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(54) **Title:** LOW POWER WUS DESIGN

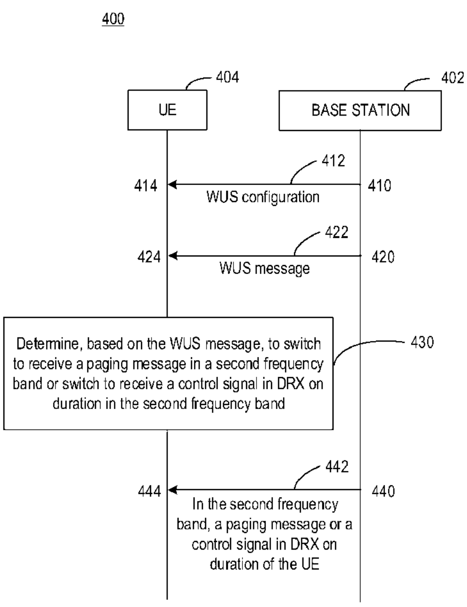

FIG. 4

(57) **Abstract:** Various aspects of the present disclosure relate to a user equipment, a base station, processors, and methods for low power wake up signal (LP-WUS) design. In an aspect, a user equipment (UE) receives, from a base station, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling. The UE monitoring a WUS message in one or more WUS resources in a first frequency band. The UE determines, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

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LOW POWER WUS DESIGN

TECHNICAL FIELD

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

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 to trigger the main radio and a separate receiver which has the ability to monitor wake-up signal with ultra-low power consumption. Main radio works for data transmission and reception, which can be turned off or set to deep sleep unless it is turned on. However, there are still some open problems related to LP-WUS design that will be studied in the future.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support low power wake up signal (LP-WUS) design.

[0005] In a first aspect of the solution, a user equipment (UE) comprises: a processor; and a transceiver coupled to the processor, wherein the processor is configured to: receive, via the transceiver, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; monitor, via the transceiver, a WUS message in one or more WUS resources in a first frequency band; and determine, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

[0006] In some implementations of the user equipment described herein, wherein monitoring the WUS message in the one or more WUS resources in the first frequency band comprises: determining time locations of the one or more WUS resources based on a reference point for WUS and one or more first offsets.

[0007] In some implementations of the user equipment described herein, wherein the reference point for WUS is a start of a reference frame.

[0008] In some implementations of the user equipment described herein, wherein the reference frame is determined by a first frame-level offset from a start of a first PF of one or more paging frames (PFs) associated with WUS, and wherein the first frame-level offset is provided by one of the following: a higher layer parameter; or a scaling factor of a second offset from a reference point for paging early indication (PEI) operation in a main radio (MR) of the UE to a first PF of one or more PFs associated with the PEI, and the scaling factor is provided by another higher layer parameter.

[0009] In some implementations of the user equipment described herein, wherein the reference frame is determined by a second frame-level offset from a reference point for PEI operation in the MR.

[0010] In some implementations of the user equipment described herein, wherein an offset among the one or more first offsets is a symbol-level or slot-level offset from the reference point for WUS to a start of the WUS message.

[0011] In some implementations of the user equipment described herein, wherein monitoring the WUS message in one or more WUS resources comprises: determining, based on the one or more first offsets, the one or more WUS resources for monitoring the WUS message.

[0012] In some implementations of the user equipment described herein, wherein monitoring the WUS message in one or more WUS resources further comprises: in the case that a WUS message is not detected in a first WUS resource among the one or more WUS resources, monitoring a WUS message in a second WUS resource or remaining resources among the one or more WUS resources.

[0013] In some implementations of the user equipment described herein, wherein the one or more first offsets are scaled based on a subcarrier spacing in the first frequency band or a subcarrier spacing in the second frequency band.

[0014] In some implementations of the user equipment described herein, wherein monitoring the WUS message in the one or more WUS resources in the first frequency band comprises: determining time locations of the one or more WUS resources based on one or more second offsets, wherein an offset among the one or more second offsets is a symbol-level or slot-level offset between a start or an end of the WUS message and a symbol or slot where a DRX on duration timer starts.

[0015] In some implementations of the user equipment described herein, wherein the WUS message comprises a first number of information bits, and a second number out of the first number of information bits are encoded to coded bits, and the coded bits are transmitted with a pattern or a form of a sequence in the one or more WUS resources.

[0016] In some implementations of the user equipment described herein, wherein the sequence is a quadrature phase shift keying (QPSK) sequence and is generated from one or more first pseudo-random sequences.

[0017] In some implementations of the user equipment described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by the following: a cell identity (ID), and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0018] In some implementations of the user equipment described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0019] In some implementations of the user equipment described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is further determined by a third number of information bits or coded bits, and the third number is determined by the first number, or the second number, or both the first number and the second number.

[0020] In some implementations of the user equipment described herein, wherein the QPSK sequence is further generated from orthogonal sequences or second pseudo-random sequences in addition to sequences generated from the one or more first pseudo-random sequences.

[0021] In some implementations of the user equipment described herein, wherein the orthogonal sequences or second pseudo-random sequences are applied to the sequences generated from the one or more first pseudo-random sequences, the orthogonal sequences or second pseudo-random sequences are determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

[0022] In some implementations of the user equipment described herein, wherein a length of the orthogonal sequences or second pseudo-random sequences is determined by the second number or determined by a symbol number configured for each WUS resource.

[0023] In some implementations of the user equipment described herein, wherein the sequence is an enhanced Zadoff-Chu sequence and is generated from one or more Zadoff-Chu sequences.

[0024] In some implementations of the user equipment described herein, wherein each of the one or more Zadoff-Chu sequences is determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0025] In some implementations of the user equipment described herein, wherein each of the one or more Zadoff-Chu sequence is determined by the following: a cell ID, and a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0026] In some implementations of the user equipment described herein, wherein the enhanced Zadoff-Chu sequence is further generated from orthogonal sequences or third pseudo-random sequences in addition to sequences generated from the one or more Zadoff-Chu sequences.

[0027] In some implementations of the user equipment described herein, wherein the orthogonal sequences or third pseudo-random sequences are applied to the sequences generated from the one or more Zadoff-Chu sequences.

[0028] In some implementations of the user equipment described herein, wherein the orthogonal sequences or third pseudo-random sequences are determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message, or a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0029] In some implementations of the user equipment described herein, wherein the orthogonal sequences or third pseudo-random sequences are determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

[0030] 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, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; transmit, via the transceiver and to a user equipment (UE), a WUS message in one or more WUS resources in a first frequency band; and transmit, via the transceiver and to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

[0031] In some implementations of the base station described herein, wherein transmitting the WUS message in the one or more WUS resources in the first frequency band comprises: determining time locations of the one or more WUS resources based on a reference point for WUS and one or more first offsets.

[0032] In some implementations of the base station described herein, wherein the reference point for WUS is a start of a reference frame.

[0033] In some implementations of the base station described herein, wherein the reference frame is determined by a first frame-level offset from a start of a first PF of one or more paging frames (PFs) associated with WUS, and wherein the first frame-level offset is provided by one of the following: a higher layer parameter; or a scaling factor of a second offset from a reference point for paging early indication (PEI) operation in a main radio (MR) of the UE to a first PF of one or more PFs associated with the PEI, and the scaling factor is provided by another higher layer parameter.

[0034] In some implementations of the base station described herein, wherein the reference frame is determined by a second frame-level offset from a reference point for PEI operation in the MR.

[0035] In some implementations of the base station described herein, wherein an offset among the one or more first offsets is a symbol-level or slot-level offset from the reference point for WUS to a start of the WUS message.

[0036] In some implementations of the base station described herein, wherein transmitting the WUS message in one or more WUS resources comprises: determining, based on the one or more first offsets, the one or more WUS resources for transmitting the WUS message.

[0037] In some implementations of the base station described herein, wherein transmitting the WUS message in one or more WUS resources further comprises: in the case that a WUS message is not transmitted in a first WUS resource among the one or more WUS resources, transmitting a WUS message in a second WUS resource among the one or more WUS resources.

[0038] In some implementations of the base station described herein, wherein the one or more first offsets are scaled based on a subcarrier spacing in the first frequency band or a subcarrier spacing in the second frequency band.

[0039] In some implementations of the base station described herein, wherein transmitting the WUS message in the one or more WUS resources in the first frequency band comprises: determining time locations of the one or more WUS resources based on one or more second offsets, wherein an offset among the one or more second offsets is a symbol-level or slot-level offset between a start or an end of the WUS message and a symbol where a DRX on duration timer starts.

[0040] In some implementations of the base station described herein, wherein the WUS message comprises a first number of information bits, and a second number out of the first number of information bits are encoded to coded bits, and the coded bits are transmitted with a pattern or a form of a sequence in the one or more WUS resources.

[0041] In some implementations of the base station described herein, wherein the sequence is a quadrature phase shift keying (QPSK) sequence and is generated from one or more first pseudo-random sequences.

[0042] In some implementations of the base station described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by the following: a cell identity (ID), and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0043] In some implementations of the base station described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0044] In some implementations of the base station described herein, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is further determined by a third number of information bits or coded bits, and the third number is determined by the first number, or the second number, or both the first number and the second number.

[0045] In some implementations of the base station described herein, wherein the QPSK sequence is further generated from orthogonal sequences or second pseudo-random sequences in addition to sequences generated from the one or more first pseudo-random sequences.

[0046] In some implementations of the base station described herein, wherein the orthogonal sequences or second pseudo-random sequences are applied to the sequences generated from the one or more first pseudo-random sequences, the orthogonal sequences or second pseudo-random sequences are determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

[0047] In some implementations of the base station described herein, wherein a length of the orthogonal sequences or second pseudo-random sequences is determined by the second number or determined by a symbol number configured for each WUS resource.

[0048] In some implementations of the base station described herein, wherein the sequence is an enhanced Zadoff-Chu sequence and is generated from one or more Zadoff-Chu sequences.

[0049] In some implementations of the base station described herein, wherein each of the one or more Zadoff-Chu sequences is determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0050] In some implementations of the base station described herein, wherein each of the one or more Zadoff-Chu sequence is determined by the following: a cell ID, and a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0051] In some implementations of the base station described herein, wherein the enhanced Zadoff-Chu sequence is further generated from orthogonal sequences or third pseudo-random sequences in addition to sequences generated from the one or more Zadoff-Chu sequences.

[0052] In some implementations of the base station described herein, wherein the orthogonal sequences or third pseudo-random sequences are applied to the sequences generated from the one or more Zadoff-Chu sequences.

[0053] In some implementations of the base station described herein, wherein the orthogonal sequences or third pseudo-random sequences are determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message, or a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0054] In some implementations of the base station described herein, wherein the orthogonal sequences or third pseudo-random sequences are further determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

[0055] 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 in system information or UE-specific radio resource control (RRC) signaling; monitor a WUS message in one or more WUS resources in a first frequency band; and determine, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

[0056] 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 in system information or UE-specific radio resource control (RRC) signaling; transmit, to the UE, a WUS message in one or more WUS resources in a first frequency band; and transmit, to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

[0057] In a fifth aspect of the solution, a method performed by a user equipment, the method comprising: receiving, from a base station, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; monitoring a WUS message in one or more WUS resources in a first frequency band; and determining, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

[0058] In a sixth aspect of the solution, a method performed by a base station, the method comprising: transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; transmitting, to the UE, a WUS message in one or more WUS resources in a first frequency band; and transmitting, to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

[0059] 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

[0060] FIG. 1A illustrates an example of a wireless communications system that supports LP-WUS design in accordance with aspects of the present disclosure.

[0061] FIG. 1B illustrates an example interaction between a main radio and a separate ultra-low power wake-up receiver within a UE.

[0062] FIG. 1C illustrates an example of the resources allocation of LP-WUS waveform.

[0063] FIG. 1D illustrates an example of the LP-WUS sequence design and resources allocation of LP-WUS waveform.

[0064] FIG. 2A illustrates an example of Release 16 power saving design.

[0065] FIG. 2B illustrates an example of Release 16 power saving configuration.

[0066] FIG. 3A illustrates an example of Release 17 Paging Early Indication (PEI) design.

[0067] FIG. 3B illustrates an example of Release 17 PEI configuration.

[0068] FIG. 4 illustrates an example signaling procedure for LP-WUS design in accordance with aspects of the present disclosure.

[0069] FIG. 5A illustrates an example of LP-WUS design in accordance with aspects of the present disclosure.

[0070] FIG. 5B illustrates an example of LP-WUS configuration in accordance with aspects of the present disclosure.

[0071] FIG. 6A illustrates a first example of LP-WUS sequence design using a quadrature phase shift keying (QPSK) sequence in accordance with aspects of the present disclosure.

[0072] FIG. 6B illustrates a second example of LP-WUS sequence design using a QPSK sequence in accordance with aspects of the present disclosure.

[0073] FIG. 6C illustrates a third example of LP-WUS sequence design using a QPSK sequence in accordance with aspects of the present disclosure.

[0074] FIG. 6D illustrates a fourth example of LP-WUS sequence design using a QPSK sequence in accordance with aspects of the present disclosure.

[0075] FIG. 6E illustrates a fifth example of LP-WUS sequence design using a QPSK sequence in accordance with aspects of the present disclosure.

[0076] FIG. 7 illustrates an example of LP-WUS sequence design using an enhanced Zadoff-Chu sequence in accordance with aspects of the present disclosure.

[0077] FIG. 8 illustrates an example of device that support LP-WUS design in accordance with aspects of the present disclosure.

[0078] FIG. 9 illustrates an example of processor that support LP-WUS design in accordance with aspects of the present disclosure.

[0079] FIG. 10 illustrates a flowchart of a method that support LP-WUS design in accordance with aspects of the present disclosure.

[0080] FIG. 11 illustrates a flowchart of a method that support LP-WUS design in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0081] 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.

[0082] 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.

[0083] 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.

[0084] 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.

[0085] 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.

[0086] 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.

[0087] 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.

[0088] 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.

[0089] Aspects of the present disclosure are described in the context of a wireless communications system.

[0090] FIG. 1A illustrates an example of a wireless communications system 100 that supports LP-WUS design in accordance with aspects of the present disclosure. The wireless communications system 100 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 100 may support various radio access technologies. In some implementations, the wireless communications system 100 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 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100 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 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0091] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. 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.

[0092] 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.

[0093] 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 100. 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 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0094] 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 100.

[0095] 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.

[0096] 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).

[0097] 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.

[0098] 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)).

[0099] 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.

[0100] 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).

[0101] 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.

[0102] 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.

[0103] 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).

[0104] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (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.

[0105] One or more numerologies may be supported in the wireless communications system 100, 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.

[0106] 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.

[0107] 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 100. 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.

[0108] In the wireless communications system 100, 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 100 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.

[0109] 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.

[0110] FIG. 1B illustrates an example interaction between a main radio 130 and a separate ultra-low power wake-up receiver 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 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 transmission and reception, 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, and the terms of "WUS" and "wake-up signal" may be used interchangeably.

[0111] 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.

[0112] 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.

[0113] 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 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.

[0114] FIG. 1C illustrates an example of the resources allocation of LP-WUS waveform, and FIG. 1D illustrates an example of the LP-WUS sequence design and resources allocation of LP-WUS waveform, where random QPSK sequence or ZC sequence can be designed for 'on' chip (e.g., OOK=1). OOK=1 means all subcarriers are modulated (can be modulated as random QPSK, ZC sequence). OOK=0 means all SCs are zero power (from base-band point of view).

[0115] For OOK-4, M-bits on/off chip is mapped to one OFDM symbol. WUS needs to carry information to distinguish UEs. In a first way, WUS carries at least one of the following information to distinguish UEs (e.g., distinguish UEs from different POs, UEs from different BWPs, UEs from different cells): start slot number, start symbol number, and start frequency subcarrier number of the corresponding DRX or PO. The above-mentioned information can be carried by the random QPSK sequence or ZC sequence in the generation of the WUS waveform. For example, the random QPSK sequence or ZC sequence (e.g. for each sequence, or for all sequence with chip on OOK=1 concatenation) is initialized with at least one of the start slot number, the start symbol number, and the start frequency subcarrier number of the corresponding DRX or PO.

[0116] The slot number, the symbol number, and the frequency subcarrier number of the corresponding DRX or PO in the second BWP (or the second carrier) are scaled to the subcarrier spacing in the first BWP (or the first carrier) if the subcarrier spacing of the first BWP and the subcarrier spacing of the second BWP are different. When the WUS is initialized, the slot number according to the subcarrier spacing of the BWP where WUS is transmitted (i.e., first BWP) is used. So, the slot number of the DRX or PO according to the subcarrier spacing of the second BWP needs to be scaled to the slot number according to the subcarrier spacing of the first BWP, e.g., by an equation of ceil {slot number / $(= 2^{\mu2}/2^{\mu1})\}$, where $\mu2$ and $\mu1$ are numerologies of the subcarrier spacings of the second BWP and the first BWP, where the numerologies of subcarrier spacings 15kHz, 30kHz, 60kHz, 120kHz and 240kHz are 0, 1, 2, 3 and 4, respectively.

[0117] In a second way, in order to support fallback mechanism of WUS and Paging Early Indication (PEI) in NR Releases 16 and 17, WUS may alternatively carry UE specific information, e.g., the RNTI information configured to UE, such as ps-rnti or pei-rnti, and/or a position indication corresponding to a control signal configured by higher layer, such as ps-positioning, to distinguish UEs. For example, UE is configured with ps-rnti or pei-rnti, and ps-positioning. The random QPSK sequence or ZC sequence is initialized with at least one of ps-rnti or pei-rnti and ps-positioning.

[0118] In a third way, the WUS can be generated with encoded bit with CRC. The encoded bit is scrambled by scramble sequence. The scramble sequence is determined by at least one of the start slot number, start symbol number, and start frequency subcarrier number of the corresponding DRX or PO. The slot number, the symbol number and frequency subcarrier number are scaled to the subcarrier spacing in the first BWP (or the first carrier). Alternatively, the scramble sequence is determined by the RNTI information configured to UE (e.g., ps-rnti or pei-rnti), and/or a position indication corresponding to a control signal configured by higher layer (e.g., ps-positioning).

[0119] Optionally, the first waveform (e.g., OOK-1) or the second waveform (e.g., OOK-4) is determined by the payload size (configured subgroup number, or associated PO number) and a threshold. For example, if the payload size (configured subgroup number, or associated PO number) is smaller than the threshold, the waveform of OOK-1 is adopted. Otherwise, if the payload size is equal to or larger than the threshold, the waveform of OOK-4 is adopted.

[0120] Further optionally, the waveform of OOK-1 or OOK-4 is determined by the UE connection mode (e.g., connected mode or idle or inactive mode). For example, if the UE is in idle or inactive mode, the waveform of OOK-4 is adopted. Otherwise, if the UE is in connected mode, the waveform of OOK-1 is adopted.

[0121] When mobile phones are used for reading web pages, there is no need to interact with the network. However, UE is required to monitor the PDCCH periodically, which leads to UE power consumption unnecessarily. FIG. 2A illustrates an example of Release 16 power saving design, and FIG. 2B illustrates an example of Release 16 power saving configuration design.

[0122] As illustrated in FIG. 2A, the DRX mechanism allows UE to switch off RF circuit and front-end hardware during DRX off. However, in the case of sporadic traffic, it is still power consuming for UE to periodically wake up to monitor PDCCH during the DRX On Duration.

[0123] As illustrated in FIG. 2B, in connected mode, WUS conveyed by a new DCI format 2_6 is introduced to inform UE whether or not to start the DRX On Duration timer for the next DRX cycle monitoring PDCCH for potential data scheduling. An offset indicated by *ps-Offset-r16* indicates a time, where the UE starts monitoring PDCCH for detection of DCI format 2_6 according to the number of search space sets, prior to a slot where the *drx-onDurationTimer* would start on the PCell or on the SpCell. A location in DCI format 2_6 of a Wake-up indication bit may be indicated by *ps-PositionDCI-2-6*.

[0124] FIG. 3A illustrates an example of Release 17 Paging Early Indication (PEI) design, and FIG. 3B illustrates an example of Release 17 PEI configuration. The UE may use DRX in RRC_IDLE and RRC_INACTIVE state in order to reduce power consumption. As illustrated in FIG. 3A, the UE monitors one paging occasion (PO) per DRX cycle. A PO is a set of PDCCH monitoring occasions and can consist of multiple time slots (e.g. subframe or OFDM symbol) where paging DCI can be sent. One Paging Frame (PF) is one Radio Frame and may contain one or multiple PO(s) or starting point of a PO.

[0125] In multi-beam operations, the UE assumes that the same paging message and the same Short Message are repeated in all transmitted beams and thus the selection of the beam(s) for the reception of the paging message and Short Message is up to UE implementation. The RRC idle/inactive state UE is required to monitor one paging occasion per DRX cycle to detect the scheduling of paging and system information update. The paging occasion location is determined by the UE ID.

[0126] The concept of Paging Early Indication (PEI), where a UE is notified in advance of its Paging Occasion (PO), whether the UE has to monitor. The PEI can be signaled via a DCI message carried in the PDCCH (e.g., DCI format 2-7). PEI is that it may carry sub-grouping information to divide the UEs, this results in lower group paging rate and fewer false paging alarms.

[0127] The UE power consumption reduction in PEI scheme is mainly from two aspects: (1) PEI search space is much smaller than PO's search space; (2) PEI specifies the UE subgroup ID, which reduces PO monitoring.

[0128] As illustrated in FIG. 3B, the configuration of WUS transmission in potential DCI in time domain includes: 1) a number of frames, by *pei-FrameOffset* (or *PEI-FOffset* in FIG. 3B), from the start of a frame to the start of a first paging frame of paging frames (e.g., Paging frame n, … etc. in FIG. 3B) associated with a number of PDCCH monitoring occasions for DCI format 2_7; 2) a number of symbols, by *firstPDCCH-MonitoringOccasionOfPEI-O*, from the start of the frame to the start of the first PDCCH monitoring occasion for DCI format 2_7. The maximal PO number associated with one PEI may be 8 and the maximal subgroup number may be 8, so the maximal bit length for PEI is 64bits.

[0129] As illustrated in FIG. 3B, when the PO number associated with the number of PDCCH monitoring occasions for DCI format 2_7 is smaller than PO number for a paging frame, the start of the first paging frame mentioned above is a start of the paging frame (e.g., Paging frame n in FIG. 3B).

[0130] Alternatively, when the PO number associated with the number of PDCCH monitoring occasions for DCI format 2_7 is larger than or equal to PO number for one paging frame, the start of the first paging frame mentioned above is a start of the first one of the paging frames (e.g., Paging frame n and Paging frame n+1 in FIG. 3B).

[0131] It should be noted that, for the bandwidth of LP-WUS, it is discussed in Rel.18 SI LP-WUS that up to 5MHz is considered. At least for IDLE/Inactive mode, at least one BW-size <= 5MHz is recommended to be supported for FR1; and LP-WUS bandwidth size (including guard-bands) is assumed to be an integer number of PRBs (up to 24PRB).

[0132] If 5MHz is considered for LP-WUS bandwidth, up to 24 bit can be carried in 1 OFDM symbol if assuming 1PRB is associated with 1 information bit with the waveform of OOK-4 as an example. Moreover, multiple OFDM symbols are considered in Rel.18 SI (up to 4), channel coding is considered in Rel.18 SI (repetition coding, Manchester coding, etc.), CRC is considered to the information bit in Rel.18 SI, and up to 64 information bits should be considered in Rel.17 PEI feature. As such, there is a need to design the LP-WUS to support higher bits of information (e.g., up to 64-bit information).

[0133] In view of the above discussions, some embodiments of the present disclosure propose a LP-WUS solution or design to improve performance in communication networks. In some embodiments of the proposed LP-WUS solution, at the UE, a wake-up signal (WUS) configuration is received in system information or UE-specific radio resource control (RRC) signaling from a base station, a WUS message is monitored in one or more WUS resources in a first frequency band (e.g., a first carrier, or a first BWP in the first carrier), and based on the WUS message, it is determined to switch to receive a paging message in a second frequency band (e.g., a second carrier, or a second BWP in the second carrier) (e.g., in IDLE/INACTIVE states) or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band (e.g., in CONNECTED states). It should be noted that, the first frequency band and the second frequency band may be the same frequency band. By implementing the example embodiments of the present disclosure, an LP-WUS design is provided to improve performance in communication networks; for example, to support higher information bits.

[0134] FIG. 4 illustrates an example signaling procedure 400 for LP-WUS design in accordance with aspects of the present disclosure. At 410, a base station 402 may transmit, to a UE 404, a WUS configuration 412 in system information or UE-specific RRC signaling, 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 in system information or UE-specific RRC signaling.

[0135] At 420, the base station 402 may transmit, to the UE 404, a WUS message 422 in one or more WUS resources in a first frequency band. Accordingly, at 424, the UE 404 may monitoring the WUS message 422 in one or more WUS resources in the first frequency band. At 430, the UE 404 may determine, based on the WUS message 422, to switch to receive a paging message in a second frequency band or switch to receive a control signal in DRX on duration in the second frequency band. At 440, the base station 402 may transmit, to the UE 404, a paging message 442 in the second frequency band or a control signal 442 in DRX on duration of the UE in the second frequency band. 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.

[0136] **<u>LP-WUS configuration</u>**

[0137] In some implementations, time locations of the one or more WUS resources are determined based on a reference point for WUS and one or more first offsets. FIG. 5A illustrates an example of LP-WUS design in accordance with aspects of the present disclosure. In Rel. 16/17 power saving design, UE needs to monitor PDCCH search space for WUS (i.e., DCI) in a long time duration (e.g. before the corresponding PO) while the WUS with DCI format 2-6 or DCI format 2-7 can be transmitted in multiple PDCCH candidates within the search space. For LP-WUS with transmission waveform of OOK or OFDM sequence, it is feasible to configure more than one WUS resources for UE (e.g., give more flexibility to gNB, support multiple UE grouping strategy (group-specific and common grouping)).

[0138] For example, the UE may monitor one or more WUS resources in time domain per DRX cycle. A WUS resource can be consisted of multiple time slots (e.g. subframes or OFDM symbols) where WUS may be sent. In multi-beam operations, the UE assumes that the same WUS is repeated in all transmitted beams, and thus the selection of the beam(s) for the reception of the WUS is up to UE implementation.

[0139] Referring back to FIG. 4, in some implementations, the reference point for WUS is a start of a reference frame, and the reference frame is determined by a first frame-level offset from a start of a first PF of one or more paging frames (PFs) associated with WUS, and the first frame-level offset is provided by a higher layer parameter or a scaling factor of a second offset. The second offset may be from a reference point for paging early indication (PEI) operation in a main radio (MR) of the UE to a first PF of one or more PFs associated with the PEI, and the scaling factor can be provided by another higher layer parameter.

[0140] Additionally or alternatively, in some implementations, the reference frame is determined by a second frame-level offset from a reference point for PEI operation in the MR. In some implementations, an offset among the one or more first offsets is a symbol-level or slot-level offset from the reference point for WUS to a start of the WUS message.

[0141] In some implementations, when monitoring the WUS message in one or more WUS resources, the UE 404 may determine, based on the one or more first offsets, the one or more WUS resources for monitoring the WUS message. In the case that a WUS message is not detected in a first WUS resource among the one or more WUS resources, the UE 404 may monitor a WUS message in a second WUS resource or remaining resources among the one or more WUS resources. In some implementations, the one or more first offsets are scaled based on a subcarrier spacing in the first frequency band or a subcarrier spacing in the second frequency band.

[0142] FIG. 5B illustrates an example of LP-WUS configuration in accordance with aspects of the present disclosure. For example, for LP-WUS for paging monitoring in idle/inactive states, the time location of WUS resource for UE's PO is determined by a reference point and one or more offsets. As illustrated in FIG. 5B, the frame level offset between the reference frame and the start frame of the first PF of the PF(s) associated with the WUS may be larger than that designed for PEI in main radio since there may be potential frequency switching between MR and LR and potential synchronization in MR before corresponding PO monitoring, where the LP-WUS and PO association follows the PEI and PO association.

[0143] For option 1 (e.g., *WUS-FOffset = K * PEI-FOffset* as illustrated in FIG. 5B), the reference point for WUS is the start of a reference frame determined by a frame-level offset from the start of the first PF of the PF(s) associated with the WUS, the frame-level offset is provided by *WUS-FrameOffset* (e.g., *WUS-FOffset* in FIG. 5B) in SIB1. Additionally or alternatively, the reference frame is provided by the scaling factor of the offset (e.g., *pei-FrameOffset*, or *PEI-FOffset* in FIG. 5B) from the reference point of PEI to the first PF of the PF(s) associated with the PEI, provided by some parameter in SIB1. It should be noted that, the PEI feature (e.g., DCI based PEI indication) operated in MR may be also configured for fallback mechanism in certain conditions (e.g., LP-WUS channel condition is not good enough).

[0144] For option 2 (e.g., *WUS-FOffset = AddFOffset + PEI-FOffset* as illustrated in FIG. 5B), the reference point for WUS is the start of a reference frame determined by a frame-level offset from the reference point for PEI operation in MR radio (e.g., *PEI-FOffset* in FIG. 5B), provided by an additional frame offset *AddFrameOffset* (e.g., *AddFOffset* in FIG. 5B) in SIB1, where the additional frame offset is to facilitate UE frequency retuning from Carrier#1 to Carrier #2 and further potential synchronization in MR before corresponding PO monitoring.

[0145] As mentioned above, for LP-WUS for paging monitoring in idle/inactive states, the time location of WUS resource for UE's PO is determined by the reference point and one or more offsets, where the one or more offsets are symbol-level offsets from the reference point to the start of the WUS, which is provided by *symbolOffset-WUS* (e.g., *symbolOffset 00-WUS, symbolOffset 01-WUS, symbolOffset 10-WUS, or symbolOffset 11-WUS* in FIG. 5B) in SIB1.

[0146] For example, the UE may determine the one or more WUS resource(s) (e.g., WUS 0-0, WUS 0-1, WUS 1-0, WUS 1-1 in FIG. 5B) based on the one or more offsets for WUS monitoring. Moreover, the UE may monitor a second WUS resource (e.g., WUS-01, if configured) only if UE does not detect the WUS in a first WUS resource (e.g., WUS-00). Moreover, the symbol number of the corresponding PO in carrier#2/BWP#2 is scaled to the subcarrier spacing in carrier #1/BWP#1 (for LP-WUS monitoring). It should be noted that, for LP-WUS for paging monitoring in idle/inactive states as mentioned above, the WUS and PO association may follow the PEI and PO association.

[0147] Referring back to FIG. 4, additionally or alternatively, in some implementations, time locations of the one or more WUS resources are determined by one or more second offsets, and an offset among the one or more second offsets is a symbol-level or slot-level offset between a start or an end of the WUS message and a symbol or slot where a DRX on duration timer starts.

[0148] For example, for LP-WUS for DRX monitoring in connected states, the time location of WUS resources for UE is determined by a time offset (with unit of symbol), where the time offset is the symbol level offset between the start/end of WUS and the symbol where DRX ON duration timer starts. For DRX monitoring in connected states, similar two options as mentioned above can be designed for LP-WUS (e.g., *WUS-symOffset* = *K* * *ps-Offset*, or *WUS-symOffset* = *ps-Offset* + *Add-offset*, where *ps-Offset* may be *ps-Offset-r16* in FIG. 2B).

[0149] **LP-WUS sequence design**

[0150] In some implementations, the WUS message comprises a first number B of information bits, and a second number B0 out of the first number B of information bits are encoded to coded bits, and the coded bits are transmitted with a pattern or a form of a sequence in the one or more WUS resources.

[0151] Additionally or alternatively, when B is equal to B0 (B = B0), the WUS message comprises the first number B of information bits, and the first number B of information bits are encoded to coded bits, and the coded bits are transmitted with a pattern or a form of a sequence in the one or more WUS resources.

[0152] In some implementations, the sequence is a quadrature phase shift keying (QPSK) sequence and is generated from one or more first pseudo-random sequences. Additionally or alternatively, the sequence is an enhanced Zadoff-Chu sequence and is generated from one or more Zadoff-Chu sequences.

[0153] When the sequence is the QPSK sequence and is generated from one or more first pseudo-random sequences, in some implementations, an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by the following: a cell identity (ID), and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0154] Additionally or alternatively, when the sequence is the enhanced Zadoff-Chu sequence and is generated from one or more Zadoff-Chu sequences, in some implementations, each of the one or more Zadoff-Chu sequences is determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message.

[0155] FIGS. 6A-6E illustrate five examples of LP-WUS sequence design using a QPSK sequence in accordance with aspects of the present disclosure, and FIG. 7 illustrates an example of LP-WUS sequence design using an enhanced Zadoff-Chu sequence in accordance with aspects of the present disclosure.

[0156] For example, the LP-WUS message includes *B* information bits (may including CRC bit), where B0 (B0 <= B) out of *B* information bits are encoded to coded bits (e.g., Manchester code). Moreover, the coded bits are transmitted with pattern or form of QPSK sequences or enhanced Zadoff-Chu sequences in WUS resource(s).

[0157] For example, when the coded bits are transmitted with a pattern or a form of a QPSK sequence and the UE is in connected mode (i.e., wakeup DRX on duration PDCCH monitoring), QPSK sequence is generated from one or more first pseudo-random sequences, the initialization of each first pseudo-random sequence is determined by the cell ID, the first frame/slot/symbol of start of DRX on duration (e.g., where DRX on duration timer starts) to which the WUS message is associated, where each first pseudo-random sequence is associated with one or more coded message with modulating 'on' chip in time domain.

[0158] It should be note that, the UE needs to detect the On chip and OFF chip based on energy detection and detect the sequence for the "On" chip based on correlator detection. That is, it belongs to a combination of the OOK solution and OFDM sequence solution.

[0159] Referring back to FIG. 4, additionally or alternatively, in some implementations, an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0160] For example, when the coded bits are transmitted with a pattern or a form of a QPSK sequence and when the UE is in idle/inactive mode (i.e., wakeup Paging message monitoring by PDCCH monitoring), QPSK sequence is generated from one or more first pseudo-random sequences, and the initialization of each first pseudo-random sequence is determined by the symbol index of the first PDCCH MO associated with the WUS message. It should be noted that, the slot/symbol number of the corresponding PO or DRX on duration in carrier#2/BWP#2 is scaled to the subcarrier spacing in carrier #1/BWP#1.

[0161] The first pseudo-random sequences are defined by a length-31 Gold sequence. The sequence c(n) may be defined by:

$$\begin{aligned} c(n) &= \left(x_1(n + N_C) + x_2(n + N_C)\right) \bmod 2 \\ x_1(n + 31) &= \left(x_1(n + 3) + x_1(n)\right) \bmod 2 \\ x_2(n + 31) &= \left(x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)\right) \bmod 2 \end{aligned}$$

[0162] The initialization of the second m-sequence can be denoted by:

$$c_{\mathrm{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$$

[0163] The initialization of the sequence may be determined by:

$$c_{\mathrm{WUS}} = \left(\left(n_{slot} * N_{sym}^{slot} + l\right) \bmod M + 1\right) 2^9 + N^{cellID}$$

where n_{slot} is the slot index in frame or among multiple frames, and l is the symbol index of slot for first PDCCH MO associated with the WUS message, M is configured value or the maximal symbol number of super frames, depends on the subcarrier spacing of the PDCCH MO. As a result, the inter-cell interference can be randomized. It should be noted that, as illustrated in FIG. 6C, the sequence associated with each bit is the same, which reduces the UE detection complexity, but increase the PAPR potentially.

[0164] Referring back to FIG. 4, in order to carry more information bits, in some implementations, an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is further determined by a third number B1 of information bits or coded bits, and the third number B1 is determined by the first number B, or the second number B0, or both the first number B and the second number B0. For example, B1=B-B0.

[0165] In some implementations, the QPSK sequence is further generated from orthogonal sequences or second pseudo-random sequences in addition to sequences generated from the one or more first pseudo-random sequences. In some implementations, the orthogonal sequences or second pseudo-random sequences are applied to the sequences generated from the one or more first pseudo-random sequences, the orthogonal sequences or second pseudo-random sequences are determined by all or partial of a fourth number B2 of information bits or coded bits, and the fourth number B2 is determined by the first number B, or the second number B0, or a third number, or a combination thereof. For example, B2=B-B0-B1.

[0166] In some implementations, a length of the orthogonal sequences or second pseudo-random sequences is determined by the second number B0 or determined by a symbol number configured for each WUS resource. For example, the initialization of the second m-sequence may be denoted by:

$$c_{\mathrm{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$$

[0167] The initialization of the m-sequence can be further determined by B1 (B1 <= B-B0) of the information bits (e.g., 2bits, with value of S of the B1 bits, see FIGS 6D-6E),

$$c_{\mathrm{WUS}} = \left(\left(n_{slot} N_{sym}^{slot} + l\right) \bmod M + 1\right) 2^{11} + \left(N^{cellID} + 1\right) 2^2 + S$$

[0168] Optionally, the B0 (B0 <= B) out of B information bits are encoded to coded bits (e.g., Manchester code), partial of coded bits may be transmitted with pattern or form of QPSK sequences in WUS resource(s) and remaining of the coded bits may determine the initialization of the m-sequence. Moreover, for example, the orthogonal sequence or second pseudo-random sequences are applied to the sequences generated from the multiple of first pseudo-random sequences, the orthogonal sequences or second pseudo-random sequences are determined by all or partial of the B1 (B1 <= B-B0) of the information bits or coded bits.

[0169] Additionally or alternatively, the orthogonal sequences are applied to among different OFDM symbols (e.g., V(0), V(1), V(2), V(3), see FIGS 6D-6E). In one hand, orthogonal sequence is applied to the QPSK sequence in time or frequency domain, for example in FIG. 6D, each element of orthogonal sequence is applied to QPSK sequence associated with one coded bit, while in another hand, for example in FIG. 6E, each element of orthogonal sequence is applied to QPSK sequence associated with one OFDM symbol (corresponding to multiple coded bits). Additionally or alternatively, for example, when the coded bits are transmitted with a pattern or a form of an enhanced Zadoff-Chu sequence and the UE is in connected mode (i.e., wakeup DRX on-duration PDCCH monitoring), enhanced Zadoff-Chu sequence is generated from the one or more Zadoff-Chu sequences, the Zadoff-Chu sequence is determined is determined by the cell ID, the first frame/slot/symbol of start of DRX on duration (e.g., where DRX on duration timer starts) to which the WUS message is associated.

[0170] Each Zadoff-Chu sequence is associated with one or more coded message with modulating ‘on’ chip in time domain. The Zadoff-Chu sequence may be as follows:

$$d_u(n) = e^{-j\frac{\pi u n(n+1)}{11}},\ \text{u is from the set U=\{2,3,5,7\}}$$

where u can be determined by:

$$\left(\left(\left(n_{slot}N_{sym}^{slot} + l\right)\bmod M + 1\right)2^9 + N^{cellID}\right)\bmod \mathrm{X},$$

where X is the element number of U.

[0171] The enhanced Zadoff-Chu sequence is further generated from an orthogonal sequences or third pseudo-random sequences in addition to sequences generated from the multiple Zadoff-Chu sequences, the orthogonal sequence or third pseudo-random sequences are applied to the sequences generated from the multiple Zadoff-Chu sequence. The orthogonal sequences or third pseudo-random sequences can be determined by the cell ID, the first frame/slot/symbol of start of DRX on duration (e.g., DRX timer starts) to which the WUS message is associated and all or partial of the B1 (B1 <= B-B0) of the information bits or coded bits.

[0172] Referring back to FIG. 4, in some implementations, each of the one or more Zadoff-Chu sequence is determined by the following: a cell ID, and a symbol index of a first control signal monitoring occasion associated with the WUS message. For example, when the coded bits are transmitted with a pattern or a form of an enhanced Zadoff-Chu sequence and the UE is in idle/inactive mode (i.e., wake up Paging message monitoring), enhanced Zadoff-Chu sequence is generated from the one or more Zadoff-Chu sequences, the Zadoff-Chu sequence is determined by the cell ID, the symbol index of the first PDCCH MO associated with the WUS message. It should be noted that, the slot/symbol number of the corresponding PO or DRX on duration in carrier#2/BWP#2 is scaled to the subcarrier spacing in carrier #1/BWP#1.

[0173] Referring back to FIG. 4, in some implementations, the enhanced Zadoff-Chu sequence is further generated from orthogonal sequences or third pseudo-random sequences in addition to sequences generated from the one or more Zadoff-Chu sequences, the orthogonal sequences or third pseudo-random sequences are applied to the sequences generated from the one or more Zadoff-Chu sequences.

[0174] In some implementations of the user equipment described herein, the orthogonal sequences or third pseudo-random sequences are determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message, or a symbol index of a first control signal monitoring occasion associated with the WUS message.

[0175] In some implementations of the user equipment described herein, the orthogonal sequences or third pseudo-random sequences are further determined by all or partial of a fourth number B2 of information bits or coded bits, and the fourth number B2 is determined by the first number B, or the second number B0, or a third number, or a combination thereof.

[0176] FIG. 8 illustrates an example of a device 800 that support LP-WUS design in accordance with aspects of the present disclosure. The device 800 may be an example of a UE 104-1 as described herein. The device 800 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 800 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 802, a memory 804, a transceiver 806, and, optionally, an I/O controller 808. 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).

[0177] The processor 802, the memory 804, the transceiver 806, 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 802, the memory 804, the transceiver 806, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0178] In some implementations, the processor 802, the memory 804, the transceiver 806, 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 802 and the memory 804 coupled with the processor 802 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 802, instructions stored in the memory 804).

[0179] For example, the processor 802 may support wireless communication at the device 800 in accordance with examples as disclosed herein. The processor 802 may be configured to operable to support means for receiving, from a base station, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; means for monitoring a WUS message in one or more WUS resources in a first frequency band; and means for determining, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

[0180] The processor 802 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 802 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 802. The processor 802 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 804) to cause the device 800 to perform various functions of the present disclosure.

[0181] The memory 804 may include random access memory (RAM) and read-only memory (ROM). The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 802 cause the device 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. In some implementations, the code may not be directly executable by the processor 802 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 804 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.

[0182] The I/O controller 808 may manage input and output signals for the device 800. The I/O controller 808 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 808 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 808 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 808 may be implemented as part of a processor, such as the processor 806. In some implementations, a user may interact with the device 800 via the I/O controller 808 or via hardware components controlled by the I/O controller 808.

[0183] In some implementations, the device 800 may include a single antenna 810. However, in some other implementations, the device 800 may have more than one antenna 810 (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 806 may communicate bi-directionally, via the one or more antennas 810, wired, or wireless links as described herein. For example, the transceiver 806 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 806 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 810 for transmission, and to demodulate packets received from the one or more antennas 810. The transceiver 806 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0184] 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 810 for transmitting the amplified signal into the air or wireless medium.

[0185] 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 810 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.

[0186] FIG. 9 illustrates an example of a processor 900 that supports LP-WUS design in accordance with aspects of the present disclosure. The processor 900 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 900 may include a controller 902 configured to perform various operations in accordance with examples as described herein. The processor 900 may optionally include at least one memory 904, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 900 may optionally include one or more arithmetic-logic units (ALUs) 900. 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).

[0187] The processor 900 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 900) 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).

[0188] The controller 902 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 900 to cause the processor 900 to support various operations of a base station in accordance with examples as described herein. For example, the controller 902 may operate as a control unit of the processor 900, generating control signals that manage the operation of various components of the processor 900. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0189] The controller 902 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 904 and determine subsequent instruction(s) to be executed to cause the processor 900 to support various operations in accordance with examples as described herein. The controller 902 may be configured to track memory address of instructions associated with the memory 904. The controller 902 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 902 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 900 to cause the processor 900 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 902 may be configured to manage flow of data within the processor 900. The controller 902 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 900.

[0190] The memory 904 may include one or more caches (e.g., memory local to or included in the processor 900 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 904 may reside within or on a processor chipset (e.g., local to the processor 900). In some other implementations, the memory 904 may reside external to the processor chipset (e.g., remote to the processor 900).

[0191] The memory 904 may store computer-readable, computer-executable code including instructions that, when executed by the processor 900, cause the processor 900 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 902 and/or the processor 900 may be configured to execute computer-readable instructions stored in the memory 904 to cause the processor 900 to perform various functions. For example, the processor 900 and/or the controller 902 may be coupled with or to the memory 904, and the processor 900, the controller 902, and the memory 904 may be configured to perform various functions described herein. In some examples, the processor 900 may include multiple processors and the memory 904 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.

[0192] The one or more ALUs 900 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 900 may reside within or on a processor chipset (e.g., the processor 900). In some other implementations, the one or more ALUs 900 may reside external to the processor chipset (e.g., the processor 900). One or more ALUs 900 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 900 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 900 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 900 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 900 to handle conditional operations, comparisons, and bitwise operations.

[0193] The processor 900 may support wireless communication in accordance with examples as disclosed herein. The processor 900 may be configured to or operable to support means for transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling; means for transmitting, to the UE, a WUS message in one or more WUS resources in a first frequency band; and means for transmitting, to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

[0194] FIG. 10 illustrates a flowchart of a method 1000 that supports LP-WUS design 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 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.

[0195] At 1010, the method may include receiving, from a base station, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling. 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.

[0196] At 1020, the method may include monitoring a WUS message in one or more WUS resources in a first frequency band. 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.

[0197] At 1030, the method may include determining, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band. 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.

[0198] FIG. 11 illustrates a flowchart of a method 1100 that supports LP-WUS design in accordance with aspects of the present disclosure. The operations of the method 1100 may be implemented by a device or its components as described herein. For example, the operations of the method 1100 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.

[0199] At 1110, the method may include transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling. The operations of 1110 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1110 may be performed by a device as described with reference to FIG. 1A.

[0200] At 1120, the method may include transmitting, to the UE, a WUS message in one or more WUS resources in a first frequency band. The operations of 1120 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1120 may be performed by a device as described with reference to FIG. 1A.

[0201] At 1130, the method may include transmitting, to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band. The operations of 1130 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1130 may be performed by a device as described with reference to FIG. 1A.

[0202] 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.

[0203] 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.

[0204] 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.

[0205] 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.

[0206] 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.

[0207] 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:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive, via the transceiver, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling;

monitor, via the transceiver, a WUS message in one or more WUS resources in a first frequency band; and

determine, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

2. The UE of claim 1, wherein monitoring the WUS message in the one or more WUS resources in the first frequency band comprises:

determining time locations of the one or more WUS resources based on a reference point for WUS and one or more first offsets.

3. The UE of claim 2, wherein the reference point for WUS is a start of a reference frame.

4. The UE of claim 3, wherein the reference frame is determined by a first frame-level offset from a start of a first PF of one or more paging frames (PFs) associated with WUS, and wherein the first frame-level offset is provided by one of the following:

a higher layer parameter; or

a scaling factor of a second offset from a reference point for paging early indication (PEI) operation in a main radio (MR) of the UE to a first PF of one or more PFs associated with the PEI, and the scaling factor is provided by another higher layer parameter.

5. The UE of claim 1, wherein the WUS message comprises a first number of

information bits, and a second number out of the first number of information bits are encoded to coded bits, and the coded bits are transmitted with a pattern or a form of a sequence in the one or more WUS resources.

6. The UE of claim 5, wherein the sequence is a quadrature phase shift keying (QPSK) sequence and is generated from one or more first pseudo-random sequences.

7. The UE of claim 6, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is determined by at least one of the following:

a cell identity (ID), and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message; or

a symbol index of a first control signal monitoring occasion associated with the WUS message.

8. The UE of claim 6, wherein an initialization of each first pseudo-random sequence among the one or more first pseudo-random sequences is further determined by a third number of information bits or coded bits, and the third number is determined by the first number, or the second number, or both the first number and the second number.

9. The UE of claim 6, wherein the QPSK sequence is further generated from orthogonal sequences or second pseudo-random sequences in addition to sequences generated from the one or more first pseudo-random sequences.

10. The UE of claim 9, wherein the orthogonal sequences or second pseudo-random sequences are applied to the sequences generated from the one or more first pseudo-random sequences, the orthogonal sequences or second pseudo-random sequences are determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

11. The UE of claim 9, wherein a length of the orthogonal sequences or second pseudo-random sequences is determined by the second number or determined by a

symbol number configured for each WUS resource.

12. The UE of claim 5, wherein the sequence is an enhanced Zadoff-Chu sequence and is generated from one or more Zadoff-Chu sequences.

13. The UE of claim 12, wherein each of the one or more Zadoff-Chu sequences is determined by at least one of the following:

a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message; or

a cell ID, and a symbol index of a first control signal monitoring occasion associated with the WUS message.

14. The UE of claim 12, wherein the enhanced Zadoff-Chu sequence is further generated from orthogonal sequences or third pseudo-random sequences in addition to sequences generated from the one or more Zadoff-Chu sequences.

15. The UE of claim 14, wherein the orthogonal sequences or third pseudo-random sequences are applied to the sequences generated from the one or more Zadoff-Chu sequences.

16. The UE of claim 14, wherein the orthogonal sequences or third pseudo-random sequences are determined by the following: a cell ID, and a first frame or a first slot or a first symbol of a start of a DRX on duration associated the WUS message, or a symbol index of a first control signal monitoring occasion associated with the WUS message, and

wherein the orthogonal sequences or third pseudo-random sequences are determined by all or partial of a fourth number of information bits or coded bits, and the fourth number is determined by the first number, or the second number, or a third number, or a combination thereof.

17. A base station, comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, via the transceiver, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling;

transmit, via the transceiver and to a user equipment (UE), a WUS message in one or more WUS resources in a first frequency band; and

transmit, via the transceiver and to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

18. 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 in system information or UE-specific radio resource control (RRC) signaling;

monitor a WUS message in one or more WUS resources in a first frequency band; and

determine, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

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

receiving, from a base station, a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling;

monitoring a WUS message in one or more WUS resources in a first frequency band; and

determining, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in discontinuous reception (DRX) on duration in the second frequency band.

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

transmitting, to a user equipment (UE), a wake-up signal (WUS) configuration in system information or UE-specific radio resource control (RRC) signaling;

transmitting, to the UE, a WUS message in one or more WUS resources in a first frequency band; and

transmitting, to the UE, a paging message in a second frequency band or a control signal in discontinuous reception (DRX) on duration of the UE in the second frequency band.

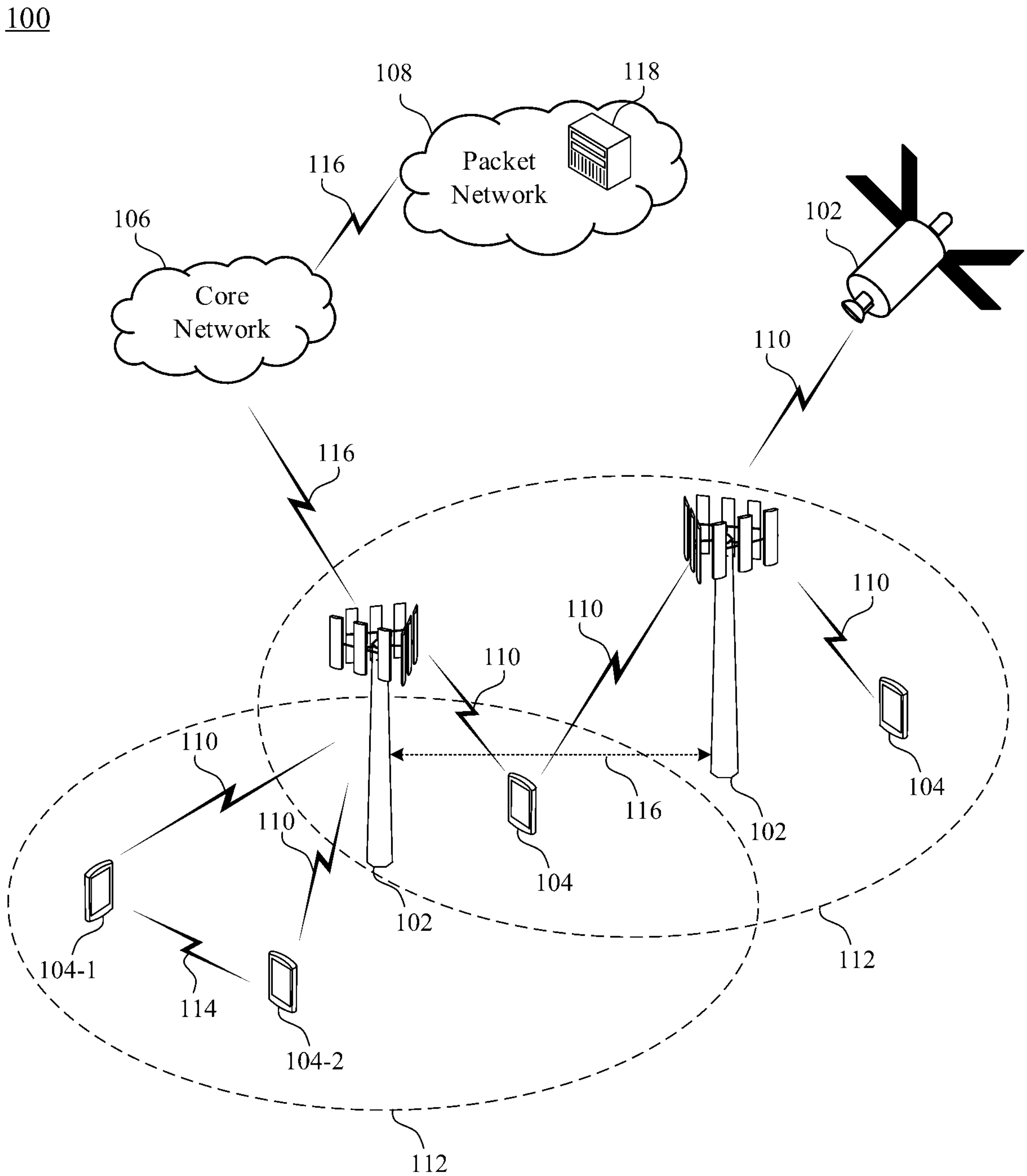
100
108
118
Packet
Network
116
106
Core
Network
102
110
116
110
110
110
110
110
104
116
102
104
104
104-1
114
104-2
102
112
112

FIG. 1A

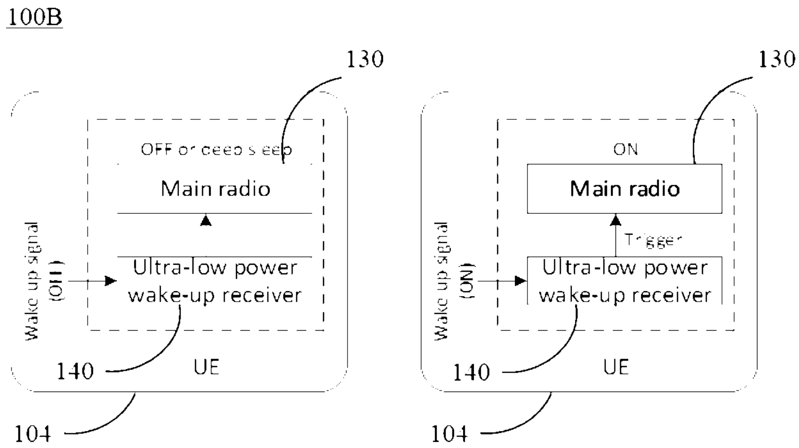

FIG. 1B

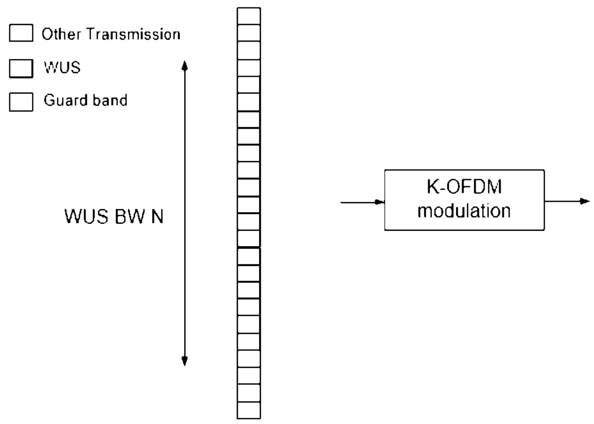

FIG. 1C

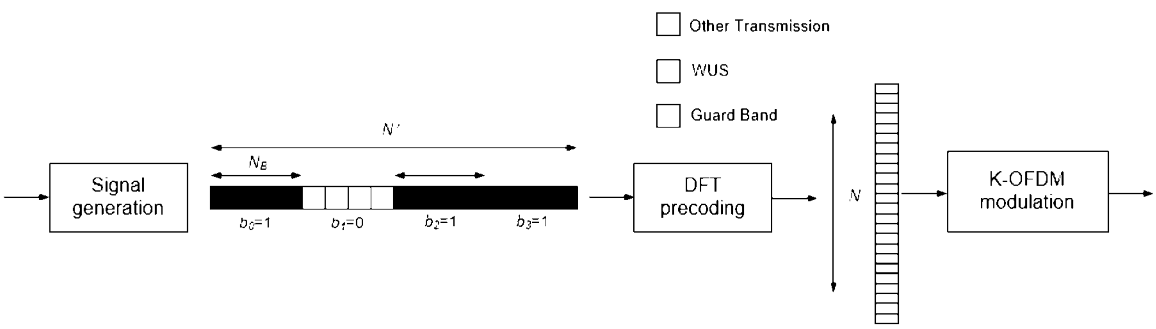

FIG. 1D

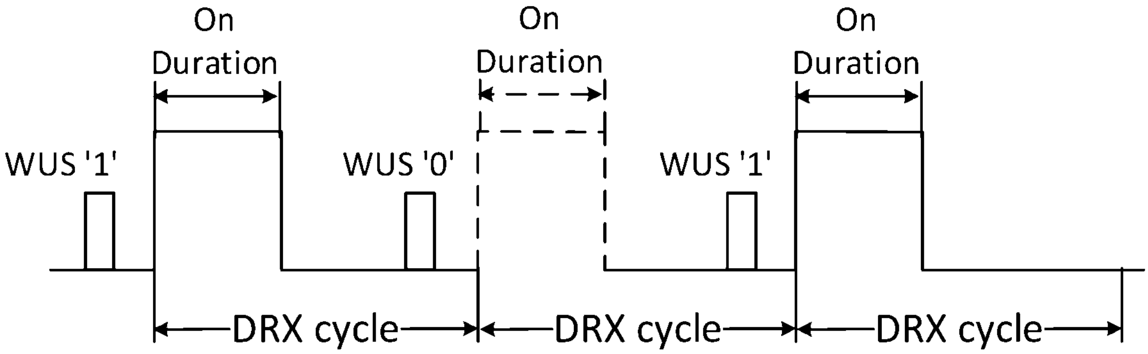
On
Duration
On
Duration
On
Duration
WUS '1'
WUS '0'
WUS '1'
DRX cycle
DRX cycle
DRX cycle

FIG. 2A

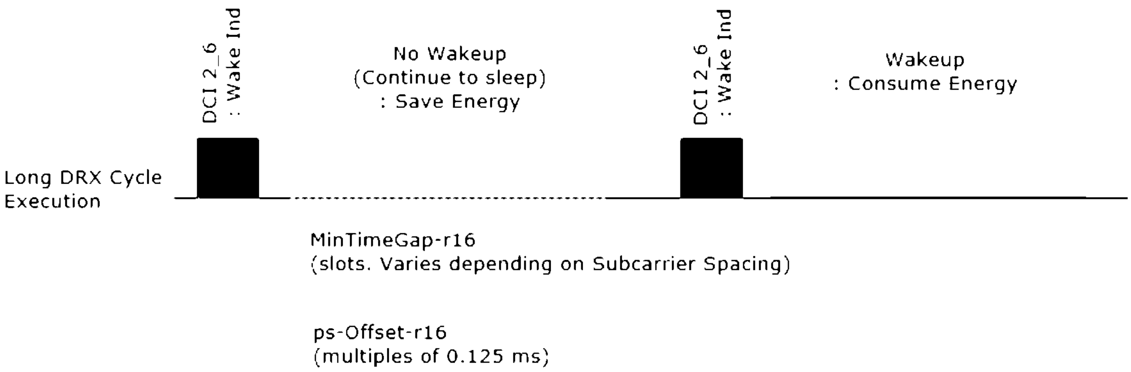
DCI 2_6
: Wake Ind
No Wakeup
(Continue to sleep)
: Save Energy
DCI 2_6
: Wake Ind
Wakeup
: Consume Energy
Long DRX Cycle
Execution
MinTimeGap-r16
(slots. Varies depending on Subcarrier Spacing)
ps-Offset-r16
(multiples of 0.125 ms)

FIG. 2B

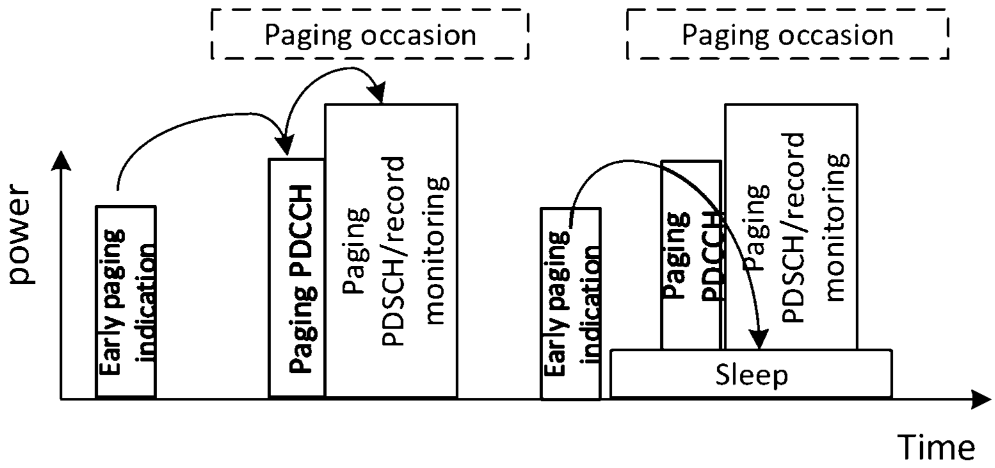
Paging occasion
Paging occasion
power
Early paging indication
Paging PDCCH
Paging PDSCH/record monitoring
Early paging indication
Paging PDCCH
Paging PDSCH/record monitoring
Sleep
Time

FIG. 3A

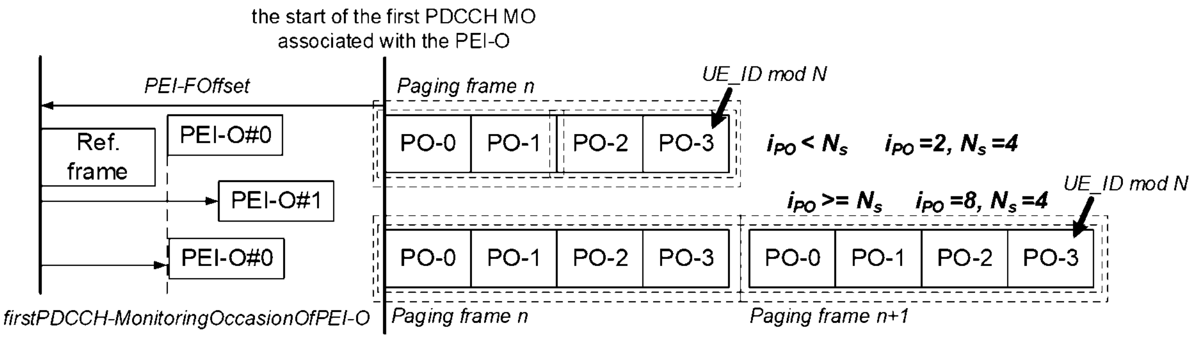
the start of the first PDCCH MO associated with the PEI-O
PEI-FOffset
Paging frame n
UE_ID mod N
Ref. frame
PEI-O#0
PO-0
PO-1
PO-2
PO-3
$i_{PO} < N_s$ $i_{PO} = 2$, $N_s = 4$
PEI-O#1
$i_{PO} >= N_s$ $i_{PO} = 8$, $N_s = 4$
UE_ID mod N
PEI-O#0
PO-0
PO-1
PO-2
PO-3
PO-0
PO-1
PO-2
PO-3
firstPDCCH-MonitoringOccasionOfPEI-O
Paging frame n
Paging frame n+1

FIG. 3B

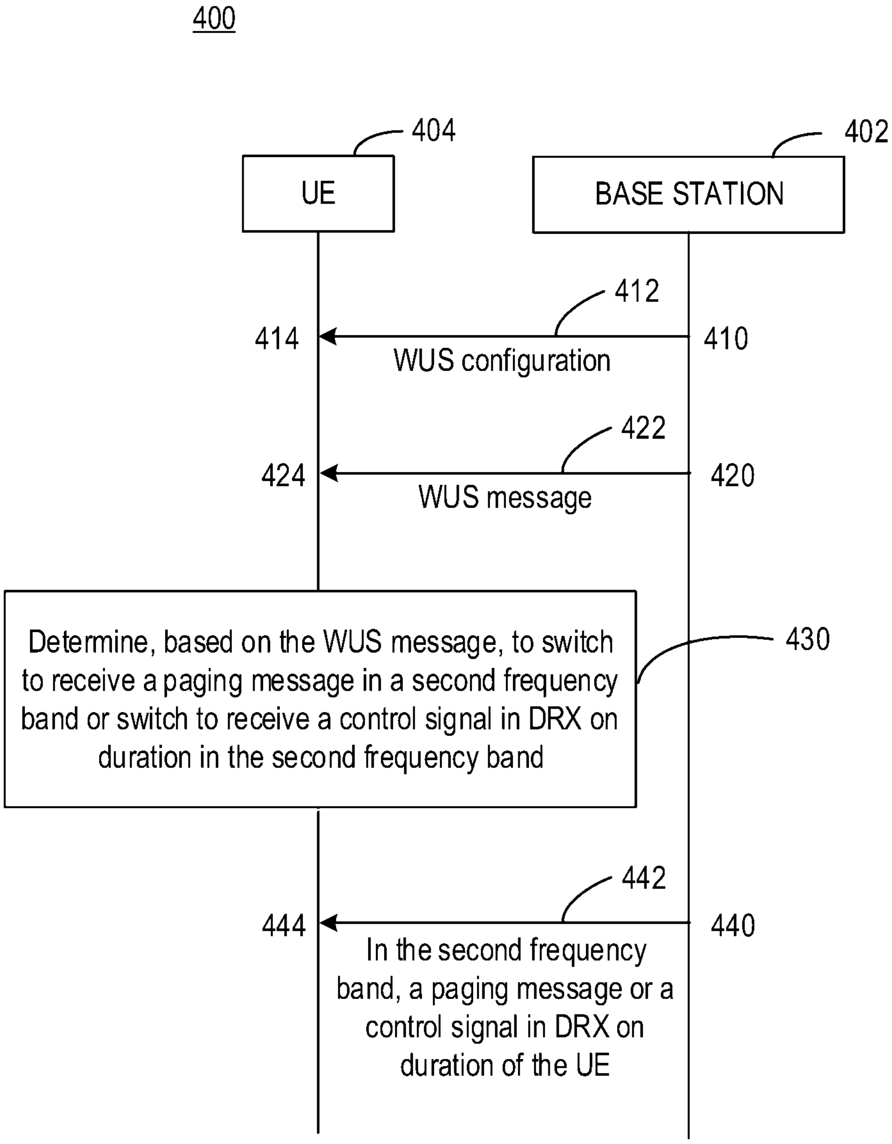
400
404
402
UE
BASE STATION
412
414
410
WUS configuration
422
424
420
WUS message
Determine, based on the WUS message, to switch to receive a paging message in a second frequency band or switch to receive a control signal in DRX on duration in the second frequency band
430
442
444
440
In the second frequency band, a paging message or a control signal in DRX on duration of the UE

FIG. 4

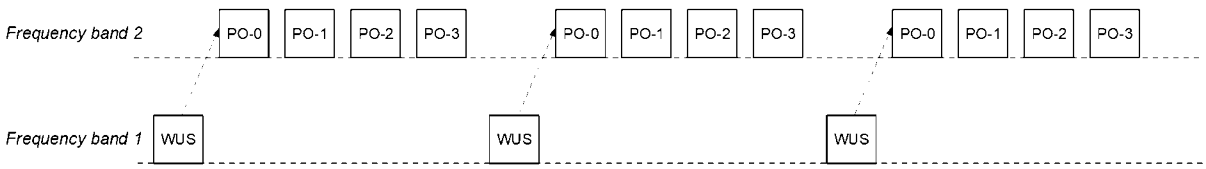
Frequency band 2
PO-0
PO-1
PO-2
PO-3
Frequency band 1
WUS

FIG. 5A

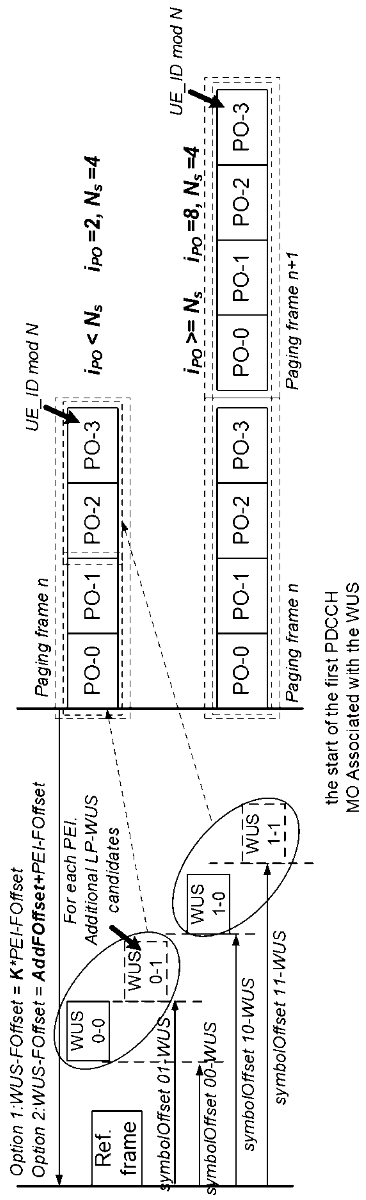
UE_ID mod N
i_{PO} < N_s
i_{PO} =2, N_s =4
i_{PO} >= N_s
i_{PO} =8, N_s =4
Paging frame n
Paging frame n+1
PO-0
PO-1
PO-2
PO-3
Option 1:WUS-FOffset = K*PEI-FOffset
Option 2:WUS-FOffset = AddFOffset+PEI-FOffset
For each PEI, Additional LP-WUS candidates
Ref. frame
WUS 0-0
WUS 0-1
WUS 1-0
WUS 1-1
symbolOffset 01-WUS
symbolOffset 00-WUS
symbolOffset 10-WUS
symbolOffset 11-WUS
the start of the first PDCCH MO Associated with the WUS

FIG. 5B

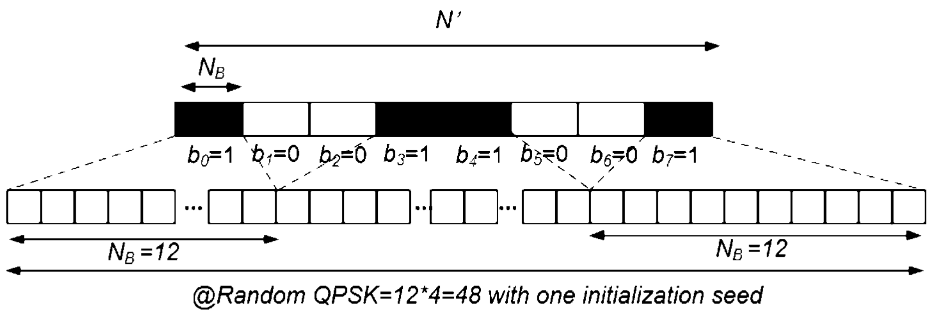
N'
N_B
b_0=1 b_1=0 b_2=0 b_3=1 b_4=1 b_5=0 b_6=0 b_7=1
N_B =12
N_B =12
@Random QPSK=12*4=48 with one initialization seed

FIG. 6A

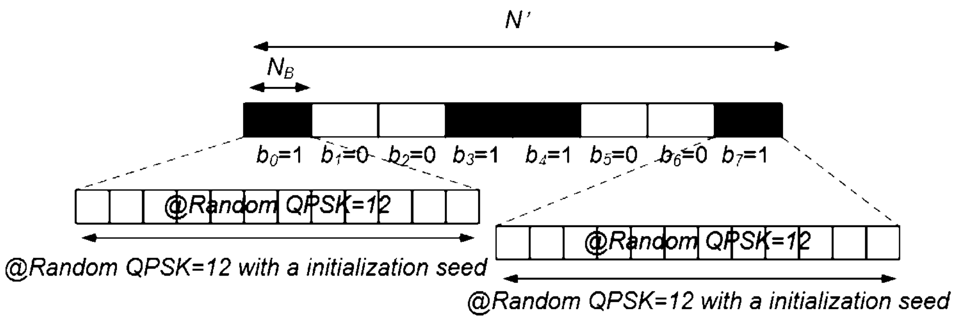
N'
N_B
b_0=1 b_1=0 b_2=0 b_3=1 b_4=1 b_5=0 b_6=0 b_7=1
@Random QPSK=12
@Random QPSK=12 with a initialization seed
@Random QPSK=12
@Random QPSK=12 with a initialization seed

FIG. 6B

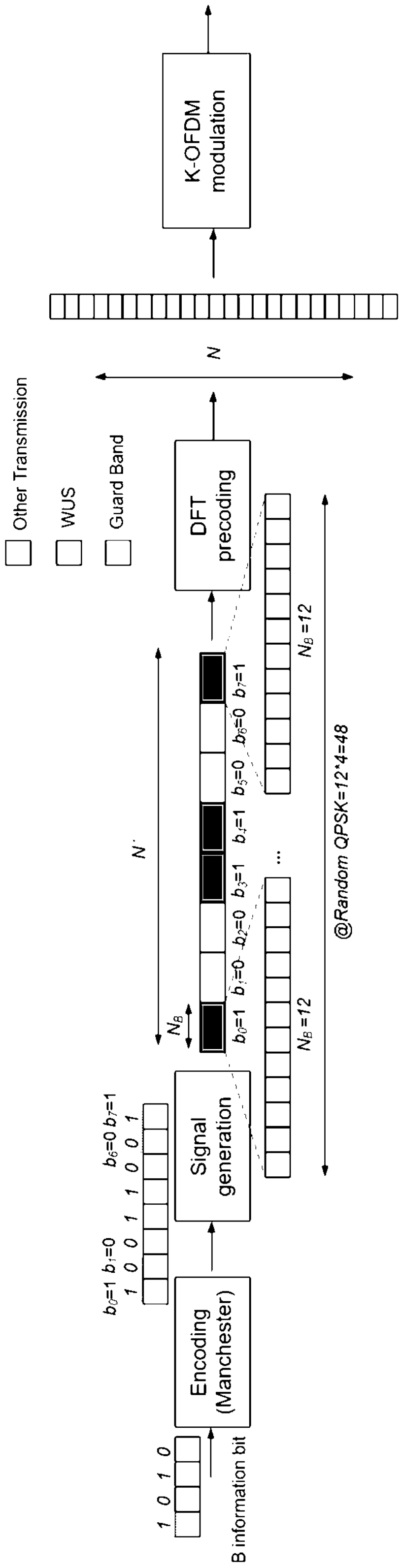
K-OFDM modulation
N
Other Transmission
WUS
Guard Band
DFT precoding
N'
N_B
b_0=1 b_1=0 b_2=0 b_3=1 b_4=1 b_5=0 b_6=0 b_7=1
...
N_B=12
N_B=12
@Random QPSK=12*4=48
Signal generation
b_0=1 b_1=0
1 0 0 1 1 0 0 1
b_6=0 b_7=1
Encoding (Manchester)
1 0 1 0
B information bit

FIG. 6C

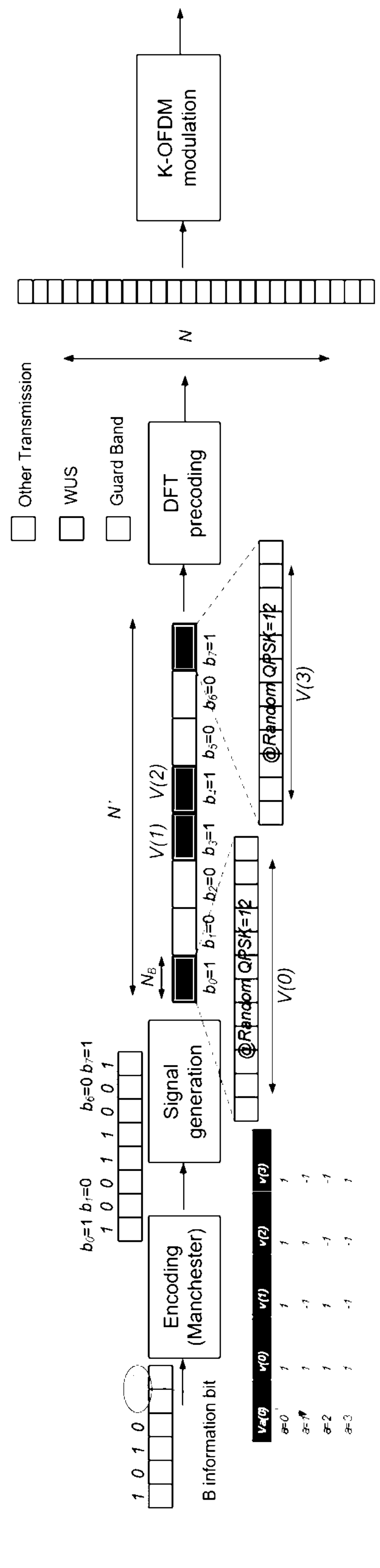
K-OFDM modulation
N
Other Transmission
WUS
Guard Band
DFT precoding
N'
V(1)
V(2)
V(3)
V(0)
@Random QPSK=12
@Random QPSK=12
Signal generation
Encoding (Manchester)
B information bit
1 0 1 0
1 0 0 1 1 0 0 1

FIG. 6D

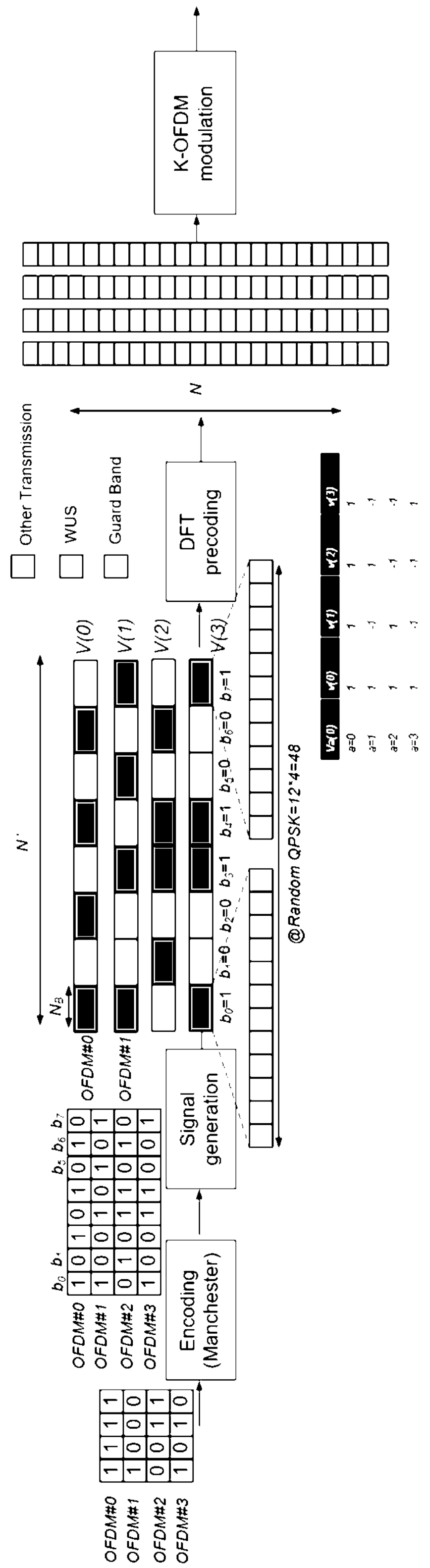
K-OFDM modulation
Other Transmission
WUS
Guard Band
DFT precoding
Signal generation
Encoding (Manchester)
OFDM#0
OFDM#1
OFDM#2
OFDM#3
@Random QPSK=12*4=48

FIG. 6E

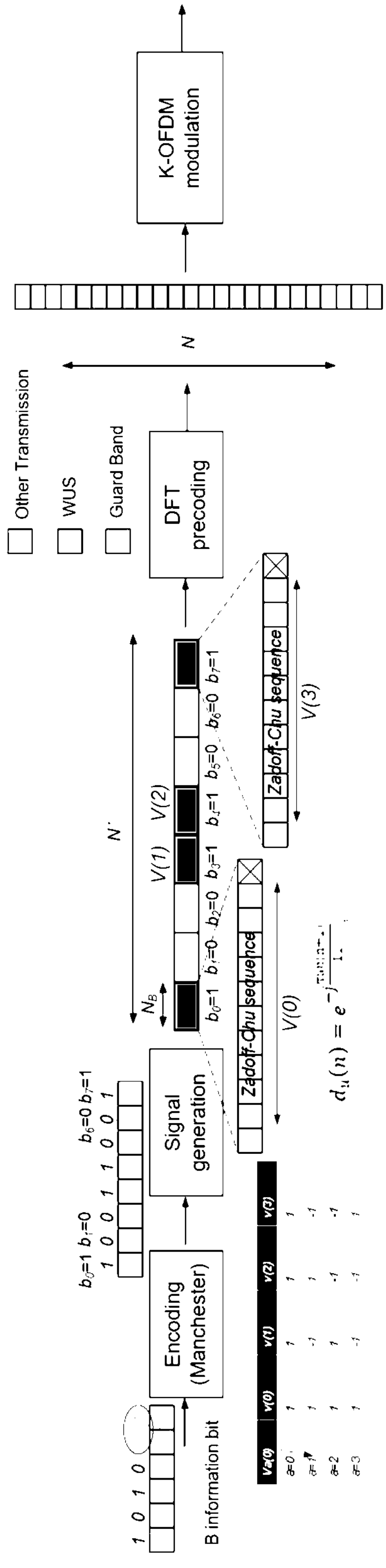
K-OFDM modulation
N
Other Transmission
WUS
Guard Band
DFT precoding
N'
V(1)
V(2)
Zadoff-Chu sequence
V(3)
V(0)
Signal generation
Encoding (Manchester)
B information bit
1 0 1 0
1 0 0 1 1 0 0 1

FIG. 7

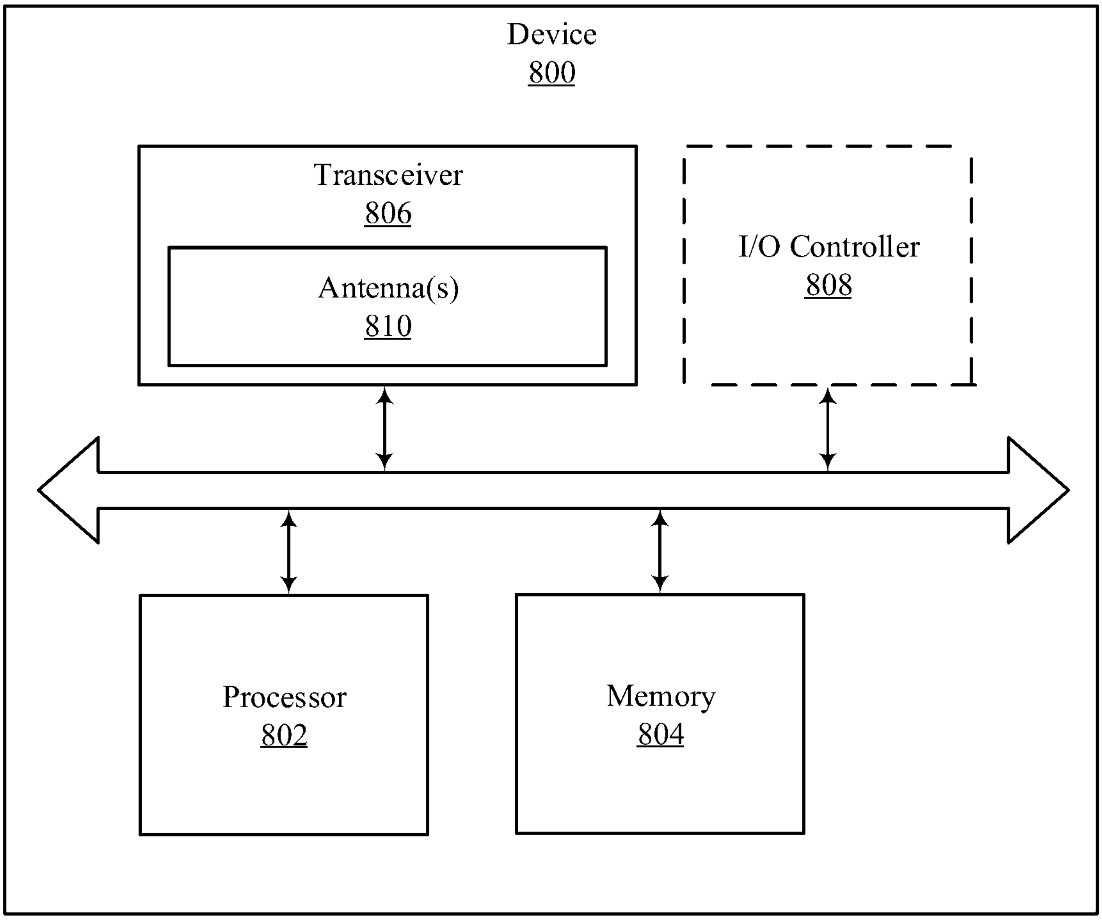
Device
800
Transceiver
806
Antenna(s)
810
I/O Controller
808
Processor
802
Memory
804

FIG. 8

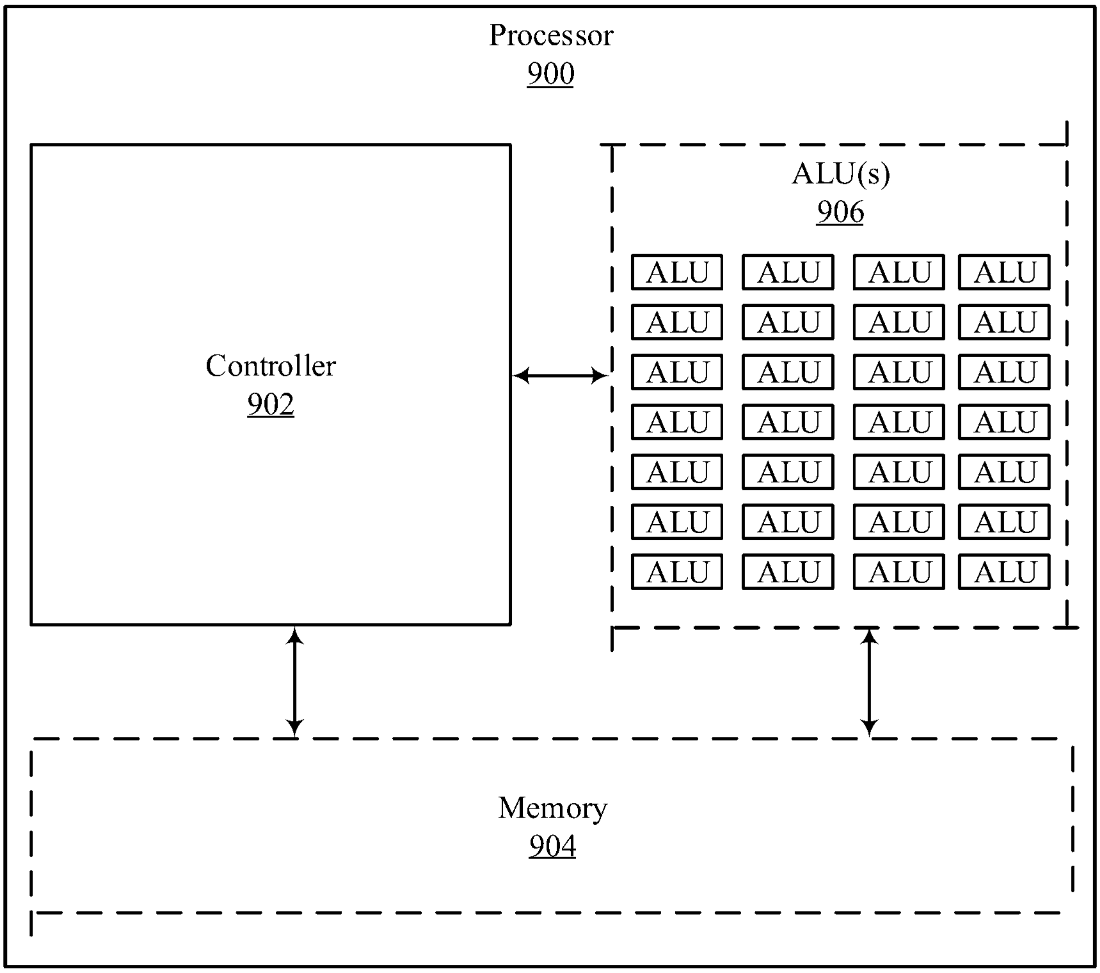
Processor
900
Controller
902
ALU(s)
906
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
Memory
904

FIG. 9

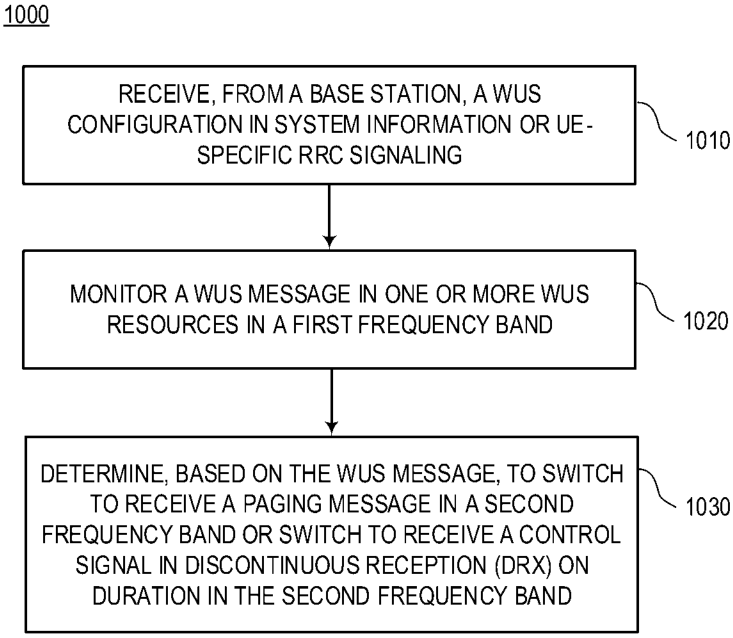
1000
RECEIVE, FROM A BASE STATION, A WUS CONFIGURATION IN SYSTEM INFORMATION OR UE-SPECIFIC RRC SIGNALING
1010
MONITOR A WUS MESSAGE IN ONE OR MORE WUS RESOURCES IN A FIRST FREQUENCY BAND
1020
DETERMINE, BASED ON THE WUS MESSAGE, TO SWITCH TO RECEIVE A PAGING MESSAGE IN A SECOND FREQUENCY BAND OR SWITCH TO RECEIVE A CONTROL SIGNAL IN DISCONTINUOUS RECEPTION (DRX) ON DURATION IN THE SECOND FREQUENCY BAND
1030

FIG. 10

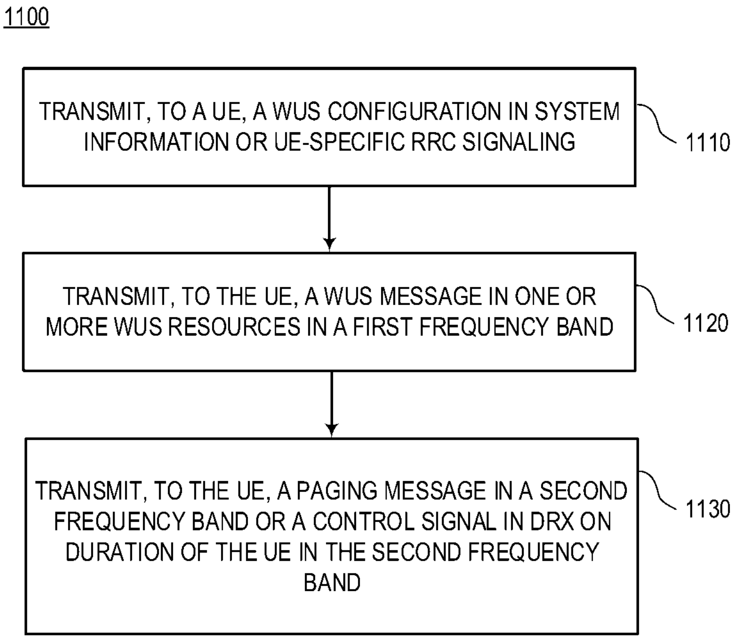
1100
TRANSMIT, TO A UE, A WUS CONFIGURATION IN SYSTEM INFORMATION OR UE-SPECIFIC RRC SIGNALING
1110
TRANSMIT, TO THE UE, A WUS MESSAGE IN ONE OR MORE WUS RESOURCES IN A FIRST FREQUENCY BAND
1120
TRANSMIT, TO THE UE, A PAGING MESSAGE IN A SECOND FREQUENCY BAND OR A CONTROL SIGNAL IN DRX ON DURATION OF THE UE IN THE SECOND FREQUENCY BAND
1130

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/076401

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

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,CNKI,DWPI,ENTXT,VCN,VEN:WUS LOW POWER REDUCE WAKE UP SIGNAL UE NETWORK IDLE PDCCH PAG+ RESOURCE FREQUENCY FIRST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018175760 A1 (INTEL CORPORATION et al.) 27 September 2018 (2018-09-27) description,paragraphs 105-279	1-20
A	CN 112567819 A (LG ELECTRONICS INC.) 26 March 2021 (2021-03-26) the whole document	1-20
A	CN 113873621 A (LG ELECTRONICS INC.) 31 December 2021 (2021-12-31) the whole document	1-20
A	CN 116158135 A (QUALCOMM INC.) 23 May 2023 (2023-05-23) the whole document	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"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
26 October 2024	**07 November 2024**

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**	**FANG,Ting** Telephone No. **(+86) 010-53961654**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/076401

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2018175760	A1	27 September 2018	US	2020029302	A1	23 January 2020
				US	11284372	B2	22 March 2022
				US	2022201649	A1	23 June 2022
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				EP	3603223	A4	13 January 2021
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CN	112567819	A	26 March 2021	EP	4236601	A2	30 August 2023
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				US	2024155496	A1	09 May 2024
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				US	11910324	B2	20 February 2024
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CN	113873621	A	31 December 2021	EP	3968709	A1	16 March 2022
				US	2021153163	A1	20 May 2021
				US	11818685	B2	14 November 2023
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				US	10904861	B2	26 January 2021
				US	2024049179	A1	08 February 2024
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				CN	109923914	A	21 June 2019
				WO	2018174635	A1	27 September 2018
CN	116158135	A	23 May 2023	KR	20230040981	A	23 March 2023
				US	2022022147	A1	20 January 2022
				US	11743848	B2	29 August 2023
				WO	2022020155	A2	27 January 2022
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				WO	2022020155	A9	09 June 2022
				EP	4183184	A2	24 May 2023