

METHODS AND APPARATUS FOR A GROUP WAKE UP SIGNAL**CROSS REFERENCE TO RELATED APPLICATION(S)**

- [0001] This application claims the benefit of U.S. Provisional Application Serial No. 62/810,334, entitled “UE GROUPING WAKE UP SIGNAL” and filed on February 25, 2019, and U.S. Patent Application No. 16/799,696, entitled “METHODS AND APPARATUS FOR A GROUP WAKE UP SIGNAL” and filed on February 24, 2020, which are expressly incorporated by reference herein in their entirety.

Technical Field

- [0002] The present disclosure relates generally to communication systems, and more particularly, to a methods and devices for transmitting and/or receiving improved notification signals.

Introduction

- [0003] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.
- [0004] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists

a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

[0005] Communication between a base station and a user equipment (UE) can include notifications and paging messages sent from the base station to the UE or vice versa. In some instances, paging message or notification can be transmitted between the base station and the UE or vice versa. Presently, there exists a need to improve upon the notification and paging ability of communications by providing new and improved signals.

SUMMARY

[0006] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0007] In wireless communications, base stations and UEs send different notification and paging signals to each other in order to facilitate communication. These signals can help to improve the overall communication system information, as well as to improve the access and control of each device within the wireless system. In some instances, a wake-up signal (WUS) can be sent between the base station and UEs in order to provide notification of an upcoming paging occasion (PO). When sending and receiving multiple WUSs and POs, it can be beneficial to determine a strategy and/or conserve the amount of WUSs and POs that are sent throughout the wireless system. By doing so, the overall power consumption of the wireless system can be improved.

[0008] The present disclosure relates to transmitting and receiving an improved wake-up signal (WUS) by grouping user equipment (UE). A base station can group a plurality of UEs into a plurality of UE groups. The base station can then assign a UE group identification to one or more sub-group UEs within a UE group. The sub-group UEs can be part of a smaller group or sub-group within a larger UE group. In some aspects, the sub-group UEs can be referred to as a sub-group of UEs or a set of sub-group UEs. Next, base station can indicate the UE group identification assignment to the UEs.

The base station can then determine and transmit a WUS identifying which UEs within the group should wake-up for a paging occasion (PO). Prior to receiving the transmission, the UEs can listen for the WUS. After receiving the WUS, the identified UEs can wake-up before receiving the corresponding PO. Each WUS comprises a certain duration, which cannot exceed a maximum allowed WUS duration. Also, between the end of the WUS and the PO, there is a gap period.

[0009] The base station can also determine the total amount of different UE groups, wherein each UE is assigned to a particular group. Within each group, there can be updated or grouping UEs and/or legacy or non-grouping UEs, wherein the updated or grouping UEs are capable of being assigned to a UE group, while the legacy or non-grouping UEs are not capable of being assigned to a UE group. Aspects presented herein address the challenges of transmitting WUS and monitoring for WUS in communication systems having both UE(s) configured for DRX and UE(s) configured for eDRX.

[0010] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a UE. The apparatus can receive a configuration for discontinuous reception (DRX) or extended DRX (eDRX). The apparatus can also determine whether to monitor for a WUS during a DRX WUS time resource or an eDRX WUS time resource. In some aspects, the UE can determine whether to monitor for the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion.

[0011] In another aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a base station. The apparatus can configure a UE for DRX or eDRX. The apparatus can also determine whether to transmit a WUS during a DRX WUS time resource or an eDRX WUS time resource. In some aspects, the base station can determine whether to transmit the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion.

[0012] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the

claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0013] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.
- [0014] FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating examples of a first 5G/NR frame, DL channels within a 5G/NR subframe, a second 5G/NR frame, and UL channels within a 5G/NR subframe, respectively.
- [0015] FIG. 3 is a diagram illustrating an example of a base station and user equipment (UE) in an access network.
- [0016] FIG. 4 is a timeline illustrating transmissions between a base station and UEs including a WUS.
- [0017] FIG. 5 is a timeline illustrating transmissions between a base station and UEs including WUSs.
- [0018] FIGs. 6A-6D are timelines illustrating transmissions between a base station and UEs including WUSs.
- [0019] FIGs. 7A-7D are timelines illustrating transmissions between a base station and UEs including WUSs.
- [0020] FIGs. 8A-8D are timelines illustrating transmissions between a base station and UEs including WUSs.
- [0021] FIGs. 9A-9D are timelines illustrating transmissions between a base station and UEs including WUSs.
- [0022] FIG. 10 illustrates one aspect of UE grouping according to the present disclosure.
- [0023] FIGs. 11A-11C illustrate examples of multiplexing according to the present disclosure.
- [0024] FIGs. 12A and 12B illustrate examples of multiplexing according to the present disclosure.
- [0025] FIG. 13 is a timeline illustrating transmissions between a base station and UEs including WUSs.

- [0026] FIG. 14 illustrates example timelines including transmissions between a base station and UEs including WUSs.
- [0027] FIG. 15 illustrates example timelines including transmissions of WUSs between a base station and UEs.
- [0028] FIG. 16 is a flowchart of a method of wireless communication.
- [0029] FIG. 17 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus.
- [0030] FIG. 18 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system.
- [0031] FIG. 19 is a flowchart of a method of wireless communication.
- [0032] FIG. 20 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus.
- [0033] FIG. 21 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system.

DETAILED DESCRIPTION

- [0034] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.
- [0035] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

- [0036] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.
- [0037] Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.
- [0038] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, an Evolved Packet Core (EPC) 160, and another core network 190 (e.g., a 5G Core (5GC)). The base stations 102 may include macrocells (high power cellular base

station) and/or small cells (low power cellular base station). The macrocells include base stations. The small cells include femtocells, picocells, and microcells.

[0039] The base stations 102 configured for 4G LTE (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) may interface with the EPC 160 through first backhaul links 132 (e.g., S1 interface). The base stations 102 configured for 5G NR (collectively referred to as Next Generation RAN (NG-RAN)) may interface with core network 190 through second backhaul links 184. In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (e.g., through the EPC 160 or core network 190) with each other over third backhaul links 134 (e.g., X2 interface). The third backhaul links 134 may be wired or wireless.

[0040] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macrocells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through

one or more carriers. The base stations 102 / UEs 104 may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100, 400, etc. MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or fewer carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

- [0041] Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 158. The D2D communication link 158 may use the DL/UL WWAN spectrum. The D2D communication link 158 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.
- [0042] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.
- [0043] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.
- [0044] A base station 102, whether a small cell 102' or a large cell (e.g., macro base station), may include and/or be referred to as an eNB, gNodeB (gNB), or another type of base station. Some base stations, such as gNB 180 may operate in a traditional sub 6 GHz spectrum, in millimeter wave (mmW) frequencies, and/or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as an mmW base station. Extremely

high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near mmW radio frequency band (e.g., 3 GHz – 300 GHz) has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 182 with the UE 104 to compensate for the extremely high path loss and short range. The base station 180 and the UE 104 may each include a plurality of antennas, such as antenna elements, antenna panels, and/or antenna arrays to facilitate the beamforming.

[0045] The base station 180 may transmit a beamformed signal to the UE 104 in one or more transmit directions 182'. The UE 104 may receive the beamformed signal from the base station 180 in one or more receive directions 182". The UE 104 may also transmit a beamformed signal to the base station 180 in one or more transmit directions. The base station 180 may receive the beamformed signal from the UE 104 in one or more receive directions. The base station 180 / UE 104 may perform beam training to determine the best receive and transmit directions for each of the base station 180 / UE 104. The transmit and receive directions for the base station 180 may or may not be the same. The transmit and receive directions for the UE 104 may or may not be the same.

[0046] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The

BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

[0047] The core network 190 may include a Access and Mobility Management Function (AMF) 192, other AMFs 193, a Session Management Function (SMF) 194, and a User Plane Function (UPF) 195. The AMF 192 may be in communication with a Unified Data Management (UDM) 196. The AMF 192 is the control node that processes the signaling between the UEs 104 and the core network 190. Generally, the AMF 192 provides QoS flow and session management. All user Internet protocol (IP) packets are transferred through the UPF 195. The UPF 195 provides UE IP address allocation as well as other functions. The UPF 195 is connected to the IP Services 197. The IP Services 197 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services.

[0048] The base station may include and/or be referred to as a gNB, Node B, eNB, an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), a transmit reception point (TRP), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 or core network 190 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device,

a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0049] Referring again to FIG. 1, in certain aspects, UE 104 may include a determination component 198 configured to receive a configuration for discontinuous reception (DRX) or extended DRX (eDRX). Determination component 198 can also be configured to determine whether to monitor for a WUS during a DRX WUS time resource or an eDRX WUS time resource. In some aspects, the UE can determine whether to monitor for the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion.

[0050] Referring again to FIG. 1, in certain aspects, base station 102/180 may include a determination component 199 configured to configure a UE for DRX or eDRX. Determination component 199 can also be configured to determine whether to transmit a WUS during a DRX WUS time resource or an eDRX WUS time resource. In some aspects, the base station can determine whether to transmit the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion.

[0051] Although the following description may be focused on 5G NR, the concepts described herein may be applicable to other similar areas, such as LTE, LTE-A, CDMA, GSM, and other wireless technologies.

[0052] FIG. 2A is a diagram 200 illustrating an example of a first subframe within a 5G/NR frame structure. FIG. 2B is a diagram 230 illustrating an example of DL channels within a 5G/NR subframe. FIG. 2C is a diagram 250 illustrating an example of a second subframe within a 5G/NR frame structure. FIG. 2D is a diagram 280 illustrating an example of UL channels within a 5G/NR subframe. The 5G/NR frame structure may be FDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for either DL or UL, or may be TDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for both DL and UL. In the examples provided by FIGs. 2A, 2C, the 5G/NR frame structure is assumed to be

TDD, with subframe 4 being configured with slot format 28 (with mostly DL), where D is DL, U is UL, and X is flexible for use between DL/UL, and subframe 3 being configured with slot format 34 (with mostly UL). While subframes 3, 4 are shown with slot formats 34, 28, respectively, any particular subframe may be configured with any of the various available slot formats 0-61. Slot formats 0, 1 are all DL, UL, respectively. Other slot formats 2-61 include a mix of DL, UL, and flexible symbols. UEs are configured with the slot format (dynamically through DL control information (DCI), or semi-statically/statically through radio resource control (RRC) signaling) through a received slot format indicator (SFI). Note that the description *infra* applies also to a 5G/NR frame structure that is TDD.

[0053] Other wireless communication technologies may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes (1 ms). Each subframe may include one or more time slots. Subframes may also include mini-slots, which may include 7, 4, or 2 symbols. Each slot may include 7 or 14 symbols, depending on the slot configuration. For slot configuration 0, each slot may include 14 symbols, and for slot configuration 1, each slot may include 7 symbols. The symbols on DL may be cyclic prefix (CP) OFDM (CP-OFDM) symbols. The symbols on UL may be CP-OFDM symbols (for high throughput scenarios) or discrete Fourier transform (DFT) spread OFDM (DFT-s-OFDM) symbols (also referred to as single carrier frequency-division multiple access (SC-FDMA) symbols) (for power limited scenarios; limited to a single stream transmission). The number of slots within a subframe is based on the slot configuration and the numerology. For slot configuration 0, different numerologies μ 0 to 5 allow for 1, 2, 4, 8, 16, and 32 slots, respectively, per subframe. For slot configuration 1, different numerologies 0 to 2 allow for 2, 4, and 8 slots, respectively, per subframe. Accordingly, for slot configuration 0 and numerology μ , there are 14 symbols/slot and 2^μ slots/subframe. The subcarrier spacing and symbol length/duration are a function of the numerology. The subcarrier spacing may be equal to $2^\mu * 15$ kHz, where μ is the numerology 0 to 5. As such, the numerology $\mu=0$ has a subcarrier spacing of 15 kHz and the numerology $\mu=5$ has a subcarrier spacing of 480 kHz. The symbol length/duration is inversely related to the subcarrier spacing. FIGs. 2A-2D provide an example of slot configuration 0 with 14 symbols

per slot and numerology $\mu=2$ with 4 slots per subframe. The slot duration is 0.25 ms, the subcarrier spacing is 60 kHz, and the symbol duration is approximately 16.67 μ s.

[0054] A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as physical RBs (PRBs)) that extends 12 consecutive subcarriers. The resource grid is divided into multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.

[0055] As illustrated in FIG. 2A, some of the REs carry reference (pilot) signals (RS) for the UE. The RS may include demodulation RS (DM-RS) (indicated as R_x for one particular configuration, where 100x is the port number, but other DM-RS configurations are possible) and channel state information reference signals (CSI-RS) for channel estimation at the UE. The RS may also include beam measurement RS (BRS), beam refinement RS (BRRS), and phase tracking RS (PT-RS).

[0056] FIG. 2B illustrates an example of various DL channels within a subframe of a frame. The physical downlink control channel (PDCCH) carries DCI within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A primary synchronization signal (PSS) may be within symbol 2 of particular subframes of a frame. The PSS is used by a UE 104 to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) may be within symbol 4 of particular subframes of a frame. The SSS is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DM-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form a synchronization signal (SS)/PBCH block. The MIB provides a number of RBs in the system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

[0057] As illustrated in FIG. 2C, some of the REs carry DM-RS (indicated as R for one particular configuration, but other DM-RS configurations are possible) for channel estimation at the base station. The UE may transmit DM-RS for the physical uplink

control channel (PUCCH) and DM-RS for the physical uplink shared channel (PUSCH). The PUSCH DM-RS may be transmitted in the first one or two symbols of the PUSCH. The PUCCH DM-RS may be transmitted in different configurations depending on whether short or long PUCCHs are transmitted and depending on the particular PUCCH format used. The UE may transmit sounding reference signals (SRS). The SRS may be transmitted in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

[0058] FIG. 2D illustrates an example of various UL channels within a subframe of a frame. The PUCCH may be located as indicated in one configuration. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

[0059] FIG. 3 is a block diagram of a base station 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and

transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0060] The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

[0061] At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain

using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0062] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0063] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0064] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided

to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0065] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0066] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0067] At least one of the TX processor 368, the RX processor 356, and the controller/processor 359 may be configured to perform aspects in connection with 198 of FIG. 1.

[0068] At least one of the TX processor 316, the RX processor 370, and the controller/processor 375 may be configured to perform aspects in connection with 199 of FIG. 1.

[0069] A UE may be configured by a base station for a discontinuous reception (DRX) mode. When there is no data to be transmitted between the UE and base station in either direction, e.g., no uplink or downlink transmissions, the UE may enter the DRX mode in which the UE may monitor a control channel discontinuously using a sleep and wake cycle. DRX conserves battery power at the UE. Without DRX, the UE would need to monitor the control channel in every subframe to check whether there is data for the UE. Continuous monitoring of the control channel places a demand on the UE's battery power. A UE and a base station can communicate during a reception cycle. In some aspects, this can occur when the UE is configured by the base station for a DRX mode or an eDRX mode. Accordingly, the reception cycle can be a DRX cycle or an eDRX cycle. In some aspects, a DRX cycle or an eDRX cycle can be a reception cycle during which the UE and a base station communicate while the UE is

in a DRX mode or an eDRX mode. Also, the UE can receive a configuration for the reception cycle from the base station. The reception cycle can also include a paging cycle. During the paging cycle between the base station and the UE, the base station can send a paging message during a period of time, also known as a paging occasion (PO). The UE can wake-up during the PO and listen to the paging message to determine if it is being paged. For instance, the base station may send a wake-up signal (WUS) to the UE in advance of the PO when the base station will transmit communication to the UE. Accordingly, the base station may send a WUS to the UE in advance of the PO during the reception cycle. In some aspects, during the reception cycle, the UE can determine whether to monitor for a WUS during a WUS time resource. Also, during the reception cycle, the UE can determine whether to monitor for the WUS based on a duration of a time gap between WUS resources and a paging occasion. If the UE receives a WUS, the UE may wake-up by preparing to receive the communication during the PO. If the UE does not receive a WUS, the UE may return to the sleep mode.

[0070] Different types of wireless communication systems can support different types of WUSs. For instance, some wireless communication systems can support at least a WUS discontinuous transmission (WUS/DTX) at least for paging UEs in radio resource control idle (RRC_IDLE) mode. One example is machine-type communication (MTC) for narrowband (NB) Internet of Things (IoT) (MTC/NB-IoT). In some aspects of the WUS sequence, the WUS can be time-varying from subframe to subframe. The WUS signal can also be designed based on a variety of information, including: cell ID information, UE group ID, time information of the starting subframe of the WUS or PO, and/or part of the system frame number (SFN) information.

[0071] As indicated above, WUSs are used to wake-up the UEs, if there is an upcoming corresponding PO. Hence, if there is no upcoming PO, then the WUS is not sent. In this manner, the WUS is based on DTX, meaning it is not always present and may instead be transmitted when needed. As further discussed herein, WUSs can wake-up or alert every UE, certain groups of UEs, individual UEs, or any other combination of UEs within a system.

[0072] FIG. 4 is a timeline 400 illustrating one such WUS transmission between a base station and UEs. FIG. 4 displays legacy WUS 402, PO 404, PO 406, PO 408, gap

410, blank WUS 412, and blank PO 414. As shown in FIG. 4, legacy WUS 402 may be used to notify or alert all UEs of any upcoming associated PO. FIG. 4 shows that in certain transmissions, a single WUS can be used to notify all UEs of an associated PO, e.g., POs 404/406/408. For instance, the WUS 402 notifies the PO for every type of UE, including legacy or non-grouping UEs, as well as new, updated or grouping UEs, e.g., UE1 and UE2. This enables UEs without grouping capability to receive the WUS for the PO. POs 404/406/408 represent that the POs can be sent using stacked paging, which can mean that the certain POs occur at the same time and correspond to a specific WUS transmission. Accordingly, the POs that correspond to a specific WUS can occur simultaneously. Although this approach can simplify the WUS transmission process, it can also increase the power usage, as a WUS needs to be sent to every UE no matter if that UE has an upcoming associated PO. The type of WUS approach does not form the UEs into groups, hence it can be referred to as a WUS without UE grouping. As indicated above, this type of WUS is sent to all UEs when there is an upcoming associated PO. Therefore, all of the UEs will wake up for the PO. Blank WUS 412 and blank PO 414 represent a PO opportunity where a WUS is not sent or does not occur, and the corresponding PO also does not occur. For instance, blank WUS 412 and blank PO 414 represent a PO opportunity without a WUS or PO because there is nothing to transmit.

[0073] For other wireless communication systems, the WUSs can be improved or enhanced for the MTC/NB-IoT. These improvements may include the ability to group different UEs for the purpose of sending a WUS. For instance, the base station can configure a particular WUS to apply to a sub-group of UEs. This particular WUS could then alert the sub-group of UEs of the need to wake up for an associated PO. By alerting a sub-group of UEs with a WUS, rather than all of the UEs, this can improve the overall power savings of the system, as the UEs in the sub-group will wake up for the PO. This allows the remaining UEs to stay in a lower power mode.

[0074] These types of systems that allow for grouping UEs and sending associated WUSs may also need to support UEs without grouping ability. A system that is able to support UEs both with and without grouping ability can be referred to as having backward compatibility. UEs with the ability to be grouped can be referred to as new, updated, and/or grouping UEs. UEs without grouping ability can be referred to as legacy, old, and/or non-grouping UEs. A UE that has grouping capability may be

configured such that it does not support grouping. Non-grouping UEs may also refer to UEs that do not currently support grouping. However, both grouping and non-grouping UEs can be referred to by any appropriate name. In these types of systems with backward compatibility, the base station can configure the WUS to enable legacy or non-grouping UEs to continue to receive the WUS. As indicated previously, legacy or non-grouping UEs may support WUSs without the ability to identify particular UE groups. Accordingly, any system with backward compatibility may need to send different types of WUSs to alert the grouping and non-grouping UEs. Backward compatible systems can also enable or configure the updated or grouping UEs with their corresponding WUS.

[0075] FIG. 5 is a timeline 500 illustrating group-specific WUS transmissions. FIG. 5 displays legacy WUS 502, WUS 504, WUS 506, PO 512, PO 514, PO 516, blank PO 520, and blank WUS 522/524/526. For instance, the base station in timeline 500 can transmit a group-specific WUS when the corresponding PO associated with the UE group is forthcoming. FIG. 5 illustrates that for grouping UEs, the base station can configure a group-specific WUS, e.g., WUS 502, WUS 504, or WUS 506, to target or alert a sub-group of UEs of an upcoming associated PO, e.g., PO 512, PO 514, or PO 516. As mentioned above, POs 512/514/516 can utilize stacked paging. For example, WUS 502 is a legacy WUS to target all UEs, WUS 504 can be a new WUS for a UE group 1, and WUS 506 can be a new WUS for a UE group 2. These group-specific WUSs can be sent, if necessary, meaning they are sent if the paging for an associated UE group is present. If an associated PO is not forthcoming, then the WUS for the corresponding group will not be sent and the UEs in that group can go to sleep or continue sleeping. This is represented by blank WUS 522/524/526 and blank PO 520. These types of group-specific WUSs can also differentiate between different UE groups. Additionally, as shown in FIG. 5, systems comprising group-specific WUSs can have backward compatibility. Indeed, FIG. 5 illustrates that a legacy or non-grouping WUS can be transmitted for all legacy or non-grouping UEs to alert them of an upcoming PO.

[0076] The system can configure WUS parameters for UE grouping in a variety of manners. In one aspect, the base station can configure the parameters for a group-specific WUS, which targets a specific group of UEs. For example, the base station can configure or define a number of UE grouping related parameters, including but not limited to: the

number of UE groups (G), the UE group identification or group WUS sequence, and/or weighting factors to decide UE groups, UE group identification, or group WUS sequence. The number of UE groups, e.g., G, can target a specific system aspect, such as being cell specific, carrier specific, or narrow band specific. As indicated above, the weighting factors can help decide to which group each UE should belong. Also, the base station can balance the number of UEs within each group. And by sending the WUS to the corresponding UE groups, the base station can help improve the overall power savings of the system.

[0077] The group WUS sequence or UE group ID can be defined based on different UE grouping related parameters, or any number of different factors, such as UE identify index value (UE_ID), the number paging frames within a discontinuous reception (DRX) cycle (N), the number of POs within a paging frame (Ns), or the number of paging narrow bands provided in system information (Nn). The UE group ID can also consider how to differentiate between the new or grouping UEs with grouping capability and the legacy or non-grouping UEs without grouping capability. Also, in some aspects, the UE group ID might be known by the grouping UEs that support UE grouping and not known by the legacy UEs. The grouping UE group ID can also depend on a pre-defined equation, wherein the base station and the UE will obtain the UE group ID intrinsically.

[0078] The base station can broadcast the number of UE groups, e.g., G, explicitly in the system information block (SIB). For example, the default value of G, the number of UE groups, can be set to 1. For example, if $G=1$, then there is one group, so the grouping UEs and the legacy UEs are all in the same group. Hence, if $G=1$, the grouping UEs can monitor or listen for the WUS directed to legacy UEs, the legacy WUS, in a similar manner to how the legacy UEs monitor or listen for the legacy WUS. Additionally, the weighting factors can be broadcast in the SIB. These parameters can be broadcast widely to reach the idle or sleeping UEs.

[0079] It is noted that the aforementioned WUS based on UE grouping can be an optional feature. Accordingly, the group-specific WUSs, which target or alert UEs with grouping capability, can be turned on or off by the base station. If there is no signaling for group-specific WUSs, then UEs can simply use the default mode, e.g., $G=1$, and monitor for the legacy WUS as a legacy UE.

- [0080] It is also noted that each WUS can have a certain duration or length. In some aspects, the duration of group-specific WUSs can be similar to the duration of legacy WUSs. FIG. 5 illustrates the legacy WUS having the same duration as the WUS for UE group 1 and the WUS for UE group 2. The maximum WUS duration (WUS_{max}) for each group-specific WUS can also be the same as that of the legacy WUS. The actual WUS duration can be smaller than WUS_{max} and aligned with its configured starting point. Thus, no matter the duration of a specific WUS, it can be aligned with the same starting point, i.e., the starting subframe relative to the associated PO. The starting point for a PO can be equal to the corresponding WUS plus the gap between the WUS and the PO. It is also noted that the valid subframes, e.g., the valid subframes are the NB-IoT DL subframes, or subframes not carrying non-BL/CE subframes and SIB1 for MTC, might be counted for the WUS_{max} and the actual WUS duration.
- [0081] As mentioned above, there can be a gap maintained between the end of the WUS duration and the associated PO, which can be referred to as a gap period, gap length, or any appropriate term. FIG. 4 illustrates an example gap between a legacy WUS and the associated PO. Gaps should satisfy the minimum UE processing time, which could be based on UE capability. In some aspects, certain gaps can be equal to or larger than the legacy gap between the end of the legacy WUS and the associated PO. Along these lines, the UE group-specific gaps can be larger than the legacy gap. For example, if time division multiplexing (TDM) is being used, the group-specific WUS can be sent prior to the legacy WUS, so that the gap between the group-specific WUS and the PO will be larger than the gap between the non-grouping WUS and the PO. If frequency division multiplexing (FDM) is being used, the group-specific WUS can be sent at the same starting time as the legacy WUS, so that the gap between the end of the group-specific max WUS duration and the PO will be equal to the gap between the end of non-grouping max WUS duration and the PO. It is noted that both the valid and invalid subframes can be counted for the gap. For MTC with a certain bandwidth of PRBs, e.g., six PRBs, a number of WUS resources, e.g., up to three WUS resources, can be configured by using FDM. Further, each WUS resource can be used to transmit the WUS sequence mapping to an amount of PRBs, e.g., two PRBs.
- [0082] For grouping UEs and the corresponding group-specific WUSs, there can be resource allocation. This can be one of the differences between the non-grouping UEs and grouping UEs, as there may not be resource allocation with non-grouping UEs. The

non-grouping UEs may not be aware of the grouping UEs and corresponding groups, so this resource allocation may not affect them. If time division multiplexing (TDM) is being used, the WUS time starting time offset can be explicitly or implicitly indicated. For instance, if the group-specific WUS for the UE group is time division multiplexed with at least one other WUS for another UE group, then the starting time offset of the group-specific WUS for the UE group can be based on an implicit indication or an explicit indication received from the base station. In some aspects, the WUS for a UE group can be time division multiplexed with at least one other WUS for another UE group or non-group specific WUS. In other aspects, the WUS for the UE group can be code division multiplexed with at least one other WUS for another UE group or non-group specific WUS. In yet other aspects, the WUS for the UE group can be frequency division multiplexed with at least one other WUS for another UE group or non-group specific WUS. If frequency division multiplexing (FDM) is being used, e.g., for MTC, the frequency starting resource block (RB) offset per group-specific WUS can be explicitly or implicitly indicated, e.g., by an equation. More specifically, if the group-specific WUS for the UE group is frequency division multiplexed with at least one other WUS for another UE group, then the frequency offset for a starting RB of the group-specific WUS for the UE group can be based on an implicit indication or an explicit indication received from the base station. These TDM and FDM options can be configured by the base station or can be predefined in different carriers/bands/systems, e.g., TDM is used for NB-IoT carrier and FDM is used for MTC narrowbands.

[0083] FIGs. 6A-6D are timelines 600, 610, 620, and 630, respectively, which display transmissions between a base station and different UEs including different WUSs. FIGs. 6A-6D display legacy WUS 602, WUS 604, WUS 606, and gap 608. WUS 602 can be for legacy UEs, WUS 604 can be for UEs in UE group 0, and WUS 606 can be for UEs in UE group 1. For instance, FIGs. 6A-6D display that there can be a variety of different ways to configure the different options and parameters for the WUS transmission. FIGs. 6A-6D display that in some aspects, all UEs, whether grouping or non-grouping, can be placed in different UE groups. In some of these aspects, the new or grouping UEs can be equally distributed per UE group. For instance, if $G > 1$, wherein G is the number of UE groups, all UEs can be divided into G groups and each group can includes grouping UEs and legacy UEs. In some

aspects, WUS 604 can be for UEs in group 0 when $G > 1$ and WUS 606 can be for UEs in group 1 when $G > 1$. FIGs. 6A-6D display an example when $G = 2$. As indicated previously, if $G = 1$, then the system can return to the a non-grouping mode, wherein there is a single non-grouping WUS for all UEs. FIGs. 6A-6D illustrate that for grouping UEs, the base station can configure a group-specific WUS, e.g., WUS 602, WUS 604, or WUS 606, to target or alert a sub-group of UEs of an upcoming associated PO, e.g., PO 642, PO 644, PO 646, or PO 648. As mentioned above, POs 642/644/646/648 can utilize stacked paging.

[0084] In some aspects, the group WUS sequence or UE group identification (UE_Group_ID), often represented by g , can be decided based on an equation. For example, UE_Group_ID: $g = \text{floor}(\text{UE_ID}/(N * N_s * N_n)) \bmod G$. As indicated above, this equation accounts for the UE identify index value (UE_ID), the number paging frames within a DRX cycle (N), the number of POs within a paging frame (N_s), and the number of carriers or NBs that support WUS UE grouping (N_n).

[0085] In examples such as FIGs. 6A-6D, the legacy or non-grouping UEs may not be aware of the UE grouping and thus may monitor the legacy WUS, as in the legacy mode. As indicated previously, the legacy WUS can be transmitted when there is a PO for legacy UEs in any one of the UE groups. Further, no matter what group the legacy UEs are in, when a legacy WUS is sent, all the legacy UEs can wake-up for the legacy PO. Grouping UEs may monitor the WUS for their UE group, rather than the legacy WUS. Grouping UEs have their own specific WUS according to their assigned group or sub-group, which can be referred to as a group-specific WUS. This enables the grouping UEs to remain in a sleep mode unless a group-specific WUS is transmitted while maintaining the ability of the non-grouping UEs to receive the non-grouping WUS.

[0086] As shown in FIGs. 6A-6D, if $G = 2$, the grouping UEs can be assigned to both group 0 and group 1, which each have a respective WUS. Accordingly, if a PO will be sent for grouping UEs in group 0, then the WUS corresponding to group 0 will be sent and notify the grouping UEs in group 0 to wake-up for the PO. Likewise, the WUS assigned to grouping UEs in group 1 will be sent if the grouping UEs in group 1 need to wake-up for a PO. As in other modes, the legacy or non-grouping UEs may monitor for the legacy WUS. As discussed above and illustrated in FIGs. 6A-6D, POs can be sent using stacked paging, which can mean that the certain POs occur at the same time

and correspond to a specific WUS transmission, e.g., WUS 602/604/606. Accordingly, the POs that correspond to a specific WUS can occur simultaneously.

[0087] The WUSs for grouping UEs in different groups can be sent at different times than the WUSs for other grouping UEs. As indicated in FIGs. 6A-6D, there can be an offset for the WUSs assigned to each group, as well as the legacy WUS. For instance, the WUS for UE groups 0 and 1 can be sent before the legacy UEs, such that there is an offset for each of these WUSs. If a WUS is not sent for a certain group of UEs, then those corresponding UEs will not wake-up or stay asleep. As mentioned, *supra*, this can help with power savings.

[0088] Resources can also be allocated for the different WUSs. For instance, the UE-group-specific WUSs can allocate resources according to an equation. For example, if $G > 1$, then the g -th UE-group-specific WUS can have the starting time offset according to: $(PO_gap - (g+1) * WUS_{max})$, wherein with $g = \{0, \dots, G-1\}$.

[0089] As displayed in FIGs. 7A-7D, further aspects can include both grouping and non-grouping UEs being placed in different UE groups. Thus, the groups may include grouping and non-grouping UEs. In some of these aspects, the grouping UEs can be equally distributed per UE group. As indicated above, if $G > 1$, all UEs can be divided into G groups, wherein each group can include both grouping UEs and legacy UEs. As further mentioned herein, the group WUS sequence or UE group identification (UE_Group_ID), often represented by g , can be decided based on an equation. For example, $UE_Group_ID: g = \text{floor}(UE_ID / (N * N_s * N_n)) \bmod G$. Once again, the non-grouping UEs are not aware of UE grouping and monitor for the legacy WUS, and the legacy WUS is transmitted when there is a PO for a non-grouping UE in any one of the UE groups.

[0090] Grouping UEs can monitor two separate WUS sequences, e.g., the WUS for their particular UE group and the legacy WUS. For instance, when the PO targets the grouping UEs in one UE group, then the corresponding group-specific WUS can be transmitted. In other aspects, when the paging targets more than one UE group or a non-grouping UE, the legacy WUS may be transmitted. Grouping UEs can also detect the legacy/non-grouping WUS. While this may increase the complexity for the grouping UEs, the additional overhead can be allocated from the base station. In some aspects, all grouping UEs can wake up when any WUS is sent, whether grouping

WUS or legacy WUS. In other aspects, all UEs can wake-up at the same time when any WUS is sent.

[0091] As indicated by timelines 700, 710, 720, and 730 in FIGs. 7A-7D, respectively, different WUSs can also be sent at the same time and/or have the same starting period. FIGs. 7A-7D display legacy WUS 702, WUS 704, WUS 706, and gap 708. WUS 702 can be for legacy UEs, WUS 704 can be for UEs in UE group 0, and WUS 706 can be for UEs in UE group 1. For example, the WUS for the grouping UEs and the legacy UEs can be sent at the same starting point, because one WUS will be sent, either one group specific WUS or the non-group specific WUS, e.g., legacy WUS. The duration length for each of the WUSs can be less than or equal to the maximum WUS duration, WUS_{max} . Also, the gap periods between each WUS and each corresponding PO can be similar in length. FIGs. 7A-7D illustrate that for grouping UEs, the base station can configure a group-specific WUS, e.g., WUS 702, WUS 704, or WUS 706, to target or alert a sub-group of UEs of an upcoming associated PO, e.g., PO 742, PO 744, PO 746, PO 748, or PO 750. As mentioned above, POs 742/744/746/748/750 can utilize stacked paging, which can mean that the certain POs occur at the same time and correspond to a specific WUS transmission, e.g., WUS 702/704/706. Thus, the POs that correspond to a specific WUS can occur simultaneously.

[0092] Similar to FIGs. 6A-6D, FIGs. 7A-7D display that if $G=2$, the grouping UEs can be assigned to both group 0 and group 1 with a respective WUS. If a PO will be sent for grouping UEs in group 0 or group 1, then the WUS corresponding to group 0 or group 1 will be sent and notify the grouping UEs in group 0 or group 1 to wake-up for the PO. As in other modes, the legacy or non-grouping UEs can monitor for the legacy WUS.

[0093] In FIGs. 7A-7D, resources can also be allocated for the different UE-group-specific WUSs according to an equation. For example, if $G>1$, then the UE-group-specific WUS can have the same starting offset as the legacy WUS. This can be represented by the equation: starting point = PO – gap – WUS_{max} , which can also be indicated by simply $WUS_{max} + \text{gap}$.

[0094] In another aspect, the grouping UEs may be placed in groups separate from the legacy or non-grouping UEs. For instance the legacy UEs can be grouped into their own separate group, and the grouping UEs may be grouped into the remaining groups.

FIGs. 8A-8D are timelines 800, 810, 820, 830, respectively, illustrating one such example of this configuration. This may enable the non-grouping UEs to be handled separately from the grouping UEs, particularly because the non-grouping UEs do not have the capability to monitor the WUSs of the grouping UEs. For example, if the amount of UE groups exceeds one, $G > 1$, then the legacy UEs can be contained in the first UE group and grouping UEs can be divided into the remaining $(G-1)$ groups. As indicated previously, if $G=1$, then the system can operate in legacy mode.

[0095] The grouping UEs can be distributed amongst the remaining groups according to a formula. One example of a formula is $UE_Group_ID: g = \text{floor}(UE_ID / (N * N_s * N_n)) \bmod (G-1)$, wherein each of the components of the formula has been identified, *supra*. Legacy UEs do not need to be distributed according to a formula, as they are isolated in the first group. As mentioned above, legacy UEs can monitor legacy WUS, which is transmitted when there is paging occasion for the legacy UEs, hence the legacy UEs do not wake-up due to paging of grouping UEs. Because the grouping UEs monitor the WUS for their respective UE group, it can ease the system configuration by placing them in groups separate from the first group, which is reserved for the legacy UEs. And because the legacy UEs are not woken up when on-legacy WUSs, by placing them in a separate group, this can further help with power savings. This type of configuration can be a good option for systems with lots of legacy UEs, as they will all be isolated in one group.

[0096] As displayed in FIGs. 8A-8D, the configuration above can work well when the number of groups is three ($G=3$). FIGs. 8A-8D display legacy WUS 802, WUS 804, WUS 806, and gap 808. WUS 802 can be for legacy UEs, WUS 804 can be for UEs in UE group 1, and WUS 806 can be for UEs in UE group 2. Timelines 800, 810, 820, and 830 in FIGs. 8A-8D, respectively, illustrate that the grouping UEs can be distributed in groups 1 and 2, while the legacy UEs can be isolated in group 0. In one aspect, the WUS for group 2 can be transmitted first, the WUS for group 1 can be transmitted next, and the legacy WUS can be transmitted last. Accordingly, in this configuration, the each WUS is sent at a different time period. As indicated above, all of these WUSs can be less than or equal to WUS_{max} . Moreover, a gap period can be present before the PO for each respective groups of UEs. FIGs. 8A-8D illustrate that for grouping UEs, the base station can configure a group-specific WUS, e.g., WUS 802, WUS, 804, or WUS 806, to target or alert a sub-group of UEs of an

upcoming associated PO, e.g., PO 842, PO 844, or PO 846. As mentioned above, POs 842/844/846 can utilize stacked paging, which can mean that the certain POs occur at the same time and correspond to a specific WUS transmission, e.g., WUS 802/804/806. Thus, the POs that correspond to a specific WUS can occur simultaneously.

[0097] As with the aforementioned configurations, the configuration in FIGs. 8A-8D can also allocate resources for the different WUSs. Similar to other configurations, the UE-group-specific WUSs can allocate resources according to an equation. For example, if $G > 1$, then the g -th UE-group-specific WUS can have the starting time offset according to: $(PO-gap-(1+g)*WUSmax)$, wherein with $g = \{0, 1, \dots, G-1\}$.

[0098] FIGs. 9A-9D are timelines 900, 910, 920, 930, respectively, illustrating a further configuration for WUS transmissions. FIGs. 9A-9D display legacy WUS 902, WUS 904, WUS 906, and gap 908. WUS 902 can be for legacy UEs, WUS 904 can be for UEs in UE group 1, and WUS 906 can be for UEs in UE group 2. For example, the configurations in FIGs. 9A-9D can group some grouping UEs together with legacy UEs in the first group. This grouping may be helpful as non-grouping UEs become less prevalent. The remaining grouping UEs can be distributed amongst the remaining UE groups. As will be further discussed, *supra*, this configuration can introduce one or more weighting factors per UE group to decide or calculate the UE group ID for each respective group. In the configurations shown in FIGs. 9A-9D, if the number of UE groups is greater than one ($G > 1$), some grouping UEs can be placed into the first UE group along with the legacy UEs. As in previous configurations, the remaining grouping UEs can be divided into the remaining $(G-1)$ UE groups. FIGs. 9A-9D illustrate that for grouping UEs, the base station can configure a group-specific WUS, e.g., WUS 902, WUS, 904, or WUS 906, to target or alert a sub-group of UEs of an upcoming associated PO, e.g., PO 942, PO 944, PO 946, or PO 948. As mentioned above, POs 942/944/946/948 can utilize stacked paging, which can mean that the certain POs occur at the same time and correspond to a specific WUS transmission, e.g., WUS 902/904/906. Therefore, the POs that correspond to a specific WUS can occur simultaneously.

[0099] In this configuration, the legacy WUS is transmitted when there is a paging occasion for legacy UEs and the grouping UEs within the first group. As in previous configurations, the legacy UEs can monitor the legacy WUS. However, the grouping

UEs in the first UE group also monitor the legacy WUS. The remaining grouping UEs monitor the WUS for their respective UE groups. Similar to other configurations, the UE-group-specific WUSs in FIGs. 9A-9D can allocate resources according to an equation. For instance, if $G > 1$, then the g -th UE-group-specific WUS can have the starting time offset according to: $(PO\text{-}gap - (1+g) \cdot WUS_{max})$, wherein with $g = \{0, 1, \dots, G-1\}$.

[00100] The configurations in FIGs. 9A-9D can also introduce one or more weighting factors to determine the UE group ID for each respective group and balance the number of UEs. One reason to do this is to balance the number of UEs in each group. In one aspect, for UEs supporting WUS with UE grouping, and if the WUS configuration for UE grouping is provided in the SIB, then the UE group ID can be determined by an equation. For example, the UE group ID can be determined by the group with smallest index g , wherein $0 \leq g \leq G-1$ that fulfills the following equation: $\text{floor}(UE_ID / (N \cdot N_s \cdot N_n)) \bmod W_G < W_G(0) + W_G(1) + \dots + W_G(g)$, where $W_G(i)$ is the weighting factor, or the weight for the i -th WUS UE group for grouping UEs, $i = 0, \dots, g$, wherein $g = 0, \dots, (G-1)$, and W_G is the total weight of all UE groups, i.e., $W_G = W_G(0) + W_G(1) + \dots + W_G(G-1)$.

[00101] Assuming X of UEs are legacy UEs and $(1-X)$ of UEs are grouping UEs, then $(W_G(0)/W_G)$ grouping UEs can be in the first ($g=0$) UE group and $W_G(g)/W_G$ grouping UEs in the g -th UE group. For example, if $X=1/4$, i.e., 25% legacy UEs and 75% grouping UEs, and the number of groups is $G=2$, then $W_G = W_G(0) + W_G(1) = 1+2 = 3$. Thus, $W_G(0)/W_G = 1/3$, which is the amount of grouping UEs together with X legacy UEs in the $g=0$ UE group. The fraction of UEs in the first group is: $1/3(1-X)+X=1/2$. The remaining $2/3$ grouping UEs are in $g=1$ UE group, and the fraction of UEs in the second group is: $2/3(1-X)=1/2$.

[00102] As another example, if $X=1/6$ legacy UEs, and $G=3$, then $W_G(0)=1$, $W_G(1)=2$, $W_G(2)=2$, such that $W_G=5$. And $W_G(0)/W_G=1/5$ grouping UEs together with the legacy UEs in the $g=0$ UE group. So the fraction of UEs in the first group is: $1/5(1-X)+X=1/3$. Remaining $2/5$ grouping UEs are in the $g=1$ UE group, which calculate to $2/5(1-X)=1/3$ fraction of UEs in the second group. Finally, there is another $2/5$ grouping UEs in $g=2$ UE group, such that $2/5(1-X)=1/3$ fraction of UEs in the third group. As indicated above, this calculation is a way to balance the legacy UEs. Gradually, there are fewer and fewer legacy UEs in the system.

- [00103] In another aspect of the present disclosure, the system can comprise carrier-specific WUSs. For example, in NB-IoT, there can be multiple carriers configured for paging. In MTC, there can be multiple narrowbands (NBs) configured for paging. But in the legacy WUS mode configuration, turning the WUS on or off (WUS on-off) is cell-specific. For grouping UEs, the WUS on-off can be carrier-specific for NB-IoT or NB-specific for MTC. If carrier-specific or NB-specific, it may be beneficial to change the way a UE selects its paging carrier or NB based on, for example, whether the UE supports WUSs. If the UE can support WUS, then the UE can select the carrier and achieve the corresponding power savings. This can help the base station balance the paging and the WUS load from the base station side.
- [00104] In one example, WUSs may be enabled in carriers {1,2,3,4}, but not in carriers {5,0}. UEs that do not support WUSs can choose between carriers {0-5}. UEs that support WUSs can choose between carriers {1-4}. Also, the base station should indicate the on/off for different carriers
- [00105] In another example, for instance a WUS-dedicated carrier, the WUS-only carriers may be {1,2}, and the non-WUS carriers may be {0,3}. In this case, the WUS enabled UEs can choose between carriers {1,2}, and the non-WUS UEs can choose between carriers {0,3}.
- [00106] Furthermore, turning the WUS grouping on or off (WUS grouping on/off) can be carrier-specific for NB-IoT or NB-specific for MTC. If carrier-specific or NB-specific WUS grouping on/off, it may be beneficial to change the way a UE selects its paging carrier based on, for example, whether the UE supports WUS and/or group-WUS.
- [00107] In another example, WUS may be enabled in carriers {0-5}, and group WUS may be enabled in carriers {2,3}. Here, WUS UEs that do not support grouping choose between carriers {0-5}, while WUS UEs that support grouping choose between carriers {2,3}. Carrier-specific or NB-specific WUS UE group configuration may be further enabled, for example, by the number of UE groups per carrier, which can be indicated in the SIB.
- [00108] The present disclosure can also provide further details on MME/base station configuration of the groups and WUS. For all the techniques and configuration explained herein, the base station should know whether the UE supports group-WUS or not. One way to enable this is that the MME stores the paging radio capabilities of

the UE, which includes whether the UE supports WUS, and, if so, whether the UE supports group WUS. This can imply that, when connecting to network, the UE reports this capability to the MME. The MME also contains the information for the idle UEs.

[00109] The above configuration can result in the following: If the MME indicates the UE does not support group WUS, then regardless of whether the base station signals support of group WUS or not, the UE and base station operate in legacy mode. If the MME indicates the UE supports group WUS, and the base station does not signal support of group WUS, then the UE and base station operate in legacy mode. Yet if the MME indicates the UE supports group WUS and the base station signals support/configuration of group WUS, then the UE and base station operate according to the UE grouping configurations mentioned above.

[00110] Aspects of the present disclosure can also group UEs in a number of different manners corresponding to the associated WUSs. In some aspects, UEs can be grouped together based on a configured gap size between a WUS and the associated PO. For example, UEs can be grouped based on the gap size between a WUS and the associated PO. In other aspects, for WUSs associated with a certain gap size, a base station can configure a number of UE groups. Other parameters associated with WUS groups or gap-specific WUS groups and corresponding UEs can be configured independently. In other aspects, base stations may adjust the number of WUS groups for each configured gap size and may adjust the WUS maximum duration and actual duration for each WUS group, e.g., through power boosting and/or transmit diversity schemes.

[00111] In some aspects, WUSs in certain types of wireless communications, e.g., MTC and NB-IoT, may have different types or sizes of associated gaps. For instance, the base station can provide the different types or sizes of gaps. In some aspects, for the same associated PO, base stations can send multiple WUSs, e.g., because there are different types or sizes of associated gaps. The ability of the base station to group the UEs based on gap size may depend on the type of UEs and/or the reported UE capability. WUSs associated with different types of reception, e.g., DRX or enhanced DRX (eDRX), can comprises different sizes of corresponding gaps. For example, a WUS associated with DRX can correspond to a short gap of 40 ms, 80 ms, 160 ms, or 240 ms. In some instances, WUSs associated with eDRX can correspond to gaps equal to or larger than the gaps corresponding to DRX. For example, a WUS associated with

eDRX can also correspond to a short gap of 40 ms, 80 ms, 160 ms, or 240 ms. In yet other aspects, a WUS associated with eDRX can correspond to a long gap of 1 second or 2 seconds. For DRX UEs, an example default processing time may be 40 ms. For eDRX UEs, the UE may use different receiver architectures for WUS or paging detection with different levels of power saving, which may include a processing time. The eDRX UE can report, e.g., at 40 ms, 240 ms, 1 second, or 2 seconds, for WUS configuration. Based on the reported UE processing time or a UE desired gap, base stations may configure multiple WUSs with different gaps for UEs belonging to the same associated PO.

[00112] In other aspects, UEs may be grouped by WUS and configured based on the gap size. For instance, UEs with same configured gap size may be grouped together and divided into subgroups. As such, in some aspects, if UEs may be grouped together and monitor the same WUS with the same gap size between the WUS and the associated PO.

[00113] FIG. 10 illustrates one aspect of a UE grouping 1000 according to the present disclosure. As displayed in FIG. 10, UEs can be grouped based on associated WUS and corresponding gap size. FIG. 10 displays that for a DRX with a short gap size, there can be $G=2$ UE-group WUSs and each UE in the g -th WUS group, e.g., $g = 0, \dots, G-1$, can have the same gap size between the end of the g -th WUS and the PO, wherein G is the number of UE groups. The G WUS groups with same type of short gap for DRX, e.g., gap DRX, may be multiplexed by TDM and a g -th WUS group may be configured with a starting time offset equal to $PO - (\text{gap_DRX}) - (g-1)WUS_{\text{max}}$. The equivalent gap between the g -th WUS and PO can be equal to or larger than the configured gap for DRX, e.g., $\text{gap_DRX} + (g-1)WUS_{\text{max}}$, where WUS_{max} is the maximum duration of WUS for each g -th group. FIG. 10 also displays that for a short gap in eDRX, there can be $G=3$ UE-group WUSs and each UE in the g -th WUS group, e.g., $g = 0, \dots, G-1$, can have the same gap size between the end of the g -th WUS and the PO. The G WUS groups with same type of short gap for eDRX, e.g., gap1_eDRX, may be multiplexed by TDM and a g -th WUS group may be configured with a starting time offset equal to $PO - (\text{gap1_eDRX}) - (g-1)WUS_{\text{max}}$ and the equivalent gap between the g -th WUS and the PO can be equal to or larger than the configured gap for DRX, e.g., $\text{gap1_eDRX} + (g-1)WUS_{\text{max}}$, where WUS_{max} is the maximum duration of WUS for each g -th group. FIG. 10 further displays that for a longer gap in eDRX, there can

be $G=4$ UE-group WUSs and each UE in the g -th WUS group, e.g., $g=0, \dots, G-1$, can have the same gap size between the end of the g -th WUS and the PO. The G WUS groups with same type of long gap for eDRX, e.g., gap2_eDRX , may be multiplexed by TDM and a g -th WUS group may be configured with a starting time offset equal to $\text{PO} - (\text{gap2_eDRX}) - (g-1)\text{WUSmax}$ and the equivalent gap between the g -th WUS and PO may be equal to or larger than the configured gap for DRX, e.g., $\text{gap2_eDRX} + (g-1)\text{WUSmax}$, where WUSmax is the maximum duration of WUS for each g -th group. Note that WUSmax can be same or different for different types of gaps. In some aspects, grouping the UEs according to WUSs with a similar gap size can be referred to as gap-specific WUS grouping. In other aspects, for UEs with different WUSs or different gap sizes, the UEs cannot be grouped together.

[00114] In other aspects, for UEs corresponding to WUSs with same size of gaps, the communication may be broadcasted in a SIB and the WUSs can have different starting time offsets or WUS max/actual durations. In aspects with a more flexible configuration, base stations can configure different the number of UE groups, G , for different sizes of gaps. The present disclosure can also include different percentages of UEs corresponding to DRX or eDRX. Accordingly, depending on the number of UEs using DRX or eDRX, a base station can divide them differently. It may be more flexible for the base station to divide the UEs based on the types of gap size. Additionally, the number of UE groups may be same or different based on the corresponding configured gap size. Other parameters associated with UEs, e.g., the maximum or actual WUS duration or the power boost, can be the same or different based on the corresponding configured gap size.

[00115] In yet other aspects, if there are multiple WUSs for the same associated PO, and if a corresponding base station allows multiple group WUS with different gap sizes, then there may be some WUS overlap. If a base station sends a different WUS for the same PO, the WUSs should avoid overlapping one another.

[00116] There can be several options available to a base station to avoid WUS overlapping. In one example, the base station may configure a separate distance of different gaps and/or a limited number of UE groups and/or different power boosting techniques to avoid overlapping amongst WUSs corresponding to a UE group with different gap sizes. In one aspect, the shorter gap size for the eDRX (e.g., gap1_eDRX) may be larger than the short gaps for the DRX (e.g., gap_DRX) so that it may be possible to

configure a number of UE-group WUSs for the DRX UEs with gap_DRX. In another aspect, the long gap size for eDRX (e.g., gap2_eDRX) may be larger than the short gap size for the eDRX (e.g., gap1_eDRX) so that it may be possible to configure a number of UE-group WUSs for the eDRX UEs with gap1_DRX. Base stations according to the present disclosure can also use power boosting or transmit diversity to configure a number of UE-group WUSs with shorter WUS max/actual duration for the DRX to fit within a time period, e.g., gap1_eDRX - gap_DRX, as well as configure a number of UE-group WUSs with shorter WUS max/actual duration for the eDRX to fit within another time period, e.g., gap2_eDRX - gap1_eDRX, to avoid overlapping.

[00117] In another example, a base station may allow overlapping of UE group WUSs. In the example of overlapping UE-group WUSs, the base station may utilize power boosting in the overlapped region of UE-group WUSs and each WUS may still have similar or even larger power as that of a non-overlapped region. Additionally, different sequences may be utilized for different UE-group WUSs so that each UE group may identify the correct WUS, even when there is interference from another WUS for a different UE group overlapping the WUS. In these aspects, allowing some type of WUS overlap can result in the configurations being more flexible.

[00118] FIGs. 11A-11C illustrate examples 1100, 1110, and 1120, respectively, of multiplexing according to the present disclosure. FIGs. 11A-11C each display an example of time division multiplexing (TDM), code division multiplexing (CDM), and frequency division multiplexing (FDM) for UE group WUS. More specifically, FIG. 11A shows an example 1100 of TDM WUS, e.g., for MTC and/or NB-IoT. FIG. 11B displays an example 1110 of CDM WUS, e.g., for MTC and/or NB-IoT. Also, FIG. 11C shows an example 1120 of FDM WUS, e.g., for MTC. For UE group WUS multiplexing, using TDM, CDM, and/or FDM can have a number of different advantages and disadvantages. For example, TDM may not have power sharing and have no impact on the legacy WUS, e.g., WUS1 as shown in FIG. 11A. Also, TDM may have more overhead for a larger number of groups, and a larger gap between the end of a UE group and a PO, and may use more power. Regarding the use of CDM, there may be no additional overhead if the transmission power is boosted. Further, there may be a common gap with same latency as the legacy WUS, e.g., WUS1 in FIG. 11B. The use of CDM may need a boost in power to maintain the same length,

and there can be a possible impact on the legacy WUS, e.g., WUS1, from multiplexed WUSs. Concerning the use of FDM, there may be no impact on the legacy WUS, e.g., WUS1 in FIG. 11C. Moreover, there may be a common gap with the same latency as the legacy WUS. There may be a need to boost the power in order to keep the same length when using FDM. Another possible design is to use a common WUS to wake up all the UEs, including non-grouped UEs, e.g., legacy UEs and grouped UEs, when there is paging for the legacy UE, or for the UEs belonging to different groups. Otherwise, the UE-group WUS may be sent instead of the common WUS in the same allocated resources. The UE-group WUS and common WUS may not be sent at the same time, which may not depend on power sharing or overhead/latency. However, one issue may be a sacrifice in the power saving gain. The legacy WUS may wake up all other UEs, even if there are 1% legacy UEs in the system. The paging of new UEs can also provide a negative impact on the legacy UE power saving as well.

[00119] FIGs. 12A and 12B illustrate examples 1200 and 1210, respectively, of multiplexing according to the present disclosure. For instance, FIGs. 12A and 12B display that the present disclosure can utilize combined multiplexing schemes, e.g., TDM, FDM, and/or CDM, with no or minimized additional signaling. In some aspects, the present disclosure can use TDM for X number of UE-group WUSs and the remaining $(G-X)$ UE-group WUSs may use CDM or FDM to multiplex on top of the TDMed WUSs. Alternatively, the present disclosure can use CDM or FDM for X UE-group WUSs and the remaining $(G-X)$ UE-group WUSs can use TDM to multiplex with the CDMed or FDMed UE-groups WUSs. Here, G , wherein $G = \{2, 3, 4, \dots\}$, is the number of UE-group WUSs, which may be configured and broadcasted in SIB, and X , wherein $2 \leq X \leq G$, may be predefined or configured by SIB.

[00120] FIG. 12A displays an example 1200 which utilizes TDM for two UE groups and CDM for another two UE groups, while boosting the power by 3dB. FIG. 12B displays an example 1210 which utilizes TDM for two UE groups and FDM for another two UE groups, while also boosting the power by 3dB. Accordingly, FIG. 12A shows an example in which TDM and CDM are combined, and FIG. 12B shows an example wherein TDM and FDM are combined. In other aspects, the present disclosure can configure more than two WUS groups by adding another multiplexing scheme. For instance, the present disclosure can select one multiplexing scheme when the number

of groups is limited to a threshold value. However, if the number of groups exceeds the threshold value, then another multiplexing scheme can be added. In one example, the present disclosure can use CDM when configuring two groups, and can add TDM to CDM when configuring more than two groups. In some aspects, the present disclosure can utilize combined multiplexing schemes, TDM/CDM/FDM and/or the scheme to select one WUS among common WUS and UE-specific WUSs, with no or minimized additional signaling. For example, the present disclosure can use TDM or CDM or FDM for a small G , e.g., $G=2$, but choose the scheme of a common WUS or UE-specific WUS for a large G , e.g., $G=4$.

[00121] In another aspect, the present disclosure can change the index order of UE group WUSs for different POs, such by using a predefined cyclic shift. This can be done to average the latency for different UE groups when waiting for the PO. For instance, if the WUS is relatively far from the PO, then there will be an increased latency, which uses power because the WUS may stay awake and not go into sleep mode. This gap between the PO can be larger than other WUS groups, which can use increased power compared to WUS groups closer to the PO. In one aspect, the present disclosure can use an index to change the WUS group order, such that the PO gap can be averaged. For instance, the present disclosure can use a predefined cyclic shift to change the index order. Accordingly, the present disclosure can adjust the order of WUS groups to save power by averaging the latency for each group. However, in some aspects, the legacy WUS, e.g., WUS1 in FIG. 12B, may not change its ordering.

[00122] For example, in FIG. 12B, WUS1 and WUS3 start closer to the PO, so their PO gap is smaller than WUS2 and WUS4. However, the order can be changed to make WUS4 closer to the PO, and then WUS2 closer to the PO. By changing the order, the average total latency for non-legacy WUS groups, e.g., WUS2, WUS3, and WUS4, can be similar. As such, each non-legacy WUS group can have the same opportunity to be close to the PO, so the latencies can be the similar and the groups can use the same amount of power. By doing so, the present disclosure can change the index order of the WUS groups, except for the legacy group. Further, this approach may not add any additional signaling. However, other aspects can also use a higher level of signaling, e.g., broadcast. Additionally, yet other aspects can predefine a pattern for the WUS group index changes. The pattern for the WUS group index may be determined by the timing of POs, e.g., a PO subframe index modified by a DRX cycle, so that the UE

can implicitly know the resources for the UE-group WUS of its UE group index for each PO.

[00123] FIG. 13 is a timeline 1300 illustrating transmissions between a base station and UEs including WUSs. More specifically, FIG. 13 displays a multiplexing scheme for NB-IoT or MTC UEs using the same configured gap. The configured gap can be one of the following gaps: a DRX gap for DRX UEs, an eDRX short gap for eDRX UEs, or an eDRX long gap for eDRX UEs. In some aspects of the present disclosure, multiplexing schemes for legacy or UE-group WUS can be TDM and/or single-sequence CDM, where TDM includes different WUSs using different time-domain resources and single-sequence CDM includes different sequences sharing the same resource and one sequence is transmitted at a given time. As mentioned previously, legacy UEs may detect a legacy WUS. Further, legacy UEs can be unaware of a UE-group WUS. In one aspect, a legacy WUS can have a starting point equal to: $PO - gap - WUS_{max}$, where the gap is the gap configured by a base station for the WUS associated with the PO and WUS_{max} is the configured maximum duration of the WUS.

[00124] As shown in FIG. 13, in some aspects, all new or grouping UEs may belong to one of two groups, e.g., G1 and G2. The UEs may be further grouped into sub-groups within G1 and G2. As indicated above, sub-group UEs can be part of a smaller group or sub-group within a larger UE group, e.g., G1 and G2. In some aspects, the sub-group UEs can be referred to as a sub-group of UEs or a set of sub-group UEs. As such, larger UE groups, e.g., G1 and G2, can include sub-group UEs, a sub-group of UEs, and/or a set of sub-group UEs. Sub-group UEs can also be divided into multiple sets of sub-group UEs. Other UEs might not be capable of being grouped, which can be referred to as legacy UEs. Thus, the WUS configuration may need to be signaled in a manner that addresses the needs/capabilities of different UEs. Among the UEs that are capable of being grouped, e.g., “grouping UEs,” a portion of grouping UEs may be mapped to G1 (e.g., new UE1) can have a number of different capabilities, such as detecting a G1 non-group specific WUS (e.g., a legacy WUS), detecting a G1 common WUS (e.g., a common WUS that can be detected by UEs capable of grouping in G1) if configured, and detecting a G1 sub-group WUS. The remaining grouping UEs may be mapped to G2 (e.g., new UE2) and can detect a G2 common WUS (e.g., a common WUS that can be detected by UEs capable of grouping in G2) and detect a

G2 sub-group WUS. FIG. 13 illustrates example WUSs that may be transmitted for two groups of UEs, e.g., G1 and G2. Within G1 and G2, the UEs that are capable of being grouped may be further grouped into subgroups, e.g., subgroups G1-0 and G1-1 and subgroups G2-0 and G2-1. Each group can share the resources for different WUS sequences but a single sequence may be transmitted at a given time, i.e., use single-sequence CDM for WUS multiplexing. In some aspects, the UE can be configured with more than one WUS sequence, e.g., up to two WUS sequences of a common WUS and a sub-group WUS in a monitored WUS resource. The UE may assume that no more than one WUS sequence is sent per WUS resource at a given time.

[00125] In one aspect, the G1 non-group specific WUS (e.g., legacy WUS) 1302 can be sent when at least one legacy UE or more than one G1 subgroup UE needs to be paged. UEs that belong to G1 can detect the G1 non-group specific WUS 1302. Also, a particular G1 sub-group WUS (e.g., G1-0 UE-group WUS or G1-1 UE-group WUS) may be sent when the grouping UE(s) from that subgroup (e.g., G1-0 or G1-1) needs to be paged. In another aspect, the non-group specific WUS 1302 can be sent when at least one legacy UE needs to be paged. Also, the G1 common WUS 1304 can be used when UEs from more than one G1 subgroup need to be paged, but no legacy UE needs to be paged. Moreover, a particular G1 UE-group WUS (e.g., G1-0 UE-group WUS or G1-1 UE-group WUS) can be sent when the grouping UE(s) from that subgroup (e.g., G1-0 or G1-1) needs to be paged. The difference between the above aspects can be the introduction of the G1 common WUS that should be detected by the new or grouping UEs in G1, but not for legacy UEs. Also, the present disclosure can continue to send a non-group specific WUS when at least a legacy UE needs to wake-up. The legacy UEs will not be woken up if new UEs in G1 are paged, i.e., G1 common WUS or G1 UE-group WUS will be transmitted. In this way, it can reduce the impact on the legacy UEs by paging new UEs.

[00126] Similar to the grouping of UEs into group G1, other grouping capable UEs may be grouped in to G2 and may be further grouped into subgroups G2-0, G2-1, etc. The configuration for G2 may be unknown by any legacy UEs. In some aspects, the legacy UEs may not detect the WUS sequences for G2 group. Therefore, the WUS used to wake-up UEs within G2 may comprise a common WUS for grouping UEs and sub-group WUSs (e.g., G2-0 UE-group WUS or G2-1 UE-group WUS). In one aspect, a

G2 common WUS can be sent when UEs from more than one G2 subgroup need to be paged. A corresponding G2 UE-group WUS can be sent when UE(s) from one subgroup (e.g., G2-0 or G2-1) need to be paged. Further, G2 may use newly configured resources orthogonal with that of a legacy WUS, e.g., TDM. The present disclosure can also consider how to group the UE1 and UE2 UEs into new groups, as well as consider the ratios of the legacy UEs. Although two groups, e.g., G1 and G2, and two subgroups within the groups, e.g., G1-0 and G1-1 for G1 and G2-0 and G2-1 for G2, any number of groups and sub-groups may be used. The example is merely illustrative of the principle and the actual number of groups/subgroups is not limited to the illustrated example.

[00127] In other aspects, the present disclosure can decide how to assign a group WUS sequence or UE group identification. The UEs may be grouped based on weighting factor(s). Information about the grouping and/or the weighting factors can be indicated to the UEs in the system information (SI). In one aspect, a first weighting factor (e.g., W1), a second weighting factor (e.g., W2), G1, and/or G2 can be indicated in the SI. For instance, new or grouping UEs may be divided into new UE1s and new UE2s with weighting factors W1 and W2, respectively. In one aspect, new UE1s for G1 can be grouped based on a formula using the weighting factors W1 and W2, e.g., $\text{floor}(\text{UE_ID}/(N*N_s*N_n)) \bmod (W1 + W2) < W1$; otherwise, new UE2s for G2 can be chosen, where W1 and W2 are the weighting factor for G1 and G2, respectively, and $W1 \geq 0$, $W2 \geq 0$ but $W1 + W2 > 0$. Also, new UE1s and UE2s can be divided into G1 and G2 subgroups, respectively. The UEs may be separated into the subgroups based on an additional formula, e.g., the group WUS sequence or UE group identification (ID) in G1 groups g1 can be equal to: $\text{UE_ID1} \bmod (G1)$. Also, UE_ID1 can be based on the following formula: $\text{UE_ID1} = \text{floor}(\text{UE_ID}/(N*N_s*N_n)/(W1 + W2))$ for the UEs belonging to G1. For a new UE2, the UE group ID in G2 groups g2 can be equal to: $\text{UE_ID2} \bmod (G2)$. UE_ID2 can be equal to: $\text{UE_ID2} = \text{floor}(\text{UE_ID}/(N*N_s*N_n)/(W1 + W2))$ for the UEs belonging to G2. Additionally, in some cases, a partial value of W1, W2, G1, or G2 may be signaled explicitly from the base station to the UEs. For example, for a fixed value of W1, e.g., $W1=1$, then W2 may be signaled from the base station to the UEs; or $W2=1$, then W1 may be signaled. Further, the relationship of G1 and G2 can be fixed, e.g., $G1=G2$ or $G1=[G2+1]$, and either G1 or G2 can be signaled. Moreover,

these parameters can be fixed in the specification. If the weighting factor is not configured, it can be equivalent to a same weighting factor of $W1=W2=1/2$ for UE distribution, i.e., with $G1=G2$, $UE_ID1 = \text{floor}(UE_ID/(N*Ns*Nn) \bmod (G1))$ and $UE_ID2 = \text{floor}(UE_ID/(N*Ns*Nn) \bmod (G2))$. With $G1$ unequal to $G2$, UE_ID1 may be applied to UEs with $\text{floor}(UE_ID/(N*Ns*Nn))$ within a range of $0 \sim (G1-1)$ and UE_ID2 may be applied to UEs with $\text{floor}(UE_ID/(N*Ns*Nn))$ within a range of $G1 \sim (G1+G2-1)$.

[00128] In another aspect, the present disclosure can decide how to assign a group WUS sequence or UE group identification based on indicating a parameter or ratio, e.g., $R0$, in the SI and implicitly indicating $W1$, $W2$, $G1$, and/or $G2$. For instance, the base station can explicitly indicate the legacy UE ratio, $R0$, in the SI. Also, $G1$ and $G2$ can be predefined based on $R0$. For example, $G1=1$, $G2=0$ if $R0 > 50\%$; or $G1=G2=4$ if $R0 \leq 50\%$. In another example, $G1=1$, $G2=0$ if $R0 \geq 75\%$; or $G1=4$, $G2=0$ if $75\% > R0 \geq 50\%$; or $G1=G2=4$ if $50\% > R0 \geq 25\%$; or $G1=G2=6$ if $25\% > R0 \geq 0\%$. Further, weighting factors $W1$ and $W2$ can be predefined based on $R0$. For example, $W1=0$ and $W2=1$ if $R1=0$; or $W1/W2=R1/(1-R1)$ if $0 < R1 < 1$; or $W1=1$ and $W2=0$ if $R1=1$, where $R1 = \max(X\% - R0, 0)$. It is noted that in the above examples X can be fixed as $X\%=50\%$ or be configurable to balance the UEs in $G1$ and $G2$. Additionally, new or grouping UEs can be divided into new UE1 and new UE2 with weighting factors $W1$ and $W2$, respectively. In one aspect, new UE1 for $G1$ can be grouped based on a formula using the weighting factors $W1$ and $W2$, e.g., $\text{floor}(UE_ID/(N*Ns*Nn)) \bmod (W1 + W2) < W1$; otherwise, new UE2 for $G2$ can be chosen. New or grouping UE1s and UE2s may further be divided into $G1$ and $G2$ groups, respectively. The UEs may be separated into the subgroups based on an additional formula, e.g., the group WUS sequence or UE group identification (ID) in $G1$ groups $g1$ can be equal to: $UE_ID1 \bmod (G1)$. Also, UE_ID1 can be based on the following formula: $UE_ID1 = \text{floor}(UE_ID/(N*Ns*Nn)/(W1 + W2))$ for the UEs belonging to $G1$. For a new UE2, the UE group ID in $G2$ groups $g2$ can be equal to: $UE_ID2 \bmod (G2)$. UE_ID2 can be equal to: $UE_ID2 = \text{floor}(UE_ID/(N*Ns*Nn)/(W1 + W2))$ for the UEs belonging to $G2$.

[00129] The present disclosure can also provide an extension to WUS multiplexing schemes to enable further power savings. In one aspect, there may be more WUSs for groups based on TDM. For instance, new or grouping UEs can be divided into new UE1s,

UE2s, UE3s, and UE4s based on TDM. New UE1s, UE2s, UE3s, and UE4s can be further divided into subgroups G1, G2, G3, and G4. Further, new UE1s, together with legacy UEs, may detect a legacy WUS. A common WUS for subgroups of each group may be multiplexed with a UE-group WUS per subgroup based on single-sequence CDM. Additionally, there can be more WUSs for subgroups based on a single-group CDM. For instance, new or grouping UEs can be divided into new UE1s and UE2s based on TDM. New UE1s and UE2s can be further divided into subgroups G1 and G2. New UE1s, together with legacy UEs, can also detect a legacy WUS. Moreover, more than one common WUS for subgroup combinations of each group can be multiplexed with a UE-group WUS per subgroup based on a single-sequence CDM. For example, if group G1=3, then there can be three UE-group WUSs per subgroup for G1-0, G1-1 and G1-2, respectively; and three common sequences for two different subgroups combinations, such as one common sequence for G1-0 and G1-1, one common sequence for G1-0 and G1-2, and one common sequence for G1-1 and G1-2; and in addition, another common sequence for all subgroups, G1-0, G1-1 and G1-2. In other aspects, the configuration or signaling can be different for the UEs with different configured gap values, such as the UEs with a configured DRX gap, the UEs with a configured eDRX short gap (e.g., if it is a different value from the DRX gap), or the UEs with a configured eDRX long gap (e.g., larger than the DRX gap and eDRX short gap). In further aspects, the configuration or signaling can be ‘per carrier’ for NB-IoT or ‘per narrowband’ for MTC.

[00130] Base stations herein can configure a number of different types of WUS resources. For instance, a base station can configure a maximum amount of WUS resources per DRX or eDRX gap for an associated PO. An example maximum amount may include two WUS resources, although in other examples the maximum amount may be more than two. In some instances, the WUS resources can be TDM resources. Thus, a single WUS may be transmitted by the base station in a particular time resource. Additionally, each WUS resource can be determined by the length of a maximum WUS duration (W_{max}). This W_{max} value can vary for NB-IoT WUS or MTC WUS. For example, W_{max} can be one set of values, e.g., 1 ms, 2 ms, 4 ms, ..., 1024 ms, for NB-IoT WUS and another set of values, e.g., 1 ms, 2 ms, 4 ms, ..., 64 ms, for MTC WUS. Also, for NB-IoT WUS, there can be one PRB resource when the present

disclosure considers how long or how many subframes are used for this resource. Further, the Wmax value may be indicated to UEs in a SIB.

[00131] In some aspects, base stations herein may configure a number of types of gaps, e.g., three types of gaps, for a WUS for DRX or eDRX UEs. Each DRX or eDRX UE may identify a unique type of gap from its own point of view. For instance, there may not be multiple different gaps from a UEs point of view. A DRX gap for DRX UEs may include a variety of potential gap values, e.g., 40 ms, 80 ms, 120 ms, or 240 ms. In some instance, the DRX gap can be less than or equal to an eDRX short gap. The eDRX short gap for eDRX UEs may include a variety of potential gap values, e.g., 40 ms, 80 ms, 120 ms, 240 ms. Also, an eDRX long gap for eDRX UEs may be larger than the eDRX short gap, e.g., 1 s or 2s. In some instances, the base station may select or choose the eDRX short gap. In other instances, the base station may select the eDRX long gap, e.g., if the network configures the eDRX long gap. Additionally, eDRX UEs may have longer sleep times compared to DRX UEs.

[00132] Time resources may be allocated, e.g., WUS time resources, based on the size of the aforementioned gaps. In some instances, if a DRX gap is less than an eDRX short gap, the distance between the paging occasion and the eDRX gap may not be sufficient to allocate multiple time resources for DRX WUSs. For instance, this distances between gaps may not be sufficient to allocate an additional WUS time resource, e.g., a group 2 time resource, for an additional group of DRX UEs. A first WUS time resource may be used for a first group of UES, which may include legacy UEs. The additional WUS time resource may include UE with additional grouping capability. The time distances between gaps might not be sufficient because legacy first WUS resources for eDRX UEs using an eDRX short gap may overlap in time with the additional WUS time resource for the additional group of DRX UEs. In some aspects, if the gap distance is greater than a WUS maximum duration, the base station may be limited from allocating the additional DRX WUS time resource. For example, if a DRX gap is 40 ms, an eDRX gap is 80 ms, then there is 40 ms difference between the DRX gap and the eDRX gap. If a WUS maximum duration is 32 ms for one DRX WUS resource, then the 40 ms may allow for a single DRX WUS resource. A second DRX WUS resource would overlap in time with the eDRX WUS resources, e.g., following the 80ms eDRX gap. The inability to schedule multiple WUS for the DRX

UEs limits the potential power saving through the use of multiple UE groups that monitor for different WUSs.

[00133] FIG. 14 illustrates timelines 1400 and 1450, respectively, having transmissions between a base station and UEs including WUSs. Timeline 1400 is for DRX UEs. For example, timeline 1400 shows new WUS resources and legacy WUS resources, as well as a WUS maximum duration. Although illustrated using the term “legacy” and “new” the two WUS resource may also correspond to group WUS for new UEs. Furthermore, although two WUS resources are illustrated, the concepts presented herein are applicable to more than two WUS resources. The DRX UEs in one group, e.g., group 2 (G2), can use the G2 WUS resources. Also, the DRX UEs in another group, e.g., group 1 (G1), as well as legacy DRX UEs can use the G1 WUS resources. The G1 WUS resources may correspond to legacy WUS resources. Further, timeline 1400 displays a DRX gap between legacy WUS resources and the paging occasion for the DRX UEs.

[00134] Timeline 1450 is for eDRX UEs, and shows new WUS resources, legacy WUS resources, and a WUS maximum duration. The new eDRX UEs in one group, e.g., group 2', can use the new WUS resources. Also, the new eDRX UEs in another group, e.g., group 1', and the WUS and legacy eDRX UEs can use the legacy WUS resources. Timeline 1450 also displays an eDRX short gap between legacy WUS resources and paging for the eDRX UEs.

[00135] Looking at both timelines in FIG. 14, the difference between the DRX gap and the eDRX short gap is greater than a single WUS maximum duration, but does not allow for two WUS resources. FIG. 14 illustrates an overlap in time between the G2 DRX WUS resource and the G1' eDRX WUS resource. The present disclosure enables a base station to continue to send a separate WUS for the G2 DRX UEs, and provides various ways for a base station to determine where to transmit the G2 WUS. For each gap, the present disclosure can consider multiple resources, so a base station may need to instruct the UEs regarding where to allocate the new WUS resources. In some aspects, the present disclosure may utilize additional resources to help with the subgrouping of UEs.

[00136] In some aspects, the present disclosure may shift the new DRX UEs in group 2 based on a number of different alternatives. For instance, the present disclosure may shift the DRX UEs in group 2 to monitor for a WUS based on a time offset. For example,

if the DRX UEs wake up more frequently than the eDRX UEs, then the present disclosure may utilize the resources for the eDRX UEs. In some instances, the base station can let the UE monitor the resources in order to achieve a power savings. Additionally, the present disclosure can group the DRX UEs with the eDRX UEs, such that the base station can transmit send the WUS to the eDRX resources.

[00137] FIG. 15 illustrates timelines 1500 and 1550, respectively, for transmissions between a base station and UEs including WUSs. Timeline 1500 shows new WUS resources and legacy WUS resources, as well as a WUS maximum duration. The DRX UEs in one group, e.g., group 1, as well as the legacy DRX UEs, can monitor the G1 time resource for WUS. The G1 time resource may correspond to the legacy WUS resources. Looking at both 1500 and 1550, the difference between the DRX gap and the eDRX short gap is greater than a single WUS maximum duration, but an overlap in time exists between the DRX G2 time resource and the eDRX G1' time resource. Accordingly, the base station may be limited from transmitting a WUS to the DRX UEs in group 2 using the G2 resources, as indicated by the "X" over the resources. Instead, the base station may transmit a WUS for the DRX UEs in group 2 using eDRX WUS time resources, e.g., either G1' or G2'. Timeline 1550 shows that eDRX UEs in group 1', as well as the legacy eDRX UEs, may monitor the G1' WUS time resources for a WUS. The G1' WUS time resources may correspond to legacy WUS resources. Also, eDRX UEs in group G2' may monitor the G1' resources for a WUS. As the resources to the new DRX UEs in G2 may not be allocated with the location of the DRX UEs in group 2, may need to determine which resources to use to monitor for a WUS. Similarly, a base station may need to determine which time resources to use to transmit a WUS for the DRX group 2 UEs.

[00138] In one aspect, the present disclosure can group the DRX UEs in group 2 together with some eDRX UEs in group 1'. The DRX UEs in group 2 can monitor for the WUS using the G1' WUS resources allocated for legacy eDRX UEs and/or eDRX UEs in group 1'. As an example, group 1' may include the legacy UEs, as the legacy UEs may not be aware of the new UEs.

[00139] In another aspect, the DRX UEs in group 2 can be grouped together with the eDRX UEs in group 2'. Accordingly, the DRX UEs in group 2 can monitor for a WUS in the WUS resources allocated for the eDRX UEs in group 2'. In some instance, the DRX UEs in group 2 can also wake up earlier in group 2'. This may result in more

power, but the present disclosure can still achieve a power savings with this configuration.

[00140] In another aspects, the present disclosure can divide the new DRX UEs in group 2 between the eDRX UEs in group 1' and the eDRX UEs in group 2'. For example, a certain percentage, e.g., X%, of new DRX UEs in group 2 can monitor for the WUS with the legacy WUS resources allocated for legacy eDRX UEs and new eDRX UEs in group 1'. The remaining percentage of new DRX UEs in group 2, e.g., 1-X%, can monitor the WUS using new WUS resource for new eDRX UEs in group 2'. In some aspects, the percentage of new DRX UEs in group 2 can be predefined. In other aspects, the percentage of new DRX UEs in group 2 can be configured. In some instance, the amount of new DRX UEs in group 2 can be divided evenly between the two resource groups.

[00141] In some aspects, the base stations can determine whether to transmit WUS for a UE configured for DRX using a DRX WUS time resource or an eDRX WUS time resource, and in which of multiple eDRX WUS time resources. In one aspect, a base station can explicitly indicate that a subset of DRX groups are merged with a particular eDRX group. For example, the base station can indicate, e.g., in SIB, that DRX UEs in group 2 should monitor eDRX resources for eDRX UE group 1'. To do so, aspects of the present disclosure introduce additional signaling from the base station to the UE, e.g., signaling in the SIB. The present disclosure can also indicate which type of UE should monitor the resources allocated to a specific type of UE. As such, the base station can indicate the index, and the UE can determine the location of the resource. In some instances, the DRX UEs may determine the gap for the eDRX UEs, e.g., by locating it in the SIB. Also, the gap for certain types of UEs can be broadcasted for other UEs, e.g., idle UEs.

[00142] In another aspect, a predefined relationship may be used by a DRX UE and by the base station to identify the particular eDRX resources. Thus, the base station and UE(s) may make the determination without needing additional signaling. However, the base station may need to define the monitoring instance in an implicit manner, such as by predefined some parameters. As such, aspects of the present disclosure may include UEs that can determine which resources to monitor based on a pre-definition. Based on the pre-defined information, the present disclosure can inform

certain UEs regarding how much time offset is needed. By doing so, certain UEs can determine which resources to monitor.

[00143] Additionally, the resources that certain UEs should monitor for WUS can be based on a number of different parameters. In one aspect, the resources to monitor can be based on a number of groups per WUS resource. For example, the present disclosure may configure the number of groups in the SIB, which can be based on different DRX and eDRX UEs. If the base station configures certain groups, the UE can monitor based on those group numbers. Some aspects of the present disclosure can include independent parameters based on the DRX and eDRX UEs when the number of groups are indicated. For example, in group 1' is less than group 2', the base station can instruct the new DRX UEs to monitor group 1'. Otherwise, the base station can instruct the UEs to monitor group 2'. Additionally, the present disclosure can set a certain percentage of new DRX UEs to monitor group 1', and the remaining percentage of new DRX UEs to monitor group 2'.

[00144] In another aspect, the resources that certain UEs should monitor can be based on the WUS maximum duration size, as well as the size of the DRX gap or the eDRX short gap. As such, the UE can monitor based on the gap distance. For instance, the present disclosure may not want to move resources far away from the PO. Rather, the present disclosure may move the new DRX UEs. For instance, the new DRX UEs are moved, then the UEs may wake up earlier, but the gap does not need to be adjusted. For example, in order to monitor a certain group, e.g., group 1', if a gap distance is larger than a predefined threshold, the present disclosure may move the new DRX UEs into the group closest to the gap. In some instances, this can result in the new DRX UEs waking up early.

[00145] In yet another aspect, the resources that certain UEs should monitor can be based on a weighting factor for a group. For example, if a weighting factor for group 1' is less than a weighting factor for group 2', then the UEs can be instructed to monitor group 1'. Otherwise, the UEs can monitor group 2'. Also, the present disclosure can divide the amount of UEs that monitor group 1' or group 2' based on a selected percentage of UEs. Additionally, the weighting factors can be broadcast by the base station.

[00146] FIG. 16 is a flowchart 1600 of a method of wireless communication. The method may be performed by a UE or a component of a UE (e.g., the UE 104, 350, 2050; apparatus 1702/1702'; processing system 1814, which may include the memory 360

and which may be the entire UE or a component of the UE, such as the TX processor 368, the RX processor 356, and/or the controller/processor 359). Optional aspects are illustrated with a dashed line. The methods described herein can provide a number of benefits, such as improving communication signaling, resource utilization, and/or power savings.

[00147] At 1602, the UE may receive a configuration for a reception cycle, e.g., a DRX cycle and/or an extended DRX cycle, as described in the examples in FIGs. 4-15. As mentioned above, a UE and a base station can communicate during a reception cycle. In some aspects, this can occur when the UE is configured by the base station for a DRX mode or an eDRX mode. Accordingly, the reception cycle can be a DRX cycle or an eDRX cycle. In some aspects, a DRX cycle or an eDRX cycle can be a reception cycle during which the UE and a base station communicate while the UE is in a DRX mode or an eDRX mode. Also, the UE can receive a configuration for the reception cycle from the base station. The reception cycle can include a paging cycle during which the base station can send the UE a PO. The base station may send a WUS to the UE in advance of the PO during the reception cycle. In some aspects, during the reception cycle, the UE can determine whether to monitor for a WUS during a WUS time resource. Also, during the reception cycle, the UE can determine whether to monitor for the WUS based on a duration of a time gap between WUS resources and the PO.

[00148] At 1606, the UE may determine whether to monitor for a WUS during a WUS time resource, e.g., a DRX WUS time resource or an eDRX WUS time resource, of the reception cycle, as described in the examples in FIGs. 4-15. In some aspects, the UE can determine whether to monitor for the WUS during the WUS time resource, e.g., the DRX WUS time resource or the eDRX WUS time resource, based on a duration of a time gap between WUS resources and a paging occasion, e.g., a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion, as described in the examples in FIGs. 4-15. A first DRX WUS time resource can be configured for a group of UEs having a DRX configuration to monitor at least one of a group-specific DRX WUS or a non-group-specific DRX WUS, as described in the examples in FIGs. 4-15. Also, a second DRX WUS time resource can be configured for a second group of UEs with a second configuration of DRX to monitor at least one of the group-specific DRX WUS and/or

non-group-specific DRX WUS, as described in the examples in FIGs. 4-15. Additionally, a first eDRX WUS time resource can be configured for a group of UEs having a first eDRX configuration to monitor at least one of a group-specific WUS or a non-group-specific WUS, as described in the examples in FIGs. 4-15. Further, a second eDRX WUS time resource can be configured for a second group of UEs having a second eDRX configuration to monitor at least one of the group-specific WUS or the non-group-specific WUS, as described in the examples in FIGs. 4-15.

[00149] At 1608, the UE can monitor for the WUS during the DRX WUS time resource if the DRX WUS time resource does not overlap the eDRX WUS time resource, as described in the examples in FIGs. 4-15. At 1612, the UE can monitor for the WUS during the eDRX WUS time resource if the DRX WUS time resource overlaps the eDRX WUS time resource, as described in the examples in FIGs. 4-15. In some aspects, the eDRX WUS time resource can be configured for a DRX UE to monitor at least one of a group-specific WUS or a non-group-specific WUS, as described in the examples in FIGs. 4-15. Further, an additional eDRX WUS time resource can be configured for the DRX UE to monitor the at least one of the group-specific WUS or non-group-specific WUS, as described in the examples in FIGs. 4-15.

[00150] At 1610, the UE can determine which of the two eDRX WUS time resources to monitor for the WUS, e.g., when two eDRX WUS time resources are configured for a group of DRX UEs, as described in the examples in FIGs. 4-15. At 1604, the UE can receive an indication from a base station that indicates a correspondence between the group of DRX UEs and an eDRX UE group, e.g., when the UE belongs to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, as described in the examples in FIGs. 4-15. The UE can determine to monitor for the WUS during the first time resources or the second time resources based on the eDRX UE group with the correspondence to the group of DRX UEs, as described in the examples in FIGs. 4-15.

[00151] In some aspects, the UE can belong to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, as described in the examples in FIGs. 4-15. Additionally, the UE can determine to monitor for the WUS during a first time resource or a second time resources based on a predefined relationship between a DRX UE group of the UE and a corresponding eDRX UE group, as described in the examples in FIGs. 4-15. The predefined

relationship can be based on a number of UE groups per eDRX WUS resource, as described in the examples in FIGs. 4-15. The predefined relationship can also be based on at least one of a maximum duration of a WUS, the DRX time gap, or the eDRX time gap, as described in the examples in FIGs. 4-15. Moreover, the predefined relationship can be based on a number of UEs, which can be dependent on a configured weighting factor for at least one of a first eDRX UE group corresponding to the first time resource or a second eDRX UE group corresponding to the second time resource, as described in the examples in FIGs. 4-15.

[00152] In some aspects, the UE can receive or define a UE group identification assigned to one or more sub-group UEs in a UE group, where the one or more sub-group UEs can include the UE, as described in the examples in FIGs. 4-15. Also, the UE can monitor for a WUS for the UE group for the one or more sub-group UEs assigned to the UE group to wake-up for the paging occasion, as described in the examples in FIGs. 4-15. In some instances, a common WUS can be configured to wake-up each of the one or more sub-group UEs monitoring a same WUS resource, e.g., when two or more of the one or more sub-group UEs are configured to monitor the same WUS resource, as described in the examples in FIGs. 4-15. Further, a common WUS for each of the one or more sub-group UEs in a same WUS resource can be configured to be a group WUS, e.g., to wake up all the sub-group UEs in a same WUS resource, or a non-group specific WUS, e.g., to wake up all the non-group UEs and/or all the sub-group UEs monitoring the same WUS resource, as described in the examples in FIGs. 4-15. In some aspects, the one or more sub-group UEs can include a first set of sub-group UEs and a second set of sub-group UEs, as described in the examples in FIGs. 4-15. Also, the WUS for the first set of sub-group UEs in a first WUS resource can comprise at least one of a non-group specific WUS, a first common WUS, or a first group WUS, wherein the WUS for the second set of sub-group UEs in a second WUS resource can comprise at least one of a second common WUS or a second group WUS, as described in the examples in FIGs. 4-15.

[00153] In some aspects, the non-group specific WUS can indicate for at least one UE without grouping capability to wake-up for the PO or for multiple UEs from different sub-groups within a first group to wake-up for the PO, wherein the first common WUS indicates for more than one first sub-group UE to wake-up for the PO without indicating for a UE without grouping capability to wake-up, wherein the first group

WUS indicates for at least one UE from a single sub-group from the first group to wake-up for the PO, as described in the examples in FIGs. 4-15. Moreover, the second common WUS can indicate for multiple UEs from different sub-groups in a second group to wake-up for the PO, wherein the second group WUS indicates for at least one UE from a second, single sub-group within the second group to wake-up for the PO, as described in the examples in FIGs. 4-15. Also, the first set of sub-group UEs may be assigned a UE group identification based on a first weighting factor, and the second set of sub-group UEs are assigned a UE group identification based on a second weighting factor, as described in the examples in FIGs. 4-15. An amount of one or more sub-group UEs in a same WUS resource can be equal to an amount of one or more sub-group UEs in each of the WUS resources or independently configured per WUS resource, as described in the examples in FIGs. 4-15. Also, the amount of one or more sub-group UEs in each of the WUS resources can be equal to 1, 2, 4, or 8, as described in the examples in FIGs. 4-15. Further, an amount of UE groups per WUS resource can be the same or independently configured for WUS resources using a different time gap between the WUS resources and an associated paging occasion, as described in the examples in FIGs. 4-15. At least one of an amount of UE groups per WUS resource or a WUS resource pattern can be the same or independently configured for WUS resources with a time gap between the WUS resources and an associated paging occasion, as described in the examples in FIGs. 4-15.

[00154] In some aspects, the reception cycle can be at least one of a discontinuous reception (DRX) cycle or an extended DRX (eDRX) cycle, as described in the examples in FIGs. 4-15. Also, the WUS time resource can be at least one of a DRX WUS time resource or an eDRX WUS time resource, as described in the examples in FIGs. 4-15. Further, the UE can determine whether to monitor for the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and the paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion, as described in the examples in FIGs. 4-15.

[00155] FIG. 17 is a conceptual data flow diagram 1700 illustrating the data flow between different means/components in an exemplary apparatus 1702. The apparatus may be a UE (e.g., UE 104, 182, 350, 2050). The apparatus can include a reception component 1704 that is configured to receive a configuration for DRX or eDRX. The

reception component 1704 can also be configured to receive an indication from a base station that indicates a correspondence between the group of DRX UEs and an eDRX UE group. The apparatus can also include a determination component 1706 that is configured to determine whether to monitor for a WUS during a DRX WUS time resource or an eDRX WUS time resource. The determination component 1706 can also be configured to determine which of the two eDRX WUS time resources to monitor for the WUS. The apparatus can also include a resource component 1708 that is configured to receive or transmit DRX and eDRX resources, e.g., via reception component 1704 or transmission component 1712. The apparatus can also include a monitoring component 1710 that is configured to monitor for the WUS during the DRX WUS time resource if the DRX WUS time resource does not overlap the eDRX WUS time resource. Also, the monitoring component 1710 can be configured to monitor for the WUS during the eDRX WUS time resource if the DRX WUS time resource overlaps the eDRX WUS time resource.

[00156] The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowcharts of FIG. 16. As such, each block in the aforementioned flowcharts of FIG. 16 may be performed by a component and the apparatus may include one or more of those components. The components may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[00157] FIG. 18 is a diagram 1800 illustrating an example of a hardware implementation for an apparatus 1702' employing a processing system 1814. The processing system 1814 may be implemented with a bus architecture, represented generally by the bus 1824. The bus 1824 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1814 and the overall design constraints. The bus 1824 links together various circuits including one or more processors and/or hardware components, represented by the processor 1804, the components 1704, 1706, 1708, 1710, 1712, and the computer-readable medium / memory 1806. The bus 1824 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[00158] The processing system 1814 may be coupled to a transceiver 1810. The transceiver 1810 is coupled to one or more antennas 1820. The transceiver 1810 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1810 receives a signal from the one or more antennas 1820, extracts information from the received signal, and provides the extracted information to the processing system 1814, specifically the reception component 1704. In addition, the transceiver 1810 receives information from the processing system 1814, specifically the transmission component 1712, and based on the received information, generates a signal to be applied to the one or more antennas 1820. The processing system 1814 includes a processor 1804 coupled to a computer-readable medium / memory 1806. The processor 1804 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1806. The software, when executed by the processor 1804, causes the processing system 1814 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1806 may also be used for storing data that is manipulated by the processor 1804 when executing software. The processing system 1814 further includes at least one of the components 1704, 1706, 1708, 1710, 1712. The components may be software components running in the processor 1804, resident/stored in the computer readable medium / memory 1806, one or more hardware components coupled to the processor 1804, or some combination thereof. The processing system 1814 may be a component of the UE 350 and may include the memory 360 and/or at least one of the TX processor 368, the RX processor 356, and the controller/processor 359.

[00159] In one configuration, the apparatus 1702/1702' for wireless communication includes means for receiving, from a base station, a UE group identification assigned to one or more sub-group UEs in a UE group; means for listening for a WUS from the base station for the sub-group UEs to wake-up for a PO; means for determining a WUS starting time offset based on an implicit or explicit indication from the base station; means for determining a WUS frequency offset for a starting resource block based on an implicit or explicit indication from the base station; means for selecting a paging carrier from a plurality of carriers; means for receiving the WUS from the base station for the sub-group UEs; and means for waking-up the sub-group UEs for the PO. The aforementioned means may be one or more of the aforementioned components of the

apparatus 1702 and/or the processing system 1814 of the apparatus 1702' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1814 may include the TX Processor 368, the RX Processor 356, and the controller/processor 359. As such, in one configuration, the aforementioned means may be the TX Processor 368, the RX Processor 356, and the controller/processor 359 configured to perform the functions recited by the aforementioned means.

[00160] FIG. 19 is a flowchart 1900 of a method of wireless communication. The method may be performed by a base station or a component of a base station (e.g., the base station 102, 310, 1750; apparatus 2002/2002'; processing system 2114, which may include the memory 376 and which may be the entire base station or a component of the base station, such as the TX processor 316, the RX processor 370, and/or the controller/processor 375). Optional aspects are illustrated with a dashed line. The methods described herein can provide a number of benefits, such as improving communication signaling, resource utilization, and/or power savings.

[00161] At 1902, the base station can configure a UE for a reception cycle, e.g., DRX or eDRX, as described in the examples in FIGs. 4-15. At 1906, the base station can determine whether to transmit a WUS during a WUS time resource, e.g., a DRX WUS time resource or an eDRX WUS time resource, of the reception cycle, as described in the examples in FIGs. 4-15. In some aspects, the base station can determine whether to transmit the WUS during the WUS time resource based on a duration of a time gap between WUS resources and a paging occasion, e.g., during a DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and a paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion, as described in the examples in FIGs. 4-15.

[00162] The base station can also configure a first DRX WUS time resource for a group of UEs having a DRX configuration to monitor at least one of a group-specific DRX WUS or a non-group-specific DRX WUS, as described in the examples in FIGs. 4-15. Further, the base station can configure a second DRX WUS time resource for a second group of UEs with a second configuration of DRX to monitor at least one of the group-specific DRX WUS and/or non-group-specific DRX WUS, as described in the examples in FIGs. 4-15. The base station can also configure a first eDRX WUS

time resource for a group of UEs having a first eDRX configuration to monitor at least one of a group-specific WUS or a non-group-specific WUS, as described in the examples in FIGs. 4-15. Moreover, the base station can configure a second eDRX WUS time resource for a second group of UEs having a second eDRX configuration to monitor at least one of the group-specific WUS or non-group-specific WUS, as described in the examples in FIGs. 4-15.

[00163] At 1908, the base station can transmit the WUS during the DRX WUS time resource if the DRX WUS time resource does not overlap the eDRX WUS time resource, as described in the examples in FIGs. 4-15. At 1912, the base station can transmit the WUS during the eDRX WUS time resource if the DRX WUS time resource overlaps the eDRX WUS time resource, as described in the examples in FIGs. 4-15. Also, the base station can configure the eDRX WUS time resource for a DRX UE to monitor at least one of a group-specific WUS or a non-group-specific WUS, as described in the examples in FIGs. 4-15. Further, the base station can configure an additional eDRX WUS time resource for the DRX UE to monitor the at least one of the group-specific WUS or the non-group-specific WUS, as described in the examples in FIGs. 4-15.

[00164] At 1910, the base station can determine which of the two eDRX WUS time resources to use to transmit the WUS, e.g., when the base station configures two eDRX WUS time resources for a group of DRX UEs, as described in the examples in FIGs. 4-15. At 1904, the base station can transmit an indication to the UE that indicates a correspondence between the group of DRX UEs and an eDRX UE group, e.g., when the UE belongs to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, as described in the examples in FIGs. 4-15. The base station can transmit the WUS during a first time resource or a second time resource based on the eDRX UE group with the correspondence to the group of DRX UEs, as described in the examples in FIGs. 4-15.

[00165] The UE can also belong to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, as described in the examples in FIGs. 4-15. Additionally, the base station can transmit the WUS during a first time resource or a second time resources based on a predefined relationship between a DRX UE group of the UE and a corresponding eDRX UE group, as described in the examples in FIGs. 4-15. The predefined relationship can be based on a number of UE groups per eDRX WUS resource, as described in the examples in

FIGs. 4-15. The predefined relationship can also be based on at least one of a maximum duration of a WUS, the DRX time gap, or the eDRX time gap, as described in the examples in FIGs. 4-15. Moreover, the predefined relationship can be based on a number of UEs, which can be dependent on a configured weighting factor for at least one of a first eDRX UE group corresponding to the first time resource or a second eDRX UE group corresponding to the second time resource, as described in the examples in FIGs. 4-15.

[00166] In some aspects, the base station can transmit a UE group identification assigned to one or more sub-group UEs in a UE group, where the one or more sub-group UEs can include the UE, as described in the examples in FIGs. 4-15. Also, the base station can configure a WUS for the UE group for the one or more sub-group UEs assigned to the UE group to wake-up for the paging occasion, as described in the examples in FIGs. 4-15. In some instances, a common WUS can be configured to wake-up each of the one or more sub-group UEs monitoring a same WUS resource, e.g., when two or more of the one or more sub-group UEs are in the same WUS resource, as described in the examples in FIGs. 4-15. Further, a common WUS for each of the one or more sub-group UEs in a same WUS resource can be configured to be a group WUS, e.g., to wake up all the sub-group UEs in a same WUS resource, or a non-group specific WUS, e.g., to wake up all the non-group UEs and/or all the sub-group UEs monitoring the same WUS resource, as described in the examples in FIGs. 4-15. In some aspects, in the first WUS resource, there may be more than one sub-group of UEs. If the first WUS resource is overlapped with the resource for a non-group specific WUS, the common WUS can be configured as a non-group specific WUS or a first common WUS. The non-group specific WUS can be used to wake up the non-group UEs and the sub-group of UEs in the first WUS resource. The first common WUS for the first WUS resource can be used to wake up the sub-group of UEs in the first WUS resource. Additionally, in the second WUS resource, there may be more than one sub-group of UEs that are different from those in the first WUS resource. The second common WUS for the second WUS resource can be used to wake up the UEs monitoring the second WUS resource. In some aspects, the one or more sub-group UEs can include a first set of sub-group UEs and a second set of sub-group UEs, as described in the examples in FIGs. 4-15. Also, the WUS for the first set of sub-group UEs in a first WUS resource can comprise at least one of a non-group specific WUS, a first common

WUS, or a first group WUS, wherein the WUS for the second set of sub-group UEs in a first WUS resource can comprise at least one of a second common WUS or a second group WUS, as described in the examples in FIGs. 4-15.

[00167] In some aspects, the non-group specific WUS can indicate for at least one UE without grouping capability to wake-up for the PO or for multiple UEs from different sub-groups within a first group to wake-up for the PO, wherein the first common WUS indicates for more than one first sub-group UE to wake-up for the PO without indicating for a UE without grouping capability to wake-up, wherein the first group WUS indicates for at least one UE from a single sub-group from the first group to wake-up for the PO, as described in the examples in FIGs. 4-15. Moreover, the second common WUS can indicate for multiple UEs from different sub-groups in a second group to wake-up for the PO, wherein the second group WUS indicates for at least one UE from a second, single sub-group within the second group to wake-up for the PO, as described in the examples in FIGs. 4-15. Also, the first set of sub-group UEs may be assigned a UE group identification based on a first weighting factor, and the second set of sub-group UEs are assigned a UE group identification based on a second weighting factor, as described in the examples in FIGs. 4-15. An amount of one or more sub-group UEs in a same WUS resource can be equal to an amount of one or more sub-group UEs in each of the WUS resources or independently configured per WUS resource, as described in the examples in FIGs. 4-15. Also, the amount of one or more sub-group UEs in each of the WUS resources can be equal to 1, 2, 4, or 8, as described in the examples in FIGs. 4-15. Further, an amount of UE groups per WUS resource can be the same or independently configured for WUS resources using a different time gap between the WUS resources and an associated paging occasion, as described in the examples in FIGs. 4-15. At least one of an amount of UE groups per WUS resource or a WUS resource pattern can be the same or independently configured for WUS resources with a time gap between the WUS resources and an associated paging occasion, as described in the examples in FIGs. 4-15.

[00168] In some aspects, the reception cycle can be at least one of a discontinuous reception (DRX) cycle or an extended DRX (eDRX) cycle, as described in the examples in FIGs. 4-15. Also, the WUS time resource can be at least one of a DRX WUS time resource or an eDRX WUS time resource, as described in the examples in FIGs. 4-15. Further, the base station can determine whether to transmit the WUS during the

DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and the paging occasion and an eDRX time gap between eDRX WUS resources and the paging occasion, as described in the examples in FIGs. 4-15.

[00169] FIG. 20 is a conceptual data flow diagram 2000 illustrating the data flow between different modules/means/components in an exemplary apparatus 2002. The apparatus may be a base station (e.g., base station 102, 180, 310, 1750). The apparatus can include a determination component 2006 that is configured to determine whether to transmit a WUS during a DRX WUS time resource or an eDRX WUS time resource. The determination component 2006 can also be configured to determine which of the two eDRX WUS time resources to use to transmit the WUS. The apparatus can also include a resource component 2008 that is configured to receive or transmit DRX and eDRX resources, e.g., via reception component 2004 or transmission component 2012. Additionally, the apparatus can include a configuration component 2010 that is configured to configure a UE for DRX or eDRX. The transmission component 2012 can also be configured to transmit the WUS during the DRX WUS time resource if the DRX WUS time resource does not overlap the eDRX WUS time resource. Further, the transmission component 2012 can be configured to transmit the WUS during the eDRX WUS time resource if the DRX WUS time resource overlaps the eDRX WUS time resource. Moreover, the transmission component 2012 can be configured to transmit an indication to the UE that indicates a correspondence between the group of DRX UEs and an eDRX UE group.

[00170] The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowcharts of FIG. 19. As such, each block in the aforementioned flowcharts of FIG. 19 may be performed by a component and the apparatus may include one or more of those components. The components may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[00171] FIG. 21 is a diagram 2100 illustrating an example of a hardware implementation for an apparatus 2002' employing a processing system 2114. The processing system 2114 may be implemented with a bus architecture, represented generally by the bus 2124.

The bus 2124 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 2114 and the overall design constraints. The bus 2124 links together various circuits including one or more processors and/or hardware components, represented by the processor 2104, the components 2004, 2006, 2008, 2010, 2012, and the computer-readable medium / memory 2106. The bus 2124 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[00172] The processing system 2114 may be coupled to a transceiver 2110. The transceiver 2110 is coupled to one or more antennas 2120. The transceiver 2110 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 2110 receives a signal from the one or more antennas 2120, extracts information from the received signal, and provides the extracted information to the processing system 2114, specifically the reception component 2004. In addition, the transceiver 2110 receives information from the processing system 2114, specifically the transmission component 2014, and based on the received information, generates a signal to be applied to the one or more antennas 2120. The processing system 2114 includes a processor 2104 coupled to a computer-readable medium / memory 2106. The processor 2104 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 2106. The software, when executed by the processor 2104, causes the processing system 2114 to perform the various functions described supra for any particular apparatus. The computer-readable medium / memory 2106 may also be used for storing data that is manipulated by the processor 2104 when executing software. The processing system 2114 further includes at least one of the components 2004, 2006, 2008, 2010, 2012. The components may be software components running in the processor 2104, resident/stored in the computer readable medium / memory 2106, one or more hardware components coupled to the processor 2104, or some combination thereof. The processing system 2114 may be a component of the base station 310 and may include the memory 376 and/or at least one of the TX processor 316, the RX processor 370, and the controller/processor 375.

[00173] In one configuration, the apparatus 2002/2002' for wireless communication includes means for grouping a plurality of UEs into a plurality of UE groups; means for

indicating an assignment to one of the UE groups to each of the UEs; means for balancing the amount of grouping UEs and non-grouping UEs in each of the UE groups; means for indicating a starting time offset of the WUS for the UE group; means for indicating a frequency offset for a starting resource block of the WUS based on an implicit indication or an explicit indication; and means for transmitting a WUS for a UE group to wake-up one or more UEs for a PO. The aforementioned means may be one or more of the aforementioned components of the apparatus 2002 and/or the processing system 2114 of the apparatus 2002' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 2114 may include the TX Processor 316, the RX Processor 370, and the controller/processor 375. As such, in one configuration, the aforementioned means may be the TX Processor 316, the RX Processor 370, and the controller/processor 375 configured to perform the functions recited by the aforementioned means.

[00174] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[00175] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term "some" refers to one or more. Combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" include any

combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

CLAIMS

1. A method of wireless communication at a User Equipment (UE), comprising:
receiving a configuration for a reception cycle; and
determining whether to monitor for a wake up signal (WUS) for a UE group including the UE during a WUS time resource of the reception cycle;
wherein the UE determines whether to monitor for the WUS during the WUS time resource based on a duration of a time gap between WUS resources and an associated paging occasion;
characterized in that
a gap period between the WUS time resource and the associated paging occasion changes between a first paging occasion and a second paging occasion.
2. The method of claim 1, further comprising:
defining a UE group identification assigned to one or more sub-group UEs in the UE group, wherein the one or more sub-group UEs include the UE; and
monitoring for the WUS for the UE group for the one or more sub-group UEs assigned to the UE group to wake-up for the associated paging occasion.
3. The method of claim 2, wherein a common WUS is configured to wake-up each of the one or more sub-group UEs monitoring a same WUS resource; or
wherein a common WUS for each of the one or more sub-group UEs in a same WUS resource is configured to be a group WUS or a non-group specific WUS.
4. The method of claim 2, wherein the one or more sub-group UEs include a first set of sub-group UEs and a second set of sub-group UEs;
wherein the WUS for the first set of sub-group UEs in a first WUS resource comprises at least one of a non-group specific WUS, a first common WUS, or a first group WUS, wherein the WUS for the second set of sub-group UEs in a second WUS resource comprises at least one of a second common WUS or a second group WUS.
5. The method of claim 4, wherein the non-group specific WUS indicates for at least one UE without grouping capability to wake-up for the associated PO or for multiple UEs from different sub-groups within a first group to wake-up for the associated PO,

the first common WUS indicates for more than one first sub-group UE to wake-up for the associated PO without indicating for a UE without grouping capability to wake-up, and

the first group WUS indicates for at least one UE from a single sub-group from the first group to wake-up for the associated PO; or

wherein the second common WUS indicates for multiple UEs from different sub-groups in a second group to wake-up for the associated PO, and

the second group WUS indicates for at least one UE from a second, single sub-group within the second group to wake-up for the associated PO; or

wherein the first set of sub-group UEs are assigned a first UE group identification based on a first weighting factor, and the second set of sub-group UEs are assigned a second UE group identification based on a second weighting factor.

6. The method of claim 2, wherein an amount of one or more sub-group UEs in a same WUS resource is equal to an amount of one or more sub-group UEs in each of the WUS resources or independently configured per WUS resource;

wherein the amount of one or more sub-group UEs in each of the WUS resources is equal to 1, 2, 4, or 8.

7. The method of claim 2, wherein an amount of UE groups per WUS resource is the same or independently configured for WUS resources using a different time gap between the WUS resources and the associated paging occasion; or

wherein at least one of the amount of UE groups per WUS resource or a WUS resource pattern is the same or independently configured for WUS resources with a time gap between the WUS resources and the associated paging occasion.

8. The method of claim 1, wherein the reception cycle is at least one of a discontinuous reception (DRX) cycle or an extended DRX (eDRX) cycle;

wherein the WUS time resource is at least one of a DRX WUS time resource or an eDRX WUS time resource;

wherein the UE determines whether to monitor for the WUS during the DRX WUS time resource or the eDRX WUS time resource based on a duration of a DRX time gap between DRX WUS resources and the associated paging occasion and an eDRX time gap between eDRX WUS resources and the associated paging occasion.

9. The method of claim 8, wherein a first DRX WUS time resource is configured for a group of UEs having a DRX configuration to monitor at least one of a group-specific DRX WUS or a non-group-specific DRX WUS, and

a second DRX WUS time resource is configured for a second group of UEs with a second configuration of DRX to monitor at least one of the group-specific DRX WUS or the non-group-specific DRX WUS; or

wherein a first eDRX WUS time resource is configured for a group of UEs having a first eDRX configuration to monitor at least one of a group-specific WUS or a non-group-specific WUS, and

a second eDRX WUS time resource is configured for a second group of UEs having a second eDRX configuration to monitor at least one of the group-specific WUS or the non-group-specific WUS.

10. The method of claim 8, further comprising:

monitoring for the WUS during the eDRX WUS time resource if the DRX WUS time resource overlaps the eDRX WUS time resource.

11. The method of claim 8, further comprising:

monitoring for the WUS during the DRX WUS time resource if the DRX WUS time resource does not overlap the eDRX WUS time resource.

12. The method of claim 10, wherein the eDRX WUS time resource is configured for a DRX UE to monitor at least one of a group-specific WUS or a non-group-specific WUS.

13. The method of claim 12, wherein an additional eDRX WUS time resource is configured for the DRX UE to monitor the at least one of the group-specific WUS or non-group-specific WUS.

14. The method of claim 10, wherein two eDRX WUS time resources are configured for a group of DRX UEs, the method further comprising:

determining which of the two eDRX WUS time resources to monitor for the WUS.

15. The method of claim 14, wherein the UE belongs to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, the method further comprising:

receiving an indication from a base station that indicates a correspondence between the group of DRX UEs and an eDRX UE group, wherein the UE determines to monitor for the WUS during the first time resources or the second time resources based on the eDRX UE group with the correspondence to the group of DRX UEs.

16. The method of claim 14, wherein the UE belongs to the group of DRX UEs having a configured DRX time resource that overlaps in time with the eDRX WUS time resource, and

wherein the UE determines to monitor for the WUS during a first time resource or a second time resources based on a predefined relationship between a DRX UE group of the UE and a corresponding eDRX UE group.

17. The method of claim 16, wherein the predefined relationship is based on a number of UE groups per eDRX WUS resource; or

wherein the predefined relationship is based on at least one of a maximum duration of a WUS, the DRX time gap, or the eDRX time gap; or

wherein the predefined relationship is based on a number of UEs, which is dependent on a configured weighting factor for at least one of a first eDRX UE group corresponding to the first time resource or a second eDRX UE group corresponding to the second time resource.

18. An apparatus for wireless communication at a User Equipment (UE), comprising a memory; and

at least one processor coupled to the memory and configured to perform the method of any of claims 1 to 17.