

LOW POWER WUS ACTIVATION AND DEACTIVATION CONFIGURATION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to wake-up signal (WUS) activation and deactivation configuration.

BACKGROUND

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

SUMMARY

[0003] 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.

[0004] The present disclosure relates to methods, apparatuses, and systems that support lower power WUS activation and deactivation.

[0005] Some implementations of the method and apparatuses described herein may further include a user equipment (UE) for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0006] Some implementations of the method and apparatuses described herein may include a processor in a UE for wireless communication, the processor comprising: at least one controller coupled with at least one memory and configured to cause the processor to: receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0007] Some implementations of the method and apparatuses described herein may include a method performed by a user equipment (UE), the method comprising: receiving, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switching between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s)

[0008] In some implementations of the method and apparatuses described herein, switch between operation in MR and operation in LP-WUR comprises:

[0009] (1) activate LP-WUS monitoring in a first frequency band in LP-WUR,

[0010] (2) deactivate LP-WUS monitoring in the first frequency band in LP-WUR,

[0011] (3) switch between monitoring LP-WUS in the first frequency band in LP-WUR and monitoring control signal in a second frequency band in MR, or

[0012] any combination of (1), (2) and (3).

[0013] In some implementations of the method and apparatuses described herein, the explicit indication is included in system information and/or RRC signaling.

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[0015] In some implementations of the method and apparatuses described herein, the explicit indication indicates the UE to switch from MR to LP-WUR, and the explicit indication is or is included in RRC connection release message.

[0016] In some implementations of the method and apparatuses described herein, a gap duration is configured or preconfigured or predetermined, where the gap duration starts from the reception of the RRC connection release message or from the UE having switched from connected mode to idle or inactive mode, and the UE switches from MR to LP-WUR after the gap duration.

[0017] In some implementations of the method and apparatuses described herein, the gap duration ends after the UE monitors a paging occasion including no paging message for the UE.

[0018] In some implementations of the method and apparatuses described herein, the time length of the gap duration is determined by the relationship of the first frequency band and second frequency band, or the time length of the gap duration is determined by the subcarrier spacing of the first frequency band and/or the subcarrier spacing of the second

frequency band, or the time length of the gap duration is configured by higher layer, or some combination of the above.

[0019] In some implementations of the method and apparatuses described herein, the explicit indication indicates the UE to switch from MR to LP-WUR, and the explicit indication is included in RRC configuration message.

[0020] In some implementations of the method and apparatuses described herein, a gap duration is configured or preconfigured or predetermined, where the gap duration starts from the reception of the RRC configuration message or from the transmission of HARQ feedback for the reception of RRC configuration message, and the UE switches from MR to LP-WUR after the gap duration.

[0021] In some implementations of the method and apparatuses described herein, the explicit indication that indicates the UE to switch from MR to LP-WUR is included in SCell activation triggering message or SCell configuration, and the explicit indication that indicates the UE to switch from LP-WUR to MR is included in SCell deactivation triggering message or SCell deactivation configuration.

[0022] In some implementations of the method and apparatuses described herein, the explicit indication indicates the UE to switch from MR to LP-WUR, and the explicit indication is included in a control signal.

[0023] In some implementations of the method and apparatuses described herein, one or more LP-WUS activation fields are included in the control signal.

[0024] In some implementations of the method and apparatuses described herein, the LP-WUS activation field and the corresponding wakeup signal indication field jointly indicate the switching from MR to LP-WUR.

[0025] In some implementations of the method and apparatuses described herein, the LP-WUS activation field is in the paging short message in the control signal with CRC scrambled by P-RNTI.

[0026] In some implementations of the method and apparatuses described herein, specific states of the paging indication field and the TRS availability indication field in the control signal indicate the switching from MR to LP-WUR.

[0027] In some implementations of the method and apparatuses described herein, the explicit indication indicates the UE to switch from LP-WUR to MR, and the explicit indication is included LP-SS or LP-WUS or a combination of LP-SS and LP-WUS, where both LP-SS and LP-WUS are transmitted in LP-WUR.

[0028] In some implementations of the method and apparatuses described herein, the pre-configured condition is the measurement value being larger or smaller than a threshold.

[0029] In some implementations of the method and apparatuses described herein, the threshold is configured by higher layer.

[0030] In some implementations of the method and apparatuses described herein, if the measurement value is larger than the threshold, the UE switches from MR to WUR after a gap duration starting from reporting the measurement value.

[0031] In some implementations of the method and apparatuses described herein, the pre-configured condition is a timer of staying in MR or a timer of staying in LP-WUR expires.

[0032] In some implementations of the method and apparatuses described herein, the timer of staying in MR or a timer of staying in LP-WUR starts from a reference time.

[0033] In some implementations of the method and apparatuses described herein, the reference time of the timer of staying in MR includes: the time of UE switching from LP-WUR to MR, the time of UE switching from connected mode to idle or inactive mode in MR; and the reference time of the timer of staying in LP-WUR includes: the time of UE switching from MR to LP-WUR, the time of UE switching from connected mode to idle or inactive mode, the time of UE switching from idle or inactive mode to connected mode.

[0034] In some implementations of the method and apparatuses described herein, pre-configured condition is periodically switching from LP-WUR to MR starting from a starting time, where a period is configured by higher layer.

[0035] In some implementations of the method and apparatuses described herein, a starting time of the period comprises: UE switches from connected mode to inactive or idle mode, UE first switching from MR to LP-WUR, or absolute time slot.

[0036] In some implementations of the method and apparatuses described herein, the at least one processor is further configured to cause the UE to: report the switching via RACH or small data transmission (SDT), where the RACH or SDT resource is dedicated configured.

[0037] Some implementations of the method and apparatuses described herein may include at least one memory; and at least one processor coupled with the at least one memory and configured to cause the base station to: transmit, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0038] Some implementations of the method and apparatuses described herein may include a processor in a base station for wireless communication, comprising: at least one controller coupled with at least one memory and configured to cause the processor to: transmit, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0039] Some implementations of the method and apparatuses described herein may include a method performed by a base station, the method comprising: transmitting, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switching between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0040] In some implementations of the method and apparatuses described herein, switch between operation in MR and operation in LP-WUR comprises:

[0041] (1) activate LP-WUS monitoring in a first frequency band in LP-WUR,

[0042] (2) deactivate LP-WUS monitoring in the first frequency band in LP-WUR,

[0043] (3) switch between monitoring LP-WUS in the first frequency band in LP-WUR and monitoring control signal in a second frequency band in MR, or

[0044] any combination of (1), (2) and (3).

[0045] In some implementations of the method and apparatuses described herein, the explicit indication is included in system information and/or RRC signaling.

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[0047] In some implementations of the method and apparatuses described herein, the explicit indication indicates the base station to switch from MR to LP-WUR, and the explicit indication is or is included in RRC connection release message.

[0048] In some implementations of the method and apparatuses described herein, a gap duration is configured or preconfigured or predetermined, where the gap duration starts from the reception of the RRC connection release message or from the base station having switched from connected mode to idle or inactive mode, and the base station switches from MR to LP-WUR after the gap duration.

[0049] In some implementations of the method and apparatuses described herein, the time length of the gap duration is determined by the relationship of the first frequency band and second frequency band, or the time length of the gap duration is determined by the subcarrier spacing of the first frequency band and/or the subcarrier spacing of the second frequency band, or the time length of the gap duration is configured by higher layer, or some combination of the above.

[0050] In some implementations of the method and apparatuses described herein, the explicit indication indicates the base station to switch from MR to LP-WUR, and the explicit indication is included in RRC configuration message.

[0051] In some implementations of the method and apparatuses described herein, a gap duration is configured or preconfigured or predetermined, where the gap duration starts

from the reception of the RRC configuration message or from the transmission of HARQ feedback for the reception of RRC configuration message, and the base station switches from MR to LP-WUR after the gap duration.

[0052] In some implementations of the method and apparatuses described herein, the explicit indication that indicates the base station to switch from MR to LP-WUR is included in SCell activation triggering message or SCell configuration, and the explicit indication that indicates the base station to switch from LP-WUR to MR is included in SCell deactivation triggering message or SCell deactivation configuration.

[0053] In some implementations of the method and apparatuses described herein, the explicit indication indicates the base station to switch from MR to LP-WUR, and the explicit indication is included in a control signal.

[0054] In some implementations of the method and apparatuses described herein, one or more LP-WUS activation fields are included in the control signal.

[0055] In some implementations of the method and apparatuses described herein, the LP-WUS activation field and the corresponding wakeup signal indication field jointly indicate the switching from MR to LP-WUR.

[0056] In some implementations of the method and apparatuses described herein, the LP-WUS activation field is in the paging short message in the control signal with CRC scrambled by P-RNTI.

[0057] In some implementations of the method and apparatuses described herein, specific states of the paging indication field and the TRS availability indication field in the control signal indicate the switching from MR to LP-WUR.

[0058] In some implementations of the method and apparatuses described herein, the explicit indication indicates the base station to switch from LP-WUR to MR, and the explicit indication is included LP-SS or LP-WUS or a combination of LP-SS and LP-WUS, where both LP-SS and LP-WUS are transmitted in LP-WUR.

[0059] In some implementations of the method and apparatuses described herein, the pre-configured condition is the measurement value being larger or smaller than a threshold.

[0060] In some implementations of the method and apparatuses described herein, the threshold is configured by higher layer.

[0061] In some implementations of the method and apparatuses described herein, if the measurement value is larger than the threshold, the base station switches from MR to WUR after a gap duration starting from reporting the measurement value.

[0062] In some implementations of the method and apparatuses described herein, the pre-configured condition is a timer of staying in MR or a timer of staying in LP-WUR expires.

[0063] In some implementations of the method and apparatuses described herein, the timer of staying in MR or a timer of staying in LP-WUR starts from a reference time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0065] Figure 2 illustrates an example of a user equipment (UE) 200 in accordance with aspects of the present disclosure.

[0066] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure.

[0067] Figure 4 illustrates an example of a network equipment (NE) 400 in accordance with aspects of the present disclosure.

[0068] Figure 5(a) and 5(b) illustrate ultra-low power wake-up receiver and main radio.

[0069] Figure 6 illustrates an example of the gap duration.

[0070] Figure 7(a)-7(c) illustrate examples of the pre-configured condition.

[0071] Figure 8 illustrates a flowchart of method performed by a UE in accordance with aspects of the present disclosure.

[0072] Figure 9 illustrates a flowchart of method performed by a NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0073] Aspects of the present disclosure are described in the context of a wireless communications system.

[0074] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. 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 (Long Term Evolution) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a New Radio (NR) network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) 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, for example, 6G. 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.

[0075] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0076] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For

example, an NE 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, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). 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 may be associated with different NE 102.

[0077] The one or more UE 104 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 remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver 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.

[0078] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. 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.

[0079] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links 116 (e.g., S1, N2, N2, or 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 NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NE 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).

[0080] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 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 NE 102 associated with the CN 106.

[0081] The CN 106 may communicate with a packet data network 108 over one or more backhaul links (e.g., via an S1, N2, N3, 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 CN 106 via an NE 102. The CN 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 CN 106 (e.g., one or more network functions of the CN 106).

[0082] In the wireless communications system 100, the NEs 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 NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 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 NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0083] 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., $\mu=0$) 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., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) 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., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0084] 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.

[0085] 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., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) 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., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0086] 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 NEs 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 NEs 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 NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0087] 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., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), 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., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0088] Figure 2 illustrates an example of a UE 200 in accordance with aspects of the present disclosure. The UE 200 may include a processor 202, a memory 204, a controller 206, and a transceiver 208. The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0089] The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0090] The processor 202 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 202 may be configured to operate the memory 204. In some other implementations, the memory 204 may be integrated into the processor 202. The processor 202 may be configured to execute computer-readable instructions stored in the memory 204 to cause the UE 200 to perform various functions of the present disclosure.

[0091] The memory 204 may include volatile or non-volatile memory. The memory 204 may store computer-readable, computer-executable code including instructions when executed by the processor 202 cause the UE 200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 204 or another type of memory. 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.

[0092] In some implementations, the processor 202 and the memory 204 coupled with the processor 202 may be configured to cause the UE 200 to perform one or more of the functions described herein (e.g., executing, by the processor 202, instructions stored in the memory 204). For example, the processor 202 may support wireless communication at the UE 200 in accordance with examples as disclosed herein. The UE 200 may be configured to receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0093] The controller 206 may manage input and output signals for the UE 200. The controller 206 may also manage peripherals not integrated into the UE 200. In some implementations, the controller 206 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 206 may be implemented as part of the processor 202.

[0094] In some implementations, the UE 200 may include at least one transceiver 208. In some other implementations, the UE 200 may have more than one transceiver 208. The transceiver 208 may represent a wireless transceiver. The transceiver 208 may include one or more receiver chains 210, one or more transmitter chains 212, or a combination thereof.

[0095] A receiver chain 210 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 210 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 210 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 210 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 receiver chain 210 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0096] A transmitter chain 212 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 212 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 transmitter chain 212 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 transmitter chain 212 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0097] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure. The processor 300 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 300 may include a controller 302 configured to perform various operations in accordance with examples as described herein. The processor 300 may optionally include at least one memory 304, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 300 may optionally include one or more arithmetic-logic units (ALUs) 306. 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).

[0098] The processor 300 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 300) 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).

[0099] The controller 302 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 300 to cause the processor 300 to support various operations in accordance with examples as described herein. For example, the controller 302 may operate as a control unit of the processor 300, generating control signals that manage the operation of various components of the processor 300. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0100] The controller 302 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 304 and determine subsequent instruction(s) to be executed to cause the processor 300 to support various operations in accordance with examples as described herein. The controller 302 may be configured to track memory address of instructions associated with the memory 304. The controller 302 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 302 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 300 to cause the processor 300 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 302 may be configured to manage flow of data within the processor 300. The controller 302 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 300.

[0101] The memory 304 may include one or more caches (e.g., memory local to or included in the processor 300 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 304 may reside within or on a processor chipset (e.g., local to the processor 300). In some other implementations, the memory 304 may reside external to the processor chipset (e.g., remote to the processor 300).

[0102] The memory 304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 300, cause the processor 300 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 302 and/or the processor 300 may be configured to execute computer-readable

instructions stored in the memory 304 to cause the processor 300 to perform various functions. For example, the processor 300 and/or the controller 302 may be coupled with or to the memory 304, the processor 300, the controller 302, and the memory 304 may be configured to perform various functions described herein. In some examples, the processor 300 may include multiple processors and the memory 304 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.

[0103] The one or more ALUs 306 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 306 may reside within or on a processor chipset (e.g., the processor 300). In some other implementations, the one or more ALUs 306 may reside external to the processor chipset (e.g., the processor 300). One or more ALUs 306 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 306 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 306 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 306 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 306 to handle conditional operations, comparisons, and bitwise operations.

[0104] The processor 300 may support wireless communication in accordance with examples as disclosed herein. The processor 300 may be configured to or operable to receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0105] Figure 4 illustrates an example of a NE 400 in accordance with aspects of the present disclosure. The NE 400 may include a processor 402, a memory 404, a controller 406, and a transceiver 408. The processor 402, the memory 404, the controller 406, or the

transceiver 408, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0106] The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0107] The processor 402 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 402 may be configured to operate the memory 404. In some other implementations, the memory 404 may be integrated into the processor 402. The processor 402 may be configured to execute computer-readable instructions stored in the memory 404 to cause the NE 400 to perform various functions of the present disclosure.

[0108] The memory 404 may include volatile or non-volatile memory. The memory 404 may store computer-readable, computer-executable code including instructions when executed by the processor 402 cause the NE 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 404 or another type of memory. 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.

[0109] In some implementations, the processor 402 and the memory 404 coupled with the processor 402 may be configured to cause the NE 400 to perform one or more of the functions described herein (e.g., executing, by the processor 402, instructions stored in the memory 404). For example, the processor 402 may support wireless communication at the

NE 400 in accordance with examples as disclosed herein. The NE 400 may be configured to transmit, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0110] The controller 406 may manage input and output signals for the NE 400. The controller 406 may also manage peripherals not integrated into the NE 400. In some implementations, the controller 406 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 406 may be implemented as part of the processor 402.

[0111] In some implementations, the NE 400 may include at least one transceiver 408. In some other implementations, the NE 400 may have more than one transceiver 408. The transceiver 408 may represent a wireless transceiver. The transceiver 408 may include one or more receiver chains 410, one or more transmitter chains 412, or a combination thereof.

[0112] A receiver chain 410 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 410 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 410 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 410 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 receiver chain 410 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0113] A transmitter chain 412 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 412 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 transmitter chain 412 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 transmitter chain 412 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0114] In NR, the UE may use Discontinuous Reception (DRX) in RRC_IDLE state (or idle mode) or RRC_INACTIVE state (or inactive mode) in order to reduce power consumption. The UE monitors one paging occasion (PO) per DRX cycle (which may also be referred to as DRX period).

[0115] UEs need to periodically wake up once per DRX cycle if DRX transmission is configured by higher layer, which dominates the power consumption in periods with no signaling or data traffic. If UEs are able to wake up only when they are triggered, e.g., when they are paged, power consumption could be dramatically reduced. This can be achieved by using a wake-up signal (WUS). For UE in idle or inactive mode, the WUS conveyed in DCI (downlink control information) format 2-7 indicates whether there is paging process in a pre-defined PO (or MO (monitoring occasion) for a particular UE) in the DRX ON duration.

[0116] DRX in RRC_CONNECTED state (or connected mode) (i.e., C-DRX) is also supported. For UE in connected mode, WUS conveyed by DCI format 2-6 is also introduced to inform UE whether or not to wake up to monitor PDCCH (Physical Downlink Control Channel) for data transmission and reception.

[0117] Lower power WUS (LP-WUS) was further introduced. A separate receiver, e.g., an ultra-low power wake-up receiver or wake-up radio (LP-WUR), was included in the UE in addition to the main radio (MR). In short, LP-WUR (which can be abbreviated as “WUR”) refers to the receiver (Rx) module operating for receiving and processing signals and channel related to low-power wake-up; MR refers to the Tx/Rx (receiver and transmitter) module operating for NR signals and channels apart from signals and channel related to low-power wake-up. The LP-WUS is monitored by the UE by WUR. As shown in Figure 5(a), if a WUS (OFF) indicates that there is no paging process in the PO for the UE, the MR in the UE is not triggered by the WUR and remains in OFF state or deep sleep

state. On the other hand, as shown in Figure 5(b), if a WUS (ON) indicates that there is paging process in the PO for the UE, the WUR triggers the MR in the UE to ON state for data transmission and reception (e.g., for receiving paging in PO in the DRX ON duration).

[0118] The MR needs to monitor SSB (SS/PBCH block, i.e., synchronization signal / Physical Broadcast Channel). The WUR needs to monitor lower power synchronization signal (LP-SS). LP-WUS in WUR and SSB in MR can be within same frequency band (e.g., FR1 (frequency range 1) band or even in the same BWP (bandwidth part)) or different frequency bands. Since LP-SS and LP-WUS are in the same frequency band, LP-SS and SSB can be configured in the same frequency band or different frequency bands.

[0119] In addition to WUS, Early Paging Indication (EPI) or Paging Early Indication (PEI) can be introduced. A UE can be notified of whether the UE has to monitor the PO by the PEI in advance its PO. The PEI can be signaled via a DCI message (e.g., DCI format 2-7) carried in PDCCH. PEI may carry sub-grouping information to divide the UEs, which results in lower group paging rate and fewer false paging alarms.

[0120] LP-WUS can be transmitted by base station (e.g., gNB) and monitored and received by UE on a first frequency band, e.g., on a first BWP of the first carrier; and the PEI and the paging message in PO can be transmitted by base station (e.g., gNB) and monitored and received by UE on a second frequency band, e.g., on a second BWP of the second carrier.

[0121] The first frequency band can be the same as or different from the second frequency band.

[0122] If the first frequency band and the second frequency band are the same, the first carrier can be the same as the second carrier and/or the first BWP can be the same as the second BWP.

[0123] Due to the consideration of coverage and/or gNB scheduling, it is preferable that the first BWP is different from the second BWP.

[0124] The LP-WUS is configured by higher layer. The configuration of LP-WUS for a UE is transmitted to the UE by being included in the system information or being included

in a UE specific RRC signaling. The UE monitors the LP-WUS in a first frequency band (e.g., a first carrier, or a first BWP in the first carrier). Based on the LP-WUS indication (e.g., WUS ON), the UE switches to MR to receive paging message in a second frequency band or switches to DRX ON duration to receive control signal in a second frequency band.

[0125] The UE may switch from WUR to MR due to other reasons, e.g., bad channel condition, etc., in addition to WUS (ON) indication.

[0126] In addition, the UE may switch from MR to WUR due to various reasons, e.g., low load, power saving, etc. When the UE switches from MR to WUR, the LP-WUS monitoring can be activated.

[0127] This disclosure proposes that UE switches between operation in MR and operation in WUR according to an explicit indication or pre-configured condition(s) (i.e., pre-configured condition(s) being met).

[0128] The switching between operation in MR and operation in WUR may refer to (1) switching between monitoring control signal in a second frequency band (e.g., a second BWP and/or a second carrier) in MR and monitoring LP-WUS in a first frequency band (e.g., a first BWP and/or a first carrier) in WUR.

[0129] The switching between operation in MR and operation in WUR may refer to (2) activating LP-WUS monitoring in the first frequency band. For example, when UE switches from MR to WUR, LP-WUS monitoring is activated.

[0130] The switching between operation in MR and operation in WUR may refer to (3) deactivating LP-WUS monitoring in the first frequency band. For example, when UE switches from WUR to MR, LP-WUS monitoring is deactivated.

[0131] The switching between operation in MR and operation in WUR may refer to any combination of (1), (2) and (3).

[0132] That is, the switching between operation in MR and operation in LP-WUR may be switching between monitoring LP-WUS in the first frequency band in LP-WUR and monitoring control signal in a second frequency band in MR. Specifically, it may comprise (1) activating LP-WUS monitoring in a first frequency band in LP-WUR, namely from MR

to LP-WUR; and/or (2) deactivating LP-WUS monitoring in the first frequency band in LP-WUR, namely from LP-WUS to MR.

[0133] A first embodiment relates to UE in idle or inactive mode switching from MR to WUR. The switching from MR to WUR implies that LP-WUS monitoring is activated.

[0134] According to a first sub-embodiment of the first embodiment, UE in idle or inactive mode switches from MR to WUR according to an explicit indication (e.g., explicit indication from gNB). For example, if the network (e.g., gNB) has low load and/or if resources can be reserved for LP-SS transmission and LP-WUS transmission, it is possible for gNB to explicitly configure or indicate the LP-WUS monitoring activation in the first frequency band (e.g., switching from MR to WUR) for UE with capability of LP-WUS monitoring.

[0135] In a first implementation of the first sub-embodiment of the first embodiment, the explicit indication is sent from gNB by system information and/or RRC signaling, and received by UE in connected mode before the UE enters into idle or inactive mode. For example, the explicit indication is included in RRC connection release message, which is an existing RRC signaling.

[0136] The RRC connection release message indicates the UE to switch to idle or inactive mode, or indicates the UE to redirect to other carriers or other frequencies.

[0137] The explicit indication can be included in RRC connection release message if the RRC connection release message indicates the UE to switch to idle or inactive mode. In this condition, upon receiving the RRC connection release message indicating the UE to switch to idle or inactive mode and including the explicit indication, the UE switches from the connected mode to the idle or inactive mode (e.g., by stopping the corresponding timer and releasing the corresponding configuration), and further switches from MR to WUR. Note that the UE can switch from the connected mode to the idle or inactive mode and switch from MR to WUR in the same procedure.

[0138] Alternative to including the explicit indication in the RRC connection release message, the RRC connection release message (that indicates the UE to switch to idle or inactive mode) itself can be used as the explicit indication. It means that, upon receiving the

RRC connection release message indicating the UE to switch to idle or inactive mode, the UE switches from the connected mode to the idle or inactive mode and switches from MR to WUR.

[0139] In a variety of the first implementation, a gap duration is introduced before UE switches from MR to WUR. The gap duration can be configured by gNB, or preconfigured, or predetermined (e.g., according to UE capability and/or gNB capability). The gap duration may depend on the operation(s) (e.g., time and frequency synchronization, message processing) to be performed within the gap duration. The gap duration can be used for the UE to return to paging BWP (e.g., CORESET#0) in MR to get initial time and frequency synchronization. In particular, upon receiving the RRC connection release message indicating the UE to switch to idle or inactive mode (where the RRC connection release message is used as the explicit indication, or the RRC connection release message includes the explicit indication), the UE first switches from the connected mode to the idle or inactive mode. Afterwards, the UE gets initial time and frequency synchronization for the paging BWP. After the gap duration, the UE switches from MR to WUR.

[0140] The gap duration may start from the reception of the RRC connection release message. That is, during the gap duration, the UE first switches from the connected mode to the idle or inactive mode. Afterwards, the UE gets initial time and frequency synchronization for the paging BWP.

[0141] Alternatively, the gap duration may start from having switched to the idle or inactive mode. That is, during the gap duration, the UE gets initial time and frequency synchronization for the paging BWP.

[0142] After the gap duration, the UE switches from MR to WUR.

[0143] The time length of the gap duration is determined by the frequency band of MR and the frequency band of WUR, or the subcarrier spacing of the MR and/or the subcarrier spacing of WUR, both the frequency bands and the subcarrier spacing(s). For example, if the frequency bands of MR and WUR are the same (e.g., intra-band: same carrier), the gap duration can be a small value, e.g., 3 ms. Otherwise, if the frequency bands of MR and WUR are different, the gap duration can be a large value, e.g., 10 ms. For another example,

if the subcarrier spacing is 15kHz ($\mu=0$), the gap duration can be 2 slots; while if the subcarrier spacing is 30kHz ($\mu=1$), the gap duration can be 4 slots.

[0144] Alternatively, the time length of the gap duration can be configured by higher layer.

[0145] Further alternatively, the time length of the gap duration can be determined as follows: the start of the gap duration can be from the reception of the RRC connection release message, or having switched to the idle or inactive mode. The UE monitors the PO(s) in MR until the PO including no paging message for UE, the gap duration ends.

[0146] Figure 6 illustrates an example of the gap duration.

[0147] The UE in connected mode is in BWP#x. The UE receives RRC connection release message in BWP#x. The UE enters into idle mode (i.e., switches from connected mode to idle or inactive mode) and returns to BWP#y (e.g., paging BWP (e.g., CORESET#0)) for paging monitoring in MR. During the gap duration, the UE gets initial time and frequency synchronization for BWP#y, which can be used later when the UE switches from BWP#z to BWP#y (i.e., from WUR to MR). After the gap duration, the UE switches from BWP#y to BWP#z (i.e., from MR to WUR).

[0148] If no gap duration is configured, UE directly enters into idle or inactive mode and switches from BWP#x to BWP#z (i.e., from MR to WUR). It means that the UE cannot get the initial time and frequency synchronization for BWP#y. That is, the UE stays in BWP#x before entering into idle or inactive mode. This will give burden to following switching from BWP#z to BWP#y.

[0149] In a second implementation of the first sub-embodiment of the first embodiment, the explicit indication is included a control signal (e.g., DCI format 2-7) that is monitored by UE in idle or inactive mode. In idle or inactive mode, UE is required to monitor DCI format 2-7. So, DCI format 2-7 can be reused to include the explicit indication.

[0150] UE in inactive or idle mode monitors and receives a control signal (e.g., DCI format 2-7). The control signal includes the explicit indication that indicates the UE to switch from MR to WUR.

[0151] A LP-WUS activation field can be introduced in DCI format 2-7 to function as the explicit indication. Based on the LP-WUS activation field, one or more groups of UEs are indicated to switch from MR to WUR.

[0152] For example, a common LP-WUS activation field is included in DCI format 2-7. If the common LP-WUS activation field is set to '1', all groups of UEs associated with the common LP-WUS activation field are indicated to switch from MR to WUR. In addition, the wakeup signal indication field for each group of UEs indicates "not required to monitor paging occasion". If the common LP-WUS activation field is set to '0', no groups of UEs switch from MR to WUR. It means all groups of UEs stay in MR and monitor control signal (e.g., DCI format 2-7).

[0153] For another example, an individual LP-WUS activation field is included for each group of UEs in DCI format 2-7. If the individual LP-WUS activation field is set to '1', the group of UEs associated with this individual LP-WUS activation field are indicated to switch from MR to WUR. In addition, the wakeup signal indication field for this group of UEs indicates "not required to monitor paging occasion".

[0154] Alternative to LP-WUS activation field, reinterpreting one of the states of existing field(s) in DCI format 2-7 indicate the group(s) of UEs to switch from MR to WUR. For example, if all '0' are set to the paging indication field and the TRS availability indication field, the indication of switching from MR to WUR is interpreted, e.g., for all groups of UEs.

[0155] Optionally, LP-WUS activation field can be introduced in paging short message in DCI format 1-0 with CRC scrambled by P-RNTI in idle or inactive mode.

[0156] According to a second sub-embodiment of the first embodiment, UE in idle or inactive mode switches from MR to WUR according to pre-configured condition(s).

[0157] In a first implementation of the second sub-embodiment of the first embodiment, the pre-configured condition is a measurement value (e.g., RSRP, RSRQ, SINR) in MR being larger than a threshold. It means that if the channel condition in MR is well (for example, UE is close the gNB), the UE may switch from MR to WUR. In particular, for UE in idle or inactive mode, if the measurement value is larger than a threshold, the UE

autonomously switches from MR to WUR. In this condition, due to the gNB being not aware of the switching from MR to WUR, it is assumed that the gNB shall both transmit legacy paging indication in MR and transmit LP-WUS in WUR simultaneously.

[0158] In a second implementation of the second sub-embodiment of the first embodiment, the pre-configured condition is a timer of staying in MR being expired. It means that, for a UE in idle or inactive mode, if the UE monitors control signal for a long period in MR, the UE switches to WUR for LP-WUS monitoring with low power consumption. In particular, a timer of staying in MR is configured. If the timer of staying in MR expires, the UE in idle or inactive mode switches from MR to WUR. The timer of staying in MR starts from a reference time point. The reference time point may be but not limited to: the time of UE switching from WUR to MR in idle or inactive mode, or the time of UE switching from connected mode to idle or inactive mode in MR.

[0159] A second embodiment relates to UE in idle or inactive mode switching from WUR to MR. The switching from WUR to MR implies that LP-WUS monitoring is deactivated.

[0160] According to a first sub-embodiment of the second embodiment, UE in idle or inactive mode switches from WUR to MR according to an explicit indication.

[0161] The explicit indication can be included in LP-SS, or in LP-WUS, or in a combination of LP-SS and LP-WUS. Upon receiving the explicit indication that indicates switching from WUR to MR, the LP-WUS monitoring is deactivated and the UE switches from WUR to MR.

[0162] According to a second sub-embodiment of the second embodiment, UE in idle or inactive mode switches from WUR to MR according to pre-configured condition(s).

[0163] In a first implementation of the second sub-embodiment of the second embodiment, the pre-configured condition is a measurement value (e.g., LP-RSRP, LP-RSRQ) in WUR is smaller than a threshold. It means that if the channel condition in WUR is bad, the UE may switch from WUR to MR. In particular, for UE in idle or inactive mode, if the measurement value is lower than a threshold, UE autonomously switches from WUR to MR. That is, LP-WUS monitoring in WUR is deactivated, while the UE in inactive or

idle mode monitors PO or PEI in MR. The UE may report the switching (from WUR to MR) via RACH or configured resource (e.g., SDT (small data transmission)). The RACH resource or SDT resource is dedicatedly configured.

[0164] In a second implementation of the second sub-embodiment of the second embodiment, the pre-configured condition is a timer of staying in WUR being expired. A timer of staying in WUR is configured. If the timer of staying in WUR expires, the UE in idle or inactive mode switches from WUR to MR (while the LP-WUS monitoring in WUR is deactivated). The timer of staying in WUR starts from a reference time point. The reference time point may be but not limited to: the time of UE switching from MR to WUR, the time of UE switching from connected mode to idle or inactive mode, the time of UE switching from idle or inactive mode to connected mode.

[0165] Figure 7(a) illustrates an example of the second implementation. In Figure 7(a), it is assumed that the timer of staying in WUR is 50 ms, and the reference time point is the time of UE switching from MR to WUR. Each time the timer of staying in WUR expires, the UE switches from WUR to MR. In addition, the timer of staying in WUR starts from the time of UE switching from MR to WUR.

[0166] Figure 7(b) illustrates another example of the second implementation, in combination with the first implementation. The UE switches from WUR to MR if the timer of staying in WUR expires. In addition, if the channel condition in WUR is bad, the UE switches from WUR to MR. Further, if the UE switches from WUR to MR due to other reasons (e.g., the channel condition in WUR is bad (a measurement value being lower than a threshold)), the timer of staying in WUR becomes invalid. The reference time point of the timer of staying in WUR is the time of UE switching from MR to WUR.

[0167] In a third implementation of the second sub-embodiment of the first embodiment, UE in idle or inactive mode periodically switches from WUR to MR, starting from a starting time point. The period is configured by higher layer. The starting time point may be but not limited to: UE switches from connected mode to inactive or idle mode, UE first switching from MR to WUR, or absolute time slot.

[0168] Figure 7(c) illustrates an example of the third implementation, in combination with the first implementation. In Figure 7(c), it is assumed that the period is 50 ms, and the starting time point is the time of UE first switching from MR to WUR. It can be seen that within period#2, UE switches from WUR to MR due to other reasons (e.g., the channel condition in WUR is bad). Afterwards, when the UE switches from MR to WUR, it is the second switching from MR to WUR (within period#2). So, period#2 continues.

[0169] A third embodiment relates to UE in connected mode switching from MR to WUR.

[0170] According to a first sub-embodiment of the third embodiment, UE in connected mode switches from MR to WUR according to an explicit indication (e.g., explicit indication from gNB).

[0171] In a first implementation of the first sub-embodiment of the third embodiment, the explicit indication is sent from gNB by system information and/or RRC signaling. For example, the explicit indication can be an RRC configuration message that indicates switching from MR to WUR. A gap duration is configured after the reception of the RRC configuration message or after the reception of HARQ feedback transmission. After the gap duration, UE switches from MR to WUR. Similar to the gap duration described in the variety of the first implementation (1.1.1') of the first sub-embodiment of the first embodiment, the gap duration described herein (in the first implementation of the first sub-embodiment of the third embodiment) can be configured by gNB, or preconfigured, or predetermined (e.g., according to UE capability and/or gNB capability). Further, the gap duration may depend on the operation(s) to be performed within the gap duration

[0172] In a second implementation of the first sub-embodiment of the third embodiment, an SCell activation triggering message or SCell configuration can serve as the explicit indication of switching from MR to WUR.

[0173] In a third implementation of the first sub-embodiment of the third embodiment, UE in connected mode switches from MR to WUR according to control signal (e.g., DCI format 2-6). In connected mode, UE is required to monitor DCI format 2-6. The DCI format 2-6 can be reused to include the explicit indication.

[0174] In legacy, DCI format 2-6 is used for notifying the power saving information outside DRX Active Time for one or more UEs. The following information is transmitted by means of the DCI format 2_6 with CRC scrambled by PS-RNTI: block number 1, block number 2, ..., block number N, where the starting position of a block is determined by the parameter ps-PositionDCI-2-6 provided by higher layers for the UE configured with the block.

[0175] A LP-WUS activation field can be introduced in DCI format 2-6.

[0176] For example, a common LP-WUS activation field is included in DCI format 2-6. If the common LP-WUS activation field is set to '1', all UEs (i.e., all UEs associated with all blocks) are indicated to switch from MR to WUR. If the common LP-WUS activation field is set to '0', DCI format 2-6 functions as legacy DCI format 2-6.

[0177] For another example, an individual LP-WUS activation field is included in DCI format 2-6 for each block. For example, the wake up indication field for each block is replaced by the individual LP-WUS activation field. If the individual LP-WUS activation field for a block is set to '1', the UEs associated with the block are indicated to switch from MR to WUR. If the individual LP-WUS activation field for a block is set to '0', the UEs associated with the block follow legacy behavior.

[0178] Alternative to LP-WUS activation field, reinterpreting one of the states of existing field(s) in DCI format 2-6 indicate UEs to switch from MR to WUR.

[0179] According to a second sub-embodiment of the third embodiment, UE in connected mode switches from MR to WUR according to pre-configured condition(s).

[0180] In a first implementation of the second sub-embodiment of the third embodiment, the pre-configured condition is a measurement value (e.g., RSRP, RSRQ, SINR) in MR being larger than a threshold. It means that if the channel condition in MR is well (for example, UE is close the gNB), the UE may switch from MR to WUR. In particular, for UE in connected mode, if the measurement value is larger than a threshold, the UE switches from MR to WUR after a gap duration starting from reporting the measurement value.

[0181] The gap duration is determined by the subcarrier spacing of the MR and the subcarrier spacing of WUR, and the frequency band of MR and the frequency band of WUR.

[0182] A fourth embodiment relates to UE in connected mode switching from WUR to MR. The switching from WUR to MR implies that LP-WUS monitoring is deactivated.

[0183] According to a first sub-embodiment of the fourth embodiment, UE in connected mode switches from WUR to MR according to an explicit indication.

[0184] In a first implementation of the first sub-embodiment of the fourth embodiment, the explicit indication can be included in LP-SS, or in LP-WUS, or in a combination of LP-SS and LP-WUS. Upon receiving the explicit indication that indicates switching from WUR to MR, the LP-WUS monitoring is deactivated and the UE switches from WUR to MR.

[0185] In a second implementation of the first sub-embodiment of the fourth embodiment, an SCell deactivation triggering message or SCell deactivation configuration can serve as an indication of switching from WUR to MR.

[0186] According to a second sub-embodiment of the fourth embodiment, UE in connected mode switches from WUR to MR according to pre-configured condition(s).

[0187] In a first implementation of the second sub-embodiment of the fourth embodiment, the pre-configured condition is a measurement value (e.g., LP-RSRP, LP-RSRQ) in WUR is smaller than a threshold. It means that if the channel condition in WUR is bad, the UE may switch from WUR to MR. In particular, for UE in connected mode, if the measurement value is lower than a threshold, UE autonomously switches from WUR to MR. That is, LP-WUS monitoring is deactivated. The UE may report the switching (from WUR to MR) via RACH or configured resource (e.g., SDT). The RACH resource or SDT resource is dedicatedly configured.

[0188] In a second implementation of the second sub-embodiment of the fourth embodiment, the pre-configured condition is a timer of staying in WUR being expired. A timer of staying in WUR is configured. If the timer of staying in WUR expires, the UE in

connected mode switches from WUR to MR (while the LP-WUS monitoring in WUR is deactivated). The timer of staying in WUR starts from a reference time point. The reference time point may be but not limited to the time of UE switching from MR to WUR.

[0189] Figure 8 illustrates a flowchart of a method 800 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions.

[0190] At 802, receiving, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR).

[0191] At 804, switching between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0192] Figure 9 illustrates a flowchart of a method 900 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0193] At 902, transmitting, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR).

[0194] At 904, switching between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

[0195] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0196] 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) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the UE to:
receive, in main radio (MR), a configuration of lower power
wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio
(LP-WUR); and
switch between operation in MR and operation in LP-WUR,
according to an explicit indication or pre-configured condition(s).
2. The UE of claim 1, wherein,
switch between operation in MR and operation in LP-WUR
comprises:
(1) activate LP-WUS monitoring in a first frequency band in LP-
WUR,
(2) deactivate LP-WUS monitoring in the first frequency band in LP-
WUR,
(3) switch between monitoring LP-WUS in the first frequency band
in LP-WUR and monitoring control signal in a second frequency band in
MR, or
any combination of (1), (2) and (3).
3. The UE of claim 1, wherein,
the explicit indication is included in system information and/or RRC
signaling.
4. The UE of claim 3, wherein,
the explicit indication indicates the UE to switch from MR to LP-
WUR, and

the explicit indication is or is included in RRC connection release message.

5. The UE of claim 4, wherein,
a gap duration is configured or preconfigured or predetermined,
where the gap duration starts from the reception of the RRC connection release message or from the UE having switched from connected mode to idle or inactive mode, and
the UE switches from MR to LP-WUR after the gap duration.
6. The UE of claim 5, wherein,
the gap duration ends after the UE monitors a paging occasion including no paging message for the UE.
7. The UE of claim 5, wherein,
the time length of the gap duration is determined by the relationship of the first frequency band and second frequency band, or
the time length of the gap duration is determined by the subcarrier spacing of the first frequency band and/or the subcarrier spacing of the second frequency band, or
the time length of the gap duration is configured by higher layer, or some combination of the above.
8. The UE of claim 3, wherein,
the explicit indication indicates the UE to switch from MR to LP-WUR, and
the explicit indication is included in RRC configuration message.
9. The UE of claim 8, wherein,
a gap duration is configured or preconfigured or predetermined,
where the gap duration starts from the reception of the RRC configuration message or from the transmission of HARQ feedback for the reception of RRC configuration message, and

the UE switches from MR to LP-WUR after the gap duration.

10. The UE of claim 3, wherein,
the explicit indication that indicates the UE to switch from MR to LP-WUR is included in SCell activation triggering message or SCell configuration, and
the explicit indication that indicates the UE to switch from LP-WUR to MR is included in SCell deactivation triggering message or SCell deactivation configuration.
11. The UE of claim 1, wherein,
the explicit indication indicates the UE to switch from MR to LP-WUR, and
the explicit indication is included in a control signal.
12. The UE of claim 11, wherein,
one or more LP-WUS activation fields are included in the control signal.
13. The UE of claim 12, wherein,
the LP-WUS activation field and the corresponding wakeup signal indication field jointly indicate the switching from MR to LP-WUR.
14. The UE of claim 12, wherein,
the LP-WUS activation field is in the paging short message in the control signal with CRC scrambled by P-RNTI.
15. The UE of claim 11, wherein,
specific states of the paging indication field and the TRS availability indication field in the control signal indicate the switching from MR to LP-WUR.
16. The UE of claim 1, wherein,

the explicit indication indicates the UE to switch from LP-WUR to MR, and

the explicit indication is included LP-SS or LP-WUS or a combination of LP-SS and LP-WUS, where both LP-SS and LP-WUS are transmitted in LP-WUR.

17. The UE of claim 1, wherein,
the pre-configured condition is the measurement value being larger or smaller than a threshold.

18. A processor in a UE for wireless communication, comprising:
at least one controller coupled with at least one memory and configured to cause the processor to:

receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and

switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

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

receive, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and

switch between operation in main radio (MR) and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).

20. A base station for wireless communication, comprising:

at least one memory; and

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

transmit, in main radio (MR), a configuration of lower power wake-up signal (LP-WUS) to be transmitted in lower power wake-up radio (LP-WUR); and

switch between operation in MR and operation in LP-WUR, according to an explicit indication or pre-configured condition(s).