

PRACH TRANSMISSION

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 physical random access channel (PRACH) transmissions.

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.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support PRACH transmissions. By determining ROs in SBFD time units and ROs in non-SBFD time units and mapping SSBs to these ROs, the PRACH transmission may be transmitted in a RO group determined from the ROs in SBFD time units and/or the ROs in non-SBFD time units. In this way, PRACH transmissions in the SBFD scheme may be supported.

[0005] In a first aspect of the solution, a user equipment determines a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units. The plurality of ROs includes ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units. A first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. The user equipment transmits, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group. Each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and includes ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs. In this way, the determination rule of RO groups for PRACH transmissions may be enhanced.

[0006] Some implementations of the method and apparatuses described herein may further include: receiving, from the base station, a first RO configuration for non-SBFD time units and a second RO configuration for SBFD time units. The ROs in non-SBFD time units are determined based on the first RO configuration, and the ROs in SBFD time units are determined based on the second RO configuration. The second RO configuration includes at least one of the following: an indication of a starting resource block (RB) of a first RO in frequency domain in SBFD time units, or an indication of an offset between a starting RB of the first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units; the number of ROs that are multiplexed in a frequency domain in a same time occasion of SBFD time units; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0007] Some implementations of the method and apparatuses described herein may further include: receiving, from the base station, a third RO configuration. The plurality of ROs in the plurality of time units are determined based on the third RO configuration. The third RO configuration includes at least one of the following: an indication of a starting resource block (RB) of a first RO in frequency domain; the number of ROs that are multiplexed in a frequency domain in a same time occasion; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0008] In some implementations of the method and apparatuses described herein, the first plurality of SSBs and the second plurality of SSBs are the same and are based on a parameter *ssb-PositionsInBurst* in system information block 1 (SIB1) or based on a parameter *ServingCellConfigCommon*.

[0009] In some implementations of the method and apparatuses described herein, the first plurality of SSBs are based on a first SSB configuration for non-SBFD time units, and the second plurality of SSBs are based on a second SSB configuration for SBFD time units.

[0010] Some implementations of the method and apparatuses described herein may further include: determining a first association period and a first association pattern period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; and determining a second association period and a second association pattern period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units.

[0011] Some implementations of the method and apparatuses described herein may further include: determining a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; determining a second association period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units; and determining a third association pattern period based on the first association period and the second association period.

[0012] In some implementations of the method and apparatuses described herein, the second plurality of SSBs are mapped to the ROs in SBFD time units based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units. Some implementations of the method and apparatuses described herein may further include:

determining a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; and determining a third association pattern period based on the first association period.

[0013] In some implementations of the method and apparatuses described herein, a mapping pattern between the first plurality of SSBs and the ROs in non-SBFD time units repeats in a period of the third association pattern period.

[0014] In some implementations of the method and apparatuses described herein, an index of a first SSB mapped to a first RO in a first SBFD time unit following a non-SBFD time unit is after an index of a last SSB mapped to a last RO in the non-SBFD time units.

[0015] In some implementations of the method and apparatuses described herein, an index of a last SSB mapped to a last RO in a last SBFD time unit is before an index of a first SSB mapped to a first RO in a first non-SBFD time unit following the last SBFD time unit.

[0016] In some implementations of the method and apparatuses described herein, the second plurality of SSBs are mapped to the ROs in SBFD time units from a smallest SSB index in the first association period. In the case that the second plurality of SSBs cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the second plurality of SSBs to ROs among the ROs in SBFD time units, no SSB is mapped to the at least one remaining RO.

[0017] Some implementations of the method and apparatuses described herein may further include: determining a time period based on the first association pattern period and the second association pattern period. The time period is a minimum time period including a first integer number of the first association pattern period and a second integer number of the second association pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions; and each of the second plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

[0018] Some implementations of the method and apparatuses described herein may further include: determining a time period based on the third association pattern period. The time period is a minimum time period including a third integer number of the third association

pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

[0019] In some implementations of the method and apparatuses described herein, transmitting the PRACH transmission includes: transmitting, to the base station, a preamble for the configured number of repetitions in the first RO group. The first RO group includes first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units.

[0020] Some implementations of the method and apparatuses described herein may further include: receiving, from the base station, an indication that the preamble is for PRACH transmission with the configured number of repetitions across at least one non-SBFD time unit and at least one SBFD time unit.

[0021] In some implementations of the method and apparatuses described herein, ROs in each RO group in the at least one RO group are consecutive in time domain and associated with a same time unit format, and occupy same frequency resources.

[0022] In some implementations of the method and apparatuses described herein, a time unit format of the ROs in each RO group in the at least one RO group is determined based on one of the following: an indication received from the base station, or a time unit format associated with a first RO.

[0023] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, and occupy same frequency resources.

[0024] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. An offset between frequency resources of the first one or more ROs and frequency resources of second one or more ROs is based on one of the following: a configuration received from the base station; a RB number between a starting RB of a first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units, wherein an indication of the

starting RB of the first RO in frequency domain in the SBFD time units and an indication of the starting RB of the first RO in frequency domain in the non-SBFD time units are received from the base station; or an indication from the base station.

[0025] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. A relative frequency domain location of the first one or more ROs relative to the ROs in non-SBFD time units is the same as a relative frequency domain location of the second one or more ROs relative to the ROs in SBFD time units.

[0026] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. Frequency resources of the first one or more ROs and frequency resources of the second one or more ROs are overlapped.

[0027] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, wherein one of the following: the first one or more ROs include ROs with a smaller frequency resource index among ROs that are in non-SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the second one or more ROs; or the second one or more ROs include ROs with a smaller frequency resource index among ROs that are in SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the first one or more ROs.

[0028] In some implementations of the method and apparatuses described herein, the first one or more ROs belong to the ROs in non-SBFD time units, and the second one or more ROs belong to the ROs in SBFD time units.

[0029] In a second aspect of the solution, a base station determines a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units. The plurality of ROs includes ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units. A first plurality of synchronization signal and physical broadcast channel (PBCH) blocks

(SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. The base station receives, from the user equipment, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group. Each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and includes ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs. In this way, the determination rule of RO groups for PRACH transmissions may be enhanced.

[0030] Some implementations of the method and apparatuses described herein may further include: transmitting, to the user equipment, a first RO configuration for non-SBFD time units and a second RO configuration for SBFD time units. The ROs in non-SBFD time unit are determined based on the first RO configuration, and the ROs in SBFD time units are determined based on the second RO configuration. The second RO configuration includes at least one of the following: an indication of a starting resource block (RB) of a first RO in frequency domain in SBFD time units, or an indication of an offset between a starting RB of the first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units; the number of ROs that are multiplexed in a frequency domain in a same time occasion of the SBFD time units; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0031] Some implementations of the method and apparatuses described herein may further include: transmitting, to the user equipment, a third RO configuration. The plurality of ROs in the plurality of time units are determined based on the third RO configuration. The third RO configuration includes at least one of the following: an indication of a starting resource block (RB) of a first RO in frequency domain; the number of ROs that are multiplexed in a frequency domain in a same time occasion; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0032] In some implementations of the method and apparatuses described herein, the first plurality of SSBs and the second plurality of SSBs are the same and are based on a parameter

ssb-PositionsInBurst in system information block 1 (SIB1) or based on a parameter *ServingCellConfigCommon*.

[0033] In some implementations of the method and apparatuses described herein, the first plurality of SSBs are based on a first SSB configuration for non-SBFD time units, and the second plurality of SSBs are based on a second SSB configuration for SBFD time units.

[0034] Some implementations of the method and apparatuses described herein may further include: determining a first association period and a first association pattern period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; and determining a second association period and a second association pattern period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units.

[0035] Some implementations of the method and apparatuses described herein may further include: determining a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time unit; determining a second association period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units; and determining a third association pattern period based on the first association period and the second association period.

[0036] In some implementations of the method and apparatuses described herein, the second plurality of SSBs are mapped to the ROs in SBFD time units based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units. Some implementations of the method and apparatuses described herein may further include: determining a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time unit; and determining a third association pattern period based on the first association period.

[0037] In some implementations of the method and apparatuses described herein, a mapping pattern between the first plurality of SSBs and the ROs in non-SBFD time units repeats in a period of the third association pattern period.

[0038] In some implementations of the method and apparatuses described herein, an index of a first SSB mapped to a first RO in a first SBFD time unit following a non-SBFD time unit is after an index of a last SSB mapped to a last RO in the non-SBFD time units.

[0039] In some implementations of the method and apparatuses described herein, an index of a last SSB mapped to a last RO in a last SBFD time unit is before an index of a first SSB mapped to a first RO in a first non-SBFD time unit following the last SBFD time units.

[0040] In some implementations of the method and apparatuses described herein, the second plurality of SSBs are mapped to the ROs in SBFD time units from a smallest SSB index in the first association period. In the case that the second plurality of SSBs cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the second plurality of SSBs to ROs among the ROs in SBFD time units, no SSB is mapped to the at least one remaining RO.

[0041] Some implementations of the method and apparatuses described herein may further include: determining a time period based on the first association pattern period and the second association pattern period. The time period is a minimum time period including a first integer number of the first association pattern period and a second integer number of the second association pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions; and each of the second plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

[0042] Some implementations of the method and apparatuses described herein may further include: determining a time period based on the third association pattern period. The time period is a minimum time period including a third integer number of the third association pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

[0043] In some implementations of the method and apparatuses described herein, receiving the PRACH transmission includes: receiving, from the user equipment, a preamble for the configured number of repetitions in the first RO group. The first RO group includes first one or more ROs in non-SBFD time unit and second one or more ROs in SBFD time units.

[0044] Some implementations of the method and apparatuses described herein may further include: transmitting, to the user equipment, an indication that the preamble is for

PRACH transmission with the configured number of repetitions across at least one non-SBFD time unit and at least one SBFD time unit.

[0045] In some implementations of the method and apparatuses described herein, ROs in each RO group in the at least one RO group are consecutive in time domain and associated with a same time unit format, and occupy same frequency resources.

[0046] In some implementations of the method and apparatuses described herein, a time unit format of the ROs in each RO group in the at least one RO group is determined based on one of the following: an indication transmitted to the user equipment, or a time unit format associated with a first RO.

[0047] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, and occupy same frequency resources

[0048] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. An offset between frequency resources of the first one or more ROs and frequency resources of second one or more ROs is based on one of the following: a configuration transmitted to the user equipment; a RB number between a starting RB of a first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units, wherein an indication of the starting RB of the first RO in frequency domain in the SBFD time units and an indication of the starting RB of the first RO in frequency domain in the non-SBFD time units are transmitted to the user equipment; or an indication transmitted to the user equipment.

[0049] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. A relative frequency domain location of the first one or more ROs relative to the ROs in non-SBFD time units is the same as a relative frequency domain location of the second one or more ROs relative to the ROs in SBFD time units.

[0050] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. Frequency resources of the first one or more ROs and frequency resources of the second one or more ROs are overlapped.

[0051] In some implementations of the method and apparatuses described herein, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, wherein one of the following: the first one or more ROs include ROs with a smaller frequency resource index among ROs that are in non-SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the second one or more ROs; or the second one or more ROs include ROs with a smaller frequency resource index among ROs that are in SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the first one or more ROs.

[0052] In some implementations of the method and apparatuses described herein, the first one or more ROs belong to the ROs in non-SBFD time units, and the second one or more ROs belong to the ROs in SBFD time units.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] FIG. 1A illustrates an example of a wireless communications system that supports PRACH transmissions in accordance with aspects of the present disclosure.

[0054] FIG. 1B illustrates an example of an NR 4-step random-access procedure that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0055] FIG. 1C illustrates an example of determination of valid ROs in accordance with some example embodiments of the present disclosure.

[0056] 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.

[0057] FIG. 1E illustrates an example of a structure of overall random access channel (RACH) resources that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0058] FIGS. 1F through 1H illustrate examples of associations between ROs and SSBs that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0059] FIG. 1I illustrates an example of a RACH resource structure.

[0060] FIG. 1J illustrates an example of determination of multiple RO groups for a PRACH transmission with a configured number of repetitions.

[0061] FIG. 1K illustrates an example diagram of a sub-band full duplex scheme.

[0062] FIG. 2 illustrates an example signaling chart of a communication process that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0063] FIG. 3A illustrates an example of mapping between SSBs and ROs in non-SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0064] FIG. 3B illustrates an example of mapping between SSBs and ROs in SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0065] FIG. 4 illustrates an example of separate mapping between SSBs and ROs in non-SBFD symbols/slots and between SSBs and ROs in SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0066] FIGS. 5A and 5B illustrate examples of jointly mapping between SSBs and ROs in non-SBFD symbols/slots and between SSBs and ROs in SBFD symbols/slots that support PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0067] FIGS. 6A through 6C illustrate examples of determination of a RO group that support PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0068] FIG. 7 illustrates an example of determination of a time period based on different association pattern periods for SBFD symbols/slots and non-SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure.

[0069] FIG. 8 illustrates an example of a device that supports PRACH transmissions in accordance with aspects of the present disclosure.

[0070] FIG. 9 illustrates an example of a processor that supports PRACH transmissions in accordance with aspects of the present disclosure.

[0071] FIGS. 10 through 11 illustrate flowcharts of methods that support PRACH transmissions in accordance with aspects of the present disclosure.

[0072] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0073] 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.

[0074] 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.

[0075] 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.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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.

[0081] 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. A PRACH preamble transmission is associated with a downlink (DL) RS. This association can help a serving BS to identify an uplink spatial reception filter or beam to receive a PRACH preamble and can help a UE to identify an uplink spatial transmission filter or beam to transmit a PRACH preamble. 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. The UE needs to determine valid ROs among the ROs configured in the time domain and frequency domain. For example, for a time division duplex (TDD) configuration, a RO within or overlapping with DL symbols is considered invalid. The valid ROs are associated with SSBs that may be transmitted with different beams. In order to increase the reliability of a PRACH transmission, the PRACH transmission may be repeatedly transmitted in a RO group associated with the same SSB.

[0082] 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, in 3GPP Release19, a duplexing 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 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.

[0083] 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 determines a plurality of ROs in a plurality of time units. The plurality of ROs includes ROs in SBFD time units and ROs in non-SBFD time units. A first plurality of SSBs are mapped

to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. The user equipment transmits, to the base station, a PRACH transmission with a configured number of repetitions in a first RO group among at least one RO group. Each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and includes ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs. By determining ROs in SBFD time units and ROs in non-SBFD time units and mapping SSBs to these ROs, the PRACH transmission may be transmitted in a RO group determined from the ROs in SBFD time units and/or the ROs in non-SBFD time units. In this way, PRACH transmissions in the SBFD scheme may be supported.

[0084] Aspects of the present disclosure are described in the context of a wireless communications system.

[0085] FIG. 1A illustrates an example of a wireless communications system 100 that supports PRACH transmissions 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.

[0086] 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.

[0087] 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.

[0088] 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.

[0089] 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.

[0090] 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.

[0091] 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).

[0092] 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.

[0093] 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)).

[0094] 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 adaptation 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.

[0095] 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).

[0096] 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.

[0097] 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.

[0098] 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, N3, or another network interface). The packet data network 108 may include an application server 118. In some implementations,

one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the 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).

[0099] 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.

[0100] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0101] 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.

[0102] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0103] 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.

[0104] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0105] FIG. 1B illustrates an example of an NR 4-step random-access procedure 120 that supports PRACH transmissions 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 BS 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.

[0106] In the random-access procedure 120, the UE 104 may firstly transmit 122 a Msg1 including a preamble to the BS 102. After receiving the Msg1, the BS 102 may transmit 124 a Random-Access Response (RAR) in Msg2 to the UE 104, indicating the reception of the preamble and providing necessary 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 BS 102. The BS 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 BS 102.

[0107] 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. Within each PRACH slot, there might be a set of RACH occasions available for PRACH Msg1 transmission. Besides, in frequency domain, the BS 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.

[0108] 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.

[0109] FIG. 1C illustrates an example 130 of determination of valid ROs in accordance with some example embodiments of the present disclosure.

[0110] 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 subframe {6} is flexible slots, and thus do not meet the condition of valid PRACH slots, these slots are PRACH slots with invalid ROs. The slots in subframes {7,8,9} are PRACH slots with valid ROs since these slots are UL slots. In frequency domain, the BS 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. Unless explicitly indicated, a “RO” hereinafter refers to a valid RO.

[0111] 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 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.

[0112] FIG. 1D illustrates an example of a structure 140 of overall RACH resources that supports PRACH transmissions 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.

[0113] 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.

[0114] The association between SSBs and ROs can be one-to-one (1-to-1), many-to-one (1-to-N), or one-to-many (N-to-1) depending on the network configuration. This may be determined by a parameter *SSB-PerRACH-Occasion*.

[0115] FIGS. 1F through 1H illustrate examples of associations 150A, 150B and 150C between ROs and SSBs that supports PRACH transmissions in accordance with some

example embodiments of the present disclosure. As shown in FIGS. 1F through 1H, eight SSBs, e.g., SSB#0 to SSB#7, are assumed.

[0116] 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.

[0117] 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.

[0118] In the example association 150C, there are two FD Med 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.

[0119] A SSB-to-RO association period, starting from frame 0, for mapping SSB indexes to ROs is the smallest integer number of the PRACH configuration periods such that N_{Tx}^{SSB} SSB indexes are mapped at least once to the ROs within the SSB-to-RO association period, where N_{Tx}^{SSB} is the number of SSBs actually transmitted by the BS. A UE obtains N_{Tx}^{SSB} from the value of *ssb-PositionsInBurst* in SIB1 or in *ServingCellConfigCommon*. If after an integer number of SSB indexes to ROs mapping cycles within the SSB-to-RO association period there is a set of ROs or PRACH preambles that are not mapped to N_{Tx}^{SSB} SSB indexes, no SSB indexes are mapped to the set of ROs or PRACH preambles.

[0120] An SSB-to-RO association pattern period includes one or more SSB-to-RO association periods and is determined so that a pattern between ROs and SSB indexes repeats at most every 160 msec. ROs not associated with SSB indexes after an integer number of SSB-to-RO association periods, if any, are not used for PRACH transmissions.

[0121] Having repeated PRACH transmission in multiple ROs associated with the same beam (i.e., the same SSB) would increase the reliability of the PRACH transmission. The candidate number $N_{preamble}^{rep}$ of repetitions for PRACH transmissions, e.g. {2,4,8}, is/are

explicitly configured. For a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions, all respective valid ROs are consecutive in time, use same frequency resources, and are associated with a same SSB index. For different numbers of repetitions, different preambles would be used for identification with single repetition. In other words, the BS may be aware of the number of repetitions for a PRACH transmission based on a received preamble associated with the number of repetitions.

[0122] For a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions, a time period, starting from frame 0, is the smallest integer number of SSB-to-RO association pattern periods such that $N_{\text{Tx}}^{\text{SSB}}$ SSB indexes are mapped to $N_{\text{preamble}}^{\text{rep}}$ ROs within the time period at least once for each configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions. The set of $N_{\text{preamble}}^{\text{rep}}$ ROs for a PRACH transmission repeats every time period.

[0123] FIG. 1I illustrates an example 160 of a RACH resource structure. As shown in FIG. 1I, an association pattern period is the smallest integer number of the SSB-to-RO association periods (not shown in FIG. 1I) such that a pattern between ROs and SSB indexes repeats. K is the smallest integer number of association pattern periods in the time period such that for each configured number of preamble repetitions, each SSB index is mapped to a RO group for the configured number of preamble repetitions at least once within the time period. In the example 160, a maximum configured number of repetitions is four. The duration X of the time period includes two association pattern periods (i.e., $K = 2$) such that each SSB index is mapped to four ROs for four preamble repetitions within the time period at least once.

[0124] For a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions within a time period for $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with an SSB, if the parameter *TimeOffsetBetweenStartingRO* is provided, for each frequency resource index for frequency multiplexed ROs, the first valid RO of the first $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is the first valid RO, and the first valid RO of subsequent $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is after *TimeOffsetBetweenStartingRO* consecutive valid ROs in time from the first valid RO corresponding to the previous $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions. For a PRACH transmission

with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions within a time period for $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with an SSB, if the parameter *TimeOffsetBetweenStartingRO* is not provided, for each frequency resource index for frequency multiplexed ROs, the first valid RO of the first $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is the first valid RO, and the first valid RO of subsequent $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions, if any, is determined after the ROs determined for the previous $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions according to the following ordering of valid ROs: first, in an increasing order of frequency resource indexes for frequency multiplexed ROs; and second, in an increasing order of time resource indexes for time multiplexed ROs.

[0125] FIG. 1J illustrates an example 170 of determination of multiple RO groups for a PRACH transmission with a configured number of repetitions. In the example 170, four RO groups associated with SSB#0 are determined. The number of preamble repetitions is two, i.e., $N_{\text{preamble}}^{\text{rep}} = 2$. The second RO group contains frequency multiplexed ROs with a frequency resource index larger than the frequency resource index of the first RO group, the third RO group contains ROs with a time resource index larger than the time resource index of the first and second RO groups, and the fourth RO group contains frequency multiplexed ROs with a frequency resource index larger than the frequency resource index of the third RO group.

[0126] 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, in 3GPP Release19, 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 BS side and not at the UE side. An example of a duplexing scheme could be seen in FIG. 1G. In the example of FIG. 1G, two downlink (DL) sub-bands are duplex with an uplink (UL) sub-band in slot #0 and slot #1.

[0127] Transmitting PRACH in the UL subband in SBFD symbols/slots will result in reduced latency and enhanced coverage. However, potential issues might arise when the

legacy methods for PRACH transmissions with repetitions (e.g., mapping between SSBs and ROs, determination of RO groups for a configured number of preamble repetitions) as described above are applied to the SBFD scheme.

[0128] In a first specific aspect, if SBFD symbols/ slots are configured for a UE, considering the access latency, the PRACH could also be transmitted in the SBFD symbols/slots. For legacy UE, the SSB-to-RO mapping should be in non-SBFD symbols/slots, but for a UE configured with the SBFD scheme, the SSB-to-RO mapping should be in both non-SBFD symbols/slots and SBFD symbols/slots. Furthermore, for both UEs, in non-SBFD symbols/slots, the mapping pattern should be same considering the compatibility. Then, how to perform the SSB-to-RO mapping in the SBFD symbols/slots should be determined.

[0129] In a second specific aspect, a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions would be across different slots as well as across SBFD symbols and non-SBFD symbols in different slots, where each PRACH transmission within a slot has either all SBFD or all non-SBFD symbols. PRACH transmissions in SBFD symbols and non-SBFD symbols might be configured with different available frequency resources in different slots. However, in the legacy methods for PRACH transmissions with repetitions as described above, for a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions, all respective valid ROs are consecutive in time, use same frequency resources, and are associated with a same SSB index. Then, how to determine all respective valid ROs for a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions across SBFD symbols and non-SBFD symbols should be designed.

[0130] Reference is now made to FIG. 2, which illustrates an example signaling chart of a communication process that supports PRACH transmissions 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 BS 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.

[0131] As shown in FIG. 2, the UE 104 determines 202 a plurality of ROs in a plurality of time units. The plurality of ROs includes ROs in SBFD time units and ROs in non-SBFD time units. A first plurality of SSBs are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. The UE 104 transmits 206, to the BS 102, a PRACH transmission 208 with a configured number of repetitions in a first RO group among at least one RO group. Each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and includes ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

[0132] In some implementations, the time unit could be a symbol or a slot. There may be four symbol formats in a system adopting the subband full duplex scheme. The four 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 a slot format indicator (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 that a slot includes only SBFD symbol or some SBFD symbols. A non-SBFD slot or symbol could be a slot or symbol not being a SBFD slot or symbol.

[0133] For example, the UE 104 may determine first multiple ROs in non-SBFD symbols/slots and second multiple ROs in SBFD symbols/slots. N1 SSBs may be mapped to the first multiple ROs and N2 SSBs may be mapped to the second multiple ROs. After receiving at least one SSB in SBFD time units and/or at least one SSB in non-SBFD time units from the BS 102, the UE 104 may measure the channel status of each SSB and select a SSB with a good channel quality. After selecting a SSB, the UE 104 may determine at least one RO group associated with the selected SSB, select one RO group from the at least one RO group and transmit PRACH repetitions in the selected RO group to the BS 102. For example, the UE 104 may transmit a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with a SSB in first group of ROs among a set of RO groups with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with the SSB. The SSB is one SSB from N1 SSBs and/or N2 SSBs. In some embodiments, the UE 104 may be configured with several PRACH repetition numbers, e.g., {2, 4, 8}. In other words, the UE 104 may determine to transmit a 2-PRACH repetition, or a 4-PRACH repetition, or an 8-PRACH repetition. If the UE 104 determines to transmit a 4-PRACH repetition, the UE 104 may determine at least one RO group in a time period X which consists of K SSB-to-RO association pattern period(s). Each RO group includes four ROs associated with the selected SSB. As mentioned above, a set of RO group(s) for a configured number of PRACH repetitions repeats every time period X. The UE 104 may select one RO group for transmitting a PRACH transmission with four repetitions. The SSBs in SBFD time units and the SSBs in non-SBFD time units transmitted by the BS 102 may be the same or at least partially different. ROs in a RO group may be located in all SBFD time units, or all non-SBFD time units, or across both SBFD time units and non-SBFD time units based on the RACH resource structure.

[0134] Similarly, the BS 102 determines 204 the plurality of ROs in the plurality of time units and receives 210 the PRACH transmission 208 with the configured number of repetitions in the first RO group. In this way, PRACH transmissions in the SBFD scheme may be supported.

[0135] For example, the BS 102 may broadcast the first plurality of SSBs corresponding to a first plurality of beams in SBFD time units and the second plurality of SSBs corresponding to a second plurality of beams in non-SBFD time units. The first plurality of

beams and the second plurality of beams may be the same or at least partially different. The BS 102 may determine corresponding ROs associated with the transmitted SSBs and determine corresponding RO groups. The BS 102 and the UE 104 may have a common understanding on the SSB-to-RO mappings in non-SBFD time units and in SBFD time units. It should be understood that the UE 104 and the BS 102 may follow the same determination rule of RO groups for PRACH transmissions. The BS 102 may monitor PRACH repetitions in the RO groups and identify a SSB associated with the RO group in which the PRACH repetitions are received.

[0136] In some embodiments, the UE 104 may receive, from the BS 102, a first RO configuration for non-SBFD time units and a second RO configuration for SBFD time units. The ROs in non-SBFD time units are determined based on the first RO configuration, and the ROs in SBFD time units are determined based on the second RO configuration. The second RO configuration may include at least one of the following: an indication of a starting RB of a first RO in frequency domain in SBFD time units, or an indication of an offset between a starting RB of the first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units; the number of ROs that are multiplexed in a frequency domain in the same time occasion of SBFD time units; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0137] In other words, the UE 104 may receive a first configuration for first multiple ROs in non-SBFD symbols/slots, and receive a second configuration for first multiple ROs in SBFD symbols/slots. The UE 104 may determine first multiple ROs in non-SBFD symbols/slots based on the first configuration and determine second multiple ROs in SBFD symbols/slots based on the second configuration. In one example implementation, the first configuration or the second configuration may indicate at least one of the following: the PRACH configuration period, a subset of subframes containing a set of PRACH slots, a set of RACH occasions available for PRACH Msg1 transmission within each PRACH slot, and the starting RB (starting position of the first RO in frequency domain) for the first RO in frequency domain and the number of FD Med ROs in frequency domain. In other words, RO configuration parameters for non-SBFD symbols/slots and RO configuration parameters for

SBFD symbols/slots may be provided separately. In another example implementation, the second configuration may indicate an offset between the starting RB of first multiple ROs in non-SBFD symbols/slots and the starting RB of second multiple ROs in SBFD symbols/slots. In other words, the RO configuration parameters for SBFD symbols/slots may be based on the RO configuration parameters for non-SBFD symbols/slots and an offset value indicated by the BS 102.

[0138] In some embodiments, the UE 104 may receive a third RO configuration from the BS 102. The plurality of ROs in the plurality of time units are determined based on the third RO configuration. The third RO configuration may include at least one of the following: an indication of a starting RB of a first RO in frequency domain; the number of ROs that are multiplexed in a frequency domain in the same time occasion; a PRACH configuration period; or an indication of subframes containing available ROs in the PRACH configuration period.

[0139] In other words, the UE 104 may receive a third configuration indicating PRACH slots and frequency number for ROs. The UE 104 may determine first multiple ROs in non-SBFD symbols/slots and second multiple ROs in SBFD symbols/slots based on the third configuration. In a PRACH slot with SBFD symbols, only ROs within the UL sub-band are valid ROs.

[0140] N1 SSBs may be mapped to the first multiple ROs and N2 SSBs may be mapped to the second multiple ROs. In some example implementations, the first plurality of SSBs and the second plurality of SSBs are the same and are based on a parameter *ssb-PositionsInBurst* in system information block 1 (SIB1) or based on a parameter *ServingCellConfigCommon*. In other words, $N1=N2=N$ and the N1 SSBs and the N2 SSBs are the same. The N1 SSBs and the N2 SSBs may be collectively referred to as N SSBs. The N SSBs may be provided by *ssb-PositionsInBurst* in SIB1 or in *ServingCellConfigCommon*, e.g., SSB#0, SSB#1, SSB#2, SSB#3, SSB#4, SSB#5. Alternatively, the first plurality of SSBs may be determined based on a first SSB configuration for non-SBFD time units, and the second plurality of SSBs may be determined based on a second SSB configuration for SBFD time units. In other words, the N1 SSBs and the N2 SSBs could be configured separately for non-SBFD symbols/slots and SBFD symbols/slots. For example, N1 SSBs are for non-SBFD symbols/slots and N2 SSBs are for SBFD symbols/slots, then the N1 SSBs

are mapped to the first multiple ROs and the N2 SSBs are mapped to the second multiple ROs.

[0141] In some embodiments, the UE 104 may determine a first association period and a first association pattern period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units. The UE 104 may determine a second association period and a second association pattern period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units. In other words, the UE 104 may determine a first association period and first association pattern period based on the mapping between the N1 SSBs to the first multiple ROs, and determine a second association period and second association pattern period based on the mapping between the N2 SSBs to the second multiple ROs. In this way, SSB-to-RO mapping in non-SBFD symbols/slots and SSB-to-RO mapping in SBFD symbols/slots may be separately performed. Association periods and association pattern periods may be determined for non-SBFD symbols/slots and for SBFD symbols/slots, respectively.

[0142] In an example implementation, for all non-SBFD symbols/slots, the N1 SSBs are mapped to the first multiple ROs in a manner similar to the legacy SSB-to-RO mapping method described in TS 38.211. In other words, for all non-SBFD symbols/slots, the N1 SSBs may be mapped to first multiple ROs in the following order: 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.

[0143] A first association period and a first association pattern period for non-SBFD symbols/slots may be determined in a manner similar to the legacy method described above. Specifically, an association period, starting from frame 0, for mapping the N1 SSB indexes to the first multiple ROs is the smallest integer number of the PRACH configuration periods such that the N1 SSB indexes are mapped at least once to the first multiple ROs within the first association period. If there is a set of ROs or PRACH preambles that are not mapped to the N1 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the first association period, no SSB indexes are mapped to the set of ROs or PRACH

preambles. In other words, if the N1 SSB indexes cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the N1 SSB indexes to the first multiple ROs, no SSB is mapped to the at least one remaining RO. A first association pattern period includes one or more first association periods and is determined so that a pattern between the first multiple ROs and the N1 SSB indexes repeats at most every 160 msec. ROs not associated with the N1 SSB indexes after an integer number of first association periods, if any, are not used for PRACH transmissions.

[0144] For all SBFD symbols/slots, the N2 SSBs are mapped to the second multiple ROs in a manner similar to the legacy SSB-to-RO mapping method described in TS 38.211. In other words, for all SBFD symbols/slots, the N2 SSBs may be mapped to the second multiple ROs in the following order: 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.

[0145] A second association period and a second association pattern period for SBFD symbols/slots may be determined in a manner similar to the legacy method described above. Specifically, an association period, starting from frame 0, for mapping the N2 SSB indexes to the second multiple ROs is the smallest integer number of the PRACH configuration period such that the N2 SSB indexes are mapped at least once to the second multiple ROs within the second association period. If there is a set of ROs or PRACH preambles that are not mapped to the N2 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the second association period, no SSB indexes are mapped to the set of ROs or PRACH preambles. In other words, if the N2 SSB indexes cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the N2 SSB indexes to the second multiple ROs, no SSB is mapped to the at least one remaining RO. A second association pattern period includes one or more second association periods and is determined so that a pattern between the second multiple ROs and the N2 SSB indexes repeats at most every 160 msec. ROs not associated with the N2 SSB indexes after an integer number of second association periods, if any, are not used for PRACH transmissions.

[0146] FIG. 3A illustrates an example of mapping 300A between SSBs and ROs in non-SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example mapping 300A, a UL PRACH slot contains two ROs in time domain and four FDMed ROs in frequency domain. Six SSBs are configured for UL slots, and each RO is associated with two SSBs. An association pattern period for UL slots is determined to include a minimum integer number of association periods for UL slots (not shown) so that a pattern between the ROs in UL slots and the SSB indexes for UL slots repeats.

[0147] FIG. 3B illustrates an example of mapping 300B between SSBs and ROs in SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example mapping 300B, a SBFD PRACH slot contains two ROs in time domain and two FDMed ROs in frequency domain. Six SSBs are configured for SBFD slots, and each RO is associated with two SSBs. An association pattern period for SBFD slots is determined to include a minimum integer number of association periods for SBFD slots (not shown) so that a pattern between the ROs in SBFD slots and the SSB indexes for SBFD slots repeats.

[0148] In some embodiments, the UE 104 may determine a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units and determine a second association period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units. In other words, the UE 104 may determine a first association period based on the mapping between the N1 SSBs to the first multiple ROs, and determine a second association period based on the mapping between the N2 SSBs to the second multiple ROs. The UE 104 may determine a third association pattern period based on the first association period and the second association period. In this way, SSB-to-RO mapping in non-SBFD symbols/slots and SSB-to-RO mapping in SBFD symbols/slots may be separately performed. Association periods may be determined for non-SBFD symbols/slots and for SBFD symbols/slots, respectively. The association pattern period may be determined based on the association periods and SSB-to-RO mapping for the non-SBFD symbols/slots and for SBFD symbols/slots.

[0149] In an example implementation, for all non-SBFD symbols/slots, the N1 SSBs are mapped to the first multiple ROs in a manner similar to the legacy SSB-to-RO mapping method described in TS 38.211. In other words, for all non-SBFD symbols/slots, the N1 SSBs may be mapped to first multiple ROs in the following order: 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. A first association period for non-SBFD symbols/slots may be determined in a manner similar to the legacy method described above. Specifically, an association period, starting from frame 0, for mapping the N1 SSB indexes to the first multiple ROs is the smallest integer number of the PRACH configuration periods such that the N1 SSB indexes are mapped at least once to the first multiple ROs within the first association period. If there is a set of ROs or PRACH preambles that are not mapped to the N1 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the first association period, no SSB indexes are mapped to the set of ROs or PRACH preambles.

[0150] For all SBFD symbols/slots, the N2 SSBs are mapped to the second multiple ROs in a manner similar to the legacy SSB-to-RO mapping method described in TS 38.211. In other words, for all SBFD symbols/slots, the N2 SSBs may be mapped to the second multiple ROs in the following order: 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. A second association period for SBFD symbols/slots may be determined in a manner similar to the legacy method described above. Specifically, an association period, starting from frame 0, for mapping the N2 SSB indexes to the second multiple ROs is the smallest integer number of the PRACH configuration period such that the N2 SSB indexes are mapped at least once to the second multiple ROs within the second association period. If there is a set of ROs or PRACH preambles that are not mapped to the N2 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the second association period, no SSB indexes are mapped to the set of ROs or PRACH preambles.

[0151] A third association pattern period includes one or more first association periods and one or more second association period and is determined so that a pattern between the ROs and the SSB indexes repeats at most every 160 msec. ROs not associated with the SSB indexes after an integer number of first association periods and an integer number of second association periods, if any, are not used for PRACH transmissions.

[0152] FIG. 4 illustrates an example of separate mapping 400 between SSBs and ROs in non-SBFD symbols/slots and between SSBs and ROs in SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example mapping 400, a UL PRACH slot contains two ROs in time domain and four FDMed ROs in frequency domain. Six SSBs are configured for UL slots, and each RO is associated with two SSBs. A SBFD PRACH slot contains two ROs in time domain and two FDMed ROs in frequency domain. Six SSBs are configured for SBFD slots, and each RO is associated with two SSBs. An association pattern period is determined to include a first integer number of association periods for UL slots (not shown) and a second integer number of association periods for SBFD slots (not shown) so that a pattern between the ROs and the SSB indexes repeats.

[0153] In some embodiments, the second plurality of SSBs are mapped to the ROs in SBFD time units based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units. The UE 104 may determine a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units and determine a third association pattern period based on the first association period. A mapping pattern between the first plurality of SSBs and the ROs in non-SBFD time units repeats in a period of the third association pattern period. In this way, SSB-to-RO mapping in non-SBFD symbols/slots and SSB-to-RO mapping in SBFD symbols/slots may be jointly performed. SSB-to-RO mapping in SBFD symbols/slots may be performed based on the SSB-to-RO mapping in non-SBFD symbols/slots. An association period may be determined for non-SBFD symbols/slots. The association pattern period may be determined based on the association period and SSB-to-RO mapping for the non-SBFD symbols/slots.

[0154] In an example implementation, for all non-SBFD symbols/slots, the N1 SSBs are mapped to the first multiple ROs in a manner similar to the legacy SSB-to-RO mapping

method described in TS 38.211. In other words, for all non-SBFD symbols/slots, the N1 SSBs may be mapped to first multiple ROs in the following order: 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. A first association period for non-SBFD symbols/slots may be determined in a manner similar to the legacy method described above. Specifically, an association period, starting from frame 0, for mapping the N1 SSB indexes to the first multiple ROs is the smallest integer number of the PRACH configuration periods such that the N1 SSB indexes are mapped at least once to the first multiple ROs within the first association period. If there is a set of ROs or PRACH preambles that are not mapped to the N1 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the first association period, no SSB indexes are mapped to the set of ROs or PRACH preambles.

[0155] For all SBFD symbols/slots, the N2 SSBs are mapped to the second multiple ROs based on the mapping of the N1 SSBs to the first multiple ROs. For example, the N2 SSBs may be mapped to the second multiple ROs in the same manner in each first association period. For all SBFD symbols/slots, the N2 SSBs are mapped to the second multiple ROs in a manner similar to the legacy SSB-to-RO mapping method described in TS 38.211. In other words, for all SBFD symbols/slots, the N2 SSBs may be mapped to the second multiple ROs in the following order: 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. Some example implementations of determining the mapping between the N2 SSBs and the second multiple ROs in SBFD symbols/slots based on the mapping between the N1 SSBs and the first multiple ROs in SBFD symbols/slots will be described with reference to FIGS. 5A and 5B.

[0156] The third association pattern period may be determined based on the first association period, wherein a third association pattern period includes one or more first association periods and is determined so that a pattern between first multiple ROs and the N1 SSB indexes in non-SBFD symbols/slots repeats at most every 160 msec. Alternatively, the

third association pattern period may be determined so that a pattern between the ROs and the SSB indexes repeats at most every 160 msec. ROs not associated with the N1 SSB indexes after an integer number of first association periods, if any, are not used for PRACH transmissions.

[0157] The N2 SSBs may be mapped to the second multiple ROs in each first association period in various manners.

[0158] In some embodiments, an index of a first SSB mapped to a first RO in a first SBFD time unit following a non-SBFD time unit is after an index of a last SSB mapped to a last RO in the non-SBFD time units. Alternatively or additionally, an index of a last SSB mapped to a last RO in a last SBFD time unit is before an index of a first SSB mapped to a first RO in a first non-SBFD time unit following the last SBFD time unit. In other words, the N2 SSBs are mapped to the second multiple ROs and the first SSB index mapped to the SBFD symbols/slots should be a next SSB index of the last SSB index in non-SBFD symbols/slots. The last SSB index mapped to the SBFD symbols/slots should be a previous SSB index of the first SSB index in the UL symbol.

[0159] FIG. 5A illustrates an example of jointly mapping 500A between SSBs and ROs in non-SBFD symbols/slots and between SSBs and ROs in SBFD symbols/slots that support PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example mapping 500A, the ROs in UL PRACH slots are mapped to the SSBs for UL slots in a manner similar to the legacy methods. An association pattern period is determined to include a minimum integer number of association periods for UL slots (not shown) so that a pattern between the ROs in UL slots and the SSB indexes for UL slots repeats. For each first association period, the RO 501 is a last RO with associated SSB index in a UL PRACH slot 511 before a SBFD PRACH slot 512. The RO 502 is a first RO with associated SSB index in the SBFD PRACH slot 512 after the UL PRACH slot 511. The last SSB index associated with the RO 501 in the UL PRACH slot 511 is 3, and a next SSB index 4 is associated with the RO 502 in the SBFD PRACH slot 512.

[0160] The RO 503 is a last RO with associated SSB index in a SBFD PRACH slot 513 before a UL PRACH slot 514. The RO 504 is a first RO with associated SSB index in the UL PRACH slot 514 after the SBFD PRACH slot 513. The first SSB index associated with

the RO 504 in the UL PRACH slot 514 is 4, and a previous SSB index 3 is associated with the RO 503 in the SBFD PRACH slot 513.

[0161] In some embodiments, the second plurality of SSBs are mapped to the ROs in SBFD time units from a smallest SSB index in the first association period. In the case that the second plurality of SSBs cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the second plurality of SSBs to ROs among the ROs in SBFD time units, no SSB is mapped to the at least one remaining RO. In other words, the N2 SSBs are mapped to the second multiple ROs from the smallest SSB index in the N2 SSBs in each first association period. If there is a set of ROs or PRACH preambles that are not mapped to N2 SSB indexes after an integer number of SSB indexes to ROs mapping cycles within the first association period, no SSB indexes are mapped to the set of ROs or PRACH preambles.

[0162] FIG. 5B illustrates an example of jointly mapping 500B between SSBs and ROs in non-SBFD symbols/slots and between SSBs and ROs in SBFD symbols/slots that support PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example mapping 500B, the ROs in UL PRSCH slots are mapped to the SSBs for UL slots in a manner similar to the legacy methods. An association pattern period is determined to include a minimum integer number of association periods for UL slots (not shown) so that a pattern between the ROs in UL slots and the SSB indexes for UL slots repeats. For each first association period, the ROs in SBFD PRACH slots are mapped to SSBs from the smallest SSB index. In the example mapping 500B, the first RO 521 in SBFD slots in each association period for UL slots (not shown) is mapped to SSB #0.

[0163] Turning back to FIG. 2, the UE 104 may transmit a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with a SSB in first group of ROs among a set of RO groups with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with the SSB. All respective ROs in a group of ROs are valid ROs. The SSB is one SSB from the N1 SSBs and/or the N2 SSB. Usually, different SSBs are transmitted with different beams. Before transmitting the PRACH transmission with repetitions, the UE 104 may measure the channel status of each SSB, select the one with good channel quality, and transmit preamble in a RO associated with the selected SSB to transmit a PRACH.

[0164] In some embodiments, when transmitting the PRACH transmission 208, the UE 104 may transmit, to the BS 102, a preamble for the configured number of repetitions in the first RO group. The first RO group may include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. In some embodiments, the first one or more ROs belong to the ROs in non-SBFD time units, and the second one or more ROs belong to the ROs in SBFD time units.

[0165] In some embodiments, the UE 104 may receive, from the BS 102, an indication that the preamble is for PRACH transmission 208 with the configured number of repetitions across at least one non-SBFD time unit and at least one SBFD time unit. In other words, at least one special preamble for a repetition number may be configured to the UE, the preamble should be used for transmission when the PRACH repetition is across the SBFD symbols/slots and non-SBFD symbols/slots. When transmitting the PRACH with preamble repetitions, the UE 104 may implicitly indicate the number of repetitions and whether the PRACH repetition is across both the SBFD symbols/slots and non-SBFD symbols/slots or not to the BS 102.

[0166] The UE 104 may first determine a first valid RO for a group of ROs in a manner similar to the legacy method of determining first valid RO, and then determine the rest $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in the group of ROs. For a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions within a time period for $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with an SSB, if the parameter *TimeOffsetBetweenStartingRO* is provided, for each frequency resource index for frequency multiplexed ROs, the first valid RO of the first $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is the first valid RO, and the first valid RO of subsequent $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is after *TimeOffsetBetweenStartingRO* consecutive valid ROs in time from the first valid RO corresponding to the previous $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions. For a PRACH transmission with $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions within a time period for $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions associated with an SSB, if the parameter *TimeOffsetBetweenStartingRO* is not provided, for each frequency resource index for frequency multiplexed ROs, the first valid RO of the first $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions is the first valid RO, and the first valid RO of subsequent $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions, if any, is determined after the ROs

determined for the previous $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions according to the following ordering of valid ROs: first, in an increasing order of frequency resource indexes for frequency multiplexed ROs; and second, in an increasing order of time resource indexes for time multiplexed ROs. The rest $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in the group of ROs may be determined in various manners.

[0167] In some embodiments, ROs in each RO group in the at least one RO group are consecutive in time domain and associated with the same time unit format, and occupy the same frequency resources. In other words, all respective ROs in a group of ROs are consecutive in time domain with the same symbol/slot type, use the same frequency resources, and are associated with the same SSB index. In some example implementations, a time unit format of the ROs in each RO group in the at least one RO group is determined based on an indication received from the BS 102. In other words, the symbol/slot type to be used could be indicated by the BS 102. Alternatively, a time unit format of the ROs in each RO group in the at least one RO group is determined based on a time unit format associated with a first RO. For example, if the first valid RO is in a non-SBFD symbol/slot, then all the ROs in the group should be in non-SBFD symbols/slots. If the first valid RO is in SBFD symbol/slot, then all the ROs in the group should be in SBFD symbols/slots.

[0168] In some embodiments, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, and occupy the same frequency resources. In other words, all respective ROs in a group of ROs are consecutive in a time domain including SBFD symbols/slots and/or in non-SBFD symbols/slots, use the same frequency resources, and are associated with the same SSB index.

[0169] In some embodiments, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. Assuming the symbol/slot type of the first RO is a first symbol/slot type, a RO among the $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with first symbol/slot type should have the same frequency resources as first RO. Another RO among $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with a second symbol/slot type should be associated with the same SSB index as the first RO.

Frequency resources of the first one or more ROs and frequency resources of second one or more ROs may have an offset. In a first example implementation, the offset may be based on a configuration received from the BS 102. In other words, the offset between frequency resources of the $N_{\text{preamble}}^{\text{rep}} - 1$ ROs and frequency resources of the first RO may be based on a special configuration for the frequency resource offset by the BS 102. In a second example implementation, the offset may be determined based on a RB number between a starting RB of a first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units, wherein an indication of the starting RB of the first RO in frequency domain in the SBFD time units and an indication of the starting RB of the first RO in frequency domain in the non-SBFD time units are received from the BS 102. In other words, the offset may be smaller than or equal to a start RO_SBFD minus a start RO_non-SBFD , i.e., $\text{offset} \leq \text{start RO_SBFD} - \text{start RO_non-SBFD}$. The start RO_non-SBFD indicating the starting RO for SBFD symbols/slots and the start RO_non-SBFD indicating the starting RO for non-SBFD symbols/slots are separately configured by the BS 102. In a third example implementation, the offset may be based on an indication from the BS 102. In other words, the BS 102 may transmit an indication of the RB number between the starting RO of the SBFD symbols/slots and non-SBFD symbols/slots to the UE 104. The frequency resource offset may be smaller than or equal to an indicated RB number.

[0170] FIG. 6A illustrates an example 600A of determination of a RO group that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example 600A, the selected SSB may be SSB#1, the RO 601 in a UL slot #1 is determined to be the first RO in a RO group for four preamble repetitions. The next two slots are SBFD slots. The offset between frequency resources of the RO 602 associated with SSB#1 in SBFD slot #2 and frequency resources of the RO 601 is within the configured/determined/indicated offset. Thus, the RO 602 is determined as a RO in the RO group. The RO 603 in SBFD slot #3 is associated with SSB#1 and occupy the same frequency resources with the RO 602 in SBFD slot #2, and thus is determined as a RO in the RO group. The RO 604 in UL slot #4 is associated with SSB#1 and occupy the same frequency resources with the RO 601 in UL slot #1, and thus is determined as a RO in the RO group. The RO group for four preamble repetitions is thus determined.

[0171] In some embodiments, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. A relative frequency domain location of the first one or more ROs relative to the ROs in non-SBFD time units is the same as a relative frequency domain location of the second one or more ROs relative to the ROs in SBFD time units. assuming the symbol/slot type of the first RO is a first symbol/slot type, a RO among the $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with first symbol/slot type should have the same frequency resources as first RO. Another RO among $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with a second symbol/slot type should be associated with the same SSB index as the first RO and have the same relative frequency location as the first RO. Two ROs with the same relative frequency location means that one RO in time domain location 1 is the i -th RO among all the ROs in time domain location 1, the other RO in time domain location 2 is also the i -th RO among all the ROs in time domain location 2.

[0172] FIG. 6B illustrates an example 600B of determination of a RO group that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example 600B, the selected SSB may be SSB#1, the RO 611 in a UL slot #1 is determined to be the first RO in a RO group for four preamble repetitions. The next two slots are SBFD slots. The RO 611 is the first RO among the four FDMed ROs in frequency domain in the same time domain location, and the RO 612 associated with SSB#1 in SBFD slot #2 is the first RO among the two FDMed ROs in frequency domain in the same time domain location. Thus, the RO 612 and the RO 611 have the same relative frequency domain location. The RO 612 is determined as a RO in the RO group. The RO 613 in SBFD slot #3 is associated with SSB#1 and occupy the same frequency resources with the RO 612 in SBFD slot #2, and thus is determined as a RO in the RO group. The RO 614 in UL slot #4 is associated with SSB#1 and occupy the same frequency resources with the RO 611 in UL slot #1, and thus is determined as a RO in the RO group. The RO group for four preamble repetitions is thus determined.

[0173] In some embodiments, ROs in a RO group among the at least one RO group include first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units. Frequency resources of the first one or more ROs and frequency resources of the second one or more ROs are overlapped. In other words, assuming the symbol/slot type of

the first RO is a first symbol/slot type, a RO among the $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with first symbol/slot type should have the same frequency resources as first RO. Another RO among $N_{\text{preamble}}^{\text{rep}} - 1$ ROs in a slot with a second symbol/slot type should be associated with the same SSB index as the first RO and have overlapping frequency resource with the frequency resource of the first RO.

[0174] In some implementations, the first one or more ROs include ROs with a smaller frequency resource index among ROs that are in non-SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the second one or more ROs. Alternatively, the second one or more ROs include ROs with a smaller frequency resource index among ROs that are in SBFD time units and associated with the SSB and occupy frequency resources overlapped with frequency resources of the first one or more ROs. In other words, when determining the $N_{\text{preamble}}^{\text{rep}} - 1$ ROs, if there are multiple ROs with overlapping frequency resources with the frequency resources of the first RO, the RO with a smaller frequency resource index should be used.

[0175] FIG. 6C illustrates an example 600C of determination of a RO group that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example 600C, the selected SSB may be SSB#1, the RO 621 in a UL slot #1 is determined to be the first RO in a RO group for four preamble repetitions. The next two slots are SBFD slots. The frequency resources of the RO 622 associated with SSB#1 in SBFD slot #2 is overlapped with the frequency resources of the RO 621. Thus, the RO 622 is determined as a RO in the RO group. The RO 623 in SBFD slot #3 is associated with SSB#1 and occupy the same frequency resources with the RO 622 in SBFD slot #2, and thus is determined as a RO in the RO group. The RO 624 in UL slot #4 is associated with SSB#1 and occupy the same frequency resources with the RO 621 in UL slot #1, and thus is determined as a RO in the RO group. The RO group for four preamble repetitions is thus determined.

[0176] In some embodiments, the first one or more ROs belong to the ROs in non-SBFD time units, and the second one or more ROs belong to the ROs in SBFD time units.

[0177] The UE 104 may determine a time period X, starting from frame 0, based on the determined RO groups. The set of RO groups for a PRACH transmission repeats every time period X.

[0178] In some embodiments, the UE 104 may determine a time period based on the first association pattern period and the second association pattern period. The time period is a minimum time period including a first integer number of the first association pattern period and a second integer number of the second association pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions; and each of the second plurality of SSBs is mapped in the time period at least once for each configured number of repetitions. In other words, the time period X is a first integer number of first association pattern periods for UL slots such that the N1 SSB indexes are mapped to $N_{\text{preamble}}^{\text{rep}}$ ROs within the time period X at least once for each configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions. In addition, the time period X is a second integer number of second association pattern periods for SBFD slots such that the N2 SSB indexes are mapped to $N_{\text{preamble}}^{\text{rep}}$ ROs within the time period at least once for each configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions. The time period X is the minimum time period fulfilling the above criterions.

[0179] FIG. 7 illustrates an example 700 of determination of a time period based on different association pattern periods for SBFD symbols/slots and non-SBFD symbols/slots that supports PRACH transmissions in accordance with some example embodiments of the present disclosure. In the example 700, the association pattern period for UL slot and the association pattern period for SBFD slot may be determined based on the mapping 300A in FIG. 3A and the mapping 300B in FIG. 3B, respectively. Other methods for determining the association pattern period for UL slot and the association pattern period for SBFD slot are also possible. For each configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions, each of the N1 SSB indexes for UL slots is mapped to a RO group for the configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions at least once within the time period X. For each configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions, each of the N2 SSB indexes for SBFD slots is mapped to a RO group for the configured number $N_{\text{preamble}}^{\text{rep}}$ of preamble repetitions at least once within

the time period X. The time period X is equal to two association pattern periods for UL slots and equal to four association pattern periods for SBFD slots and is the minimum time period implementing the above criterions.

[0180] In some embodiments, the UE 104 may determine a time period based on the third association pattern period. The time period is a minimum time period including a third integer number of the third association pattern period and fulfilling the following: each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions. In other words, the time period X is the smallest integer number of third association pattern periods such that N SSB indexes are mapped to $N_{\text{preamble}}^{\text{rep}}$ ROs within the time period X at least once for each configured $N_{\text{preamble}}^{\text{rep}}$ number of preamble repetitions. The third association pattern period may be determined based on the mappings 400, 500A or 500B in FIG. 4, 5A or 5B. Other methods for determining the third association pattern period are also possible.

[0181] FIG. 8 illustrates an example of a device 800 that supports PRACH transmissions in accordance with aspects of the present disclosure. The device 800 may be an example of a network entity 102 or a UE 104 as described herein. The device 800 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 800 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 802, a memory 804, a transceiver 806, and, optionally, an I/O controller 808. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0182] The processor 802, the memory 804, the transceiver 806, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 802, the memory 804, the transceiver 806, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0183] In some implementations, the processor 802, the memory 804, the transceiver 806, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 802 and the memory 804 coupled with the processor 802 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 802, instructions stored in the memory 804).

[0184] For example, the processor 802 may support wireless communication at the device 800 in accordance with examples as disclosed herein. The processor 802 may be configured to operable to support a means for determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units; a means for transmitting, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

[0185] In another example, the processor 802 may support wireless communication at the device 800 in accordance with examples as disclosed herein. The processor 802 may be configured to operable to support a means for determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of

SSBs are mapped to the ROs in SBFD time units; a means for receiving, from the user equipment, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

[0186] The processor 802 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 802 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 802. The processor 802 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 804) to cause the device 800 to perform various functions of the present disclosure such that the device 800 may perform any process of the disclosure as discussed with reference to FIGS. 2 to 6.

[0187] The memory 804 may include random access memory (RAM) and read-only memory (ROM). The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 802 cause the device 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 802 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 804 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0188] The I/O controller 808 may manage input and output signals for the device 800. The I/O controller 808 may also manage peripherals not integrated into the device 802. In some implementations, the I/O controller 808 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 808 may utilize an

operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 808 may be implemented as part of a processor, such as the processor 806. In some implementations, a user may interact with the device 800 via the I/O controller 808 or via hardware components controlled by the I/O controller 808.

[0189] In some implementations, the device 800 may include a single antenna 810. However, in some other implementations, the device 800 may have more than one antenna 810 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 806 may communicate bi-directionally, via the one or more antennas 810, wired, or wireless links as described herein. For example, the transceiver 806 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 806 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 810 for transmission, and to demodulate packets received from the one or more antennas 810. The transceiver 806 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0190] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 810 for transmitting the amplified signal into the air or wireless medium.

[0191] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 810 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify

the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0192] FIG. 9 illustrates an example of a processor 900 that supports PRACH transmissions in accordance with aspects of the present disclosure. The processor 900 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 900 may 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 900 may include a controller 902 configured to perform various operations in accordance with examples as described herein. The processor 900 may optionally include at least one memory 904, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 900 may optionally include one or more arithmetic-logic units (ALUs) 900. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0193] The processor 900 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 900) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0194] The controller 902 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor

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

[0195] The controller 902 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 904 and determine subsequent instruction(s) to be executed to cause the processor 900 to support various operations in accordance with examples as described herein. The controller 902 may be configured to track memory address of instructions associated with the memory 904. The controller 902 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 902 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 900 to cause the processor 900 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 902 may be configured to manage flow of data within the processor 900. The controller 902 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 900.

[0196] The memory 904 may include one or more caches (e.g., memory local to or included in the processor 900 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 904 may reside within or on a processor chipset (e.g., local to the processor 900). In some other implementations, the memory 904 may reside external to the processor chipset (e.g., remote to the processor 900).

[0197] The memory 904 may store computer-readable, computer-executable code including instructions that, when executed by the processor 900, cause the processor 900 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 902 and/or the processor 900 may be configured to execute computer-readable instructions stored in the memory 904 to cause the processor 900 to perform various functions. For example, the processor 900 and/or the controller 902 may be coupled with or to the

memory 904, and the processor 900, the controller 902, and the memory 904 may be configured to perform various functions described herein. In some examples, the processor 900 may include multiple processors and the memory 904 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0198] The one or more ALUs 900 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 900 may reside within or on a processor chipset (e.g., the processor 900). In some other implementations, the one or more ALUs 900 may reside external to the processor chipset (e.g., the processor 900). One or more ALUs 900 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 900 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 900 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 900 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 900 to handle conditional operations, comparisons, and bitwise operations.

[0199] For example, the processor 900 may support wireless communication in accordance with examples as disclosed herein. The processor 900 may be configured to or operable to support a means for determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units; a means for transmitting, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB,

the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

[0200] In another example, the processor 900 may support wireless communication in accordance with examples as disclosed herein. The processor 900 may be configured to or operable to support a means for determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units; a means for receiving, from the user equipment, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

[0201] FIG. 10 illustrates a flowchart of a method 1000 that supports PRACH transmissions in accordance with aspects of the present disclosure. The operations of the method 1000 may be implemented by a device or its components as described herein. For example, the operations of the method 1000 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0202] At 1005, the method may include determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. 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.

[0203] At 1010, the method may include transmitting, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs. 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.

[0204] FIG. 11 illustrates a flowchart of a method 1100 that supports PRACH transmissions in accordance with aspects of the present disclosure. The operations of the method 1100 may be implemented by a device or its components as described herein. For example, the operations of the method 1100 may be performed by a 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.

[0205] At 1105, the method may include determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units. The operations of 1105 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1105 may be performed by a device as described with reference to FIG. 1A.

[0206] At 1110, the method may include receiving, from the user equipment, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group, wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated

with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs. The operations of 1110 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1110 may be performed by a device as described with reference to FIG. 1A.

[0207] 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.

[0208] 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).

[0209] 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.

[0210] 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.

[0211] 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.

[0212] 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:

determine a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units;

transmit, to the base station via the transceiver, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group,

wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

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

receive, from the base station via the transceiver, a first RO configuration for non-SBFD time units and a second RO configuration for SBFD time units,

wherein the ROs in non-SBFD time units are determined based on the first RO configuration, and the ROs in SBFD time units are determined based on the second RO configuration,

wherein the second RO configuration comprises at least one of the following:

an indication of a starting resource block (RB) of a first RO in frequency domain in SBFD time units, or an indication of an offset between a starting RB of the first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units;

the number of ROs that are multiplexed in a frequency domain in a same time occasion of SBFD time units;

a PRACH configuration period; or

an indication of subframes containing available ROs in the PRACH configuration period.

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

receive, from the base station via the transceiver, a third RO configuration,

wherein the plurality of ROs in the plurality of time units are determined based on the third RO configuration,

wherein the third RO configuration comprises at least one of the following:

an indication of a starting resource block (RB) of a first RO in frequency domain;

the number of ROs that are multiplexed in a frequency domain in a same time occasion;

a PRACH configuration period; or

an indication of subframes containing available ROs in the PRACH configuration period.

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

determine a first association period and a first association pattern period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; and

determine a second association period and a second association pattern period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units.

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

determine a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units;

determine a second association period based on the mapping between the second plurality of SSBs and the ROs in SBFD time units; and

determine a third association pattern period based on the first association period and the second association period.

6. The user equipment of claim 1, wherein the second plurality of SSBs are mapped to the ROs in SBFD time units based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units, and the processor is further configured to:

determine a first association period based on the mapping between the first plurality of SSBs and the ROs in non-SBFD time units; and

determine a third association pattern period based on the first association period.

7. The user equipment of claim 6, wherein a mapping pattern between the first plurality of SSBs and the ROs in non-SBFD time units repeats in a period of the third association pattern period.

8. The user equipment of claim 6, wherein at least one of the following:

an index of a first SSB mapped to a first RO in a first SBFD time unit following a non-SBFD time unit is after an index of a last SSB mapped to a last RO in the non-SBFD time units; or

an index of a last SSB mapped to a last RO in a last SBFD time unit is before an index of a first SSB mapped to a first RO in a first non-SBFD time unit following the last SBFD time unit.

9. The user equipment of claim 6, wherein the second plurality of SSBs are mapped to the ROs in SBFD time units from a smallest SSB index in the first association period, and

wherein in the case that the second plurality of SSBs cannot form a mapping cycle with at least one remaining RO after an integer number of mapping cycles between the second plurality of SSBs to ROs among the ROs in SBFD time units, no SSB is mapped to the at least one remaining RO.

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

determine a time period based on the first association pattern period and the second association pattern period,

wherein the time period is a minimum time period comprising a first integer number of the first association pattern period and a second integer number of the second association pattern period and fulfilling the following:

each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions; and

each of the second plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

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

determine a time period based on the third association pattern period,

wherein the time period is a minimum time period comprising a third integer number of the third association pattern period and fulfilling the following:

each of the first plurality of SSBs is mapped in the time period at least once for each configured number of repetitions.

12. The user equipment of claim 1, wherein transmitting the PRACH transmission comprises:

transmitting, to the base station via the transceiver, a preamble for the configured number of repetitions in the first RO group, wherein the first RO group comprises first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units.

13. The user equipment of claim 12, wherein the processor is further configured to:

receive, from the base station via the transceiver, an indication that the preamble is for PRACH transmission with the configured number of repetitions across at least one non-SBFD time unit and at least one SBFD time unit.

14. The user equipment of claim 1, wherein ROs in each RO group in the at least one RO group are consecutive in time domain and associated with a same time unit format, and occupy same frequency resources.

15. The user equipment of claim 14, wherein a time unit format of the ROs in each RO group in the at least one RO group is determined based on one of the following:

an indication received from the base station, or

a time unit format associated with a first RO.

16. The user equipment of claim 1, wherein ROs in a RO group among the at least one RO group comprise first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units, and occupy same frequency resources.

17. The user equipment of claim 1, wherein ROs in a RO group among the at least one RO group comprise first one or more ROs in non-SBFD time units and second one or more ROs in SBFD time units,

wherein an offset between frequency resources of the first one or more ROs and frequency resources of second one or more ROs is based on one of the following:

a configuration received from the base station;

a RB number between a starting RB of a first RO in frequency domain in SBFD time units and a starting RO of a first RO in frequency domain in non-SBFD time units, wherein an indication of the starting RB of the first RO in frequency domain in the SBFD time units and an indication of the starting RB of the first RO in frequency domain in the non-SBFD time units are received from the base station; or

an indication from the base station.

18. A base station comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

determine a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units; and

receive, from the user equipment via the transceiver, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group,

wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

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

determining a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units;

transmitting, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group,

wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.

20. A processor for wireless communication, comprising:

at least one memory; and

a controller coupled with the at least one memory and configured to cause the controller to:

determine a plurality of random access channel (RACH) occasions (ROs) in a plurality of time units, wherein the plurality of ROs comprises ROs in sub-band full duplex (SBFD) time units and ROs in non-SBFD time units, and wherein a first plurality of synchronization signal and physical broadcast channel (PBCH) blocks (SSBs) are mapped to the ROs in non-SBFD time units, and a second plurality of SSBs are mapped to the ROs in SBFD time units;

transmit, to the base station, a physical RACH (PRACH) transmission with a configured number of repetitions in a first RO group among at least one RO group,

wherein each RO group in the at least one RO group is a candidate RO group for the configured number of repetitions and comprises ROs associated with a SSB, the SSB is one SSB among at least one of the first plurality of SSBs or the second plurality of SSBs.