VALID RACH OCCASION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment (UE), a base station, processors for wireless communication and methods for valid random access channel (RACH) occasions (ROs).

BACKGROUND

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

[0003] In 5G new radio (NR) systems, the random-access procedure is utilized for various purposes. For example, the random-access procedure may be utilized by a UE in initial access to find a cell to camp on; or utilized by a radio resource control (RRC) IDLE/INACTIVE UE to switch to a RRC Connected mode to start data transmission/reception; or utilized by a RRC Connected UE to re-establish the lost uplink (UL) synchronization, etc. Enhancements on the random-access procedure are still needed. In particular, studies related to valid ROs in sub-band full duplex (SBFD) scheme are needed.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support valid ROs. By determining valid ROs in SBFD time units based on types of the SBFD time units, PRACH transmissions in the SBFD scheme may be supported.

[0005] In a first aspect of the solution, a user equipment receives, from a base station, a random access channel (RACH) configuration. The RACH configuration indicates a set of configured RACH occasions (ROs). The user equipment determines at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units. In this way, the determination rule of valid ROs for PRACH transmissions may be enhanced. The PRACH may also be transmitted in the valid ROs in SBFD symbols/slots, thus reducing the access latency.

[0006] In some implementations of the method and apparatuses described herein, determining the at least one valid RO may include at least one of following: determining a first set of valid ROs; or determining a second set of valid ROs. The first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule. The second set of valid ROs are in SBFD time units configured as downlink (DL) and meet a second predefined rule.

[0007] In some implementations of the method and apparatuses described herein, the at least one valid RO meets a second predefined rule, and the at least one valid RO may include at least one of a first set of valid ROs in SBFD time units configured as flexible and a second set of valid ROs in SBFD time units configured as DL.

[0008] In some implementations of the method and apparatuses described herein, the RACH configuration is a first RACH configuration, the set of configured ROs is a first set of configured ROs. Some implementations of the method and apparatuses described herein may further include: receiving, from the base station, a second RACH configuration, wherein the second RACH configuration indicates a second set of configured ROs; and determining a third set of valid ROs among the second set of configured ROs, wherein the third set of valid ROs are in SBFD time units configured as DL and meet a second predefined rule. Determining the at least one valid RO may include: determining a first set of valid ROs among the first set of configured ROs, wherein the first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule or the second predefined rule.

[0009] Some implementations of the method and apparatuses described herein may further include: determining a fourth set of valid ROs among the second set of configured ROs, wherein the fourth set of valid ROs are in SBFD time units configured as flexible and meet the second predefined rule.

[0010] Some implementations of the method and apparatuses described herein may further include: determining that a first RO in a first SBFD time unit configured as flexible among the second set of configured ROs is invalid in the case of one of the following: at least one RO among the first set of valid ROs is in the first SBFD time unit configured as flexible; or resources for the first RO are at least partially overlapped with resources for at least one of the first set of valid ROs.

[0011] Some implementations of the method and apparatuses described herein may further include: mapping a plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) to a plurality of valid ROs based on types of time units in which the plurality of valid ROs are, wherein the plurality of valid ROs at least include the at least one valid RO and valid ROs in non-SBFD time units among the set of configured ROs.

[0012] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to the second set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0013] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the second set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0014] Some implementations of the method and apparatuses described herein may further include: separately perform at least one of the following: mapping a plurality of SSBs to the third set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0015] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the third set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0016] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0017] Some implementations of the method and apparatuses described herein may further include: separately perform at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs, the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0018] In some implementations of the method and apparatuses described herein, the plurality of SSBs are mapped to the first set of valid ROs according to a mapping between the plurality of SSBs and configured ROs in the SBFD time units configured as flexible assuming the SBFD time units configured as flexible are non-SBFD time units.

[0019] In some implementations of the method and apparatuses described herein, an SSB index for each of the first set of valid ROs is same as an SSB index for a corresponding configured RO in a same time unit assuming the time unit is non-SBFD time unit.

[0020] In some implementations of the method and apparatuses described herein, the first predefined rule may include at least one of the following: a valid RO does not precede a SSB block in a physical RACH slot; or a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

[0021] In some implementations of the method and apparatuses described herein, the second predefined rule may include at least one of the following: a valid RO is fully within UL usable physical resource blocks (PRBs); a valid RO is not overlapped with

SSBs; or a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

[0022] In a second aspect of the solution, a base station transmits, to a user equipment, a random access channel (RACH) configuration. The RACH configuration indicates a set of configured RACH occasions (ROs). The base station determines at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units. In this way, the determination rule of valid ROs for PRACH transmissions may be enhanced. The PRACH may also be received in the valid ROs in SBFD symbols/slots, thus reducing the access latency of the SBFD-aware UEs.

[0023] In some implementations of the method and apparatuses described herein, determining the at least one valid RO may include at least one of following: determining a first set of valid ROs; or determining a second set of valid ROs. The first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule. The second set of valid ROs are in SBFD time units configured as downlink (DL) and meet a second predefined rule.

[0024] In some implementations of the method and apparatuses described herein, the at least one valid RO meets a second predefined rule, and the at least one valid RO may include at least one of a first set of valid ROs in SBFD time units configured as flexible and a second set of valid ROs in SBFD time units configured as DL.

[0025] In some implementations of the method and apparatuses described herein, the RACH configuration is a first RACH configuration, the set of configured ROs is a first set of configured ROs. Some implementations of the method and apparatuses described herein may further include: transmitting, to the user equipment, a second RACH configuration, wherein the second RACH configuration indicates a second set of configured ROs; and determining a third set of valid ROs among the second set of configured ROs, wherein the third set of valid ROs are in SBFD time units configured as DL and meet a second predefined rule. Determining the at least one valid RO may include: determining a first set of valid ROs among the first set of configured ROs, wherein the first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule or the second predefined rule.

[0026] Some implementations of the method and apparatuses described herein may further include: determining a fourth set of valid ROs among the second set of configured ROs, wherein the fourth set of valid ROs are in SBFD time units configured as flexible and meet the second predefined rule.

[0027] Some implementations of the method and apparatuses described herein may further include: determining that a first RO in a first SBFD time unit configured as flexible among the second set of configured ROs is invalid in the case of one of the following: at least one RO among the first set of valid ROs is in the first SBFD time unit configured as flexible; or resources for the first RO are at least partially overlapped with resources for at least one of the first set of valid ROs.

[0028] Some implementations of the method and apparatuses described herein may further include: mapping a plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) to a plurality of valid ROs based on types of time units in which the plurality of valid ROs are, wherein the plurality of valid ROs at least include the at least one valid RO and valid ROs in non-SBFD time units among the set of configured ROs.

[0029] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to the second set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0030] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the second set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0031] Some implementations of the method and apparatuses described herein may further include: separately perform at least one of the following: mapping a plurality of SSBs to the third set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0032] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the third set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0033] Some implementations of the method and apparatuses described herein may further include separately performing at least one of the following: mapping a plurality of SSBs to at least one of the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

[0034] Some implementations of the method and apparatuses described herein may further include: separately perform at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs, the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

[0035] In some implementations of the method and apparatuses described herein, the plurality of SSBs are mapped to the first set of valid ROs according to a mapping between the plurality of SSBs and configured ROs in the SBFD time units configured as flexible assuming the SBFD time units configured as flexible are non-SBFD time units.

[0036] In some implementations of the method and apparatuses described herein, an SSB index for each of the first set of valid ROs is same as an SSB index for a corresponding configured RO in a same time unit assuming the time unit is non-SBFD time unit.

[0037] In some implementations of the method and apparatuses described herein, the first predefined rule may include at least one of the following: a valid RO does not precede a SSB block in a physical RACH slot; or a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

[0038] In some implementations of the method and apparatuses described herein, the second predefined rule may include at least one of the following: a valid RO is fully within UL usable PRBs; a valid RO is not overlapped with SSBs; or a valid RO starts at

least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] FIG. 1A illustrates an example of a wireless communications system that supports valid ROs in accordance with aspects of the present disclosure.

[0040] FIG. 1B illustrates an example of an NR 4-step random-access procedure that supports valid ROs in accordance with some example embodiments of the present disclosure.

[0041] FIG. 1C illustrates an example of determination of valid ROs in accordance with some example embodiments of the present disclosure.

[0042] FIG. 1D illustrates an example of frequency-division-multiplexed (FDMed) ROs in a same time occasion in accordance with some example embodiments of the present disclosure.

[0043] FIG. 1E illustrates an example of a structure of overall random access channel (RACH) resources that supports valid ROs in accordance with some example embodiments of the present disclosure.

[0044] FIGS. 1F-1H illustrate examples of associations between ROs and SSBs that supports valid ROs in accordance with some example embodiments of the present disclosure.

[0045] FIG. 1I illustrates an example diagram of a sub-band full duplex scheme.

[0046] FIG. 2 illustrates an example signaling chart of a communication process that supports valid ROs in accordance with some example embodiments of the present disclosure.

[0047] FIGS. 3A-3C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on the same RACH configuration in accordance with some example embodiments of the present disclosure.

[0048] FIGS. 4A-4C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on

different RACH configurations in accordance with some example embodiments of the present disclosure.

[0049] FIGS. 5A-5C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on two RACH configurations in accordance with some example embodiments of the present disclosure.

[0050] FIG. 6 illustrates an example of mapping between SSBs and ROs in SBFD symbols configured as flexible in accordance with some example embodiments of the present disclosure.

[0051] FIG. 7 illustrates an example of a device that supports valid ROs in accordance with aspects of the present disclosure.

[0052] FIG. 8 illustrates an example of a processor that supports valid ROs in accordance with aspects of the present disclosure.

[0053] FIGS. 9 through 10 illustrate flowcharts of methods that support valid ROs in accordance with aspects of the present disclosure.

[0054] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0055] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein may be implemented in various manners other than the ones described below.

[0056] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0057] References in the present disclosure to "one embodiment," "an example embodiment," "an embodiment," "some embodiments," and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but

it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0058] It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0059] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0060] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as, 5G NR, long term evolution (LTE), LTE-advanced (LTE-A), wideband code division multiple access (WCDMA), high-speed packet access (HSPA), narrow band internet of things (NB-IoT), and so on. Further, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid

development in communications, there will also be future type communication technologies and systems in which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned systems.

[0061] As used herein, the term "network device" generally refers to a node in a communication network via which a terminal device can access the communication network and receive services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), a radio access network (RAN) node, an evolved NodeB (eNodeB or eNB), an NR NB (also referred to as a gNB), a remote radio unit (RRU), a radio header (RH), an infrastructure device for a V2X (vehicle-to-everything) communication, a transmission and reception point (TRP), a reception point (RP), a remote radio head (RRH), a relay, an integrated access and backhaul (IAB) node, a low power node such as a femto BS, a pico BS, and so forth, depending on the applied terminology and technology.

[0062] As used herein, the term "terminal device" generally refers to any end device that may be capable of wireless communications. By way of example rather than a limitation, a terminal device may also be referred to as a communication device, a user equipment (UE), an end user device, a subscriber station (SS), an unmanned aerial vehicle (UAV), a portable subscriber station, a mobile station (MS), or an access terminal (AT). The terminal device may include, but is not limited to, a mobile phone, a cellular phone, a smart phone, a voice over IP (VoIP) phone, a wireless local loop phone, a tablet, a wearable terminal device, a personal digital assistant (PDA), a portable computer, a desktop computer, an image capture terminal device such as a digital camera, a gaming terminal device, a music storage and playback appliance, a vehicle-mounted wireless terminal device, a wireless endpoint, a mobile station, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), a USB dongle, a smart device, wireless customer-premises equipment (CPE), an internet of things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device (for example, a remote surgery device), an industrial device (for example, a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms: "terminal device," "communication device," "terminal," "user equipment" and "UE," may be used interchangeably.

[0063] In an NR 4-step random-access procedure, the UE firstly transmits a PRACH preamble in Msg1 to the BS, and then receives a Random-Access Response (RAR) in Msg2, indicating reception of the preamble and providing scheduling information for the transmission of Msg3. The PRACH preamble transmission takes place in RACH occasions (ROs), each of which occupies multiple consecutive resource blocks in frequency domain. In time domain, the ROs are configured in every PRACH configuration period, which contains a set of radio frames. The UE needs to determine valid ROs among the ROs configured in the time domain and frequency domain. The valid ROs are associated with SSBs that may be transmitted with different beams.

[0064] In order to realize the superior data rate and latency, 5G spectrum on higher frequency band is inevitable. In order to overcome the coverage reduction on such carriers, a duplexing scheme is to be introduced so as to enable simultaneous use of downlink and uplink within a Time Division Duplexing (TDD) carrier using non-overlapped frequency resource. The duplexing scheme could be named as sub-band full duplex (SBFD). The intention of the SBFD scheme is to extend the duration over which uplink transmission could occur for improved the uplink coverage and capacity. Studies on PRACH transmissions in the SBFD scheme are still needed.

[0065] In view of the above, embodiments of the present disclosure provide a solution for PRACH transmissions in the SBFD scheme. In an aspect of the solution, a user equipment receives, from a base station, a RACH configuration. The RACH configuration indicates a set of configured ROs. The user equipment determines at least one valid RO in SBFD time units among the set of configured ROs at least based on types of the SBFD time units. In this way, the determination rule of valid ROs for PRACH transmissions may be enhanced and could provide better compatibility with UEs not supporting the SBFD scheme.

[0066] Aspects of the present disclosure are described in the context of a wireless communications system.

[0067] FIG. 1A illustrates an example of a wireless communications system 100 that supports valid ROs in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio

access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0068] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0069] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the

description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0070] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0071] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1A. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1A. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0072] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0073] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network

interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0074] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0075] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0076] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host

upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0077] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0078] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0079] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers,

signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0080] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0081] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0082] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an

extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0083] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0084] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots. A time unit could include frame, slot, symbol and so on.

[0085] There may be multiple symbol type in a system adopting the subband full duplex scheme. The symbol formats include DL, flexible, SBFD, and UL. For example, a DL or UL symbol may mean that the transmission direction on this symbol is DL or UL.

For example, a flexible symbol may mean that a UE cannot make any assumptions on the transmission direction of this symbol. For example, an SBFD symbol may mean that this symbol can support simultaneous DL and UL transmissions in gNB side. For example, a symbol being SBFD may mean the symbol being indicated as DL with a UL frequency region or a UL subband; the symbol being indicated as flexible with a UL frequency region or a UL subband; or the symbol being indicated as flexible and a DL reception and a UL reception being configured to be performed in the symbol simultaneously (e.g., configured by a BS for a UE). For example, an SBFD symbol may include a UL frequency domain resource or UL subband and be initially indicated or configured by a high layer configuration or an SFI from a BS as downlink or flexible (for example, there could be at least two subbands or frequency domain regions with different transmission directions in this symbol). For example, a BS may simultaneously perform a DL transmission and a UL reception in an SBFD symbol while a UE can only perform a DL reception or a UL transmission. For example, an SBFD symbol may be configured with a UL subband, a DL subband, a flexible subband or any combination thereof. For example, an SBFD symbol may include a UL subband configuration. A slot format being SBFD may mean a slot includes only SBFD symbol or some SBFD symbols. A slot format being SBFD could named as SBFD slot.

[0086] The term "SBFD" used herein is merely for illustration, and not for limitation. Other terms may also be used to refer to the same function or meaning.

[0087] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0088] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0089] FIG. 1B illustrates an example of an NR 4-step random-access procedure 120 that supports valid ROs in accordance with some example embodiments of the present disclosure. For the purpose of discussion, the procedure 120 will be described with reference to FIG. 1A. The procedure 120 may involve a UE 104 and a base station 102 as illustrated in FIG. 1A. It is noted that the 4-step random-access procedure is merely for illustration, and not for limitation. Embodiments of the present disclosure may apply to other random-access procedures.

[0090] In the random-access procedure 120, the UE 104 may firstly transmit 122 a Msg1 including a preamble to the base station 102. After receiving the Msg1, the base station 102 may transmit 124 a Random-Access Response (RAR) in Msg2 to the UE 104, indicating the reception of the preamble and providing scheduling information for the transmission of Msg3. The RAR may be received by the UE 104 in a RAR window, which starts after a time gap after the UE 104 transmits the Msg1. The UE 104 may then transmit 126 a Msg3 to the base station 102 according to the scheduling information. The base station 102 may transmit 128 a Msg4 to the UE 104. The Msg3 and Msg4 may be used to solve potential collisions due to simultaneous transmissions of the same preamble from different UEs to the base station 102.

[0091] The PRACH Msg1 transmission takes place in ROs, each of which occupies multiple consecutive resource blocks in frequency domain. In time domain, ROs are configured in every PRACH configuration period, which contains a set of radio frames. Within a PRACH configuration period, a subset of subframes is indicated to contain a set of PRACH slots. Besides, in frequency domain, the base station may configure FDMed ROs. A parameter *msg1-FDM* indicates the number of FDMed ROs in frequency domain. The starting position of the first RO in frequency domain is also configured by the BS.

Within each PRACH slot, there might be a set of RACH occasions available for PRACH Msg1 transmission.

[0092] The UE needs to determine valid ROs among the ROs configured in the time domain and frequency domain. Specifically, for a TDD configuration, a RO in a PRACH slot is considered valid if the RO is within UL symbols of the cell common configuration *tdd-UL-DL-ConfigCommon* or if it doesn't overlap with or precede a DL symbol configured by *tdd-UL-DL-ConfigCommon* or SSB in a slot, and is at least a gap (>=0 symbols) after the last DL symbol or SSB.

[0093] FIG. 1C illustrates an example 130 of determination of valid ROs in accordance with some example embodiments of the present disclosure.

[0094] In the example 130 in FIG. 1C, a slot pattern "DDDDDDFUUU" may be indicated by *tdd-UL-DL-ConfigCommon*. The PRACH configuration index indicates that within a PRACH resource periodicity of 10ms, the slots in subframes {0,1,2,3,4,5,6,7,8,9} are PRACH slots. Here it is assumed that one subframe contains one slot (i.e., with 15kHz subcarrier spacing), therefore, each slot is indicated as a PRACH slot in the example 130. Since the slots in subframes {0,1,2,3,4,5} are DL, and thus do not meet the condition of valid PRACH slots, these slots are PRACH slots with invalid ROs. The slots in subframe {6} are flexible slots and the slots in subframes {7,8,9} are UL slots, thus these slots are PRACH slots with valid ROs. In frequency domain, the base station may configure FDMed ROs. FIG. 1D illustrates an example 131 of frequency-division-multiplexed (FDMed) ROs in a same time occasion in accordance with some example embodiments of the present disclosure. For example, the parameter *msg1-FDM* indicates that the number of FDMed ROs in frequency domain is 2. In a PRACH slot with valid ROs, two FDMed ROs may be configured in the same time occasion.

[0095] The valid ROs are associated with SSBs that may be transmitted with different beams. A SSB consist of a primary synchronization signal (PSS)/a secondary synchronization signal (SSS) and physical broadcast channel (PBCH) signal for the UE to sync. to the DL, to obtain the cell ID, and to acquire the system information. Usually, different SSBs are transmitted with different beams. The UE will measure the channel status of each SSB, select the one with good channel quality, and transmit a preamble in a RO associated with the SSB to transmit a PRACH. In this way, the transmitted PRACH is associated with the beam corresponding to the selected SSB. Thus, the preamble can

be received in the base station by a proper receive beam, which is assumed to be correspondent with selected beam for SSB transmission.

[0096] FIG. 1D illustrates an example of a structure 140 of overall RACH resources that supports valid ROs in accordance with some example embodiments of the present disclosure. In the example structure 140, a PRACH configuration period may contain 10 subframes, e.g., subframe #0 to subframe #9. Within the PRACH configuration period, subframe #0 and subframe #6 are indicated to contain a set of PRACH slots. A PRACH slot is configured with two ROs in the time domain and four ROs (i.e., *msg1-FDM* = 4) in the frequency domain. As shown in FIG. 1D, RO#0 to RO#7 are available for PRACH Msg1 transmission in a PRACH slot in subframe #0, and RO#8 to RO#15 are available for PRACH Msg1 transmission in a PRACH slot in subframe #6.

[0097] The indexes of available SSBs can be obtained in the system information. For example, SSB indexes provided by *ssb-PositionsInBurst* in SIB1 or in *ServingCellConfigCommon* are mapped to valid ROs in the following order where the parameters are described in technical specification (TS) 38.211: first, in an increasing order of preamble indexes within a single RO; second, in an increasing order of frequency resource indexes for frequency multiplexed ROs; third, in an increasing order of time resource indexes for time multiplexed ROs within a PRACH slot; fourth, in an increasing order of indexes for PRACH slots.

[0098] The association between SSBs and ROs can be one-to-one (1-to-1), many-to-one (N-to-1), or one-to-many (1-to-N) depending on the network configuration. This may be determined by a parameter *SSB-PerRACH-Occasion*.

[0099] FIGS. 1F-1H illustrate examples of associations 150A, 150B and 150C between ROs and SSBs that supports valid ROs in accordance with some example embodiments of the present disclosure. As shown in FIGS. 1F-1H, eight SSBs, e.g., SSB#0 to SSB#7, are assumed.

[0100] In the example association 150A, there is one RO in the frequency domain. The parameter *SSB-PerRACH-Occasion* = 1 for the association 150A. Each RO among the RO#0 to RO#7 is mapped to one corresponding SSB. For example, RO#0 is mapped to SSB#0 and RO#1 is mapped to SSB#1.

[0101] In the example association 150B, there is one RO in the frequency domain. The parameter *SSB-PerRACH-Occasion* = 2 for the association 150B. Each RO among the RO#0 to RO#7 is mapped to two corresponding SSBs. For example, RO#0 is mapped to SSB#0 and SSB#1 and RO#1 is mapped to SSB#2 and SSB#3.

[0102] In the example association 150C, there are two FDMed ROs in the frequency domain. The parameter *SSB-PerRACH-Occasion* = 1/2 for the association 150C. Two ROs among the RO#0 to RO#15 are mapped to one corresponding SSBs. For example, RO#0 and RO#1 are mapped to SSB#0 and RO#2 and RO#3 are mapped to SSB#1.

[0103] As mentioned above, in order to realize the superior data rate and latency, 5G spectrum on higher frequency band is inevitable. To overcome the coverage reduction on such carriers, a duplexing scheme (referred to as a SBFD scheme) is to be introduced so as to enable simultaneous use of downlink and uplink within a TDD carrier using non-overlapped frequency resource. The intention of this scheme is to extend the duration over which uplink transmission could occur for improved the uplink coverage and capacity. The simultaneous use of DL and UL is only at the base station side and not at the UE side. A UL subband could be configured, and the SBFD symbol/slot could be configured in DL symbol/slot or flexible symbol/slot in *TDD-UL-DL-ConfigCommon*. An example of a duplexing scheme could be seen in FIG. 1I. In the example of FIG. 1I, two downlink (DL) sub-bands are duplexed with an uplink (UL) sub-band in slot #0 and slot #1. The slot #0 and the slot #1 may be SBFD slots configured as flexible by *TDD-UL-DL-ConfigCommon* or SBFD slots configured as DL by *TDD-UL-DL-ConfigCommon*.

[0104] If SBFD symbols/ slots are configured for a UE, considering the access latency, the PRACH could also be transmitted in the SBFD symbols/slots. The RO determination, the RO validation and the SSB-to-RO mapping could be different for SBFD symbols/slots configured as DL and SBFD symbols/slots configured as flexible. Studies related to valid ROs in SBFD symbols/slots are needed. SBFD time units configured as flexible means SBFD time units configured as flexible by *TDD-UL-DL-ConfigCommon*, and SBFD time units configured as DL means SBFD time units configured as DL by *TDD-UL-DL-ConfigCommon*.

[0105] Reference is now made to FIG. 2, which illustrates an example signaling chart of a communication process that supports valid ROs in accordance with some example

embodiments of the present disclosure. For the purpose of discussion, the process 200 will be described with reference to FIG. 1A. The process 200 may involve the UE 104 and the base station 102. It is to be understood that the steps and the order of the steps in FIG. 2 are merely for illustration, and not for limitation. It is to be understood that process 200 may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0106] As shown in FIG. 2, the base station 102 transmits (202) a RACH configuration 204 to the UE 104. The RACH configuration 204 indicates a set of configured ROs. The UE 104 receives (206) the RACH configuration 204 from the base station 102 and determines (208) at least one valid RO in SBFD time units among the set of configured ROs at least based on types of the SBFD time units. In this way, the latency of the PRACH transmissions of a SBFD-aware UE may be reduced.

[0107] The base station 102 determines (210) the at least one valid RO in the SBFD time units. The determination 208 and the determination 210 may be performed in the same manner, thus the UE 104 and the base station 102 may have the same understanding on the valid ROs in SBFD time units. The PRACH could be received by the base station and the reliability of the PRACH transmissions of SBFD-aware UE may be improved.

[0108] In some embodiments, when determining the at least one valid RO, the UE 104 may determine a first set of valid ROs in SBFD time units configured as flexible. In other words, the first set of valid ROs in SBFD time units configured as flexible may be determined based on the RACH configuration 204. The first set of valid ROs in SBFD time units configured as flexible belong to the set of configured ROs. For example, if there are SBFD symbols/slots configured as flexible by *tdd-UL-DL-ConfigurationCommon*, and some of the configured ROs based on the RACH configuration 204 are in these SBFD symbols/slots configured as flexible, the UE 104 may determine whether these ROs are valid.

[0109] In some embodiments, the first set of valid ROs meet a first predefined rule. In some embodiments, the first predefined rule may include at least one of the following: a valid RO does not precede a SSB block in a physical RACH slot; or a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol. For example, a configured RO in SBFD symbols/slots configured as flexible may be

determined as a valid RO, if the configured RO meets a predefined rule (1), i.e., the configured RO does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last downlink symbol and at least N_{gap} symbols after a last SS/PBCH block symbol. The N_{gap} may be predefined or specified. For example, the N_{gap} may be specified based on Table 8.1-2 of TS 38.213.

[0110] In some embodiments, the first set of valid ROs meet a second predefined rule. In some embodiments, the second predefined rule may include at least one of the following: a valid RO is fully within UL usable PRBs; a valid RO is not overlapped with SSBs; or a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol. For example, a configured RO may be determined as a valid RO in SBFD symbols/slots configured as flexible, if the configured RO meets a predefined rule (2), i.e., the configured RO does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last downlink symbol without SBFD configuration and at least N_{gap} symbols after a last SS/PBCH block symbol, and the configured RO is in the UL usable resources. The N_{gap} may be predefined or specified. For example, the N_{gap} may be specified based on Table 8.1-2 of TS 38.213.

[0111] In some embodiments, when determining the at least one valid RO, the UE 104 may determine a second set of valid ROs in SBFD time units configured as DL. In other words, the second set of valid ROs in SBFD time units configured as DL may be determined based on the RACH configuration 204. The second set of valid ROs in SBFD time units configured as DL belong to the set of configured ROs. For example, if there are SBFD symbols/slots configured as DL by *tdd-UL-DL-ConfigurationCommon*, and some of the configured ROs based on the RACH configuration 204 are in these SBFD symbols/slots configured as DL, the UE 104 may determine whether these ROs are valid. The second set of valid ROs meet the second predefined rule.

[0112] In this way, one single RACH configuration may be used for RO configuration in SBFD symbols/slots. In other words, the same RACH configuration information may be used for determining ROs in SBFD symbols/slots and non-SBFD symbols/slots for SBFD-aware UEs and for determining ROs for UEs not supporting the SBFD scheme. The rules for determining valid ROs in SBFD symbols/slots are designed.

[0113] In some embodiments, the RACH configuration 204 is a first RACH configuration, the set of configured ROs is a first set of configured ROs. The UE 104 may further receive a second RACH configuration from the base station 102. The second RACH configuration indicates a second set of configured ROs. The UE 104 may determine a third set of valid ROs among the second set of configured ROs. The third set of valid ROs are in SBFD time units configured as DL and meet the second predefined rule. When determining the at least one valid RO, the UE 104 may determine a first set of valid ROs among the first set of configured ROs. The first set of valid ROs are in SBFD time units configured as flexible and meet the first predefined rule or the second predefined rule. In other words, the first set of valid ROs in SBFD time units configured as flexible may be determined based on the first RACH configuration 204 and the third set of valid ROs are in SBFD time units configured as DL may be determined based on the second RACH configuration.

[0114] In some embodiments, the UE 104 may determine a fourth set of valid ROs among the second set of configured ROs. The fourth set of valid ROs are in SBFD time units configured as flexible and meet the second predefined rule. In other words, in SBFD time units configured as flexible, in addition to the first set of valid ROs determined based on the first RACH configuration 204, the UE 104 may also determine additional valid ROs, if any, based on the second RACH configuration. Ins some embodiments, the UE 104 may determine that a first RO in a first SBFD time unit configured as flexible among the second set of configured ROs is invalid if at least one RO among the first set of valid ROs is in the first SBFD time unit configured as flexible. In other words, a configured RO determined based on the second RACH configuration and a valid RO determined based on the first RACH configuration are in the same SBFD symbol/slot configured as flexible, the configured RO determined based on the second RACH configuration is invalid. Alternatively, the UE 104 may not expect that any ROs in a first SBFD time unit configured as flexible among the second set of configured ROs are at least partially overlapped with resources for at least one of the first set of valid ROs. Alternatively, the UE 104 may determine that a first RO in a first SBFD time unit configured as flexible among the second set of configured ROs is invalid if resources for the first RO are at least partially overlapped with resources for at least one of the first set of valid ROs. In other words, if a configured RO determined based on the second RACH configuration and a valid RO determined based on the first RACH configuration are fully or partially

overlapped, the configured RO determined based on the second RACH configuration is invalid.

[0115] In this way, two separate RACH configurations may be used for RO configuration in SBFD symbols/slots. First RACH configuration information may be used for determining ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots for SBFD-aware UEs and for determining ROs for UEs not supporting the SBFD scheme. Second RACH configuration information may be used for determining ROs in SBFD symbols/slots configured as DL. In some implementations, the second RACH configuration information may also be used for determining additional ROs in SBFD symbols/slots configured as flexible. The rules for determining valid ROs in SBFD symbols/slots are designed.

[0116] In some embodiments, the UE 104 may map a plurality of SSBs to a plurality of valid ROs based on types of time units in which the plurality of valid ROs are. The plurality of valid ROs at least include the at least one valid RO in SBFD time units and valid ROs in non-SBFD time units among the set of configured ROs.

[0117] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to the second set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs are based on the same RACH configuration for SBFD symbols/slots and non-SBFD symbols/slots for SBFD-aware UEs, a first SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots configured as DL, and a second SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots. For example, the configured ROs may occupy the same frequency resources for SBFD symbols/slots and non-SBFD symbols/slots and thus the SSB index for the same valid RO in flexible symbols/slots may be the same for SBFD-aware UEs and UEs not supporting the SBFD scheme.

[0118] For each SSB-to-RO mapping, the SSBs are mapped to valid ROs in the following order where the parameters are described in technical specification (TS) 38.211: first, in an increasing order of preamble indexes within a single RO; second, in an increasing order of frequency resource indexes for frequency multiplexed ROs; third, in

an increasing order of time resource indexes for time multiplexed ROs within a PRACH slot; fourth, in an increasing order of indexes for PRACH slots.

[0119] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the second set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs are determined based on the same RACH configuration for SBFD symbols/slots and non-SBFD symbols/slots for SBFD-aware UEs, a first SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots, and a second SSB-to RO mapping may be performed for valid ROs in non-SBFD symbols/slots. For example, frequency resources of the configured ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots may be different. For example, the first configured RO in UL subband of SBFD symbols/slots may be determined based on the starting position of UL usable resource. The SSB-to-RO mapping may be jointly performed for valid ROs in SBFD symbols/slots.

[0120] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to the third set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots are determined based on a first RACH configuration and valid ROs in SBFD symbols/slots configured as DL are determined based on a second RACH configuration, a first SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots configured as DL, and a second SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots. For example, the configured ROs may occupy the same frequency resources for SBFD symbols/slots configured as flexible and non-SBFD symbols/slots, or in other words, the configured ROs for SBFD symbols/slots configured as flexible are the configured ROs in UL usable resource for non-SBFD symbols/slots. The SSB index for the same valid RO in flexible symbols/slots may be the same for SBFD-aware UEs and UEs not supporting the SBFD scheme.

[0121] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs or the

third set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots are determined based on a first RACH configuration and valid ROs in SBFD symbols/slots configured as DL are determined based on a second RACH configuration, a first SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots, and a second SSB-to RO mapping may be performed for valid ROs in non-SBFD symbols/slots. For example, frequency resources of the configured ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots may be different. For example, the first configured RO in UL subband of SBFD symbols/slots may be determined based on the starting position of UL usable resource. The SSB-to-RO mapping may be jointly performed for valid ROs in SBFD symbols/slots.

[0122] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to at least one of the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots are determined based on a first RACH configuration and additional valid ROs in SBFD symbols/slots are determined based on a second RACH configuration, a first SSB-to RO mapping may be performed for additional valid ROs in SBFD symbols/slots, and a second SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots based on the first RACH configuration.

[0123] In some embodiments, the UE 104 may separately perform at least one of the following: mapping a plurality of SSBs to at least one of the first set of valid ROs, the third set of valid ROs or the fourth set of valid ROs; and mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs. In other words, if valid ROs in SBFD symbols/slots configured as flexible and non-SBFD symbols/slots are determined based on a first RACH configuration and additional valid ROs in SBFD symbols/slots are determined based on a second RACH configuration, a first SSB-to RO mapping may be performed for valid ROs in SBFD symbols/slots determined based on the first and second RACH configurations, and a second SSB-to RO mapping may be performed for valid ROs in non-SBFD symbols/slots.

[0124] In some embodiments, the plurality of SSBs are mapped to the first set of valid ROs according to a mapping between the plurality of SSBs and configured ROs in the SBFD time units configured as flexible assuming the SBFD time units configured as flexible are non-SBFD time units. In some embodiments, an SSB index for each of the first set of valid ROs is same as an SSB index for a corresponding configured RO in a same time unit assuming the time unit is non-SBFD time unit. In other words, when mapping the SSBs to the first set of valid ROs in SBFD symbols/slots configured as flexible determined based on the first RACH configuration, the SBFD symbols/slots configured as flexible may be treated as SBFD symbols/slots. Thus, the SSB index for the same valid RO in flexible symbols/slots may be the same for SBFD-aware UEs and UEs not supporting the SBFD scheme.

[0125] Specific examples will be described below with respect to FIGS. 3A-5C to illustrate how to determine valid ROs for SBFD symbols configured as DL and for SBFD symbols configured as flexible.

[0126] In some embodiments, the UE may receive first RACH configuration information from the base station, and the first RACH configuration information indicates configured ROs. For example, in time domain, the ROs are configured in every PRACH configuration period, which contains a set of radio frames. Within a PRACH configuration period, a subset of subframes is indicated to contain a set of PRACH slots, and within each PRACH slot, there might be a set of RACH occasions available for PRACH Msg1 transmission. Besides, in frequency domain, the base station may configure FDMed ROs. The parameter msg1-FDM indicates the number of FDMed ROs in frequency domain. And the starting position of the first RO in frequency domain is also configured by the base station. The valid ROs for SBFD-aware UEs in non-SBFD symbols and valid ROs for UEs not supporting the SBFD scheme may be determined based on the same RACH configuration (i.e., the first RACH configuration information). In an example implementation, the configured RO could be implemented in FIG. 1E. The configured ROs in SBFD slots and non-SBFD slots may occupy the same frequency resources. Alternatively, the first configured RO in UL subband of SBFD slots may be determined based on the indication of starting position of the first RO in frequency domain in the first RACH configuration information.

[0127] In some examples, the UE may determine valid ROs among the configured ROs in SBFD symbols/slots according to the type of the SBFD symbols/slots in which the ROs are. For SBFD symbols configured as DL, valid ROs could be determined, which could be in UL useable resource in SBFD symbols. For SBFD symbol configured as flexible, there could be two options, one is determining valid ROs in the same manner as the valid RO determination for UEs not supporting the SBFD scheme, and a RO could be valid if it meets the first predefined rule. The other option is that a RO could be valid if it meets the second predefined rule, thus only the RO in the UL sub band could be valid.

[0128] If the symbol/slot type of the configured RO is SBFD symbol/slot configured as DL, the configured RO is valid if it meets the predefined rule (2), i.e., the configured RO does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last downlink symbol without SBFD configuration and at least N_{gap} symbols after a last SS/PBCH block symbol, and the configured RO is in the UL usable resources. If the symbol type of the configured RO is SBFD symbol/slot configured as flexible, the configured RO is valid if it meets the predefined rule (1), i.e., the configured RO does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last downlink symbol and at least N_{gap} symbols after a last SS/PBCH block symbol. Alternatively, if the symbol type of the configured RO is SBFD symbol/slot configured as flexible, the configured RO is valid if it meets the predefined rule (2).

[0129] FIGS. 3A-3C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on the same RACH configuration in accordance with some example embodiments of the present disclosure. In the examples in FIGS. 3A-3C, the valid ROs for SBFD-aware UEs in non-SBFD symbols and in SBFD symbols and valid ROs for UEs not supporting the SBFD scheme may be determined based on the same RACH configuration (i.e., the first RACH configuration information).

[0130] In FIG. 3A, the configured ROs in SBFD symbols may be determined in a similar manner as the configured ROs in non-SBFD symbols. A first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (1). A second set of valid ROs are determined in SBFD symbols configured as DL based on the first RACH configuration

information and the predefined rule (2). The configured ROs in DL subbands of the SBFD symbols configured as DL are invalid ROs. SSB-to-RO mapping may be jointly performed in SBFD symbols configured as DL. Another SSB-to-RO mapping may be jointly performed in SBFD symbols configured as flexible and non-SBFD symbols.

[0131] In FIG. 3B, the configured ROs in SBFD symbols may be determined in a similar manner as the configured ROs in non-SBFD symbols. A first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A second set of valid ROs are determined in SBFD symbols configured as DL based on the first RACH configuration information and the predefined rule (2). The configured ROs in DL subbands of the SBFD symbols are invalid ROs. SSB-to-RO mapping may be jointly performed in SBFD symbols configured as DL. Another SSB-to-RO mapping may be jointly performed in SBFD symbols configured as flexible and non-SBFD symbols.

[0132] In FIG. 3C, the offset of the first RO in frequency domain in UL subbands of the SBFD symbols may be the same with the offset of the first RO in frequency domain in non-SBFD symbols. A first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A second set of valid ROs are determined in SBFD symbols configured as DL based on the first RACH configuration information and the predefined rule (2). The configured ROs in DL subbands of the SBFD symbols are invalid ROs. SSB-to-RO mapping may be jointly performed in SBFD symbols. Another SSB-to-RO mapping may be jointly performed in non-SBFD symbols.

[0133] In some embodiments, in addition to the first RACH configuration information, the UE may also receive second RACH configuration information from the base station, and the second RACH configuration information indicates configured ROs in SBFD symbols. The configured ROs based on the first RACH configuration information may be referred to as the first set of configured ROs. The configured ROs based on the second RACH configuration information may be referred to as the second set of configured ROs. The valid ROs for SBFD-aware UEs in non-SBFD symbols and valid ROs for UEs not supporting the SBFD scheme may be determined based on the first RACH configuration information.

[0134] The first RACH configuration information and the second RACH configuration information may be used to determine the valid ROs in SBFD symbols according to the type of the SBFD symbols/slots in which the ROs are. For SBFD symbols configured as DL, only the ROs configured by the second RACH configuration information may be used for determining valid ROs. For SBFD symbols configured as flexible, there could be three options. In the first option, only ROs configured by the first RACH configuration information may be used for determining the valid ROs. In the second option, only ROs configured by the second configuration information may be used for determining the valid ROs. In the third option, ROs configured by both the first and second configuration information may be used for determining the valid ROs.

[0135] If the symbol/slot type of the configured RO is SBFD symbol/slot configured as DL, the configured RO is determined based on the second RACH configuration information, and is valid if the configured RO meets the predefined rules (2). If the symbol/slot type of the configured RO is SBFD symbol/slot configured as flexible, there may be different options and will be described with reference to FIGS. 4A-5C.

[0136] FIGS. 4A-4C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on different RACH configurations in accordance with some example embodiments of the present disclosure. The examples in FIGS. 4A-4C are similar to the examples in FIGS. 3A-3C, respectively, and only differ in that the configured ROs in SBFD symbols configured as DL are determined based on the second RACH configuration information. In other words, the first RACH configuration information is used to determine the configured ROs in SBFD symbol/slot configured as flexible, and the second RACH configuration information is used to determine the configured ROs in SBFD symbol/slot configured as DL.

[0137] In FIG. 4A, a first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (1). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed in SBFD symbols configured as DL. Another SSB-to-RO mapping may be jointly performed in SBFD symbols configured as flexible and non-SBFD symbols.

[0138] In FIG. 4B, a first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed in SBFD symbols configured as DL. Another SSB-to-RO mapping may be jointly performed in SBFD symbols configured as flexible and non-SBFD symbols.

[0139] In FIG. 4C, the offset of the first RO in frequency domain in UL subbands of the SBFD symbols configured as flexible may be the same with the offset of the first RO in frequency domain in non-SBFD symbols. A first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed in SBFD symbols. Another SSB-to-RO mapping may be jointly performed in non-SBFD symbols.

[0140] FIGS. 5A-5C illustrate examples of determining valid ROs in SBFD symbols configured as DL and valid ROs in SBFD symbols configured as flexible based on two RACH configurations in accordance with some example embodiments of the present disclosure. The examples in FIGS. 5A-5C are similar to the examples in FIGS. 4A-4C, respectively, and only differ in that the additional configured ROs in SBFD symbols configured as flexible are determined based on the second RACH configuration information. In other words, both the first and second RACH configuration information are used to determine the configured RO in SBFD symbol/slot configured as flexible, and the second RACH configuration information is used to determine the configured ROs in SBFD symbol/slot configured as DL.

[0141] In FIG. 5A, a first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (1). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). A fourth set of valid ROs are determined in SBFD symbols configured as flexible based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed for the third and fourth sets of valid ROs. Another

SSB-to-RO mapping may be jointly performed for the valid ROs in non-SBFD symbols and the first set of valid ROs.

[0142] In FIG. 5B, a first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). A fourth set of valid ROs are determined in SBFD symbols configured as flexible based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed for the third and fourth sets of valid ROs. Another SSB-to-RO mapping may be jointly performed for the valid ROs in non-SBFD symbols and the first set of valid ROs.

[0143] In FIG. 5C, the offset of the first RO in frequency domain in UL subbands of the SBFD symbols configured as flexible may be the same with the offset of the first RO in frequency domain in non-SBFD symbols. A first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A third set of valid ROs are determined in SBFD symbols configured as DL based on the second RACH configuration information and the predefined rule (2). A fourth set of valid ROs are determined in SBFD symbols configured as flexible based on the second RACH configuration information and the predefined rule (2). SSB-to-RO mapping may be jointly performed in SBFD symbols. Another SSB-to-RO mapping may be jointly performed in non-SBFD symbols.

[0144] In some implementations, when determining the fourth set of valid ROs among the configured ROs in SBFD symbols configured as flexible based on the second RACH configuration information, the configured RO is valid if the configured RO meets the predefined rule (2) and there is no valid RO belonging to the first set of valid ROs in the same symbol. In other words, if there is a valid RO in a SBFD symbol configured as flexible determined by the first RACH configuration, all the ROs determine by the second RACH configuration in this SBFD symbol is invalid.

[0145] The valid ROs in the SBFD symbols configured as flexible include the first set of valid ROs and the fourth set of valid ROs. If a RO determined by the second RACH configuration is fully or partially overlapped with a RO determined by the first RACH configuration, only the RO determined by the first RACH configuration is valid.

[0146] The UE may determine the SSB-to-RO mapping in SBFD symbols according to the symbol type of the valid ROs. For different symbol type, the SSB-to-RO mapping may be jointly performed with different valid RO sets.

[0147] If the symbol/slot type of the valid RO is SBFD symbol/slot configured as DL, the SSB-to-RO mapping may be jointly performed with the valid ROs determined based on predefined rule (2) or determined based on the second RACH configuration.

[0148] If the symbol/slot type of the RO is SBFD symbol/slot configured as flexible, the SSB-to-RO mapping may be jointly performed with the valid RO(s) determined based on predefined rule (1) or determined based on the first RACH configuration.

[0149] FIG. 6 illustrates an example of mapping between SSBs and ROs in SBFD symbols configured as flexible in accordance with some example embodiments of the present disclosure. The mapping in FIG. 6 may apply to the first set of valid ROs in the examples in FIGS. 3B, 4B and 5B. The configured ROs in SBFD symbols configured as flexible are determined in a similar manner as the configured ROs in non-SBFD symbols and the configured ROs for UEs not supporting the SBFD scheme. The first set of valid ROs are determined in SBFD symbols configured as flexible based on the first RACH configuration information and the predefined rule (2). A SSB-to-RO mapping may be jointly performed for the valid ROs in non-SBFD symbols and the first set of valid ROs. When performing the SSB-to-RO mapping for the first set of valid ROs, the SBFD symbols configured as flexible may be treated as non-SBFD symbols. In other words, the invalid ROs may be taken into account for the SSB-to-RO mapping. In this way, a valid RO in the SBFD symbols configured as flexible determined based on the first RACH configuration and the corresponding RO for the UEs not supporting the SBFD scheme may be associated with the same SSB index.

[0150] FIG. 7 illustrates an example of a device 700 that supports valid ROs in accordance with aspects of the present disclosure. The device 700 may be an example of a network entity 102 or a UE 104 as described herein. The device 700 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 700 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 702, a memory 704, a transceiver 706, and, optionally, an I/O controller 708. These components may be in electronic communication or otherwise

coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0151] The processor 702, the memory 704, the transceiver 706, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0152] In some implementations, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704).

[0153] For example, the processor 702 may support wireless communication at the device 700 in accordance with examples as disclosed herein. The processor 702 may be configured to operable to support a means for receiving, from a base station, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and a means for determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

[0154] In another example, the processor 702 may support wireless communication at the device 700 in accordance with examples as disclosed herein. The processor 702 may be configured to operable to support a means for transmitting, to a user equipment, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and a means for determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

[0155] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 702 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 704) to cause the device 700 to perform various functions of the present disclosure such that the device 700 may perform any process of the disclosure as discussed with reference to FIGS. 2 to 6.

[0156] The memory 704 may include random access memory (RAM) and read-only memory (ROM). The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 702 cause the device 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 702 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 704 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0157] The I/O controller 708 may manage input and output signals for the device 700. The I/O controller 708 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 708 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 708 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 708 may be implemented as part of a processor, such as the processor 706. In some implementations, a user may interact with the device 700 via the I/O controller 708 or via hardware components controlled by the I/O controller 708.

[0158] In some implementations, the device 700 may include a single antenna 710. However, in some other implementations, the device 700 may have more than one

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

[0159] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 710 for transmitting the amplified signal into the air or wireless medium.

[0160] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 710 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0161] FIG. 8 illustrates an example of a processor 800 that supports valid ROs in accordance with aspects of the present disclosure. The processor 800 may be an example of a processor configured to perform various operations in accordance with examples as

described herein. The processor 800 may be implemented in a device or its components as described herein. For example, the device may be an example of a network entity 102 or a UE 104 as described herein. The processor 800 may include a controller 802 configured to perform various operations in accordance with examples as described herein. The processor 800 may optionally include at least one memory 804, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 800 may optionally include one or more arithmetic-logic units (ALUs) 806. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0162] The processor 800 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 800) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0163] The controller 802 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. For example, the controller 802 may operate as a control unit of the processor 800, generating control signals that manage the operation of various components of the processor 800. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0164] The controller 802 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 804 and determine subsequent instruction(s) to be executed to cause the processor 800 to support various operations in accordance with examples as described herein. The controller 802 may be configured to track memory address of

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

[0165] The memory 804 may include one or more caches (e.g., memory local to or included in the processor 800 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 804 may reside within or on a processor chipset (e.g., local to the processor 800). In some other implementations, the memory 804 may reside external to the processor chipset (e.g., remote to the processor 800).

[0166] The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 800, cause the processor 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 802 and/or the processor 800 may be configured to execute computer-readable instructions stored in the memory 804 to cause the processor 800 to perform various functions. For example, the processor 800 and/or the controller 802 may be coupled with or to the memory 804, and the processor 800, the controller 802, and the memory 804 may be configured to perform various functions described herein. In some examples, the processor 800 may include multiple processors and the memory 804 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0167] The one or more ALUs 806 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 806 may reside within or on a processor chipset (e.g., the processor 800). In some other implementations, the one or more ALUs 806 may reside external to the

processor chipset (e.g., the processor 800). One or more ALUs 806 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 806 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 806 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 806 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 806 to handle conditional operations, comparisons, and bitwise operations.

[0168] For example, the processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to or operable to support a means for receiving, from a base station, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and a means for determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

[0169] In another example, the processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to or operable to support a means for transmitting, to a user equipment, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and a means for determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

[0170] FIG. 9 illustrates a flowchart of a method 900 that supports valid ROs in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a device or its components as described herein. For example, the operations of the method 900 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0171] At 905, the method may include receiving, from a base station, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs). The operations of 905 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 905 may be performed by a device as described with reference to FIG. 1A.

[0172] At 910, the method may include determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910 may be performed by a device as described with reference to FIG. 1A.

[0173] FIG. 10 illustrates a flowchart of a method 1000 that supports valid ROs in accordance with aspects of the present disclosure. The operations of the method 1000 may be implemented by a device or its components as described herein. For example, the operations of the method 1000 may be performed by a network entity 102 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0174] At 1005, the method may include transmitting, to a user equipment, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs). The operations of 1005 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1005 may be performed by a device as described with reference to FIG. 1A.

[0175] At 1010, the method may include determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units. The operations of 1010 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1010 may be performed by a device as described with reference to FIG. 1A.

[0176] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0177] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0178] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0179] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0180] As used herein, including in the claims, an article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

[0181] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A user equipment comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive, via the transceiver from a base station, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and

determine at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

2. The user equipment of claim 1, wherein determining the at least one valid RO comprises at least one of following:

determining a first set of valid ROs, wherein the first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule; or

determining a second set of valid ROs, wherein the second set of valid ROs are in SBFD time units configured as downlink (DL) and meet a second predefined rule.

3. The user equipment of claim 1, wherein the at least one valid RO meets a second predefined rule, and the at least one valid RO comprises at least one of a first set of valid ROs in SBFD time units configured as flexible and a second set of valid ROs in SBFD time units configured as DL.

4. The user equipment of claim 1, wherein the RACH configuration is a first RACH configuration, the set of configured ROs is a first set of configured ROs, and the processor is further configured to:

receive, via the transceiver from the base station, a second RACH configuration, wherein the second RACH configuration indicates a second set of configured ROs; and

determine a third set of valid ROs among the second set of configured ROs, wherein the third set of valid ROs are in SBFD time units configured as DL and meet a second predefined rule, and

wherein determining the at least one valid RO comprises:

determining a first set of valid ROs among the first set of configured ROs, wherein the first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule or the second predefined rule.

5. The user equipment of claim 4, wherein the processor is further configured to:

determine a fourth set of valid ROs among the second set of configured ROs, wherein the fourth set of valid ROs are in SBFD time units configured as flexible and meet the second predefined rule.

6. The user equipment of claim 5, wherein the processor is further configured to:

determine that a first RO in a first SBFD time unit configured as flexible among the second set of configured ROs is invalid in the case of one of the following:

at least one RO among the first set of valid ROs is in the first SBFD time unit configured as flexible; or

resources for the first RO are at least partially overlapped with resources for at least one of the first set of valid ROs.

7. The user equipment of claim 1, wherein the processor is further configured to:

mapping a plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) to a plurality of valid ROs based on types of time units in which the plurality of valid ROs are, wherein the plurality of valid ROs at least comprise the at least one valid RO and valid ROs in non-SBFD time units among the set of configured ROs.

8. The user equipment of claim 2 or 3, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to the second set of valid ROs; and

mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

9. The user equipment of any of claims 2-4, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to at least one of the first set of valid ROs or the second set of valid ROs; and

mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

10. The user equipment of claim 4, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to the third set of valid ROs; and

mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

11. The user equipment of claim 4, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to at least one of the first set of valid ROs or the third set of valid ROs; and

mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

12. The user equipment of claim 5, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to at least one of the third set of valid ROs or the fourth set of valid ROs; and

mapping the plurality of SSBs to at least one of the first set of valid ROs or valid ROs in non-SBFD time units among the set of configured ROs.

13. The user equipment of claim 5, wherein the processor is further configured to separately perform at least one of the following:

mapping a plurality of SSBs to at least one of the first set of valid ROs, the third set of valid ROs or the fourth set of valid ROs; and

mapping the plurality of SSBs to valid ROs in non-SBFD time units among the set of configured ROs.

14. The user equipment of any of claims 8, 10 or 12, wherein the plurality of SSBs are mapped to the first set of valid ROs according to a mapping between the plurality of SSBs and configured ROs in the SBFD time units configured as flexible assuming the SBFD time units configured as flexible are non-SBFD time units.

15. The user equipment of claim 14, wherein an SSB index for each of the first set of valid ROs is same as an SSB index for a corresponding configured RO in a same time unit assuming the time unit is non-SBFD time unit.

16. The user equipment of claim 2 or 4, wherein the first predefined rule comprises at least one of the following:

a valid RO does not precede a SSB block in a physical RACH slot; or

a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

17. The user equipment of any of claims 2-5, wherein the second predefined rule comprises at least one of the following:

a valid RO is fully within UL usable physical resource blocks (PRBs);

a valid RO is not overlapped with SSBs; or

a valid RO starts at least at least a predefined number of symbols after a last downlink symbol without SBFD configuration and at least a predefined number of symbols after a last SSB symbol.

18. A base station, comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, via the transceiver to a user equipment, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and

determine at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.

19. The base station of claim 18, wherein the RACH configuration is a first RACH configuration, the set of configured ROs is a first set of configured ROs, and the processor is further configured to:

transmit, via the transceiver to the user equipment, a second RACH configuration, wherein the second RACH configuration indicates a second set of configured ROs; and

determine a third set of valid ROs among the second set of configured ROs, wherein the third set of valid ROs are in SBFD time units configured as DL and meet a second predefined rule, and

wherein determining the at least one valid RO comprises:

determining a first set of valid ROs among the first set of configured ROs, wherein the first set of valid ROs are in SBFD time units configured as flexible and meet a first predefined rule or the second predefined rule.

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

receiving, from a base station, a random access channel (RACH) configuration, wherein the RACH configuration indicates a set of configured RACH occasions (ROs); and

determining at least one valid RO in sub-band full duplex (SBFD) time units among the set of configured ROs at least based on types of the SBFD time units.