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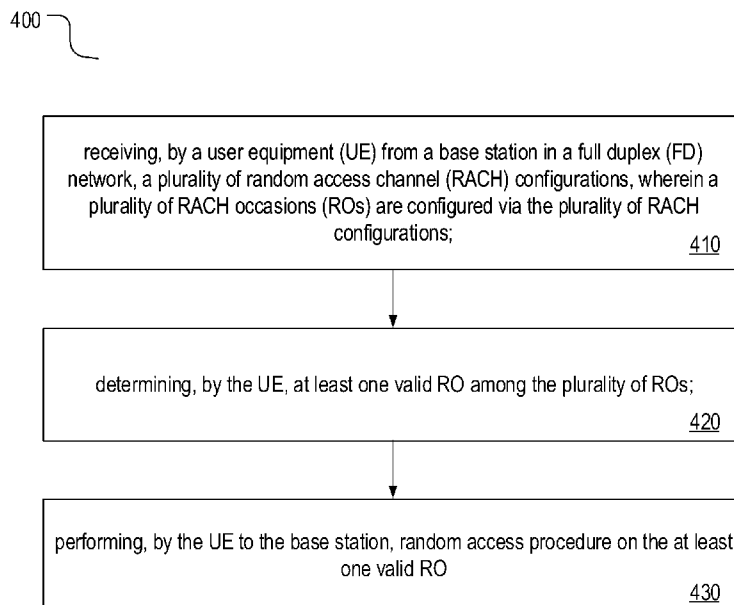


FIG. 4A

(57) Abstract: The present disclosure describes methods, system, and devices for random access (RA) in a full duplex network. One method includes receiving, by a user equipment (UE) from a base station in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations; determining at least one valid RO among the plurality of ROs; and performing, by the UE to the base station, random access procedure on the at least one valid RO. Another method includes sending, by a base station to a UE in a FD network, a plurality of RACH configurations, wherein a plurality of ROs are configured; determining at least one valid RO among the plurality of ROs; and receiving, by the base station from the UE, random access procedure on the at least one valid RO.



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METHODS, DEVICES, AND SYSTEMS FOR RANDOM ACCESS IN FULL DUPLEX NETWORK

TECHNICAL FIELD

The present disclosure is directed generally to wireless communications. Particularly, the present disclosure relates to methods, devices, and systems for random access (RA) in a full duplex network.

BACKGROUND

Wireless communication technologies are moving the world toward an increasingly connected and networked society. High-speed and low-latency wireless communications rely on efficient network resource management and allocation between user equipment and wireless access network nodes (including but not limited to base stations). A new generation network is expected to provide high speed, low latency and ultra-reliable communication capabilities and fulfill the requirements from different industries and users.

In some implementations, a subband full duplex (SBFD) technique may be implemented in a time division duplex (TDD) wireless communication system. A radio access network (RAN) node may allocate some frequency resources as an uplink (UL) subband for UL transmission inside a downlink (DL) carrier. The RAN node may schedule a user equipment (UE) to transmit UL reference signals or UL data transmission in the UL subband within the DL carrier. The implementation has the potential of increasing UL capacity and UL coverage and reducing the UL transmission latency. In some implementations, an uplink transmission during access procedure includes a physical random access channel (PRACH) signal, msg3 physical uplink shared channel (PUSCH), which may include initial transmission and retransmission, and/or hybrid automatic repeat request (HARQ) acknowledgement (HARQ-ACK) for msg4 physical downlink shared channel (PDSCH). However, there may be various problems/issues associated with such implementations. For example, one of the problems/issues may include how to configure and/or enable a UE to perform RACH on SBFD resources.

The present disclosure describes various embodiments for operation (e.g., random access (RA)) in a full duplex network, addressing at least one of the issues/problems discussed in the present disclosure, increasing efficiency of the SBFD technique, increasing performance of wireless communication, and/or improving the field of telecommunication.

SUMMARY

This document relates to methods, systems, and devices for wireless communication, and more specifically, for random access (RA) in a full duplex network. The various embodiments in the present disclosure may be beneficial to enhance efficiency of the SBFD technique, increase the overall transmission efficiency and speed, and/or boost performance of the wireless communication.

In one embodiment, the present disclosure describes a method for wireless communication, performed by a wireless communication device. The method includes receiving, by a user equipment (UE) from a base station in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations; determining, by the UE, at least one valid RO among the plurality of ROs; and performing, by the UE to the base station, random access procedure on the at least one valid RO.

In one embodiment, the present disclosure describes another method for wireless communication, performed by a wireless communication node. The method includes sending, by a base station to a user equipment (UE) in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations; determining, by the base station, at least one valid RO among the plurality of ROs; and receiving, by the base station from the UE, random access procedure on the at least one valid RO.

In some other embodiments, an apparatus for wireless communication may include a memory storing instructions and at least one processing circuitry in communication with the memory. When the at least one processing circuitry executes the instructions, the at least one processing circuitry is configured to carry out the above methods.

In some other embodiments, a device for wireless communication may include a memory storing instructions and at least one processing circuitry in communication with the memory. When the at least one processing circuitry executes the instructions, the at least one processing circuitry is configured to carry out the above methods.

In some other embodiments, a computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the above methods. The computer-readable medium may be a non-transitory computer-readable medium.

The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows an example of a wireless communication system include one wireless network node and one or more user equipment.

FIG. 1B shows one exemplary configuration pattern of an uplink (UL) subband in the present disclosure.

FIG. 1C shows another exemplary configuration pattern of a UL subband in the present disclosure.

FIG. 1D shows another exemplary configuration pattern of a UL subband in the present disclosure.

FIG. 1E shows another exemplary configuration pattern of a UL subband in the present disclosure.

FIG. 2 shows an example of a network node.

FIG. 3 shows an example of a user equipment.

FIG. 4A shows a flow diagram of a method for wireless communication.

FIG. 4B shows a flow diagram of another method for wireless communication.

FIG. 5A shows a schematic diagram of one exemplary embodiment in the present disclosure.

FIG. 5B shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 5C shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 5D shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 6A shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 6B shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 7 shows a schematic diagram of another exemplary embodiment in the present disclosure.

FIG. 8 shows a schematic diagram of another exemplary embodiment in the present disclosure.

DETAILED DESCRIPTION

The present disclosure will now be described in detail hereinafter with reference to the accompanied drawings, which form a part of the present disclosure, and which show, by way of illustration, specific examples of embodiments. Please note that the present disclosure may, however, be embodied in a variety of different forms and, therefore, the covered or claimed subject matter is intended to be construed as not being limited to any of the embodiments to be set forth below.

Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase “in one embodiment” or “in some embodiments” as used herein does not necessarily refer to the same embodiment and the phrase “in another embodiment” or “in other embodiments” as used herein does not necessarily refer to a different embodiment. The phrase “in one implementation” or “in some implementations” as used herein does not necessarily refer to the same implementation and

the phrase “in another implementation” or “in other implementations” as used herein does not necessarily refer to a different implementation. It is intended, for example, that claimed subject matter includes combinations of exemplary embodiments or implementations in whole or in part.

In general, terminology may be understood at least in part from usage in context. For example, terms, such as “and”, “or”, or “and/or,” as used herein may include a variety of meanings that may depend at least in part upon the context in which such terms are used. Typically, “or” if used to associate a list, such as A, B or C, is intended to mean A, B, and C, here used in the inclusive sense, as well as A, B or C, here used in the exclusive sense. In addition, the term “one or more” or “at least one” as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures or characteristics in a plural sense. Similarly, terms, such as “a”, “an”, or “the”, again, may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the term “based on” or “determined by” may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for existence of additional factors not necessarily expressly described, again, depending at least in part on context.

The present disclosure describes methods and devices for random access (RA) in a full duplex network.

The 5th Generation mobile communication technology (5G) or further 6th Generation mobile communication technology (6G) face more and more demands. Based on the current development trend, 5G systems are developing supports on features of enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC). Optionally, Artificial Intelligence/Machine Learning (AI/ML) can be used in 5G, 6G or further wireless communication system to improve the efficiency of communication system.

In some implementations, a subband full duplex (SBFD) technique may be implemented in a time division duplex (TDD) wireless communication system. A radio access network (RAN) node may allocate some frequency resources as a uplink (UL) subband for UL transmission inside downlink (DL) or flexible symbols. The RAN node may schedule a user

equipment (UE) to transmit UL reference signals or UL data transmission in the UL subband within the DL or flexible symbols. The implementation has the potential of increasing UL capacity and UL coverage and reducing the UL transmission latency.

In some implementations, to enhance the conventional TDD operation, simultaneous existence of downlink and uplink may be allowed, which may be also known as (a.k.a.) full duplex, or more specifically, subband non-overlapping full duplex (SBFD) or in-band full duplex (IBFD) at a base station (e.g., gNB) side within a conventional TDD band. For some symbols configured as semi-static downlink resource or flexible resource, a part of frequency resource may be configured as UL resource, e.g., UL subband/UL usable PRBs. The downlink or flexible symbols configured with UL subband can be called as full duplex symbols. For some symbols configured as semi-static uplink resource or flexible resource, a part of frequency resource may be configured as DL resource, e.g., DL subband/DL usable PRBs. The uplink or flexible symbols configured with DL subband may also be called as full duplex symbols. In either way, there may be both of uplink and downlink in different frequency domain resource of a same time domain resource. As an example shown in FIG. 1B, a frame structure may be configured as DDDFU, and some frequency domain resource of the part of downlink resource and/or flexible resource (e.g., slot 1~3) are configured as UL subband.

In some implementations, UL subband/UL usable PRBs in one or more full duplex symbols may be used for performing uplink transmission for a UE that has capability to identify and use of the UL subband. In some implementations, the UEs that do not have the capability to identify and use of the UL subband may only perform UL transmission by using a conventional UL symbol or flexible symbol.

In some implementations, an uplink transmission during access procedure includes a physical random access channel (PRACH) signal, msg3 physical uplink shared channel (PUSCH), which may include initial transmission and retransmission, and/or hybrid automatic repeat request (HARQ) acknowledgement (HARQ-ACK) for msg4 physical downlink shared channel (PDSCH). In a full-duplex scenario, full duplex symbols and conventional UL symbols or flexible symbols may extend total uplink transmission time domain resource, so that available random access resources can be increased or coverage of a random access signal can be enhanced.

In some implementations, there may be various problems/issues associated with utilizing SBFD resources. For example, one of the problems/issues may include how to configure and/or enable a UE to perform UL transmission on SBFD resources.

FIG. 1A shows a wireless communication system 100 including a wireless network node (or a wireless communication node) 118 and one or more user equipment (UE) (or a wireless communication device or terminal) 110. The wireless network node may include a network base station, which may be a nodeB (NB, e.g., a gNB, eNB, or xNB) in a mobile telecommunications context. Each of the UE may wirelessly communicate with the wireless network node via one or more radio channels 115 for downlink/uplink communication. For example, a first UE 110 may wirelessly communicate with a wireless network node 118 via a channel including a plurality of radio channels during a certain period of time. The network base station 118 may send high layer signaling to the UE 110. The high layer signaling may include configuration information for communication between the UE and the base station. In one implementation, the high layer signaling may include a radio resource control (RRC) message.

In the present disclosure, the description of various embodiments/implementations may focus on the level of slots (or the level of symbols in some other various embodiments and/or implementations), which is not a limitation to the embodiment(s)/implementation(s) and the described embodiments/implementations may be applicable to both the level of slots and the level of symbols.

For a non-limiting example, referring to FIG. 1B, a typical symbol/slot structure is DDDSU (151, 152, 153, 154, and 155). Here, D represents a downlink (DL) symbol/slot, U represents an uplink (UL) symbol/slot, and S or F represents a flexible symbol/slot, which can be used for DL or UL transmission. Obviously, UL slots are fewer and discontinuous, and these characteristics affect the performance of UL transmission. For example, due to no more consecutive or available UL slots, a large data volume of UL may not be supported, and/or more importantly, a timeliness and edge coverage of UL transmission may be relatively poor.

In some implementations, the full-duplex technology based on the UL subband may be implemented as subband full duplex (SBFD), wherein the configuration patterns of the UL subband may have various types.

FIG. 1B shows one type of the configuration pattern of the UL subband, wherein a UL subband 160 is configured only in DL symbols/slots. In some implementations, the UL subbands may be configured in some or all DL symbols/slots.

FIG. 1C shows another type of the configuration pattern of the UL subband, wherein a UL subband 170 is configured in DL symbols/slots and flexible symbols/slots. In some implementations, the UL subbands may be configured in some or all of the DL symbols/slots and some or all of the flexible symbols/slots.

FIG. 1D shows another type of the configuration pattern of the UL subband, wherein a UL subband 180 is configured in DL symbols/slots, flexible symbols/slots and UL symbols/slots. In some implementations, the UL subbands may be configured in some or all of the DL symbols/slots, some or all of the flexible symbols/slots, and some or all of the UL symbols/slots.

FIG. 1E shows another type of the configuration pattern of the UL subband, wherein a UL subband 190 is configured in DL symbols/slots and flexible symbols/slots. In some implementations, the UL subbands may be configured in some of the DL symbols/slots and some or all of the flexible symbols/slots.

In some implementations, a UL subband may be configured to contain at least one DL symbol/slot. In some implementations, a UL subband may provide continuous UL symbols/slots, which is beneficial to expand UL resources, to reduce the delay of UL transmission, for example, by reducing the time waiting for UL opportunities to improve performance in terms of UL capacity, delay, and/or coverage.

In the current technology, SBFD subbands (one UL subband or up to 2 DL subbands) are configured in DL symbols or F symbols. The frequency domain pattern of SBFD subbands includes "DU" and "DUD", where D represents a DL subband for DL reception, and U represents an UL subband for UL transmission. The DL and UL subbands in the frequency domain are continuous but with necessary frequency gaps.

In some implementations, DL reception is only allowed within the DL usable PRBs. The DL usable PRBs are determined as intersection between cell-specific DL subband(s) and active DL BWP in SBFD symbols. In some implementations, there may be the following cases when scheduling a PDSCH in DL subband(s) through DCI in the PDCCH of the UE-specific

search space (USS):

For one case (Case 1): all the PRBs of PDSCH are within the DL usable PRBs.

For another case (Case 2): some of the PRBs of PDSCH are within the DL usable PRBs in DL subband 1, while the rest of the PRBs are outside this DL subband 1 (for example, in UL subband), and none of the PRBs of this PDSCH are within the DL usable PRBs in DL subband 2.

For another case (Case 3): The first part of PRBs of PDSCH is within the DL usable PRBs in DL subband 1, the second part of PRBs of the PDSCH is within the DL usable PRBs in UL subband, and the remaining PRBs of the PDSCH are within the DL usable PRBs in DL subband 2.

In some implementations, with respect to Case 2 and/or Case 3, due to the fact that some PRBs of the PDSCH are in a UL subband (outside the DL subband 1 and DL subband 2), the following rules may be defined/determine the transport block (TB) size (TBS) for the PDSCH. The TBS of the TB corresponding to the PDSCH is determined based on the first PRBs, where the first PRBs are determined as the intersection between the PRBs allocated to the PDSCH and the DL usable PRBs. Furthermore, all encoded and modulated data of the TB are mapped to the first PRBs, and the data mapped to the first PRBs is transmitted (that is, the all data of the TB processed through encoding and modulation is transmitted in the first PRBs in the allocated PRBs). Based on this rule, a TBS that better matches with the actual effective PRBs is determined.

In some implementations, there may be potential issues with the above-mentioned rules for case where PDSCH is scheduled in DL subband(s) through DCI in PDCCH within a common search space (CSS). It should be noted that this PDSCH needs to be received by all types of UEs, including UEs that do not support SBFD subbands. For example, when one or more rules used for TBS mentioned above are applied to the TB corresponding to the common PDSCH, UEs that do not support SBFD subbands may not be able to decode the PDSCH because they do not understand this new rule.

In some implementations, to overcome at least one of the above-mentioned issues, the following rules are proposed for the PDSCH scheduled within the DL subband(s) by DCI in the PDCCH of CSS.

For one rule (Rule 1): When PDSCH is scheduled within the SBFD symbols through DCI in PDCCH in CSS, TBS of a TB corresponding to the PDSCH is determined based on all allocated PRBs (including PRBs outside of the DL usable PRBs). The encoded and modulated data of the TB is mapped to the all allocated PRBs, but only the data mapped to the first PRBs is transmitted (the data mapped to PRBs outside of the DL usable PRBs is not transmitted), wherein the first PRBs are determined as the intersection between the PRBs allocated to the PDSCH and the DL usable PRBs. In other words, a portion of the data of the TB processed through encoding and modulation is actually transmitted in the first PRBs. The remaining portion of the data of the TB processed through encoding and modulation is punctured and not transmitted.

For another rule (Rule 2): When PDSCH is scheduled within the SBFD symbols through DCI in PDCCH in CSS, TBS of a TB corresponding to the PDSCH is determined based on the first PRBs, wherein the first PRBs are determined as the intersection between the PRBs allocated to the PDSCH and the DL usable PRBs. The VRB-to-PRB mapping field in the DCI is always set to disable, or ignored by the UE, or always assumes that the prohibited interleaved VRB-to-PRB mapping is present. The encoded and modulated data of the TB is mapped and transmitted to the all allocated PRBs (other than PRBs outside the DL usable PRBs).

In some implementations with Rule 2, the base station ensures that all PRBs allocated to the PDSCH are within the above-mentioned DL usable PRBs. In other words, the UE expects all PRBs of the PDSCH to be within the above-mentioned DL usable PRBs. By setting the VRB-to-PRB mapping field to disabled, the interleave mapping of VRBs to PRBs is prohibited. Consequently, all PRBs allocated to the PDSCH can be easily ensured to fall within the aforementioned DL usable PRBs.

In the aforementioned case, when Rule 2 is adopted, the VRB-to-PRB mapping field in the DCI can be reinterpreted as content related to SBFD operations.

For one non-limiting example, the VRB-to-PRB mapping field in the DCI indicates that a UL transmission or DL reception with periodic or repetition is performed: 1) only in SBFD symbols, or 2) only in non-SBFD symbols. In other words, a parameter in DCI is used to indicate that a UL transmission or DL reception with periodic or repetition is performed: 1) only in SBFD symbols, or 2) only in non-SBFD symbols.

For another non-limiting example, the VRB-to-PRB mapping field in the DCI indicates that a UL transmission or DL reception with periodic or repetition is performed: 1) in the SBFD slot and non-SBFD slot (note: using only SBFD symbols or non-SBFD symbols in different slots), or 2) in the SBFD slot or non-SBFD slot. In other words, a parameter in DCI is used to indicate that a UL transmission or DL reception with periodic or repetition is performed: 1) in the SBFD slot and non-SBFD slot (note: using only SBFD symbols or non-SBFD symbols in different slots), or 2) in the SBFD slot or non-SBFD slot.

FIG. 2 shows an example of electronic device 200 to implement a network base station. The example electronic device 200 may include radio transmitting/receiving (Tx/Rx) circuitry 208 to transmit/receive communication with UEs and/or other base stations. The electronic device 200 may also include network interface circuitry 209 to communicate the base station with other base stations and/or a core network, e.g., optical or wireline interconnects, Ethernet, and/or other data transmission mediums/protocols. The electronic device 200 may optionally include an input/output (I/O) interface 206 to communicate with an operator or the like.

The electronic device 200 may also include system circuitry 204. System circuitry 204 may include processor(s) 221 and/or memory 222. Memory 222 may include an operating system 224, instructions 226, and parameters 228. Instructions 226 may be configured for the one or more of the processors 124 to perform the functions of the network node. The parameters 228 may include parameters to support execution of the instructions 226. For example, parameters may include network protocol settings, bandwidth parameters, radio frequency mapping assignments, and/or other parameters.

FIG. 3 shows an example of an electronic device to implement a terminal device 300 (for example, user equipment (UE)). The UE 300 may be a mobile device, for example, a smart phone or a mobile communication module disposed in a vehicle. The UE 300 may include communication interfaces 302, a system circuitry 304, an input/output interfaces (I/O) 306, a display circuitry 308, and a storage 309. The display circuitry may include a user interface 310. The system circuitry 304 may include any combination of hardware, software, firmware, or other logic/circuitry. The system circuitry 304 may be implemented, for example, with one or more systems on a chip (SoC), application specific integrated circuits (ASIC), discrete analog and digital circuits, and other circuitry. The system circuitry 304 may be a part of the implementation of any

desired functionality in the UE 300. In that regard, the system circuitry 304 may include logic that facilitates, as examples, decoding and playing music and video, e.g., MP3, MP4, MPEG, AVI, FLAC, AC3, or WAV decoding and playback; running applications; accepting user inputs; saving and retrieving application data; establishing, maintaining, and terminating cellular phone calls or data connections for, as one example, internet connectivity; establishing, maintaining, and terminating wireless network connections, Bluetooth connections, or other connections; and displaying relevant information on the user interface 310. The user interface 310 and the inputs/output (I/O) interfaces 306 may include a graphical user interface, touch sensitive display, haptic feedback or other haptic output, voice or facial recognition inputs, buttons, switches, speakers and other user interface elements. Additional examples of the I/O interfaces 306 may include microphones, video and still image cameras, temperature sensors, vibration sensors, rotation and orientation sensors, headset and microphone input / output jacks, Universal Serial Bus (USB) connectors, memory card slots, radiation sensors (e.g., IR sensors), and other types of inputs.

Referring to FIG. 3, the communication interfaces 302 may include a Radio Frequency (RF) transmit (Tx) and receive (Rx) circuitry 316 which handles transmission and reception of signals through one or more antennas 314. The communication interface 302 may include one or more transceivers. The transceivers may be wireless transceivers that include modulation / demodulation circuitry, digital to analog converters (DACs), shaping tables, analog to digital converters (ADCs), filters, waveform shapers, filters, pre-amplifiers, power amplifiers and/or other logic for transmitting and receiving through one or more antennas, or (for some devices) through a physical (e.g., wireline) medium. The transmitted and received signals may adhere to any of a diverse array of formats, protocols, modulations (e.g., QPSK, 16-QAM, 64-QAM, or 256-QAM), frequency channels, bit rates, and encodings. As one specific example, the communication interfaces 302 may include transceivers that support transmission and reception under the 2G, 3G, BT, WiFi, Universal Mobile Telecommunications System (UMTS), High Speed Packet Access (HSPA)+, 4G / Long Term Evolution (LTE), 5G standards, 6G, and/or any further generation standards. The techniques described below, however, are applicable to other wireless communications technologies whether arising from the 3rd Generation Partnership Project (3GPP), GSM Association, 3GPP2, IEEE, or other partnerships or standards bodies.

Referring to FIG. 3, the system circuitry 304 may include one or more processors 321 and memories 322. The memory 322 stores, for example, an operating system 324, instructions 326, and parameters 328. The processor 321 is configured to execute the instructions 326 to carry out desired functionality for the UE 300. The parameters 328 may provide and specify configuration and operating options for the instructions 326. The memory 322 may also store any BT, WiFi, 3G, 4G, 5G, 6G, or other data that the UE 300 may send, or has received, through the communication interfaces 302. In various implementations, a system power for the UE 300 may be supplied by a power storage device, such as a battery or a transformer.

The present disclosure describes various embodiment for random access (RA) in a full duplex network, which may be implemented, partly or totally, by one or more network base station and/or one or more user equipment described above in FIGs. 2-3. The various embodiments in the present disclosure may enable efficient wireless transmission in the telecommunication system, which may increase the resource utilization efficiency and/or boost wireless communication performance.

In various embodiments, methods are related to full-duplex RACH operation, and more specifically, are about rule definition of RO validation based on priority or time-frequency resource location and RA-RNTI calculation for overlapped ROs from different RACH configurations. In addition, transmission power and frequency domain resource determination methods are also provided for full duplex RACH mode. In some implementations, the understanding of RO validation between the terminal and the base station can be reached. RA-RNTI of different RO under multiple RACH configurations can be effectively distinguished, thereby avoiding the problem that the terminal cannot distinguish whether the detected RA-RNTI belongs to itself, and effectively saving uplink resources and improving system efficiency.

Referring to FIG. 4A, the present disclosure describes various embodiments of a method 400 for wireless communication. The method 400 may be performed by a wireless communication device (e.g., a user equipment). The method 400 may include a portion or all of the following: step 410, receiving, by a user equipment (UE) from a base station in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations; step 420, determining, by the UE, at least one valid RO among the plurality of ROs; and/or step 430,

performing, by the UE to the base station, random access procedure on the at least one valid RO. In some implementations, step 430 may include transmitting, by the UE to the base station, physical random access channel (PRACH) on the at least one valid RO.

Referring to FIG. 4B, the present disclosure describes various embodiments of a method 450 for wireless communication. The method 450 may be performed by a wireless communication node (e.g., a base station or a radio access network (RAN)). The method 450 may include a portion or all of the following: step 460, sending, by a base station to a user equipment (UE) in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations; step 470, determining, by the base station, at least one valid RO among the plurality of ROs; and/or step 480, receiving, by the base station from the UE, random access procedure on the at least one valid RO. In some implementations, step 480 may include receiving, by the base station from the UE, physical random access channel (PRACH) on the at least one valid RO.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the plurality of ROs overlap in the time domain or in both the time and frequency domains.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the determining the at least one valid RO among the plurality of ROs comprises: determining the at least one valid RO among the plurality of ROs based on at least one of the following: a priority of a RACH configuration corresponding to each of the plurality of ROs, a time domain position of each of the plurality of ROs, and/or a frequency domain location of each of the plurality of ROs.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, a RO in one RACH configuration with a higher priority is determined as a valid RO, and a RO in other RACH configuration with a lower priority is determined as an invalid RO; a RO with an earlier time domain starting position is determined as a valid RO, and a RO with a later time domain starting position is determined as an invalid RO; and/or a RO in one RACH configuration with a lower frequency domain location is determined as a valid RO, and a RO in other RACH configuration

with a higher frequency domain location is determined as an invalid RO. In some implementations, the RACH configuration with a lower frequency domain location represents that the lowest PRB of the lowest RO of this RACH configuration is lower than that of other RACH configurations. For example, the RACH configuration has a lowest frequency domain location.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the determining the at least one valid RO among the plurality of ROs comprises: in response to a first RO and a second RO being associated with a same synchronization signal physical broadcast channel (PBCH) block (SSB) or a same group of SSBs, determining the first RO and the second RO as valid ROs; and/or in response to the first RO and the second RO being associated with a different SSB or a different group of SSBs, determining only one of the first RO and the second RO as a valid RO.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, a first RO in a first RACH configuration overlaps with more than one ROs in a second RACH configuration.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the determining the at least one valid RO among the plurality of ROs comprises at least one of the following: in response to the first RACH configuration having a higher priority than the second RACH configuration: determining the first RO as a valid RO, determining, among the more than one ROs in the second RACH configuration, any RO that is associated with a same SSB or a same group of SSBs as the first RO, as a valid RO, and/or determining, among the more than one ROs in the second RACH configuration, any other RO that is associated with a different SSB or a different group of SSBs as the first RO, as an invalid RO.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the determining the at least one valid RO among the plurality of ROs comprises: in response to the second RACH configuration having a higher priority than the first RACH configuration, determining the first RO as an invalid RO; and/or in response to the second RACH configuration having a higher priority than the first RACH configuration and the more than one ROs and the first RO are associated with

different SSBs or different groups of SSBs, determining the first RO as an invalid RO.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the determining the at least one valid RO among the plurality of ROs further comprises: selecting a RACH configuration according to at least one of the following: a measurement threshold and a measurement result, and/or a priority of the RACH configuration; and/or wherein: the measurement threshold is configured by the base station, and/or the priority of the RACH configuration is configured by the base station.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the method may further include calculating a random access radio network temporary identifier (RA-RNTI) according to an index of a RACH configuration.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the RA-RNTI is calculated according to $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id + 14 \times 80 \times 8 \times 2 \times configuration_id$, wherein: s_id is an index of a first orthogonal frequency-division multiplexing (OFDM) symbol of a physical random access channel (PRACH) occasion, t_id is an index of a first slot of the PRACH occasion in a system frame, f_id is an index of the PRACH occasion in the frequency domain, $ul_carrier_id$ is an uplink (UL) carrier for random access preamble transmission, and $configuration_id$ is an index of a RACH configuration.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, a first RACH configuration is configured for both of a SBFD RACH mode and non-SBFD RACH mode, and a second RACH configuration is configured for the SBFD RACH mode; and/or the $configuration_id$ for the first RACH configuration is "0", and the $configuration_id$ for the second RACH configuration is "1".

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the RA-RNTI is calculated according to $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id$, wherein: s_id is an index of a first orthogonal frequency-division multiplexing (OFDM) symbol of

a physical random access channel (PRACH) occasion, t_id is an index of a first slot of the PRACH occasion in a system frame, f_id is a frequency index of the ROs across multiple RACH configurations, $ul_carrier_id$ is an uplink (UL) carrier for random access preamble transmission.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, in response to ROs from different RACH configurations having different time domain starting points, f_id of the ROs are defined as frequency index within one RACH configuration.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, in response to ROs from different RACH configurations having same time domain starting point, f_id of ROs in a first RACH configuration is smaller than f_id of ROs in a second RACH configuration; and/or the f_id of the ROs in the first RACH configuration are numbered from “0”, and the f_id of the ROs in the second RACH configuration are numbered from a maximum number of FDMed ROs in the first RACH configuration.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the method may further include determining a frequency domain of the at least one valid RO within SBFD symbols or downlink (DL) symbols configured with a UL subband by determining a lowest physical resource block (PRB) of a lowest valid RO as a lowest PRB of the UL subband or or UL usable PRBs.

In some implementations, optionally or additional to any one or any combinations of one or more implementations or embodiments in the present disclosure, the method may further include determining a frequency domain of the at least one valid RO within SBFD symbols or downlink (DL) symbols configured with a UL subband by determining a frequency domain reference point as a lowest PRB of the UL subband or UL usable PRBs and determining an offset value as “0” or a predefined value.

The present disclosure describes various exemplary embodiments for random access (RA) in a full duplex network in a wireless communication system, and the exemplary embodiments merely serve as examples and do not pose limitations. Any steps and/or operations in one same embodiment/implementation or more than one different embodiments/implementation in

the present disclosure may be combined or arranged in any amount or order, as desired. Two or more of the steps and/or operations may be performed in parallel. Embodiments and implementations in the disclosure may be used separately or combined in any order. Further, each of the methods (or embodiments) may be implemented by processing circuitry (e.g., one or more processors or one or more integrated circuits).

Embodiment Set I

The present disclosure describes various embodiments for methods about how to define/determine PRACH occasion validation rule. In various embodiments, the determining step may be defined/determined by a UE or a base station, or by both the UE and the base station.

In some implementations, multiple RACH configurations may be configured. ROs configured via different RACH configurations may overlap with each other in the time domain or in both of time and frequency domain. In some implementations, the priority of RACH configuration is predefined or indicated by the network side.

In some implementations, for the overlapped ROs, the ROs in one RACH configuration with a higher priority may be determined as a valid ROs, and ROs in other RACH configuration may be defined as invalid ROs.

In some implementations, the validation of the overlapped ROs from different RACH configurations may be determined according to at least one time domain position and frequency domain position of RO. For example, the RO with an earliest time domain starting point and/or a lowest frequency domain location may be determined as a valid RO.

For a non-limiting example as shown in FIG. 5A, a time domain position (e.g., starting point) is used for determining validation of overlapping ROs, such as, the validation rule is defined as that RO with an earlier starting point is determined as a valid RO. Then the RO1 is valid (i.e., the RO1 is determined as a valid RO), and the RO2 is invalid (i.e., the RO2 is determined as an invalid RO).

For another non-limiting example, the validation rule is defined as that a RO with a lower frequency domain location is determined as a valid RO. As shown in FIG. 5A, the RO2 is a valid RO, and the RO1 is invalid.

For another non-limiting example, the validation rule can be defined as that, RO with earliest starting point is selected: when there is only one RO, the RO with earliest starting point is determined as a valid RO; and/or when there are more than one ROs has the same earliest starting point, the RO of the more than one ROs has the lowest frequency domain location may be determined as a valid RO. As shown in FIG. 5B, a RO1, a RO2 and a RO3 are overlapping with each other, and the RO1 and the RO2 have a same earliest starting point. Then, the RO2 with the lowest frequency domain location is determined as a valid RO.

In some implementations, when one or more ROs (e.g., RO1) in one RACH configuration (e.g., configuration1) overlaps with another RO (e.g., RO2) in another RACH configuration (e.g., configuration2), both of RO1 and RO2 are defined/determined as valid RO when they are associated with the same SSB or the same group of SSBs. However, when they are associated with different SSBs or different groups of SSBs, only one of them may be defined/determined as valid RO. The validation may be defined according to the priority of RACH configuration. For example, when configuration1 has a higher priority than configuration 2, RO1 configured by configuration1 may be determined as a valid RO; and/or RO2 configured by configuration2 may be determined as an invalid RO. In some implementations, the RO with an earlier starting time domain point (e.g., starting symbol, or starting slot, etc) and/or a lowest frequency domain location will be determined as a valid RO.

In some embodiments, there are more than two ROs (e.g., RO1, RO2 and RO3) overlapping with each others, and the more than two ROs is configured by different RACH configurations (e.g., configuration1, configuration2, and configuration3) respectively. Then, only the RO configured by the RACH configuration with the highest priority is determined as valid RO; and/or other ROs are determined as invalid ROs. In some implementations, the RO with an earliest starting time domain point (e.g., starting symbol, or starting slot, etc.) and/or a lowest frequency domain location may be determined as valid RO.

In some implementations as shown in FIG. 5C, different PRACH formats (e.g., 0, 1, 2, 3, A1, A2, A3, B1, B4, A1/B1, A2/B2, A3/B3, C0, C2, etc) may have a different time domain length.

In some implementations as shown in FIG. 5D, a RO (e.g., RO1) under one RACH

configuration (configuration 1) may overlap multiple ROs (e.g., RO2, RO3) under another RACH configuration (Configuration 2) due to the different time domain lengths of the different PRACH formats. When the RACH configuration1 is defined/determined with a higher priority than RACH configuration2, RO1 configured by RACH configuration1 may be determined as valid RO. Among the multiple ROs configured in RACH configuration 2, the RO that is associated with the same SSB or SSB group of RO1 is defined/determined as valid RO, and the other ROs are defined/determined as invalid ROs. When the RACH configuration2 is defined/determined with a higher priority than RACH configuration1, the RO under configuration1 is defined/determined as an invalid RO.

In some implementations, when the RACH configuration2 is defined/determined with a higher priority than RACH configuration1, and when multiple ROs configured by RACH configuration2 and overlapping with one RO configured by RACH configuration1 are associated with different SSBs or SSB groups, RO under configuration1 is defined/determined as an invalid RO. For non-limiting examples, RO2 and RO3 are associated with different SSBs or different SSB groups, RO1 is defined as an invalid RO.

In some implementations, when the RACH configuration2 is defined/determined with a higher priority than RACH configuration1, and when multiple ROs configured by RACH configuration2 and overlapping with one RO configured by RACH configuration1 are associated with a same SSB or SSB group associated with the one RO configured by the RACH configuration1, the RO under configuration1 is defined/determined as a valid RO. For a non-limiting example, all of RO1, RO2 and RO3 are associated with a same SSB or a same SSB groups, RO1 is defined/determined as a valid RO. Otherwise, when RO2 and RO3 are associated with a same SSB or a same SSB group, and RO1 is associated with a different SSB or a different SSB group, the RO1 is defined/determined as an invalid RO.

In some implementations, multiple RACH configurations include but are not limited to: the first RACH configuration configured for both of the SBFD RACH mode and non-SBFD RACH mode, and/or the second RACH configuration configured for the SBFD RACH mode. When the first RACH configuration is used to configure the RACH resource for the non-SBFD RACH mode, the RACH resource is only valid on the uplink symbol or on the flexible symbol that meets certain conditions. In this case, ROs from the first RACH configuration and the second RACH

configuration may overlap in the time domain on the UL/flexible symbol. When the first RACH configuration is used to configure the RACH resource for the SBFD RACH mode, the RACH resource may also be valid within the DL symbol configured with the UL subband. In this case, ROs from the first RACH configuration and the second RACH configuration, respectively, may overlap in the time domain on any type of symbol.

In some implementations, when both the first RACH configuration and the second RACH configuration are configured, and a UE supports both of the first RACH configuration and the second RACH configuration, at least one of the following methods may be used for the UE for selecting one of the RACH configuration to initiate a RACH procedure.

In some implementations, a measurement (e.g., synchronization signal reference signal received power (SS-RSRP)) threshold is configured by a base station (e.g., a gNB), e.g., via a first system information block (SIB1), and a UE determines a RACH configuration according to the measurement threshold and a measurement result. For a non-limiting example, when the measurement result of the UE is higher than or no lower than the SS-RSRP threshold, one of RACH configuration (e.g., the first RACH configuration) may be selected. When the measurement result of the UE is lower than or no higher than the SS-RSRP threshold, one RACH configuration (e.g., the first RACH configuration) may be selected.

In some implementations, the priority of RACH configuration is predefined or configured by a base station (e.g., a gNB), and the RACH configuration with a higher priority may be selected/determined. The priority configuration can be either a high layer signaling (e.g., SIB1, or medium access control (MAC) layer signaling) or a physical layer signaling (e.g., information in downlink control information (DCI) format, in some example, the DCI format is used as a physical downlink control channel (PDCCH) order).

The various embodiments provide methods about how to define/determine PRACH occasion validation rule. More specifically, when terminals are provided with multiple RACH configurations, ROs from multiple RACH configurations may overlap in time or time-frequency domains, and various embodiments include methods for determining RO validation based on priority or time-frequency resource location. Through the above method, the understanding of RO effectiveness between the terminal and the base station can be reached, effectively saving uplink

resources and improving system efficiency.

Embodiment Set II

The present disclosure describes various embodiments for RA-RNTI calculation for overlapped ROs from different RACH configurations. RA-RNTI is a scramble sequence used for scrambling cyclic redundancy check (CRC) of Msg2 PDCCH. In some implementations, RA-RNTI is calculated according to the time and frequency domain position of the RO which is selected for transmitting the PRACH. More specifically, $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id$; The s_id is the index of the first OFDM symbol of the PRACH occasion ($0 \leq s_id < 14$). The t_id is the index of the first slot of the PRACH occasion in a system frame ($0 \leq t_id < 80$), where the subcarrier spacing to determine t_id is based on the value of μ as previously specified for $\mu = \{0, 1, 2, 3\}$, and for $\mu = \{5, 6\}$, the t_id is the index of the 120 kHz slot in a system frame that contains the PRACH occasion ($0 \leq t_id < 80$). The f_id is the index of the PRACH occasion in the frequency domain ($0 \leq f_id < 8$). For example, the f_id is frequency index within one RACH configuration, when 2 FDMed ROs are configured by one RACH configuration, the f_id is 0 for the lower frequency RO and 1 for the higher frequency RO. The $ul_carrier_id$ is the UL carrier used for Random Access Preamble transmission (0 for normal uplink (NUL) carrier, and 1 for supplementary uplink (SUL) carrier).

In some implementations, multiple RACH configurations are provided for one carrier (i.e., same $ul_carrier_id$). ROs configured by different RACH configurations may have a same time domain starting point, i.e., same s_id and t_id . Then, a same RA-RNTI value may be obtained for ROs configured by different RACH configurations. Thus, the UE may not be able to distinguish whether the detected Msg2 PDCCH is its own. For an example shown in FIG. 6A, RO1 is configured by RACH configuration 1, and RO2, RO3 are configured by RACH configuration2; and they have a same starting point. Therefore, for RO1 and RO2, same RA-RNTI value may be obtained according to the above calculation formula.

In some implementations, a new parameter, e.g., $configuration_id$, is introduced for the RA-RNTI calculation and ($0 \leq configuration_id < N_{max_configuration}$). Wherein, $N_{max_configuration}$ is the maximum number of RACH configuration can be configured simultaneously. More specifically, the following formula is used for calculating the RA-RNTI by

considering multiple RACH configurations. $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id + 14 \times 80 \times 8 \times 2 \times configuration_id$. In some implementations with a full duplex system, multiple RACH configurations include but are not limited to: the first RACH configuration configured for both of the SBFD RACH mode and non-SBFD RACH mode, and/or the second RACH configuration configured for the SBFD RACH mode. The $configuration_id$ of the first RACH configuration may be defined/determined as 0, the $configuration_id$ of the second RACH configuration may be defined/determined as 1. In this case, the $configuration_id$ can also be defined as $SBFD_id$, that is, when the RACH configuration is for SBFD RACH only, $SBFD_id$ is 1. When the RACH configuration can be used for non-SBFD RACH, $SBFD_id$ is 0.

In some implementations, f_id is defined as frequency index of ROs across multiple RACH configurations. For a non-limiting example as shown in FIG. 6B, in a certain order (for example, from low frequency to high frequency), ROs from different RACH configurations with the same starting point are numbered as the f_id of each RO (i.e., $f_id = 0$ for RO1, $f_id = 1$ for RO2, and $f_id = 2$ for RO3).

In some implementations, when ROs from different RACH configurations have different starting points (e.g., different s_id or different t_id), f_id for these ROs is defined/determined as frequency index within one RACH configuration.

In some implementations under a full duplex system, the f_id of ROs in the first RACH configuration is lower than the f_id of ROs in the second RACH configuration. In some implementations, f_id of ROs in the first RACH configuration is numbered from 0, and f_id of ROs in the second RACH configuration are numbered from maximum number of FDMed ROs in the first RACH configuration.

The various embodiments provide methods for RA-RNTI calculation for overlapped ROs from different RACH configuration. In order to distinguish RA-RNTI corresponding to RO from different RACH configurations, one method includes introducing an additional configuration index to calculate RA-RNTI; another method includes defining frequency domain numbering rules across RACH configurations. Through the above one or more methods, RA-RNTI of different RO under multiple RACH configurations can be effectively distinguished, thereby avoiding the problem that the terminal cannot distinguish whether the detected RA-RNTI belongs to itself.

Embodiment Set III

The present disclosure describes various embodiments for methods for determining the transmission power according to the RACH configuration under full duplex RACH mode.

In some implementations, the configured ROs for SBFD RACH mode can be located within different resource types, e.g., DL symbols with UL subband/UL usable PRBs (SBFD symbols) or UL symbols (non-SBFD symbols). One non-limiting example is shown in FIG. 7, wherein 710 refers to UL subband, and 720 refers to the configured ROs. The power control parameter of PRACH transmission can be configured separately.

In some implementations, the transmission power of PRACH transmission is determined according to the following formula, $P_{\text{PRACH}} = \min\{P_{\text{CMAX}}(i), \text{PREAMBLE_RECEIVED_TARGET_POWER} + \text{PL_c}\}$ [dBm]; wherein $P_{\text{CMAX}}(i)$ is the configured UE transmit power for subframe i of serving cell c , and PL_c is the downlink path loss estimate calculated in the UE for serving cell.

In some implementations, when the selected RO is within non-SBFD symbols, the value of $\text{PREAMBLE_RECEIVED_TARGET_POWER}$ is determined according to the following formula, $\text{PREAMBLE_RECEIVED_TARGET_POWER} = \text{preambleReceivedTargetPower} + \text{DELTA_PREAMBLE} + (\text{PREAMBLE_POWER_RAMPING_COUNTER} - 1) \times \text{PREAMBLE_POWER_RAMPING_STEP}$; wherein $\text{preambleReceivedTargetPower}$ is an RRC parameter used for configuring target power of preamble reception in RO located within non-SBFD symbols. DELTA_PREAMBLE is a power adjustment value defined for preamble transmission in RO located with non-SBFD symbols. $\text{PREAMBLE_POWER_RAMPING_COUNTER}$ is a counter for counting number of RACH attempt. In some implementations, the counter is shared for SBFD RACH (i.e., PRACH transmission in RO located within SBFD symbols) and non-SBFD RACH (i.e., PRACH transmission in RO located within non-SBFD symbols). $\text{PREAMBLE_POWER_RAMPING_STEP}$ is provided by RRC parameter powerRampingStep for indicating the ramping power between different RACH attempts for non-SBFD RACH.

In some implementations, when the selected RO is within non-SBFD symbols, the value of $\text{PREAMBLE_RECEIVED_TARGET_POWER}$ is determined according to the following formula,

$$\text{PREAMBLE_RECEIVED_TARGET_POWER} = \text{preambleReceivedTargetPower} +$$

$$DELTA_PREAMBLE + (PREAMBLE_POWER_RAMPING_COUNTER - 1) \times \\ PREAMBLE_POWER_RAMPING_STEP + POWER_OFFSET_RA.$$

When RACH type is switched from SBFD RACH to non-SBFD RACH, during this random access procedure: *POWER_OFFSET_RA* is set to

$$(PREAMBLE_POWER_RAMPING_COUNTER - 1) \times (PREAMBLE_POWER_RAMPING_STEP - PREAMBLE_POWER_RAMPING_STEP_SBFD).$$

Otherwise, *POWER_OFFSET_RA* is set to 0.

In some implementations, the value of *POWER_OFFSET_RA* is non-positive integer.

In some implementations, when the selected RO is within SBFD symbols, the value of *PREAMBLE_RECEIVED_TARGET_POWER* is determined according to the following formula,

$$PREAMBLE_RECEIVED_TARGET_POWER = preambleReceivedTargetPower_SBFD \\ + DELTA_PREAMBLE_SBFD + (PREAMBLE_POWER_RAMPING_COUNTER - 1) \times \\ PREAMBLE_POWER_RAMPING_STEP_SBFD + POWER_OFFSET_SBFD_RA;$$

wherein *preambleReceivedTargetPower_SBFD* is an RRC parameter used for configuring target power of preamble reception in RO located within SBFD symbols. *DELTA_PREAMBLE_SBFD* is a power adjustment value defined for preamble transmission in RO located with SBFD symbols. *PREAMBLE_POWER_RAMPING_COUNTER* is a counter for counting number of RACH attempt. In some implementations, the counter is shared for SBFD RACH and non-SBFD RACH. *PREAMBLE_POWER_RAMPING_STEP_SBFD* is provided by RRC parameter *powerRampingStep* for indicating the ramping power between different RACH attempts for SBFD RACH.

When a RACH type is switched from SBFD RACH to non-SBFD RACH, during this random access procedure: *POWER_OFFSET_SBFD_RA* is set to

$$(PREAMBLE_POWER_RAMPING_COUNTER - 1) \times \\ (PREAMBLE_POWER_RAMPING_STEP_SBFD - PREAMBLE_POWER_RAMPING_STEP).$$

In some implementations, the value of *POWER_OFFSET_SBFD_RA* is non-negative integer.

Otherwise, *POWER_OFFSET_SBFD_RA* is set to 0.

In some implementations, for multiple PRACH transmissions, when ROs located within

different resource types (i.e., non-SBFD symbols, SBFD symbols) are selected for the PRACH transmissions. The power control parameter of the multiple PRACH transmissions is determined according to the resource type of the first RO. Alternatively, the power control parameter used for the multiple PRACH transmissions is configured by the gNB.

The various embodiment provide methods for determining PRACH transmission power by considering different power control parameters are defined for different resource types, i.e., non-SBFD symbols or SBFD symbols. More specifically, the method for determining the transmission power for RACH reattempt and multiple PRACH transmissions across different resource types are provided. Through one or more of the above methods, the PRACH transmission power on different resources can be effectively determined.

Embodiment Set IV

The present disclosure describes various embodiments for methods for determining the frequency domain position of a configured RO in the UL subband/UL usable PRBs.

In some implementations as shown in FIG. 8, 810 refers to a UL subband, and 820 indicates a set of configured ROs. The UL subband/UL usable PRBs may be configured in the middle of the DL/UL BWPs in the frequency domain. The frequency domain location of ROs are configured by parameter 'Msg1-FrequencyStart' and 'Msg1-FDM'. More specifically, parameter 'Msg1-FrequencyStart' indicates an offset of lowest PRACH transmission occasion in frequency domain with respect to PRB 0. PRB 0 is the lowest PRB of the UL BWP. 'Msg1-FDM' indicates the number of PRACH transmission occasions (RO) FDMed in one time instance.

In some implementations, as the RO frequency domain location is configured based on the starting PRB of UL BWP, it is likely that the configured RO is not in the frequency range of UL subband/UL usable PRBs, and the configured RO may be determined as invalid RO.

In some implementations, in order to ensure that the frequency domain of RO can fall into the frequency range of the UL subband/UL usable PRBs, when determining the frequency domain of RO within SBFD symbols or DL symbols configured with UL subband, the RRC signaling 'Msg1-FrequencyStart' is omitted by the UE and the lowest PRB of the lowest RO can be defined/determined as the lowest PRB of UL subband/UL usable PRBs, that is, the frequency domain reference point can be defined/determined as the lowest PRB of UL subband/UL usable

PRBs, and configured value of 'Msg1-FrequencyStart' can be replaced by 0 by default. In other words, the RRC signaling 'Msg1-FrequencyStart' is omitted by the UE and maps RO from the start of UL subband/UL usable PRBs.

In some implementations, the frequency domain reference point can be defined/determined as the lowest PRB of the UL subband/UL usable PRBs, and the configured value of 'Msg1-FrequencyStart' can be replaced by N PRBs, which can be predefined in the specification.

In some other implementations, the starting PRB of RO in the SBFD symbols/DL symbols with UL subband configuration can be defined/determined by using a modulo operation. For example, the starting PRB of RO in the SBFD symbols/DL symbols with UL subband configuration can be determined according to the following formula,

$RB_{start}^{n^{th} RO} = \widetilde{RB}_{start}^{n^{th} RO} \bmod (N_{UL\ subband}^{size} - N_{RO}^{size})$. Wherein, $RB_{start}^{n^{th} RO}$ is starting PRB index of the n^{th} RO within the UL subband/UL usable PRBs, $\widetilde{RB}_{start}^{n^{th} RO}$ is starting PRB index of the n^{th} RO within the UL symbols/non-SBFD symbols, $N_{UL\ subband}^{size}$ is number of PRBs within the UL subband/UL usable PRBs, N_{RO}^{size} is number of PRBs of a RO.

In some implementations, according to the starting PRB index of each RO within the UL subband/UL usable PRBs calculated by the above formula, there may be frequency domain overlap between different ROs. At this time, the starting PRB index of each RO can be calculated in a certain order. When the PRBs occupied by a certain RO overlaps with the PRBs occupied by the previously calculated RO in the frequency domain, the certain RO is defined/determined as an invalid RO.

For non-limiting examples, when the bandwidth of the UL BWP is 100MHz (i.e., 273 PRBs with 30kHz), the bandwidth of the UL subband/UL usable PRBs is 20MHz (i.e., 51 PRBs with 30kHz). For a short PRACH format, e.g., B4, with 30kHz, a RO occupies 12 PRBs. Assuming msg1-FDM = 8 and msg1-FrequencyStart = 5 PRBs.

Then, the starting PRB indexes of 8 ROs in UL slot may be PRB5, PRB17, PRB29, PRB41, PRB53, PRB65, PRB77, and PRB89, respectively; and corresponding starting PRB indexes in UL subband/UL usable PRBs are: PRB5, PRB17, PRB29, PRB2, PRB14, PRB26,

PRB38, and PRB11; The last five ROs may overlap with at least one of the first three ROs, and they (last five ROs) are defined/determined as invalid ROs.

In some other implementations, after calculating the starting PRB index of all ROs in UL subband according to the above formula, the lowest PRB index of all ROs is taken as the starting PRB index of the lowest RO, and the frequency domain position of other FDMed ROs are defined/determined according to the ascending order of frequency domain. RO that is outside the UL subband/UL usable PRBs in frequency domain or overlapping with previous RO in frequency domain is considered invalid RO. Taking the configuration assumed above as an example, PRB2 is the lowest PRB index of all ROs. Then, ROs with starting PRB index 2, 14, 26, 38 may be defined/determined as valid ROs in the UL subband/UL usable PRBs.

In some implementations, the frequency domain reference point may be defined/determined as the lowest PRB of the UL subband/UL usable PRBs, and the configured value of 'Msg1-FrequencyStart' can be scaled based on a certain ratio. The scaled value is used to determine the frequency domain location of RO in the UL subband/UL usable PRBs. In some examples, the certain ratio is defined/determined according to the bandwidth of the UL subband/UL usable PRBs and the bandwidth of the UL BWP. Then, the starting PRB of lowest RO is defined/determined according to $F_{Offset_UL_subband} = \left\lceil F_{Offset_UL_BWP} \times \left(\frac{BW_{UL_subband}}{BW_{UL_BWP}} \right) \right\rceil$ or, $F_{Offset_UL_subband} = \left\lfloor F_{Offset_UL_BWP} \times \left(\frac{BW_{UL_subband}}{BW_{UL_BWP}} \right) \right\rfloor$. Wherein, $F_{Offset_UL_BWP}$ is configured value of 'Msg1-FrequencyStart'. $F_{Offset_UL_subband}$ is a scaled value of 'Msg1-FrequencyStart' for determining the starting PRB of the lowest RO.

Embodiment Set V

In some implementations, the base station may schedule at least one physical uplink shared channel (PUSCH) or physical uplink control channel (PUCCH) for the UE. The at least one PUSCH or PUCCH may be scheduled by at least one downlink control information (DCI), a radio resource control (RRC) signaling or a RAR UL grant transmitted from the base station to the UE. The at least one PUSCH may include one or more PUSCH or one or more PUSCH repetitions. In some implementations, the at least one DCI may include one or more DCIs. The UE may transmit the at least one PUSCH or PUCCH to the base station. Within a PUSCH resource, there may be one or more reserved (or muted) resources. The reserved resource may include one or more

reserved resource elements (RE) or reserved resource blocks (RBs). The reserved resource may not be available for the PUSCH transmission. The modulation symbol(s) of the PUSCH may not be able to be mapped to the reserved resource(s). That is, the modulation symbol(s) of the PUSCH may be able to be mapped to a RE or a RB when the RE or the RB is not a reserved RE or RB. When mapping the modulation symbol(s) to the resource of the PUSCH, the reserved resource(s) may be skipped. The size of the output sequence after rate matching may be determined based on the available resource of the PUSCH (e.g., the PUSCH resource not including the reserved resource). The reserved resource can be used to obtain the exact interference and therefore improve the PUSCH decoding or demodulation performance by removing the interference. How to determine or configure the reserved resource can be achieved by the following one or more methods.

In some implementations, the reserved resource may be on an OFDM symbol in the time domain. Such symbol is referred to as reserved symbol. A reserved symbol pattern may include one or more reserved symbols. The different reserved symbol pattern may have the different number of reserved symbols or have the different reserved symbol indexes. The reserved resource may be on the one or more OFDM symbols in the PUSCH or in one or more slots. In addition or alternatively, the reserved symbol pattern may include the frequency configuration of the muting resource.

In a first method, the OFDM symbol of the reserved resource may be determined (or defined) with reference to the slot (e.g., the slot boundary, or the first symbol of the slot). The reserved resource may be on the one or more fixed symbols of the one or more slots. That is, the OFDM symbol of the reserved resource in one or more slots may be fixed regardless of the time domain resource allocation of the PUSCH. When a PUSCH resource includes such symbol, there may be reserved resource in the PUSCH. When a PUSCH resource does not include such symbol, there may not be reserved resource in the PUSCH. For non-limiting examples, in some implementations, a slot may include 14 OFDM symbols, denoted by symbol #0-#13, respectively. The reserved resource may include two OFDM symbols. The reserved resource may be always in symbol #1 and symbol #7. In a first case, the time domain resource of the PUSCH include symbol #0-#6. There may be only one reserved symbol in the PUSCH. The reserved resource may be in the second symbol of the PUSCH. In a second case, the time domain resource of the PUSCH include

symbol #0-#12. There may be two reserved symbols in the PUSCH. The reserved resource may be in the second symbol and the eighth symbol of the PUSCH. In a third case, the time domain resource of the PUSCH include symbol #7-#13. There may be only one reserved symbol in the PUSCH. The reserved resource may be in the first symbol of the PUSCH. In some implementations, the first method may be only applied to the PUSCH with a first PUSCH mapping type and/or a second PUSCH mapping type. In the first PUSCH mapping type, the PUSCH resource may start from the first OFDM symbol of a slot. The demodulation reference signal (DMRS) may not be on the first OFDM symbol of the PUSCH. In the second PUSCH mapping type, the PUSCH resource may start from any one of the OFDM symbols of the slot. The DMRS may be on the first OFDM symbol of a PUSCH.

In a second method, the OFDM symbol of the reserved resource may be determined (or defined) with reference to (or according to) a reference symbol. In some implementations, the reference symbol may be one symbol of the PUSCH (e.g., the first symbol of the PUSCH, or the last symbol of the PUSCH). The position of the reserved symbol within the PUSCH may be fixed. For non-limiting examples, the reserved symbol may be the first symbol, the second symbol, and/or the third symbol of the PUSCH, and so on. In addition or alternatively, the reserved symbol may be the last symbol, the second last symbol, and/or the third last symbol of the PUSCH, and so on. To illustrate as a non-limiting example, the reserved symbol may be the second symbol of the PUSCH. When the time domain resource of the PUSCH includes symbol #0-#6, the reserved symbol may be symbol #1. When the time domain resource of the PUSCH includes symbol #7-#13, the reserved symbol may be symbol #8. In some implementations, the reference symbol may be the DMRS symbol of the PUSCH (e.g., the first DMRS symbol of the PUSCH). The offset between the reserved symbol and the DMRS symbol of the PUSCH may be fixed. For non-limiting examples, the reserved symbol may be the first symbol, the second symbol, and/or the third symbol before or after the DMRS symbol of the PUSCH, and so on. In addition or alternatively, in some implementations, the reserved symbol may be determined according to the uplink control information (UCI) symbol. The UCI symbol is the symbol to which the UCI is mapped. The reserved symbol may not be the UCI symbol or the UCI symbol to which the 1 bit or 2 bits Hybrid automatic repeat request acknowledgement (HARQ-ACK) information are mapped. When the reserved symbol determined in accordance with the various implementations described herein is

the UCI symbol or the UCI symbol to which the 1 bit or 2 bits HARQ-ACK information are mapped, the reserved symbol is the one after or before the UCI symbol. In some implementations, the second method may be only applied to the PUSCH with the first PUSCH mapping type or the second PUSCH mapping type.

In a third method, the reserved symbol may be configured by the base station. The base station may configure the reserved symbol by a bitmap. The bitmap may be included in the RRC signaling, a medium access control (MAC) control element (CE), or a DCI. The length of the bitmap may be equal to the number of symbols within a slot or within a PUSCH. Each bit may correspond to one symbol. The first bit may correspond to the first symbol of the slot or the PUSCH, the second bit may correspond to the second symbol of the slot or the PUSCH, and so on. A first value of a bit (e.g., '0') may indicate that the corresponding symbol is not reserved symbol. A second value of a bit (e.g., '1') may indicate that the corresponding symbol is reserved symbol. In some implementations, the base station may indicate the offset between the reserved symbol and the reference symbol. The offset may be indicated by a RRC signaling, a MAC CE, or a DCI. In addition or alternatively, the reference symbol may include the first symbol of the slot, the first symbol of the PUSCH, the first DMRS symbol, or a given symbol. In some implementations, the reference symbol may be the first symbol of the slot for the PUSCH with the first PUSCH mapping type. The reference symbol may be the first symbol of the PUSCH for the PUSCH with the second PUSCH mapping type. In some implementations, there may be one DMRS in the PUSCH. The reference symbol may be the DMRS symbol. There may be two or more DMRS in the PUSCH. The reference symbol for the first and second reserved symbol may be the first and second DMRS symbol, respectively. There may be more than two DMRS in the PUSCH. The reference symbol for the first and second reserved symbol may be the first and third DMRS symbol, respectively. The base station may indicate the offset for each reserved symbol. In addition or alternatively, the base station may indicate a common offset for each reserved symbol. The offset value may be '-N', '0', or 'N', etc, where N may be any integer. The offset value '0' means that the reference symbol is the reserved symbol. The offset value '-N' and 'N' mean that the N-th symbol before and after the reference symbol is the reserved symbol, respectively. For non-limiting examples, the reference symbol is symbol #8. The offset value '-N' means that the symbol #(8-N) is the reserved symbol. The offset value 'N' means that the symbol #(8+N) is the reserved symbol. In some embodiments,

the indicated reserved symbol may not be included in the PUSCH. It means that there is no reserved symbol within the PUSCH. The given symbol may be configured by the base station or specified by the protocol according to which the communication nodes of the wireless communication system communicate and/or operate.

In some implementations, the number of reserved symbols may depend on the number of DMRS or the length of the PUSCH. The length of the PUSCH may be the number of the symbols of the PUSCH (e.g., two symbols, three symbols, etc). When the number of DMRS or the number of symbols of the PUSCH is greater than or equal to a given threshold, there may be two reserved symbols. When the number of DMRS or the number of symbols of the PUSCH is less than or equal to the given threshold, there may be one reserved symbol. The given threshold may be configured by the base station or specified by the protocol according to which the communication nodes of the wireless communication system communicate and/or operate. For non-limiting examples, the given threshold may be one DMRS or 7 symbols. The UE may determine the number of reserved symbols based on the number of DMRS or the length of the PUSCH.

In some implementations, the number of reserved symbols may depend on the frequency hopping method. The frequency hopping method may include no frequency hopping (e.g., the frequency hopping is disabled) or frequency hopping (e.g., the frequency hopping is enabled). The reserved symbol pattern may include a first number of reserved symbols when frequency hopping is disabled. The reserved symbol pattern may include a second number of reserved symbols when frequency hopping is enabled. The first number may be one. The second number may be two. The UE may determine the number of reserved symbols based on the frequency hopping method.

In some implementations, the base station may configure one or more reserved symbol patterns for the UE. Each of the one or more reserved symbol patterns may correspond to a frequency hopping method, a PUSCH length, a PUSCH time domain resource allocation (TDRA), a DMRS type, a number of DMRS, an antenna port configuration, a phase-tracking reference signal (PTRS) configuration, a PUSCH mapping type, a DMRS position, or any combination thereof. It is understood that more than one reserved symbol patterns may correspond a frequency hopping method, a PUSCH length, a PUSCH TDRA, a DMRS type, a number of DMRS, a PUSCH

mapping type, a DMRS position, or any combination thereof. The PUSCH TDRA may include the symbols/slots allocated for the PUSCH (e.g., the starting symbol/slot and/or the number of symbols/slots of the PUSCH). The DMRS type may include at least one of a first DMRS type, or a second DMRS type, etc. The antenna port configuration may include at least the antenna port number used for the PUSCH or the DMRS of the PUSCH. The PTRS configuration may include at least one of the time domain resource of the PTRS, or the frequency domain resource of the PTRS. The PUSCH mapping type may include at least one of the first PUSCH mapping type or the second PUSCH mapping type. The DMRS position may include at least the OFDM symbol of the DMRS within the PUSCH or slot. The base station may configure the correspondence for each of the one or more reserved symbol patterns. For a PUSCH transmission, the frequency hopping method, the PUSCH length, the PUSCH TDRA, the DMRS type, the number of DMRS, the antenna port configuration, the PUSCH mapping type, the DMRS position, or the PTRS configuration may be indicated by the DCI or RRC signaling. For non-limiting examples, the frequency hopping method and the PUSCH TDRA may be indicated by the frequency hopping field and the TDRA field in the DCI, respectively. The UE may determine the reserved symbol pattern for the PUSCH transmission according to the frequency hopping method of the PUSCH transmission, the PUSCH length of the PUSCH transmission, the TDRA of the PUSCH transmission, the DMRS type of the PUSCH transmission, the number of DMRS of the PUSCH transmission, the antenna port configuration of the PUSCH transmission, the PTRS configuration of the PUSCH transmission, the PUSCH mapping type of the PUSCH transmission, the DMRS position of the PUSCH transmission, or any combination thereof. The reserved symbol pattern corresponding to the frequency hopping method of the PUSCH transmission, the PUSCH length of the PUSCH transmission, the TDRA of the PUSCH transmission, the DMRS type of the PUSCH transmission, the number of DMRS of the PUSCH transmission, the antenna port configuration of the PUSCH transmission, the PTRS configuration of the PUSCH transmission, the PUSCH mapping type of the PUSCH transmission, the DMRS position of the PUSCH transmission, or any combination thereof, may be determined for the PUSCH transmission. To illustrate by taking PUSCH length and the frequency hopping as a non-limiting example, the base station may configure a first, a second, a third and a fourth reserved symbol pattern for the PUSCH with 8 symbols and no frequency hopping, PUSCH with 8 symbols and frequency hopping, PUSCH with 11 symbols and no frequency hopping, and PUSCH with 11 symbols and frequency hopping, respectively. The DCI or RRC signaling may schedule a PUSCH

transmission. Based on the scheduling, when the PUSCH transmission has 8 symbols and frequency hopping is disabled for the PUSCH, the first reserved symbol pattern may be determined for the PUSCH. It means the PUSCH may have the first reserved symbol pattern. When the PUSCH transmission has 11 symbols and frequency hopping is enabled for the PUSCH, the fourth reserved symbol pattern may be determined for the PUSCH. It means that the PUSCH may have the fourth reserved symbol pattern.

In a fourth method, the base station may configure at least one TDRA table for the UE. The TDRA table may include one or more rows. Each row may include at least one of a offset between the DCI and the PUSCH, a PUSCH TDRA, a PUSCH mapping type, a number of PUSCH repetitions, or one or more reserved symbol patterns. The DCI may indicate one of the one or more rows of TDRA table. For non-limiting examples, the DCI may indicate the row index of the TDRA table. The one or more reserved symbol patterns of the indicated row may be indicated for the PUSCH. In other words, the one or more reserved symbol patterns may be indicated by the row index. In case more than one reserved symbols patterns are indicated, the UE may determine the reserved symbol pattern according to at least one of the frequency hopping method, the PUSCH length, the PUSCH TDRA, the DMRS type, the number of DMRS, the antenna port configuration, the PUSCH mapping type, the DMRS position, or the PTRS configuration in accordance with the various implementations described herein.

In a fifth method, the base station may indicate the reserved symbols by DCI. In some implementations, the DCI may include the bitmap for indicating the reserved symbols. In some implementations, the DCI may indicate the index or the position of the reserved symbol. the DCI may indicate the index or the position for each reserved symbol. For non-limiting examples, 4 bits may be used to indicate the reserved symbol index (e.g., #0-#13). A reserved value of the 4 bits (e.g., '1111') may indicate there is no reserved symbol. In some implementations, the base station may configure one or more candidate positions or candidate indexes of the reserved symbol for the UE. The DCI may indicate the index or the position of the reserved symbol from the one or more candidate positions or candidate indexes. For non-limiting examples, the configured candidate index of reserved symbol may include {#0, #1, #2, #4}. The DCI may include 2 bits for indicating the reserved symbol index from {#0, #1, #2, #4}. In some implementations, the base station may configure one or more reserved symbol patterns for the UE. The DCI may indicate reserved symbol

pattern from the one or more reserved symbol patterns. For non-limiting examples, the DCI may indicate the index or the position of the reserved symbol pattern. The position of the reserved symbol pattern may include a first pattern, or a second pattern, and so on. In case more than one reserved symbols patterns are indicated by the DCI, the UE may determine the reserved symbol pattern according to at least one of the frequency hopping method, the PUSCH length, the PUSCH TDRA, the DMRS type, the number of DMRS, the antenna port configuration, the PUSCH mapping type, the DMRS position, or the PTRS configuration in accordance with the the various implementations described herein.

In addition or alternatively, in some implementations, in the frequency domain, the reserved resource may occupy one or more RE within the PUSCH resource. The reserved resource may include odd RE(s) or even RE(s) within the PUSCH resource. The base station may configure the frequency configuration of the muting resource (e.g., the reserved resource include the odd RE(s) or even RE(s) within the PUSCH resource) by RRC signaling, MAC CE or DCI.

In addition or alternatively, the method used for PUSCH can be used for PUCCH (i.e., “PUSCH” may be replaced with “PUCCH”).

The various embodiments describe methods for determining the frequency domain position of a configured RO in the UL subband/UL usable PRBs. According to at least one of the above methods, a UE can effectively determine the frequency domain resource of a configured RO under the full duplex RACH mode. The overall access efficiency is improved.

The present disclosure describes various embodiments on full-duplex RACH operation. More specifically, the methods are about rule definition of RO validation based on priority or time-frequency resource location and RA-RNTI calculation for overlapped ROs from different RACH configurations. In addition, transmission power and frequency domain resource determination methods are also provided for full duplex RACH mode. According to at least one of the embodiments in the present disclosure, the understanding of RO validation between the terminal and the base station can be reached. RA-RNTI of different RO under multiple RACH configurations can be effectively distinguished, thereby avoiding the problem that the terminal cannot distinguish whether the detected RA-RNTI belongs to itself, and effectively saving uplink resources and improving system efficiency.

The present disclosure describes methods, apparatus, and computer-readable medium for random access (RA) in a full duplex network. The present disclosure addressed the issues with RA in a full duplex implementation in a wireless communication system. The methods, devices, and computer-readable medium described in the present disclosure may facilitate the performance of SBFD technique in wireless communication, thus improving efficiency and overall performance. The methods, devices, and computer-readable medium described in the present disclosure may improve the overall efficiency of the wireless communication systems.

In some other embodiments, a computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the above methods. The computer-readable medium may be referred to as non-transitory computer-readable media (CRM) that stores data for extended periods such as a flash drive or compact disk (CD), or for short periods in the presence of power such as a memory device or random access memory (RAM). In some embodiments, computer-readable instructions may be included in a software, which is embodied in one or more tangible, non-transitory, computer-readable media. Such non-transitory computer-readable media can be media associated with user-accessible mass storage as well as certain short-duration storage that are of non-transitory nature, such as internal mass storage or ROM. The software implementing various embodiments of the present disclosure can be stored in such devices and executed by a processor (or processing circuitry). A computer-readable medium can include one or more memory devices or chips, according to particular needs. The software can cause the processor (including CPU, GPU, FPGA, and the like) to execute particular processes or particular parts of particular processes described herein, including defining data structures stored in RAM and modifying such data structures according to the processes defined by the software. In various embodiments in the present disclosure, the term “processor” may mean one processor that performs the defined functions, steps, or operations or a plurality of processors that collectively perform defined functions, steps, or operations, such that the execution of the individual defined functions may be divided amongst such plurality of processors.

Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present solution should be or are included in any single implementation thereof. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic

described in connection with an embodiment is included in at least one embodiment of the present solution. Thus, discussions of the features and advantages, and similar language, throughout the specification may, but do not necessarily, refer to the same embodiment.

Furthermore, the described features, advantages and characteristics of the present solution may be combined in any suitable manner in one or more embodiments, for non-limiting examples, a portion from one or more embodiment may be combined with another portion of other embodiments. One of ordinary skill in the relevant art will recognize, in light of the description herein, that the present solution can be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the present solution.

C L A I M S

1. A method for wireless communication, comprising:

receiving, by a user equipment (UE) from a base station in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations;

determining, by the UE, at least one valid RO among the plurality of ROs; and

transmitting, by the UE to the base station, physical random access channel (PRACH) on the at least one valid RO.

2. A method for wireless communication, comprising:

sending, by a base station to a user equipment (UE) in a full duplex (FD) network, a plurality of random access channel (RACH) configurations, wherein a plurality of RACH occasions (ROs) are configured via the plurality of RACH configurations;

determining, by the base station, at least one valid RO among the plurality of ROs; and

receiving, by the base station from the UE, physical random access channel (PRACH) on the at least one valid RO.

3. The method according to any of claims 1 to 2, wherein:

the plurality of ROs overlap in the time domain or in both the time and frequency domains.

4. The method according to any of claims 1 to 3, wherein the determining the at least one valid RO among the plurality of ROs comprises:

determining the at least one valid RO among the plurality of ROs based on at least one of the following:

a priority of a RACH configuration corresponding to each of the plurality of ROs,
a time domain position of each of the plurality of ROs, or
a frequency domain location of each of the plurality of ROs.

5. The method according to claim 4, wherein:

a RO in one RACH configuration with a higher priority is determined as a valid RO, and
a RO in other RACH configuration with a lower priority is determined as an invalid RO;

a RO with an earlier time domain starting position is determined as a valid RO, and a RO
with a later time domain starting position is determined as an invalid RO; or

a RO in one RACH configuration with a lower frequency domain location is determined
as a valid RO, and a RO in other RACH configuration with a higher frequency domain
location is determined as an invalid RO.

6. The method according to any of claims 1 to 3, wherein the determining the at least one
valid RO among the plurality of ROs comprises:

in response to a first RO and a second RO being associated with a same synchronization
signal physical broadcast channel (PBCH) block (SSB) or a same group of SSBs, determining
the first RO and the second RO as valid ROs; and

in response to the first RO and the second RO being associated with a different SSB or a
different group of SSBs, determining only one of the first RO and the second RO as a valid
RO.

7. The method according to any of claims 1 to 3, wherein:

a first RO in a first RACH configuration overlaps with more than one ROs in a second
RACH configuration.

8. The method according to claim 7, wherein the determining the at least one valid RO among the plurality of ROs comprises at least one of the following:

in response to the first RACH configuration having a higher priority than the second RACH configuration:

determining the first RO as a valid RO,

determining, among the more than one ROs in the second RACH configuration, any RO that is associated with a same SSB or a same group of SSBs as the first RO, as a valid RO, or

determining, among the more than one ROs in the second RACH configuration, any other RO that is associated with a different SSB or a different group of SSBs as the first RO, as an invalid RO.

9. The method according to claim 7, wherein the determining the at least one valid RO among the plurality of ROs comprises:

in response to the second RACH configuration having a higher priority than the first RACH configuration, determining the first RO as an invalid RO; or

in response to the second RACH configuration having a higher priority than the first RACH configuration and the more than one ROs and the first RO are associated with different SSBs or different groups of SSBs, determining the first RO as an invalid RO.

10. The method according to any of claims 1 to 3, wherein the determining the at least one valid RO among the plurality of ROs further comprises:

selecting a RACH configuration according to at least one of the following:

a measurement threshold and a measurement result, or

a priority of the RACH configuration; and

wherein:

the measurement threshold is configured by the base station, or

the priority of the RACH configuration is configured by the base station.

11. The method according to any of claims 1 to 3, further comprising:

calculating a random access radio network temporary identifier (RA-RNTI) according to an index of a RACH configuration.

12. The method according to any of claims 11:

the RA-RNTI is calculated according to $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id + 14 \times 80 \times 8 \times 2 \times configuration_id$,

wherein: s_id is an index of a first orthogonal frequency-division multiplexing (OFDM) symbol of a physical random access channel (PRACH) occasion, t_id is an index of a first slot of the PRACH occasion in a system frame, f_id is an index of the PRACH occasion in the frequency domain, $ul_carrier_id$ is an uplink (UL) carrier for random access preamble transmission, and $configuration_id$ is an index of a RACH configuration.

13. The method according to claim 11, wherein:

a first RACH configuration is configured for both of a SBFD RACH mode and non-SBFD RACH mode, and a second RACH configuration is configured for the SBFD RACH mode; and

the $configuration_id$ for the first RACH configuration is "0", and the $configuration_id$ for the second RACH configuration is "1".

14. The method according to any of claims 1 to 3, further comprising:

the RA-RNTI is calculated according to $RA-RNTI = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id$,

wherein: s_id is an index of a first orthogonal frequency-division multiplexing (OFDM) symbol of a physical random access channel (PRACH) occasion, t_id is an index of a first slot of the PRACH occasion in a system frame, f_id is a frequency index of the ROs across multiple RACH configurations, $ul_carrier_id$ is an uplink (UL) carrier for random access preamble transmission.

15. The method according to claim 14, wherein:

in response to ROs from different RACH configurations having different time domain starting points, f_id of the ROs are defined as frequency index within one RACH configuration.

16. The method according to claim 14, wherein:

in response to ROs from different RACH configurations having same time domain starting point, f_id of ROs in a first RACH configuration is smaller than f_id of ROs in a second RACH configuration; and

the f_id of the ROs in the first RACH configuration are numbered from "0", and the f_id of the ROs in the second RACH configuration are numbered from a maximum number of FDMed ROs in the first RACH configuration.

17. The method according to any of claims 1 to 3, further comprising:

determining a frequency domain of the at least one valid RO within SBFD symbols or downlink (DL) symbols configured with a UL subband by determining a lowest physical

resource block (PRB) of a lowest valid RO as a lowest PRB of the UL subband or or UL usable PRBs.

18. The method according to any of claims 1 to 3, further comprising:

determining a frequency domain of the at least one valid RO within SBFD symbols or downlink (DL) symbols configured with a UL subband by determining a frequency domain reference point as a lowest PRB of the UL subband or UL usable PRBs and determining an offset value as “0” or a predefined value.

19. A wireless communications apparatus comprising at least one processor and a memory, wherein the at least one processor is configured to read code from the memory and implement a method recited in any of claims 1 to 18.

20. A computer program product comprising a computer-readable program medium code stored thereupon, the computer-readable program medium code, when executed by at least one processor, causing the at least one processor to implement a method recited in any of claims 1 to 18.

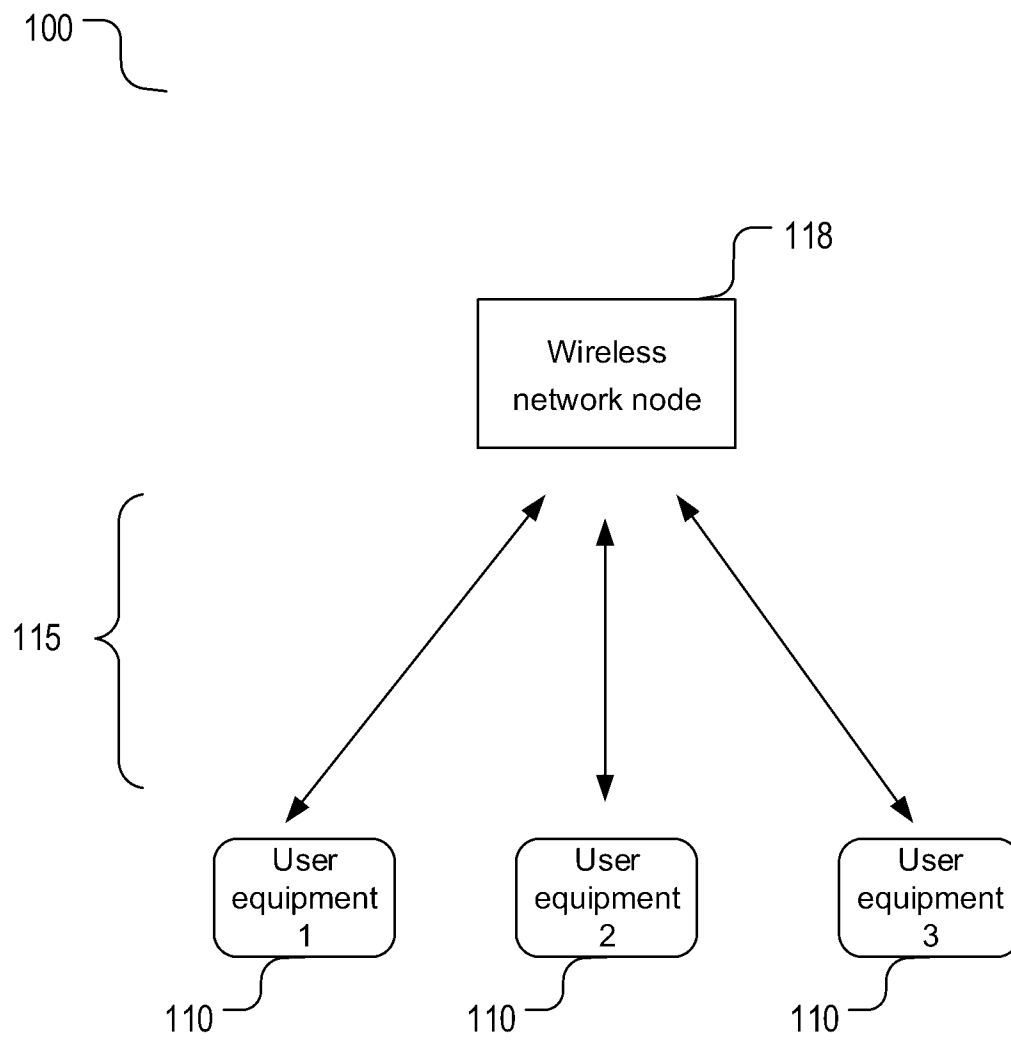


FIG. 1A

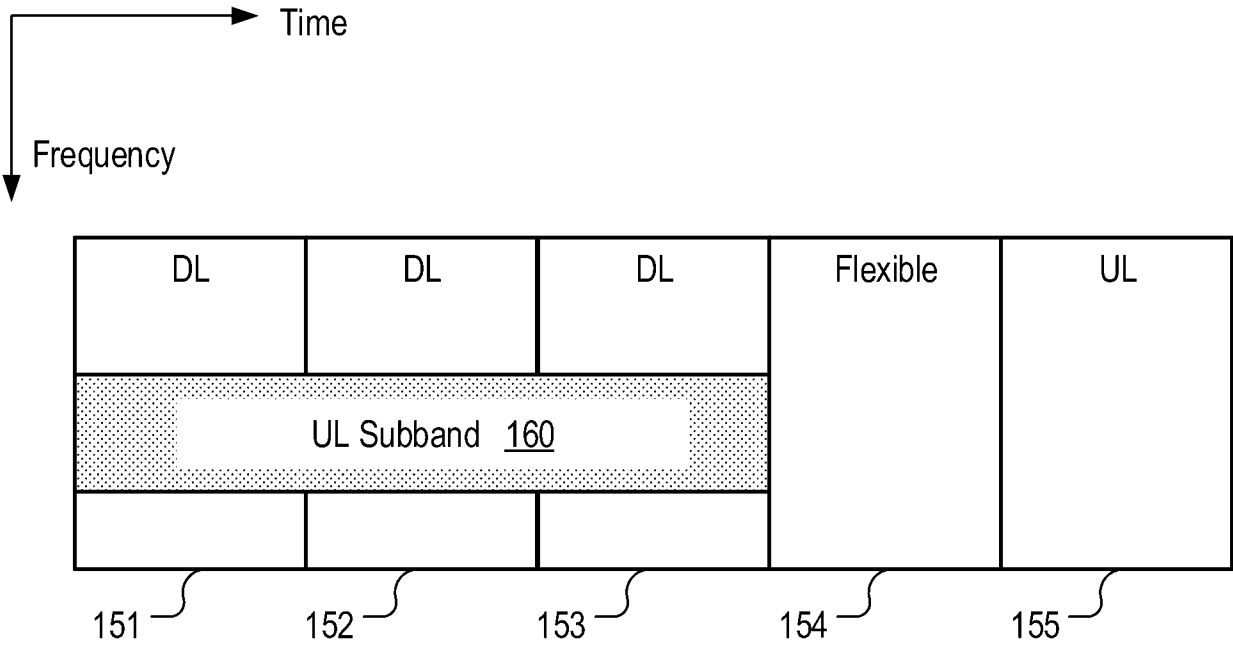


FIG. 1B

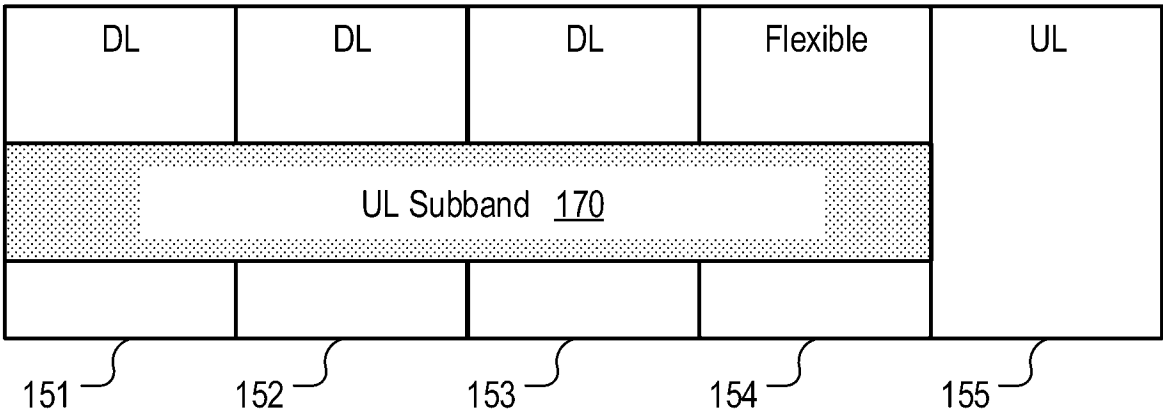


FIG. 1C

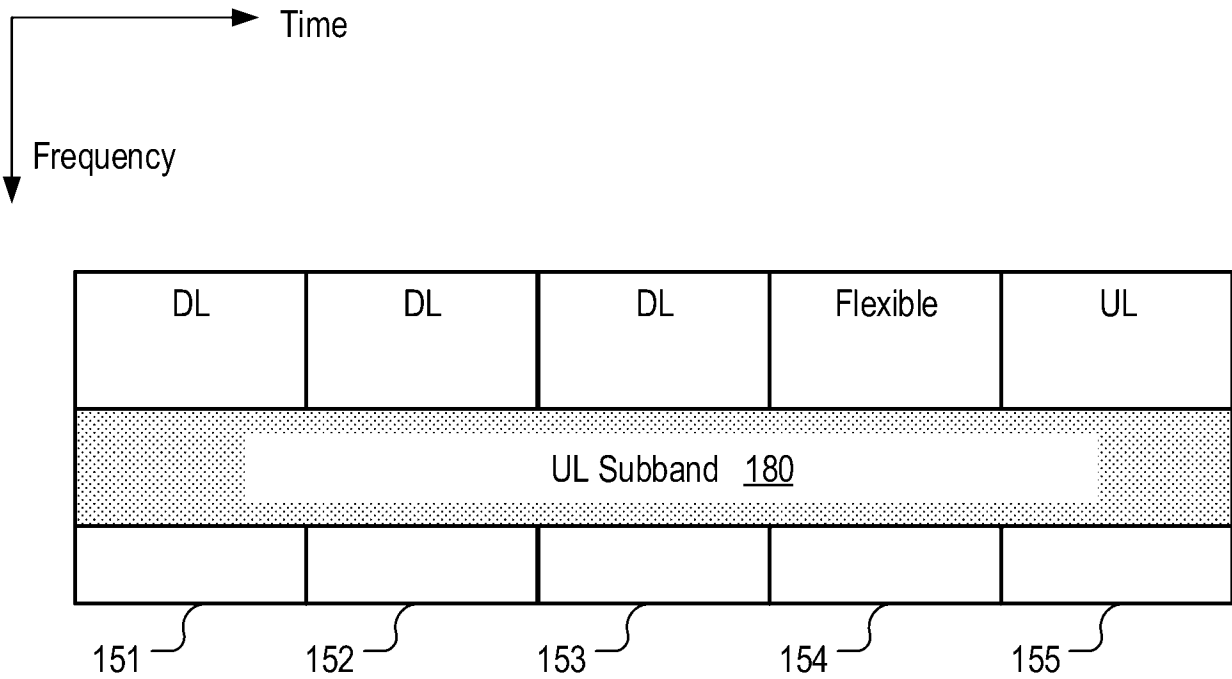


FIG. 1D

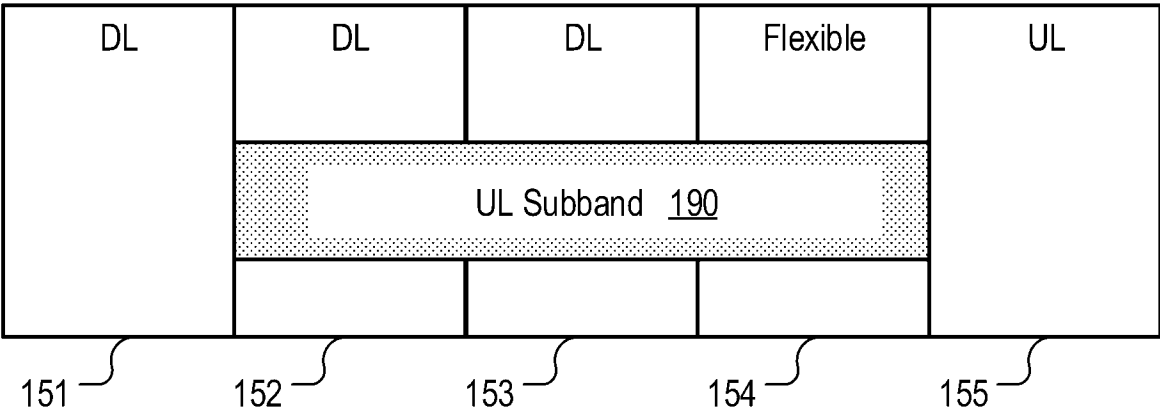


FIG. 1E

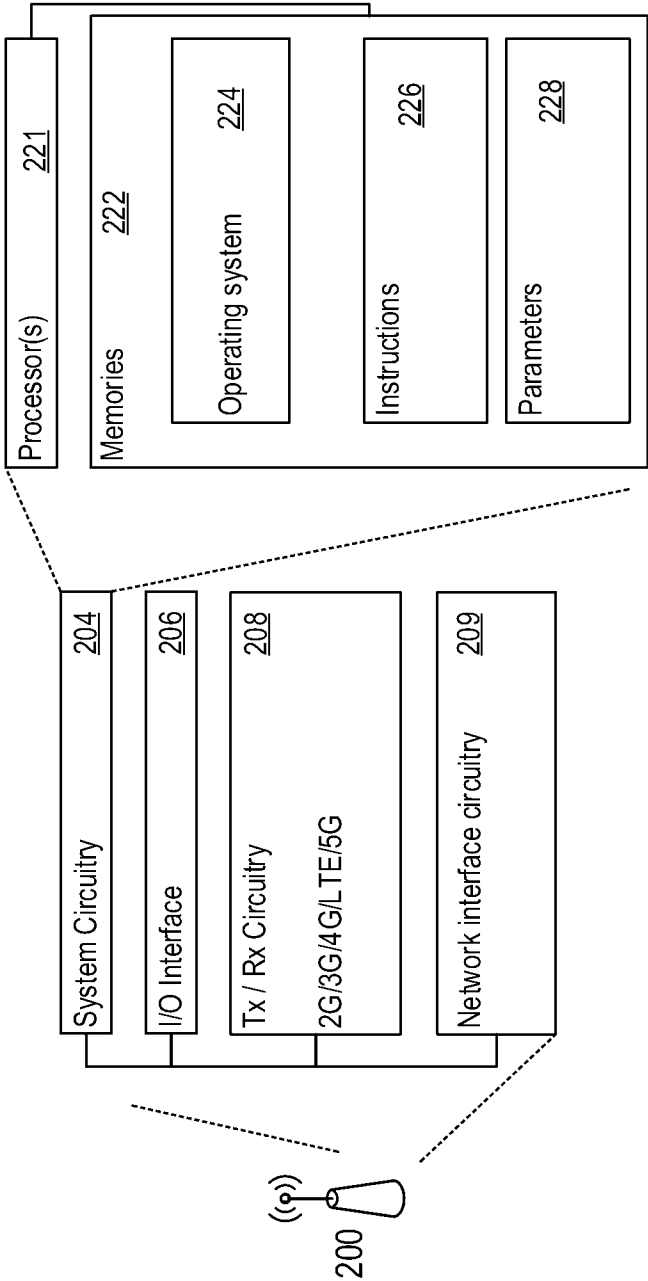


FIG. 2

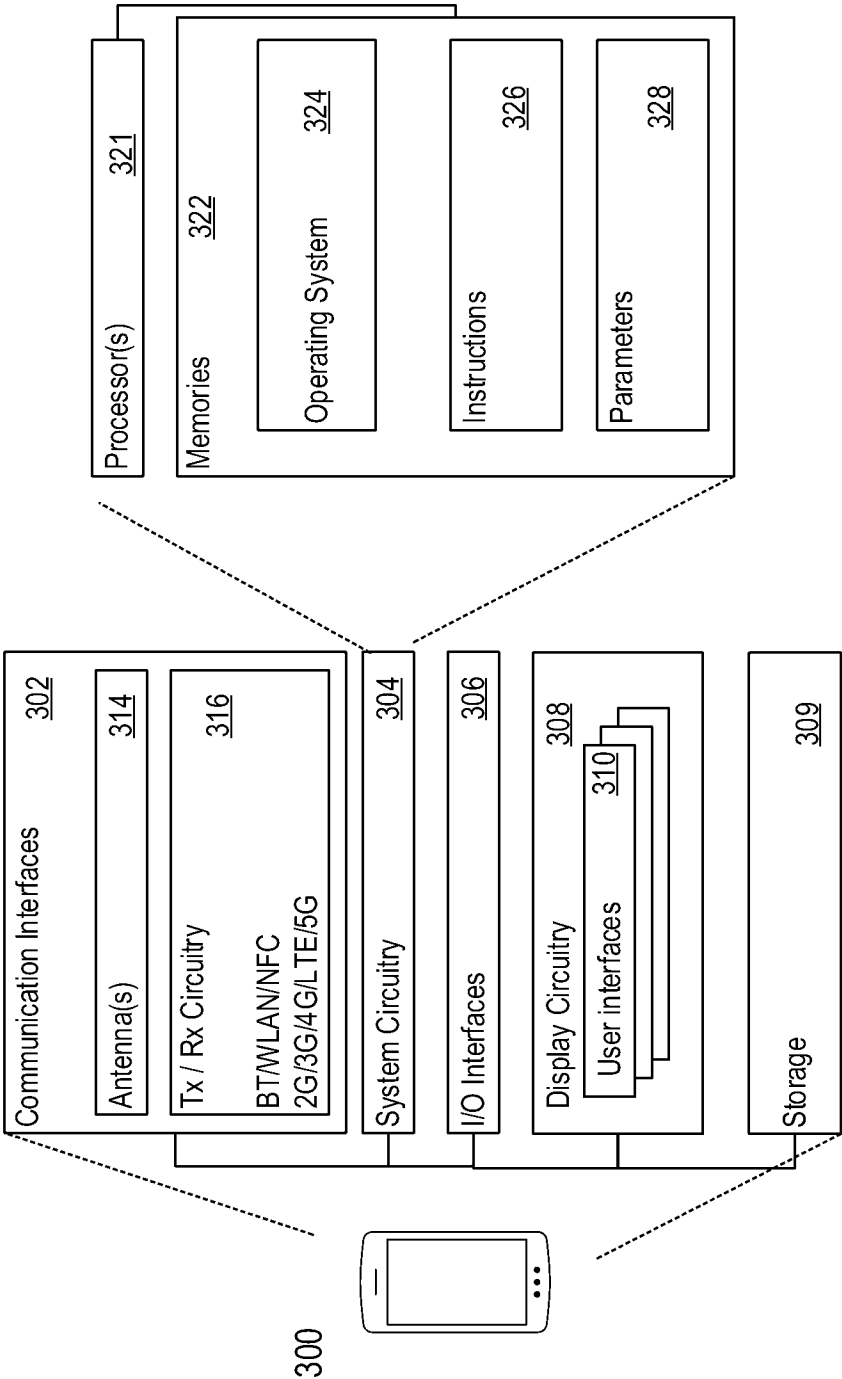


FIG. 3

400

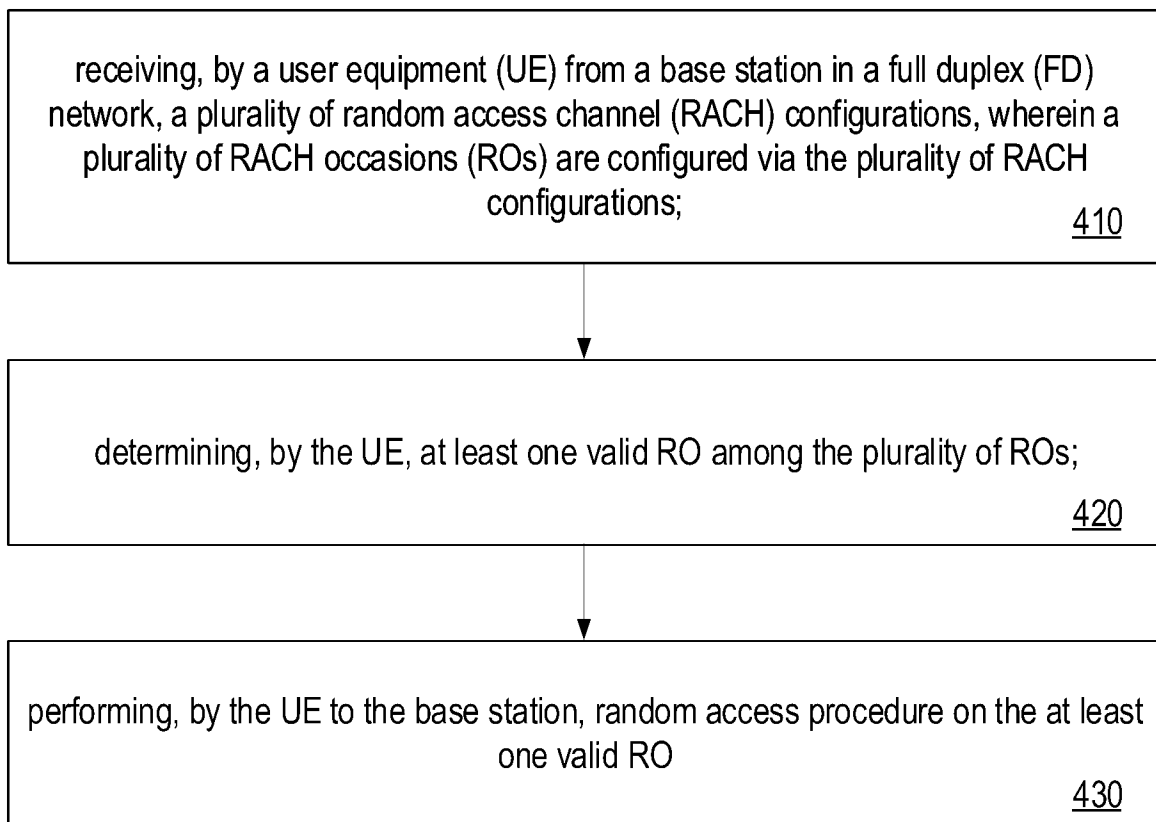


FIG. 4A

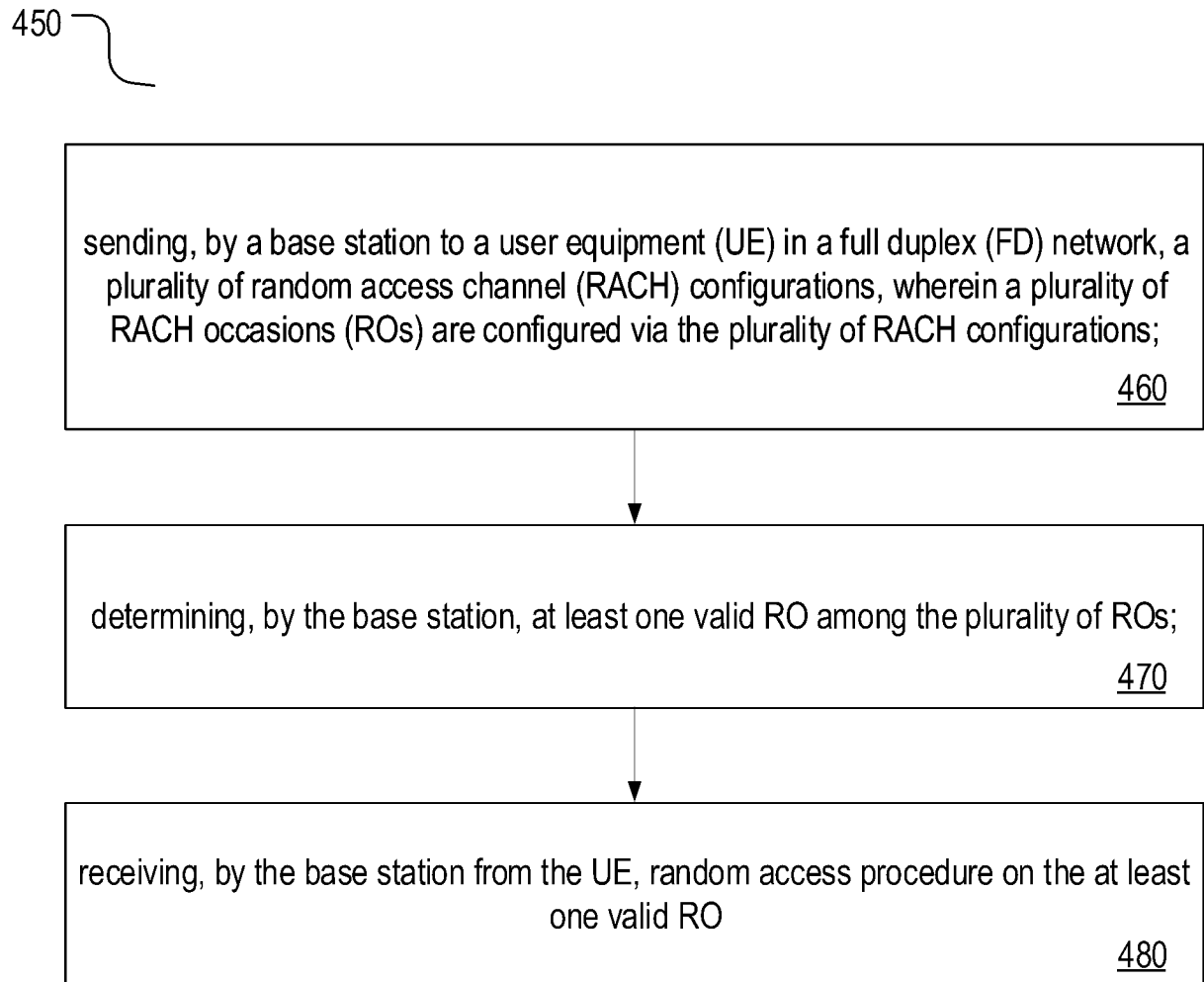


FIG. 4B

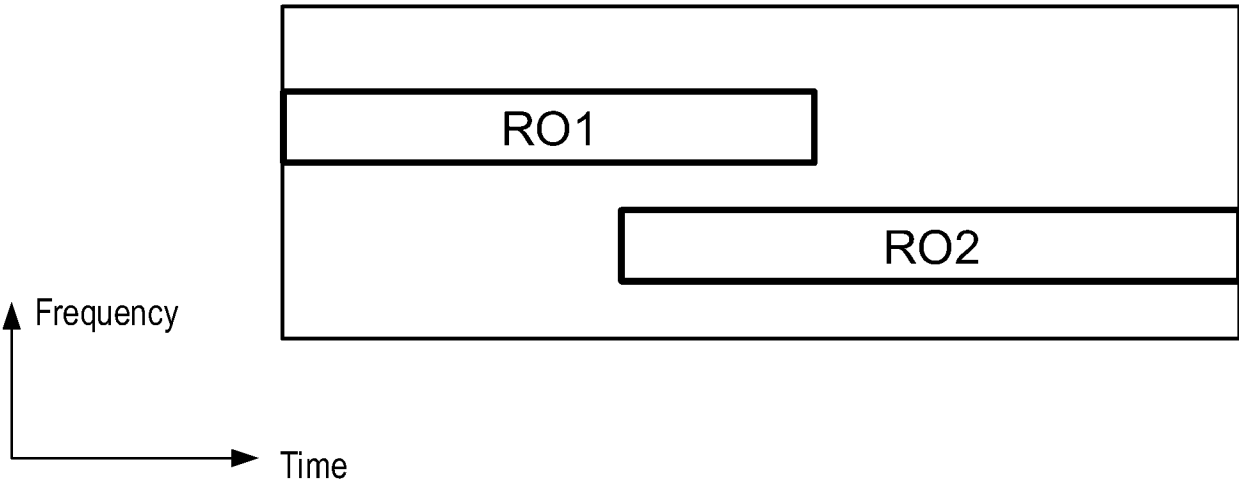


FIG. 5A

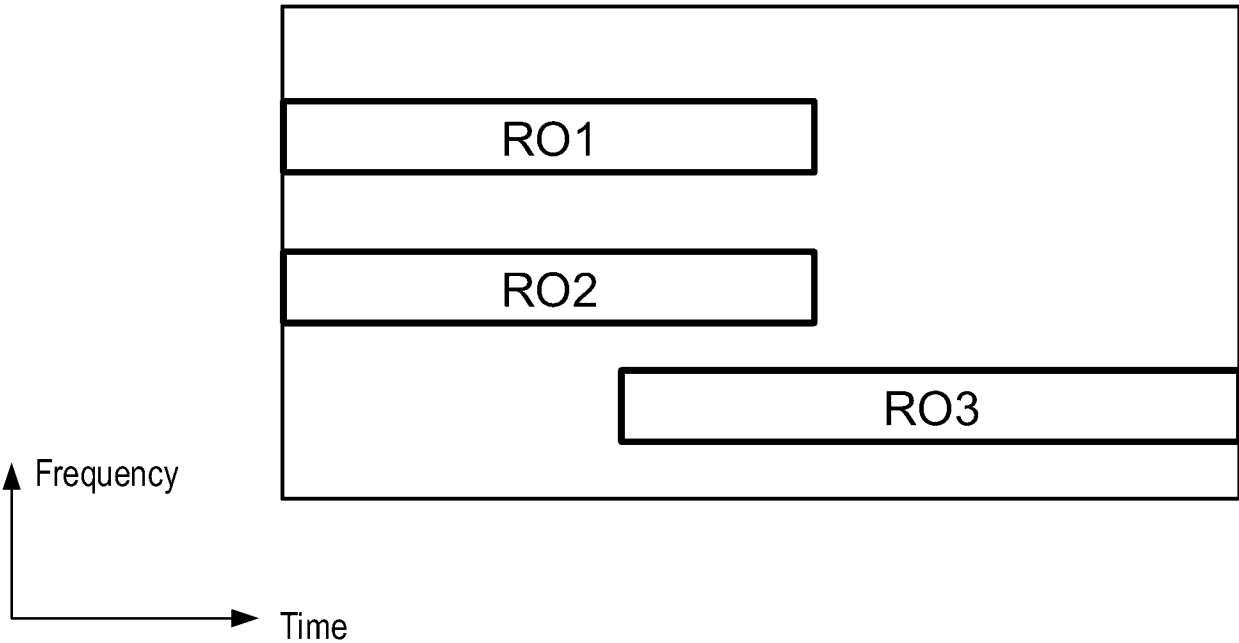


FIG. 5B

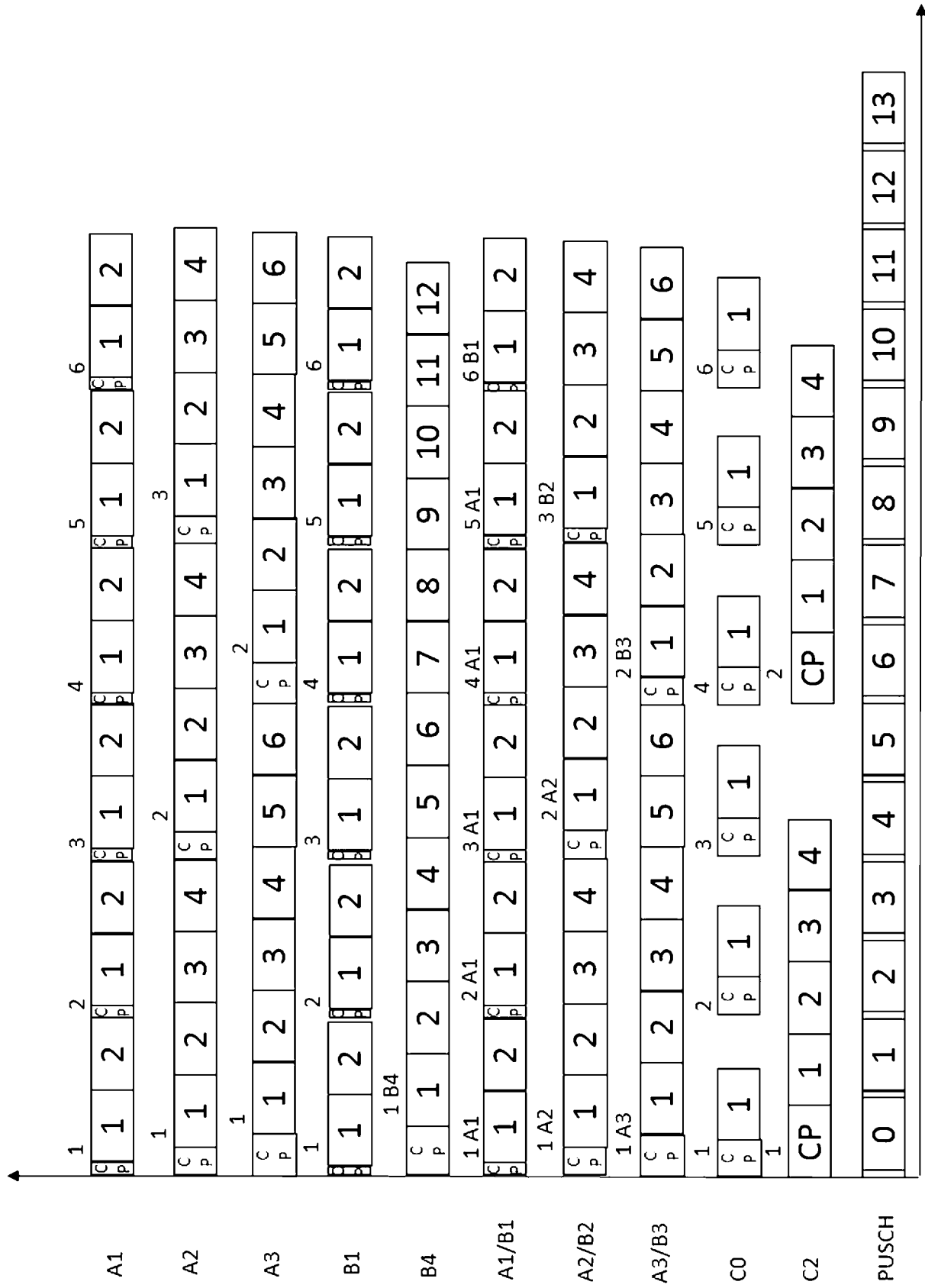


FIG. 5C

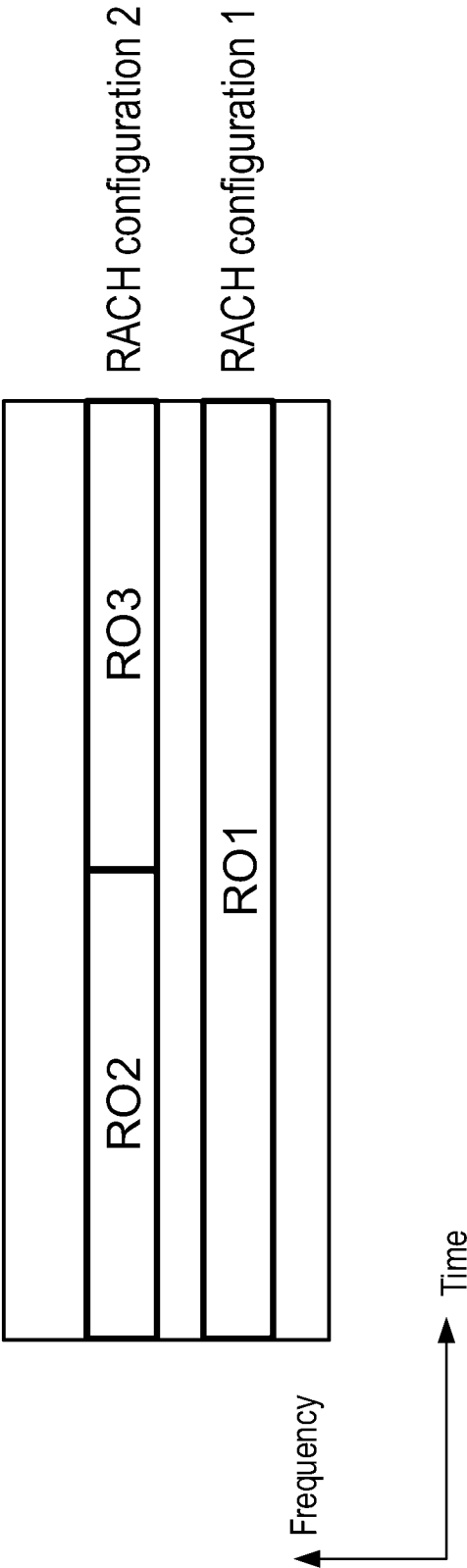


FIG. 5D

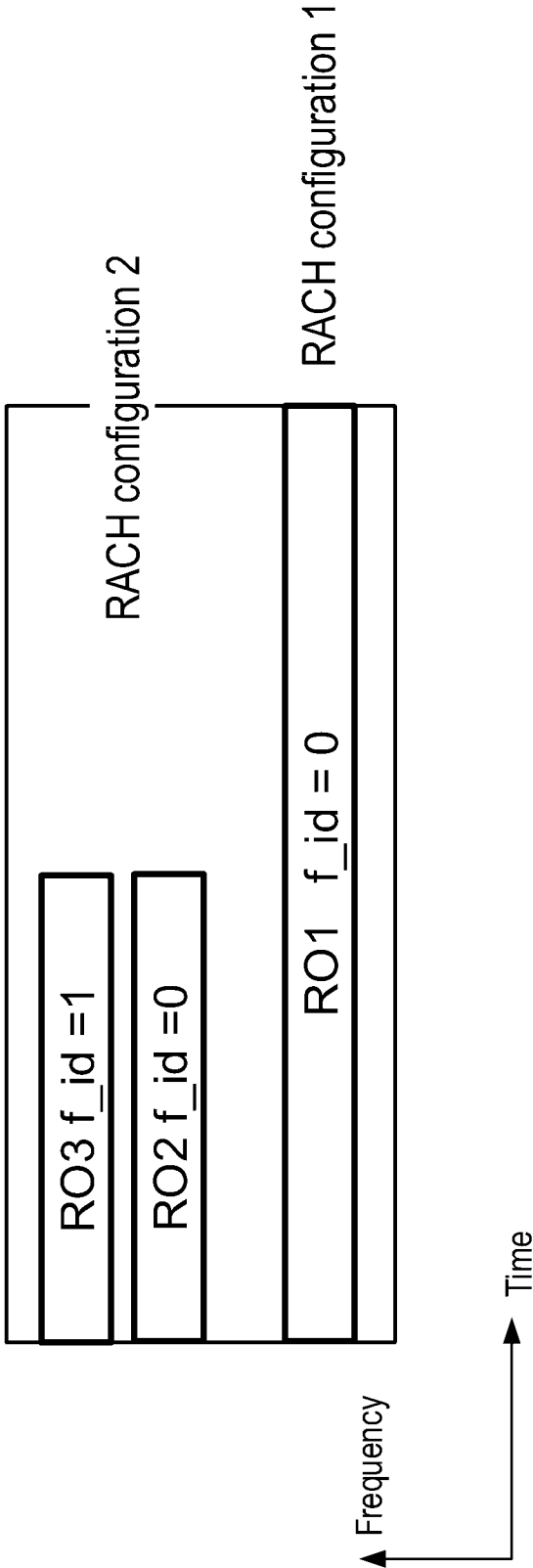


FIG. 6A

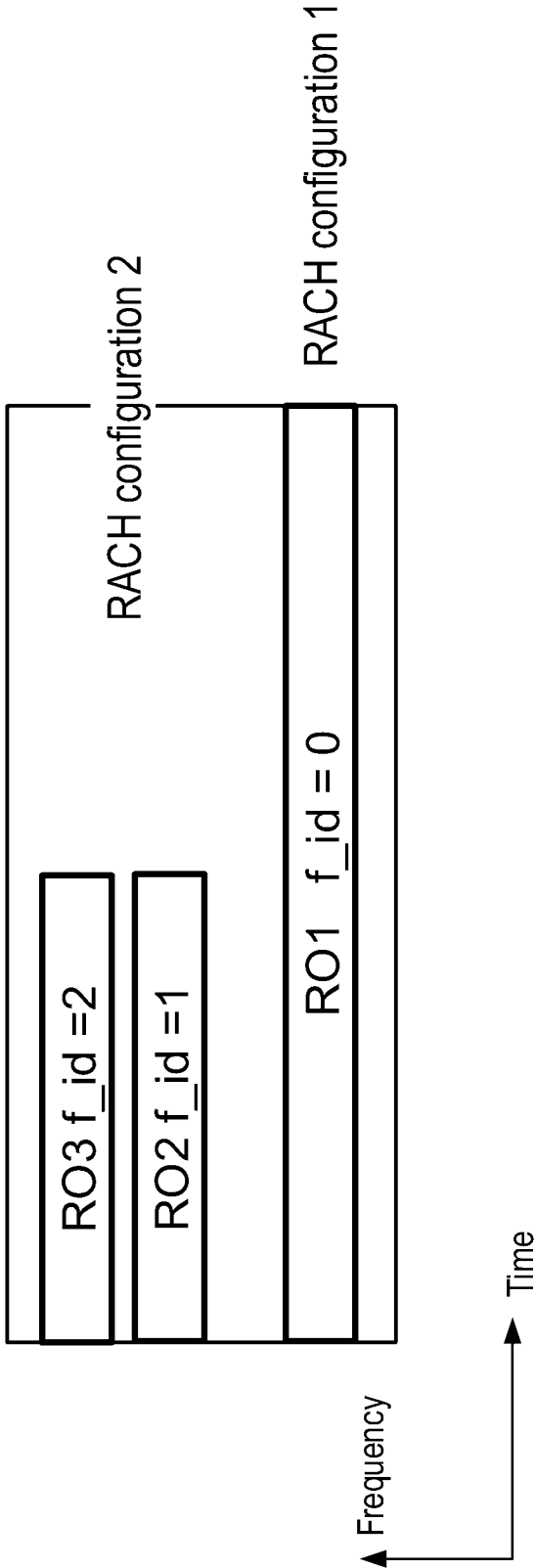


FIG. 6B

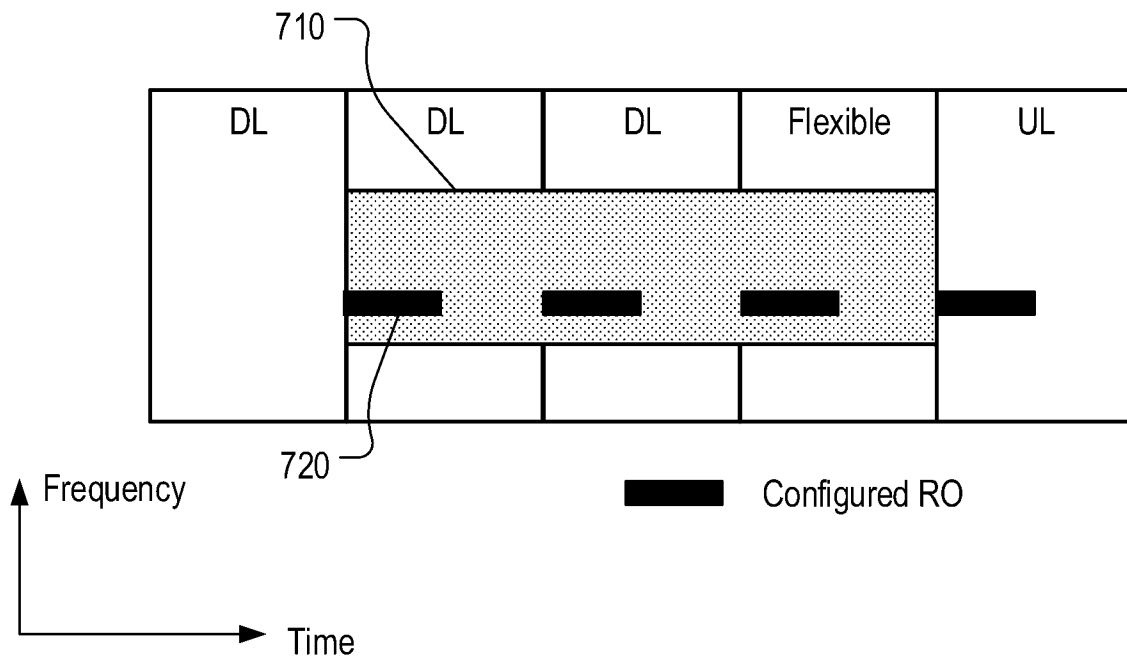


FIG. 7

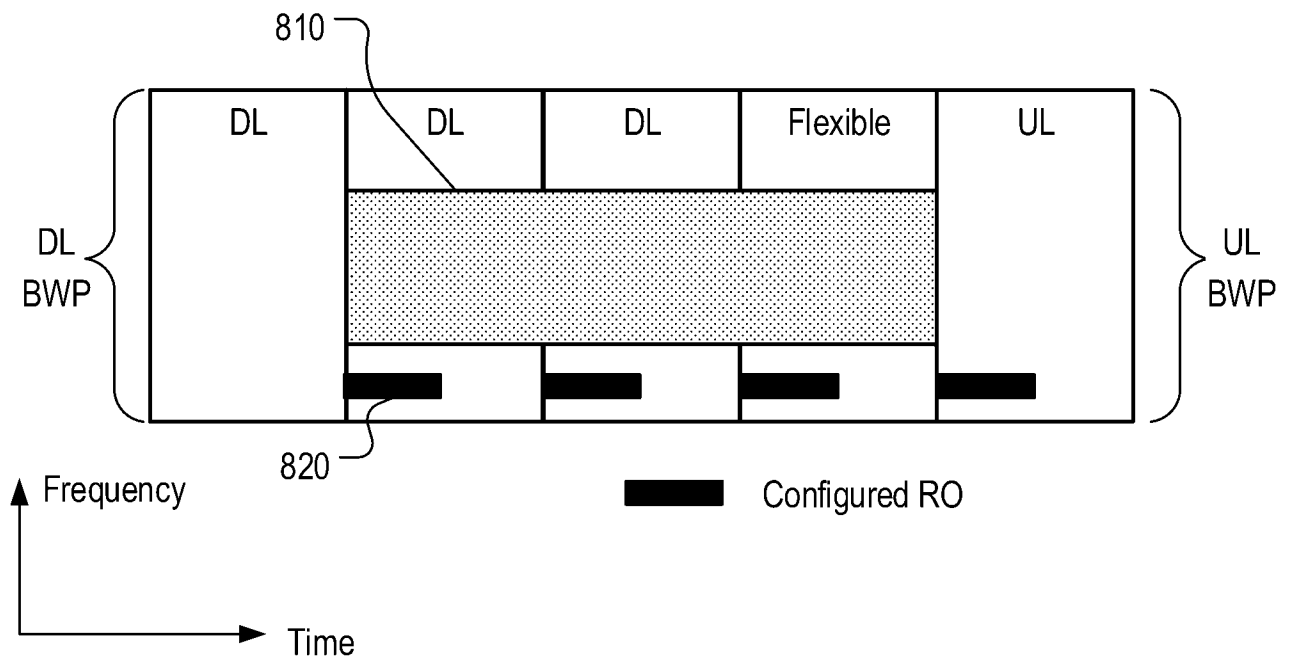


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/110911

A. CLASSIFICATION OF SUBJECT MATTER H04W 74/00(2009.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: H04W, H04L Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT, ENTXT, DWPI, CNKI, 3GPP: full duplex, FD, random access channel, RACH, occasion, RO, valid, configuration		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023115575 A1 (LENOVO (BEIJING) LIMITED) 29 June 2023 (2023-06-29) description, paragraphs 88-109 and 144-172	1-20
X	US 2024137972 A1 (QUALCOMM INCORPORATED) 25 April 2024 (2024-04-25) description, paragraphs 114, 133-143 and 271-273	1-20
A	CN 114208382 A (CONVIDA WIRELESS, LLC) 18 March 2022 (2022-03-18) the whole document	1-20
A	HUAWEI et al. "Remaining issues on physical random access channel and procedure" 3GPP TSG RAN WG1 Meeting #95 R1-1812179, 16 November 2018 (2018-11-16), the whole document	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 23 April 2025		Date of mailing of the international search report 27 April 2025
Name and mailing address of the ISA/CN CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China		Authorized officer TIAN,Tao Telephone No. (+86) 010-53961637

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/110911

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2023115575	A1	29 June 2023	GB	202409603	D0	14 August 2024
				GB	2629691	A	06 November 2024
				US	2025089099	A1	13 March 2025
				EP	4454395	A1	30 October 2024
				CN	118160399	A	07 June 2024

US	2024137972	A1	25 April 2024	US	2024237055	A9	11 July 2024

CN	114208382	A	18 March 2022	WO	2021026118	A1	11 February 2021
				EP	3994946	A1	11 May 2022
				US	2022272760	A1	25 August 2022
