WUS

FIG. 6E

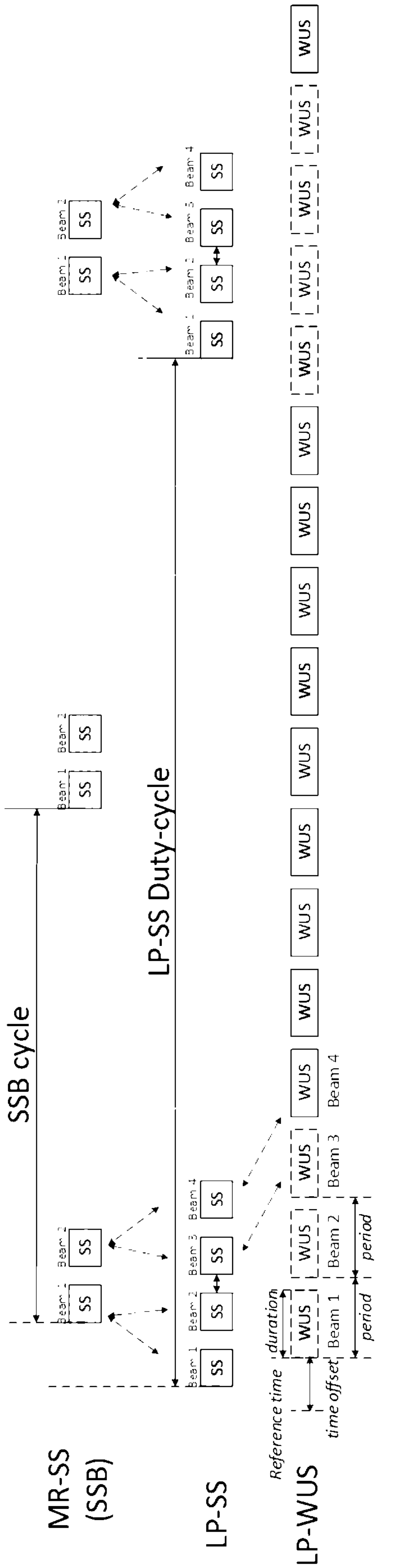

MR-SS
(SSB)
LP-SS
LP-WUS
SSB cycle
LP-SS Duty-cycle
SS
Beam 1
Beam 2
Beam 3
Beam 4
WUS
Reference time
time offset
duration
period
period

FIG. 6F

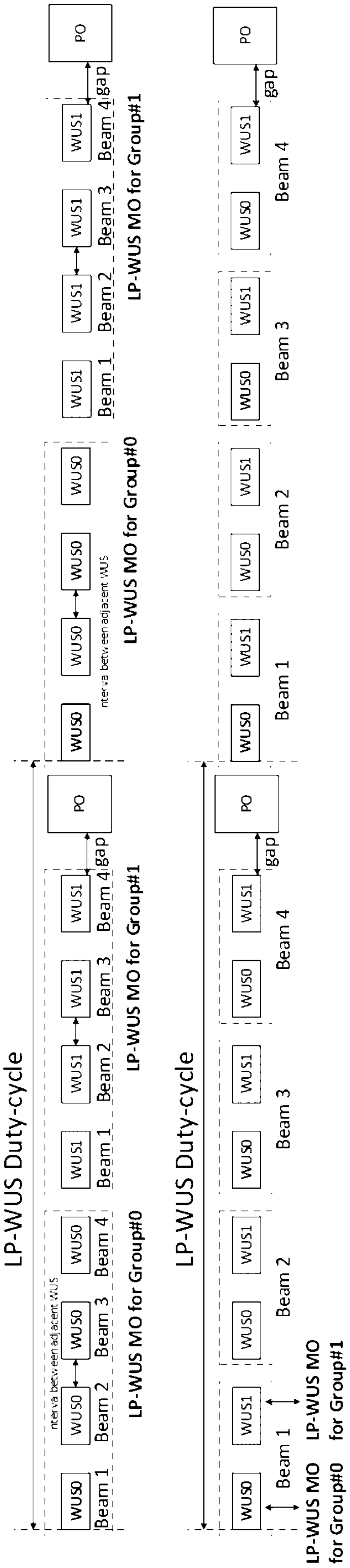

LP-WUS Duty-cycle
WUS0
WUS1
PO
Beam 1
Beam 2
Beam 3
Beam 4
gap
interval between adjacent WUS
LP-WUS MO for Group#0
LP-WUS MO for Group#1
LP-WUS MO for Group#0
LP-WUS MO for Group#1

FIG. 6G

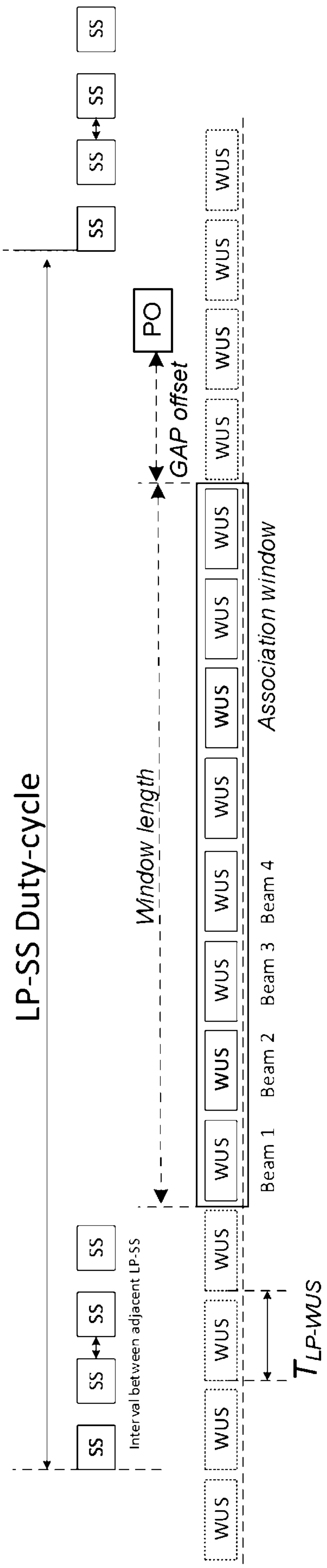

LP-SS Duty-cycle
SS
Interval between adjacent LP-SS
PO
GAP offset
Window length
WUS
Association window
Beam 1
Beam 2
Beam 3
Beam 4
$T_{LP\text{-}WUS}$

FIG. 6H

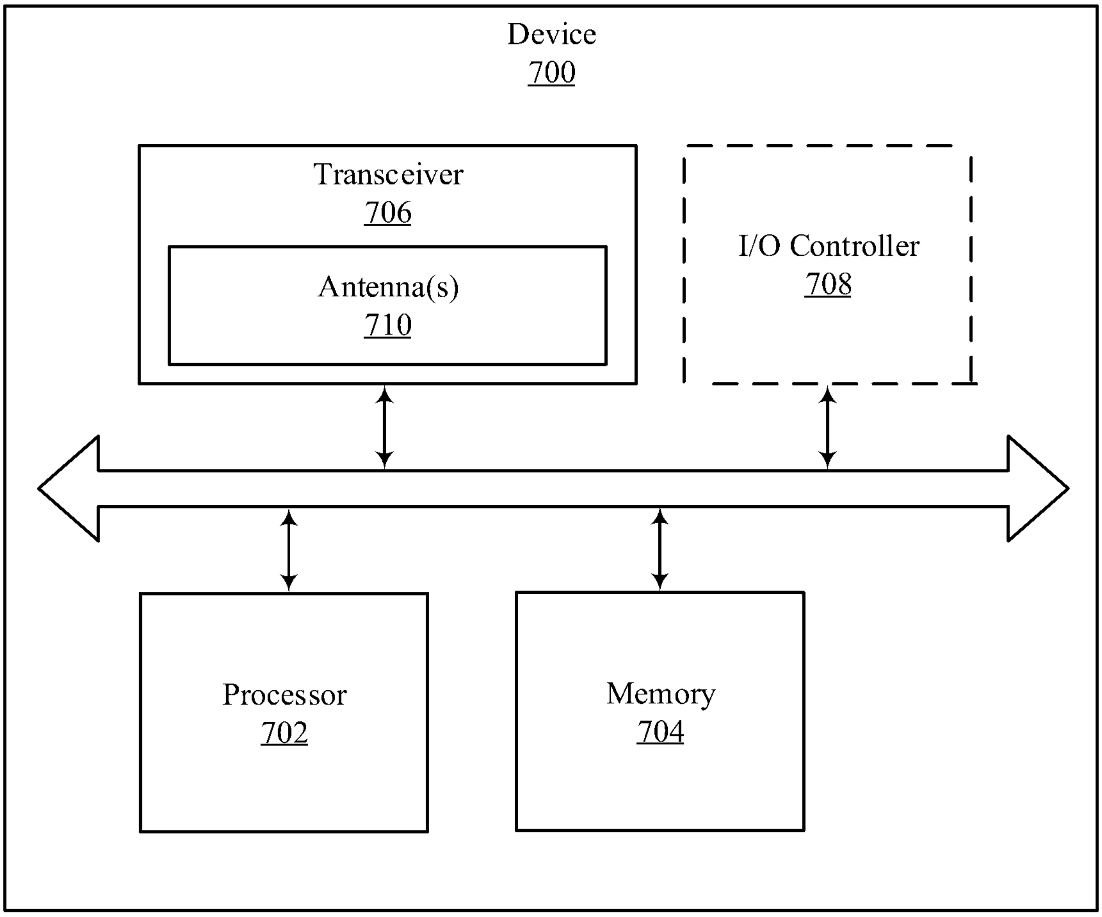

Device
700
Transceiver
706
Antenna(s)
710
I/O Controller
708
Processor
702
Memory
704

FIG. 7

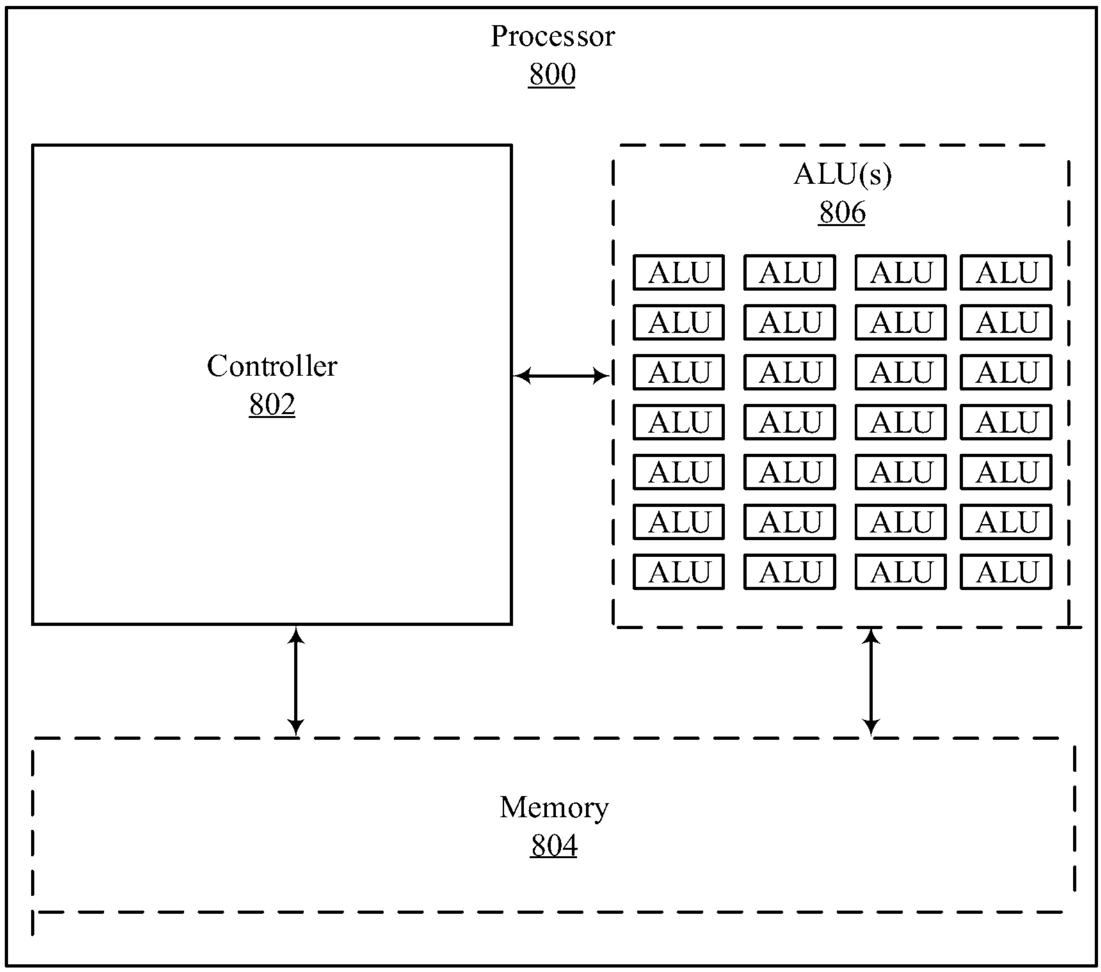


FIG. 8

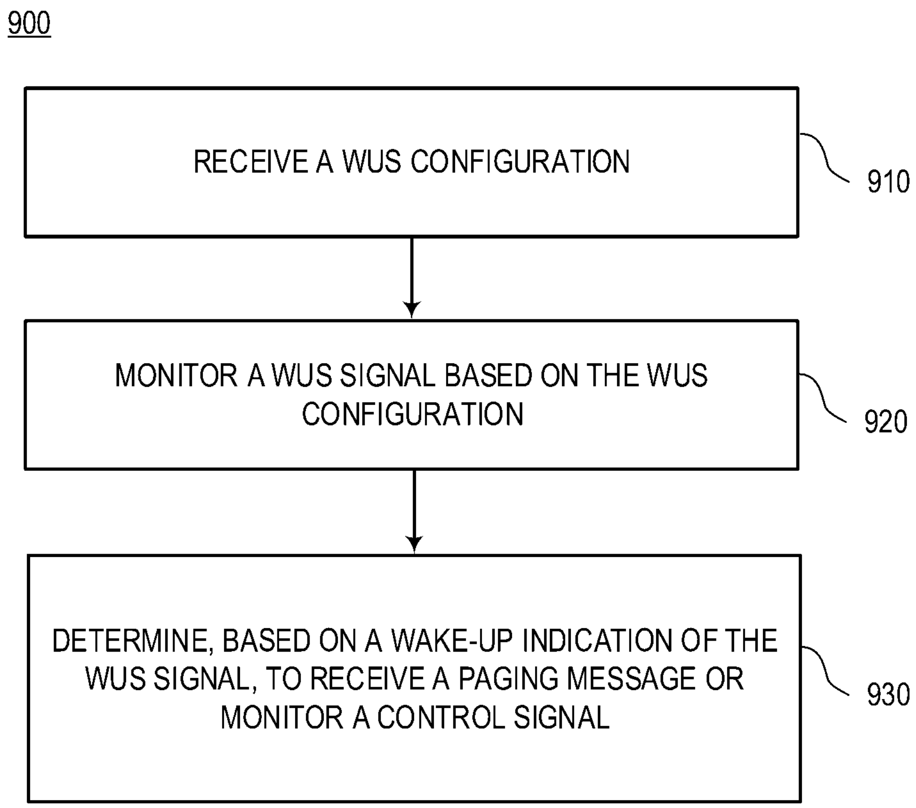

900
RECEIVE A WUS CONFIGURATION
910
MONITOR A WUS SIGNAL BASED ON THE WUS CONFIGURATION
920
DETERMINE, BASED ON A WAKE-UP INDICATION OF THE WUS SIGNAL, TO RECEIVE A PAGING MESSAGE OR MONITOR A CONTROL SIGNAL
930

FIG. 9

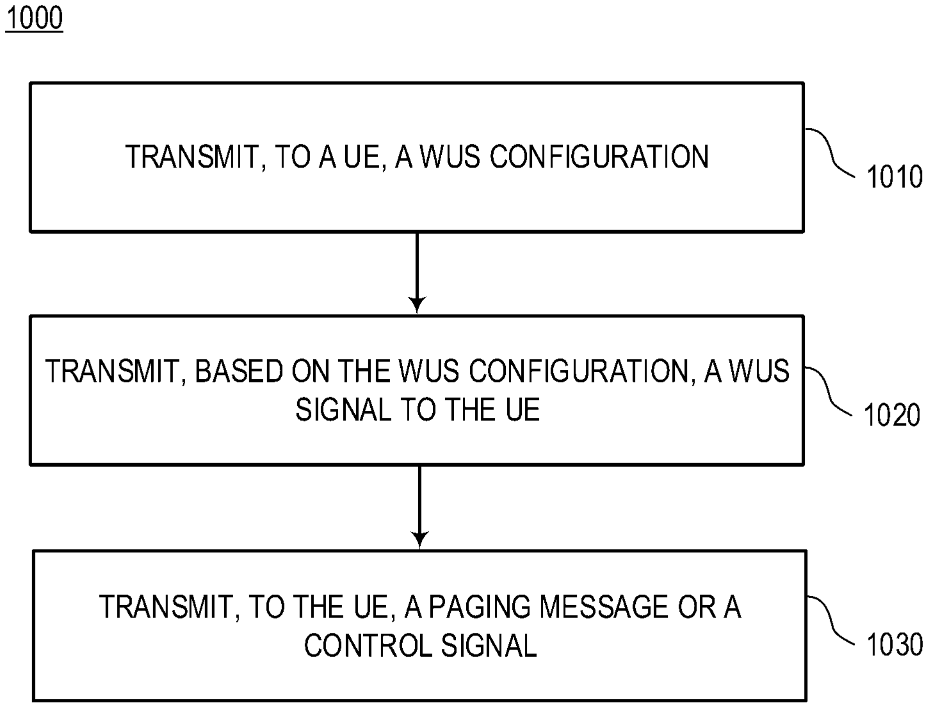

1000
TRANSMIT, TO A UE, A WUS CONFIGURATION
1010
TRANSMIT, BASED ON THE WUS CONFIGURATION, A WUS SIGNAL TO THE UE
1020
TRANSMIT, TO THE UE, A PAGING MESSAGE OR A CONTROL SIGNAL
1030

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/110494

A. CLASSIFICATION OF SUBJECT MATTER

H04W 52/02(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)

IPC: 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)

CNTXT,ENTXT,ENTXTC,DWPI,3GPP,CNKI:control,idle,inactive,deactivate,indication,monitor,WUS,wake-up signal,configur+,pag+,consumpt+,LP-SS,period,time offset

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2024146147 A1 (LENOVO (BEIJING) LTD.) 11 July 2024 (2024-07-11) claims 1-20 and description, paragraphs [0003]-[0104]	1-60
X	CN 110830225 A (SPREADTRUM COMMUNICATIONS (SHANGHAI) INC.) 21 February 2020 (2020-02-21) description, paragraphs [0007]-[0161]	1-60
A	US 2020029302 A1 (INTEL CORPORATION AND INTEL IP CORPORATION) 23 January 2020 (2020-01-23) the whole document	1-60
A	ERICSSON. "Wake-up signal configurations and procedures for NB-IoT" *3GPP TSG-RAN WG1 Meeting #93 R1-1805855*, 24 May 2018 (2018-05-24), the whole document	1-60

☐ 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

"D" document cited by the applicant in the international application

"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
15 April 2025	**25 April 2025**

Name and mailing address of the ISA/CN	Authorized officer
CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**KOU,LiMin** Telephone No. **(+86) 010-53961731**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/110494

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2024146147	A1	11 July 2024	None			
CN	110830225	A	21 February 2020	WO	2021093440	A1	20 May 2021
US	2020029302	A1	23 January 2020	WO	2018175760	A1	27 September 2018
				US	2022201649	A1	23 June 2022
				EP	3603223	A1	05 February 2020
				CN	116709271	A	05 September 2023
				CN	110463285	A	15 November 2019