Description

Title of Invention: COMMUNICATION APPARATUSES AND COMMUNICATION METHODS FOR RESOURCE ASSIGNMENT FOR MULTI-PHYSICAL RANDOM ACCESS CHANNEL TRANSMISSIONS

TECHNICAL FIELD

[1] The present disclosure relates to communication apparatuses and communication methods. In particular, it may relate to communication apparatuses and communication methods for resource assignment for multi-physical Random Access Channel (multi-PRACH) transmissions.

BACKGROUND

[2] It has been identified that Physical Random Access Channel (PRACH) is a bottleneck channel in term of coverage performance in new radio (NR). Therefore, in Release 18 of relevant 3rd Generation Partnership Project (3GPP) technical specifications (TSs), for example, in RP-213579, a new working item (WI) for new radio (NR) coverage enhancement (CovEnh) has been approved with the objective of specifying PRACH coverage enhancements under the 3GPP physical layer working group RAN1 and RAN2. The WI further studies multiple PRACH transmissions with a same beam for a 4-step random access channel (RACH) procedure, as well as study, and if justified, specify PRACH transmissions with different beams for 4-step RACH procedure.

[3] Under Release (Rel.) 15, 16 and 17 of the technical specifications (TSs), PRACH preamble resources are partitioned to differentiate multiple features for different purposes, such as preamble for a feature of contention free random access (CFRA), preambles for a feature of 2-step RACH, preambles for a feature of 4-step RACH, and preamble for a feature combination (including reduced capability (RedCap), small data transmission, slice group, and message 3 (Msg3) repetition request)). Further, for a multi-PRACH transmission, separate preambles are needed for the different numbers of PRACH transmissions such as 2 PRACH transmissions, 4 PRACH transmissions and 8 PRACH transmissions. It is appreciated that a multi-PRACH transmission can be referred to as a multiple

PRACH transmission or a number of PRACH transmissions or one PRACH attempt.

[4] However, it is not specified in the Rel. 15/16/17 technical specifications how PRACH preamble resource for a multi-PRACH transmission is realized. When the existing PRACH preamble partitioning as mentioned above is used to partition separate preambles for multiple values for the number of PRACH transmissions, usage of preamble resource is not fully utilized, and the number of available preambles may be not enough for other purposes, resulting in inefficient usage of preamble resources.

[5] Further, synchronization signal block to RACH occasion (SSB-to-RO) mapping as currently specified in the TSs is mainly designed for single PRACH transmission and may not work well for a multi-PRACH transmission. For example, when a RO group consists of shared ROs and a SSB-to-RO association period is configured shortly, a user equipment (UE) may not be able to determine enough shared ROs for a large number of PRACH transmissions. Hence, the UE may only be able to transmit fewer PRACHs and a base station (gNB) cannot achieve a desirable combined gain of preamble detection. The shared RO means that the RO is shared between a single PRACH transmission and a multi-PRACH transmission.

[6] Thus, there is a need to provide communication apparatuses and methods for resource assignment for multi-PRACH transmissions that resolve above problems.

SUMMARY

[7] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and methods for resource assignment for multi-PRACH transmissions.

[8] According to a first embodiment of the present disclosure, there is provided a communication apparatus comprising: circuitry, which in operation, determines a Random Access Channel Occasion (RO) group based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH

transmission, and determines a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and a transmitter, which in operation, transmits the preamble.

[9] According to a second embodiment of the present disclosure, there is provided a base station comprising: circuitry, which in operation, determines a mapping between one or more preambles and one or more Random Access Channel Occasion (RO) groups based on an index associated with one or more multiple physical Random Access Channel (PRACH) transmissions; and a transmitter, which in operation, signals the mapping to a communication apparatus.

[10] According to a third embodiment of the present disclosure, there is provided a communication method comprising: determining a Random Access Channel Occasion (RO) group based on a number of multiple physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission; determining a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and transmitting the preamble.

[11] It should be noted that general or specific embodiments may be implemented as a system, a method, an integrated circuit, a computer program, a storage medium, or any selective combination thereof.

[12] Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[13] Embodiments of the disclosure will be better understood and readily apparent to one of ordinary skilled in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[14] Fig. 1 shows an exemplary 3GPP NR radio access network (NR-RAN) architecture to which exemplary embodiments of the present disclosure can be applied.

[15] Fig. 2 depicts a schematic drawing which shows functional split between NG-RAN and 5G Core Network (5GC) to which exemplary embodiments of the present disclosure may be applied.

[16] Fig. 3 depicts a sequence diagram for RRC (radio resource control) connection setup/reconfiguration procedures to which exemplary embodiments of the present disclosure may be applied.

[17] Fig. 4 depicts a schematic drawing showing usage scenarios of Enhanced mobile broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra Reliable and Low Latency Communications (URLLC) to which exemplary embodiments of the present disclosure may be applied.

[18] Fig. 5 shows a block diagram showing an exemplary 5G system architecture for vehicle to everything (V2X) communication in a non-roaming scenario to which exemplary embodiments of the present disclosure may be applied.

[19] Fig. 6 shows an exemplary illustration of a partitioning of PRACH preamble resources according to the current technical specifications.

[20] Fig. 7 shows an illustration of a SSB-to-RO mapping as specified in the current TS when used for a multi-PRACH transmission according to an example.

[21] Fig. 8A shows an exemplary illustration of how a RO group and a preamble may be determined for a multi-PRACH transmission according to various embodiments of the present disclosure.

[22] Fig. 8B shows another exemplary illustration of how a RO group and a preamble may be determined for a multi-PRACH transmission according to various embodiments of the present disclosure.

[23] Fig. 9 shows an exemplary illustration of how a set of preambles may be determined for a multi-PRACH transmission according to various embodiments of the present disclosure.

[24] Fig. 10A shows an exemplary illustration of determining a preamble per RO group for a 2-PRACH transmission according to the current technical specifications.

[25] Fig. 10B shows an exemplary illustration of determining a preamble per RO group for a 2-PRACH transmission according to various embodiments of the present disclosure.

[26] Fig. 11 shows an exemplary illustration of determining a preamble per RO group per SSB index according to a sequential mapping for a multi-PRACH transmission according to various embodiments of the present disclosure.

[27] Fig. 12 shows an exemplary illustration of the multi-PRACH transmission of Fig. 11 within a configuration period of 10ms according to various embodiments of the present disclosure.

[28] Fig. 13 shows an exemplary illustration of determining a preamble per RO group per SSB index according to a cyclic mapping for a multi-PRACH transmission according to various embodiments of the present disclosure.

[29] Fig. 14 shows an exemplary illustration of how a first set of preambles may be mapped to a set of RO groups for a multi-PRACH transmission according to various embodiments of the present disclosure.

[30] Fig. 15 shows an exemplary illustration of how a second set of preambles may be mapped to the set of RO groups shown in Fig. 14 for a multi-PRACH transmission according to various embodiments of the present disclosure.

[31] Fig. 16 shows an exemplary illustration of the multi-PRACH transmissions of Figs. 14 and 15 within a configuration period of 20ms according to various embodiments of the present disclosure.

[32] Fig. 17 shows an exemplary illustration of how a table-based indication may be used to indicate two sets of preambles for a multi-PRACH transmission according to various embodiments of the present disclosure.

[33] Fig. 18 shows an exemplary illustration of the multi-PRACH transmission of Fig. 17 within a configuration period of 20ms according to various embodiments of the present disclosure.

[34] Fig. 19 shows an exemplary illustration of how each preamble of a set of preambles may be mapped to more than one RO group for a number of multi-PRACH transmissions in a frequency division multiplexing (FDM) scheme according to various embodiments of the present disclosure.

[35] Fig. 20 shows an exemplary illustration of a table in which each row indicates a preamble from a set of preambles and its mapping with a RO group that is associated with a SSB index for a number of multi-PRACH transmissions according to various embodiments of the present disclosure.

[36] Fig. 21 shows an exemplary illustration of an alternative version of the table in Fig. 20 in which each preamble may be mapped to more than one RO group according to various embodiments of the present disclosure.

[37] Fig. 22 shows a flow chart for a UE according to various embodiments of the present disclosure.

[38] Fig. 23 shows a flow chart for a gNB according to various embodiments of the present disclosure.

[39] Fig. 24 shows an exemplary illustration of a flow of interaction between a UE and a gNB in a 4-step RACH procedure according to various embodiments of the present disclosure.

[40] Fig. 25 shows a flow chart illustrating a communication method according to various embodiments of the present disclosure.

[41] Fig. 26 shows a schematic block diagram of an exemplary communication apparatus in accordance with a single antenna with various embodiments of the present disclosure.

[42] Fig. 27 shows a schematic block diagram of an exemplary communication apparatus with multiple antennas in accordance with various embodiments of the present disclosure.

[43] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

DETAILED DESCRIPTION

[44] Some embodiments of the present disclosure will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[45] Among other things, the overall system architecture assumes an NG-RAN (Next Generation – Radio Access Network) that comprises gNBs, providing the NG-radio access user plane (SDAP/PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the user equipment (UE). The gNBs are interconnected with each other by means of the Xn interface. The gNBs are also connected by means of the Next Generation (NG) interface to the NGC (Next Generation Core), more specifically to the AMF (Access and Mobility Management Function) (e.g., a particular core entity performing the AMF) by means of the NG-C interface and to the UPF (User Plane Function) (e.g., a particular core entity performing the UPF) by means of the NG-U interface. The NG-RAN architecture 100 is illustrated in Fig. 1 (see e.g., 3GPP TS 38.300 v16.3.0, section 4).

[46] The user plane protocol stack for NR (see e.g., 3GPP TS 38.300, section 4.4.1) comprises the PDCP (Packet Data Convergence Protocol, see section 6.4 of TS 38.300), RLC (Radio Link Control, see section 6.3 of TS 38.300) and MAC (Medium Access Control, see section 6.2 of TS 38.300) sublayers, which are terminated in the gNB on the network side. Additionally, a new access stratum (AS) sublayer (SDAP, Service Data Adaptation Protocol) is introduced above PDCP (see e.g., sub-clause 6.5 of 3GPP TS 38.300). A control plane protocol

stack is also defined for NR (see for instance TS 38.300, section 4.4.2). An overview of the Layer 2 functions is given in sub-clause 6 of TS 38.300. The functions of the PDCP, RLC and MAC sublayers are listed respectively in sections 6.4, 6.3, and 6.2 of TS 38.300. The functions of the RRC layer are listed in sub-clause 7 of TS 38.300. Further, sidelink communications is introduced in 3GPP TS 38.300 v16.3.0. Sidelink supports UE-to-UE direct communication using the sidelink resource allocation modes, physical-layer signals/channels, and physical layer procedures (see for instance section 5.7 of TS 38.300).

[47] For instance, the Medium-Access-Control layer handles logical-channel multiplexing, and scheduling and scheduling-related functions, including handling of different numerologies.

[48] The physical layer (PHY) is for example responsible for coding, PHY HARQ processing, modulation, multi-antenna processing, and mapping of the signal to the appropriate physical time-frequency resources. It also handles mapping of transport channels to physical channels. The physical layer provides services to the MAC layer in the form of transport channels. A physical channel corresponds to the set of time-frequency resources used for transmission of a particular transport channel, and each transport channel is mapped to a corresponding physical channel. For instance, the physical channels are Physical Random Access Channel (PRACH), Physical Uplink Shared Channel (PUSCH) and Physical Uplink Control Channel (PUCCH) for uplink and Physical Downlink Shared Channel (PDSCH), Physical Downlink Control Channel (PDCCH) and Physical Broadcast Channel (PBCH) for downlink. Further, physical sidelink channels include Physical Sidelink Control Channel (PSCCH), Physical Sidelink Shared Channel (PSSCH), Physical Sidelink Feedback Channel (PSFCH) and Physical Sidelink Broadcast Channel (PSBCH).

[49] Use cases / deployment scenarios for NR could include enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC), massive machine type communication (mMTC), which have diverse requirements in terms of data rates, latency, and coverage. For example, eMBB is expected to support peak data rates (20Gbps for downlink and 10Gbps for uplink) and user-experienced data rates in the order of three times what is offered by IMT-Advanced. On the other hand, in case of URLLC, the tighter requirements are put on ultra-low latency (0.5ms for UL and DL each for user plane latency) and high

reliability ($1\text{-}10^{-5}$ within 1ms). Finally, mMTC may preferably require high connection density (1,000,000 devices/km^2 in an urban environment), large coverage in harsh environments, and extremely long-life battery for low cost devices (15 years).

[50] Therefore, the OFDM numerology (e.g., subcarrier spacing, OFDM symbol duration, cyclic prefix (CP) duration, number of symbols per scheduling interval) that is suitable for one use case might not work well for another. For example, low-latency services may preferably require a shorter symbol duration (and thus larger subcarrier spacing) and/or fewer symbols per scheduling interval (aka, TTI) than a mMTC service. Furthermore, deployment scenarios with large channel delay spreads may preferably require a longer CP duration than scenarios with short delay spreads. The subcarrier spacing should be optimized accordingly to retain the similar CP overhead. NR may support more than one value of subcarrier spacing. Correspondingly, subcarrier spacing of 15kHz, 30kHz, 60 kHz… are being considered at the moment. The symbol duration T_u and the subcarrier spacing Δf are directly related through the formula $\Delta f = 1 / T_u$. In a similar manner as in LTE systems, the term “resource element” can be used to denote a minimum resource unit being composed of one subcarrier for the length of one OFDM/SC-FDMA symbol.

[51] In the new radio system 5G-NR for each numerology and carrier a resource grid of subcarriers and OFDM symbols is defined respectively for uplink and downlink. Each element in the resource grid is called a resource element and is identified based on the frequency index in the frequency domain and the symbol position in the time domain (see 3GPP TS 38.211 v16.3.0).

[52] Schematic drawing 200 of Fig. 2 illustrates functional split between NG-RAN and 5GC. NG-RAN logical node is a gNB or ng-eNB. The 5GC has logical nodes Access and Mobility Management Function (AMF), User Plane Function (UPF) and Session Management Function (SMF).

[53] In particular, the gNB and ng-eNB host the following main functions:

- Functions for Radio Resource Management such as Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

- IP header compression, encryption and integrity protection of data;
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE;
- Routing of User Plane data towards UPF(s);
- Routing of Control Plane information towards AMF;
- Connection setup and release;
- Scheduling and transmission of paging messages;
- Scheduling and transmission of system broadcast information (originated from the AMF or OAM);
- Measurement and measurement reporting configuration for mobility and scheduling;
- Transport level packet marking in the uplink;
- Session Management;
- Support of Network Slicing;
- QoS Flow management and mapping to data radio bearers;
- Support of UEs in RRC_INACTIVE state;
- Distribution function for NAS messages;
- Radio access network sharing;
- Dual Connectivity;
- Tight interworking between NR and E-UTRA.

[54] The Access and Mobility Management Function (AMF) hosts the following main functions:

- Non-Access Stratum, NAS, signaling termination;

- NAS signaling security;
- Access Stratum, AS, Security control;
- Inter Core Network, CN, node signaling for mobility between 3GPP access networks;
- Idle mode UE Reachability (including control and execution of paging retransmission);
- Registration Area management;
- Support of intra-system and inter-system mobility;
- Access Authentication;
- Access Authorization including check of roaming rights;
- Mobility management control (subscription and policies);
- Support of Network Slicing;
- Session Management Function, SMF, selection.

[55] Furthermore, the User Plane Function, UPF, hosts the following main functions:

- Anchor point for Intra-/Inter-RAT mobility (when applicable);
- External PDU session point of interconnect to Data Network;
- Packet routing & forwarding;
- Packet inspection and User plane part of Policy rule enforcement;
- Traffic usage reporting;
- Uplink classifier to support routing traffic flows to a data network;
- Branching point to support multi-homed PDU session;

- QoS handling for user plane, e.g. packet filtering, gating, UL/DL rate enforcement;
- Uplink Traffic verification (SDF to QoS flow mapping);
- Downlink packet buffering and downlink data notification triggering.

[56] Finally, the Session Management function, SMF, hosts the following main functions:

- Session Management;
- UE IP address allocation and management;
- Selection and control of UP function;
- Configures traffic steering at User Plane Function, UPF, to route traffic to proper destination;
- Control part of policy enforcement and QoS;
- Downlink Data Notification.

[57] Sequence diagram 300 in Fig. 3 illustrates some interactions between a UE, gNB, and AMF (an 5GC entity) in the context of a transition of the UE from RRC_IDLE to RRC_CONNECTED for the NAS part (see TS 38.300 v16.3.0). The transition steps are as follows:

1. The UE requests to setup a new connection from RRC_IDLE.

2/2a. The gNB completes the RRC setup procedure.

NOTE: The scenario where the gNB rejects the request is described below.

3. The first NAS message from the UE, piggybacked in *RRCSetupComplete*, is sent to AMF.

4/4a/5/5a. Additional NAS messages may be exchanged between UE and AMF, see TS 23.502 reference [22] (3GPP TS 23.122: "Non-Access-Stratum (NAS) functions related to Mobile Station in idle mode").

6. The AMF prepares the UE context data (including PDU session context, the Security Key, UE Radio Capability and UE Security Capabilities, etc.) and sends it to the gNB.

7/7a. The gNB activates the AS security with the UE.

8/8a. The gNB performs the reconfiguration to setup SRB2 and DRBs.

9. The gNB informs the AMF that the setup procedure is completed.

[58] RRC is a higher layer signalling (protocol) used for UE and gNB configuration. In particular, this transition involves that the AMF prepares the UE context data (including e.g., PDU session context, the Security Key, UE Radio Capability and UE Security Capabilities, etc.) and sends it to the gNB with the INITIAL CONTEXT SETUP REQUEST. Then, the gNB activates the AS security with the UE, which is performed by the gNB transmitting to the UE a SecurityModeCommand message and by the UE responding to the gNB with the SecurityModeComplete message. Afterwards, the gNB performs the reconfiguration to setup the Signaling Radio Bearer 2, SRB2, and Data Radio Bearer(s), DRB(s) by means of transmitting to the UE the RRCReconfiguration message and, in response, receiving by the gNB the RRCReconfigurationComplete from the UE. For a signaling-only connection, the steps relating to the RRCReconfiguration are skipped since SRB2 and DRBs are not setup. Finally, the gNB informs the AMF that the setup procedure is completed with the INITIAL CONTEXT SETUP RESPONSE.

[59] Schematic drawing 400 in Fig. 4 illustrates some use cases for 5G NR. In third generation partnership project new radio (3GPP NR), three use cases are being considered that have been envisaged to support a wide variety of services and applications by IMT-2020. The technical specification (TS) for the phase 1 of enhanced mobile-broadband (eMBB) has been concluded. In addition to further extending the eMBB support, the current and future work would involve the standardization for ultra-reliable and low-latency communications (URLLC) and massive machine-type communications (mMTC). Fig. 4 illustrates some examples of envisioned usage scenarios for IMT for 2020 and beyond (see e.g., ITU-R M.2083 Fig.2).

[60] The URLLC use case has stringent requirements for capabilities such as throughput, latency and availability and has been envisioned as one of the enablers for future vertical applications such as wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc. Ultra-reliability for URLLC is to be supported by identifying the techniques to meet the requirements set by TR 38.913. For NR URLLC in Release 15, key requirements include a target user plane latency of 0.5 ms for UL (uplink) and 0.5 ms for DL (downlink). The general URLLC requirement for one transmission of a packet is a BLER (block error rate) of 1E-5 for a packet size of 32 bytes with a user plane latency of 1ms.

[61] From the physical layer perspective, reliability can be improved in a number of possible ways. The current scope for improving the reliability involves defining separate CQI tables for URLLC, more compact DCI formats, repetition of PDCCH, etc. However, the scope may widen for achieving ultra-reliability as the NR becomes more stable and developed (for NR URLLC key requirements). Particular use cases of NR URLLC in Rel. 15 include Augmented Reality/Virtual Reality (AR/VR), e-health, e-safety, and mission-critical applications.

[62] Moreover, technology enhancements targeted by NR URLLC aim at latency improvement and reliability improvement. Technology enhancements for latency improvement include configurable numerology, mini-slot-based scheduling with flexible mapping, grant free (configured grant) uplink, mini-slot-level repetition for data channels, and downlink pre-emption. Pre-emption means that a transmission for which resources have already been allocated is stopped, and the already allocated resources are used for another transmission that has been requested later, but has lower latency / higher priority requirements. Accordingly, the already granted transmission is pre-empted by a later transmission. Pre-emption is applicable independent of the particular service type. For example, a transmission for a service-type A (URLLC) may be pre-empted by a transmission for a service type B (such as eMBB). Technology enhancements with respect to reliability improvement include dedicated Channel Quality Indicator/Modulation and Coding Scheme (CQI/MCS) tables for the target BLER of 1E-5.

[63] The use case of mMTC (massive machine-type communication) is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay sensitive data. Devices are required to be low

cost and to have a very long battery life. From NR perspective, utilizing very narrow bandwidth parts is one possible solution to have power saving from UE perspective and enable long battery life.

[64] As mentioned above, it is expected that the scope of reliability in NR becomes wider. One key requirement to all the cases, and especially necessary for URLLC and mMTC, is high reliability or ultra-reliability. Several mechanisms can be considered to improve the reliability from radio perspective and network perspective. In general, there are a few key potential areas that can help improve the reliability. Among these areas are compact control channel information, data/control channel repetition, and diversity with respect to frequency, time and/or the spatial domain. These areas are applicable to reliability in general, regardless of particular communication scenarios.

[65] For NR URLLC, further use cases with tighter requirements have been identified such as factory automation, transport industry and electrical power distribution, including factory automation, transport industry, and electrical power distribution. The tighter requirements are higher reliability (up to 10^{-6} level), higher availability, packet sizes of up to 256 bytes, time synchronization down to the order of a few μs where the value can be one or a few μs depending on frequency range and short latency in the order of 0.5 to 1 ms in particular a target user plane latency of 0.5 ms, depending on the use cases.

[66] Moreover, for NR URLLC, several technology enhancements from the physical layer perspective have been identified. Among these are PDCCH (Physical Downlink Control Channel) enhancements related to compact DCI, PDCCH repetition, increased PDCCH monitoring. Moreover, UCI (Uplink Control Information) enhancements are related to enhanced HARQ (Hybrid Automatic Repeat Request) and channel state information (CSI) feedback enhancements. Also PUSCH enhancements related to mini-slot level hopping and retransmission/repetition enhancements have been identified. The term “mini-slot” refers to a Transmission Time Interval (TTI) including a smaller number of symbols than a slot (a slot comprising fourteen symbols).

[67] The 5G QoS (Quality of Service) model is based on QoS flows and supports both QoS flows that require guaranteed flow bit rate (GBR QoS flows) and QoS flows that do not require guaranteed flow bit rate (non-GBR QoS Flows). At NAS

level, the QoS flow is thus the finest granularity of QoS differentiation in a PDU session. A QoS flow is identified within a PDU session by a QoS flow ID (QFI) carried in an encapsulation header over NG-U interface.

[68] For each UE, 5GC establishes one or more PDU Sessions. For each UE, the NG-RAN establishes at least one Data Radio Bearers (DRB) together with the PDU Session, and additional DRB(s) for QoS flow(s) of that PDU session can be subsequently configured (it is up to NG-RAN when to do so), e.g., as shown above with reference to Fig. 3. The NG-RAN maps packets belonging to different PDU sessions to different DRBs. NAS level packet filters in the UE and in the 5GC associate UL and DL packets with QoS Flows, whereas AS-level mapping rules in the UE and in the NG-RAN associate UL and DL QoS Flows with DRBs.

[69] Block diagram 500 in Fig. 5 illustrates a 5G NR non-roaming reference architecture (see TS 23.287 v16.4.0, section 4.2.1.1). An Application Function (AF), e.g., an external application server hosting 5G services, exemplarily described in Fig. 4, interacts with the 3GPP Core Network in order to provide services, for example to support application influence on traffic routing, accessing Network Exposure Function (NEF) or interacting with the Policy framework for policy control (see Policy Control Function, PCF), e.g., QoS control. Based on operator deployment, Application Functions considered to be trusted by the operator can be allowed to interact directly with relevant Network Functions. Application Functions not allowed by the operator to access directly the Network Functions use the external exposure framework via the NEF to interact with relevant Network Functions.

[70] Fig. 5 shows further functional units of the 5G architecture for V2X communication, namely, Unified Data Management (UDM), Policy Control Function (PCF), Network Exposure Function (NEF), Application Function (AF), Unified Data Repository (UDR), Access and Mobility Management Function (AMF), Session Management Function (SMF), and User Plane Function (UPF) in the 5GC, as well as with V2X Application Server (V2AS) and Data Network (DN), e.g. operator services, Internet access or third party services. All of or a part of the core network functions and the application services may be deployed and running on cloud computing environments.

[71] In recent 3GPP RAN1 meetings, for a multi-PRACH transmission with a same beam, it has been agreed that a concept of RO group may be introduced to include ROs that are used for sending a specific number of PRACH transmissions. To differentiate between a single PRACH transmission and a multi-PRACH transmission, a RO group may be implemented such that the RO group consists of shared ROs (e.g., shared ROs may be used by both single PRACH and multi-PRACH transmissions) only with a different preamble for single PRACH transmission and multi-PRACH transmission, or the RO group consists of separate ROs (e.g., separate ROs are configured for use only for multi-PRACH transmission and they are independent of that used for single PRACH transmission) only. A gNB may configure a value of one (e.g., for a single-PRACH transmission) or multiple values for a number of PRACH transmissions (e.g., multiple values being 2, 4 or 8 PRACH transmissions). If multiple values are configured, the number of ROs in a RO group may be equal to a corresponding number of PRACH transmissions for each value. However, details for how PRACH resources may be differentiated for multi-PRACH transmissions with different number of PRACH transmissions are not discussed.

[72] In addition, in regards to the periodic manner in which RO groups are configured, a set of RO group(s) may be determined or configured for a number of PRACH transmissions within a period X, and the determined or configured set of RO groups can be repeated at every period X (e.g., a period X being a configuration period or a periodicity of a multi-PRACH transmission) to minimize effort of a UE for determining separate sets of RO group(s) for a multi-PRACH transmission, such that there is no need for the UE to keep determining the required set of RO group(s) at each period X.

[73] PRACH preamble resources (e.g., up to 64 preambles per serving cell is supported) have been partitioned to differentiate multiple features for different purposes. For example, referring to illustration 600 of Fig. 6 illustrating the existing PRACH preamble partitioning in Release 15, 16 and 17, PRACH preamble resources are partitioned according to preambles for contention-free random access procedure (CFRA) 602 and preambles for contention-based random access (CBRA) 604, in which preambles for CBRA 604 comprise preambles for 4-step RACH 606, 2-step RACH 608, feature combination 610 (e.g., comprising preambles for reduced capacity (RedCap), small data transmission (SmallData), SliceGroup, and message 3 (Msg3)-Repetition request) and also, in remaining

available preambles 612, separate preambles for different numbers of PRACH transmissions 614 in a multi-PRACH transmission. For example, when the existing PRACH preamble partitioning is reused, from the remaining available preambles 612, separate preambles for 2 PRACH transmissions 616, 4 PRACH transmissions 618, and 8 PRACH transmissions 620 may be used.

[74] It is not specified in the current (Rel. 15/16/17) TSs how PRACH preamble resource for a multi-PRACH transmission is realized. When the existing PRACH preamble partitioning according to the current TSs is used to partition separate preambles for multiple values for a number of PRACH transmissions, usage of preamble resource is not fully utilized, and the number of available preambles may be not enough for other purposes, resulting in inefficient usage of preamble resources. For example (referring to illustration 600 of Fig. 6), for N SSBs, it may be required to reserve $(M_1+M_2+M_3)*N$ preambles, where M_1, M_2, M_3 denote preambles for 2, 4, and 8 PRACH transmissions per SSB, respectively (e.g., separate preambles for 2 PRACH transmissions 616, 4 PRACH transmissions 618, and 8 PRACH transmissions 620 as shown in Fig. 6). In a serving cell, a total number of preambles is 64. For each SSB, it requires at least $M_1=M_2=M_3=1$ preamble to support the 2, 4, and 8 PRACH transmissions. For a low frequency band case (e.g., FR1) with a maximum of $N=8$ SSBs, it may require at least $(1+1+1)*8=24$ preambles which may lead to a heavy and excessive usage of preamble resources. Further, for a high frequency band case (e.g., FR2) with a maximum of $N=64$ SSBs, it may require at least $(1+1+1)*64=192$ preambles which is greater than 64, resulting in an issue of insufficient preambles.

[75] Further, synchronization signal block to RACH occasion (SSB-to-RO) mapping as currently specified in the TSs is mainly designed for single PRACH transmission and may not work well for a multi-PRACH transmission. For example, referring to illustration 700 of Fig. 7, a UE may be configured to transmit 8 PRACHs 702 (e.g., PRACH#0-PRACH#7) within a configuration period 708. It is expected that a same preamble#a is sent in 8 PRACHs in order to achieve a combined gain to improve coverage performance at the gNB side. However, as the UE can only determine 4 ROs only (i.e., 4 RO#i with preamble#a) for only first 4 PRACH transmissions 704 within a configuration period 708 (e.g., comprising 4 SSB-to-RO association periods 710), the remaining 4 PRACH transmissions 706 are not completed, such that gNB does not achieve a desirable combined gain to compensate the pathloss of the PRACH. Thus, when a RO group consists of shared ROs and a

SSB-to-RO association period is configured shortly, a UE may not be able to determine enough shared ROs for a large number of PRACH transmissions. The UE may only be able to transmit fewer PRACHs and a base station (gNB) cannot achieve a desirable combined gain of preamble detection. Furthermore, even if each of the SSB-to-RO association period 710 is configured to be longer, the potential issues of heavy and excessive usage of preambles or insufficient number of preambles are still not addressed. It is thus necessary to specify solutions to realize PRACH preamble resource for multi-PRACH transmission and to overcome the above-mentioned issues.

[76] In the present disclosure, a UE may be configured to determine a RO group based on a number of PRACH transmissions in a multiple PRACH transmission, and determine a preamble to be sent in the RO group based on a mapping between the preamble and the RO group. The RO group may comprise one or more ROs that are equal to the number of PRACH transmissions in the multiple PRACH transmission. The mapping may be between one or more preambles and one or more RO groups. The mapping may further be between the preamble, the RO group and an SSB index. The mapping may be to indicate the preamble per the RO group per the SSB index, where the preamble is a preamble from a set of preambles defined based on a configurable number of *N* SSBs and *K* options for the one or more multiple PRACH transmissions. K is referred to herein as an index associated with one or more multiple PRACH transmissions, and indicates a number of options that are available for the one or more multiple PRACH transmissions. For example, *K*=1 (e.g., the index indicates 1) may denote 2, 4 or 8 PRACH transmissions (e.g., 1 multiple PRACH transmission comprising 2, 4 or 8 PRACH transmissions), *K*=2 (e.g., the index indicates 2) may denote 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions (e.g., 2 multiple PRACH transmissions comprising 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions), and *K*=3 (e.g., the index indicates 3) may denote 2, 4, and 8 PRACH transmissions (e.g., 3 multiple PRACH transmissions comprising 2, 4, and 8 PRACH transmissions). It may be *N*>=1 and 1<=*K*<=3. The index K may not be limited to 3 options, and expanded options may be applicable to embodiments with more than 8 PRACH transmissions e.g., embodiments where K = 4, 5, 6 may be associated with 16, 32 or 64 PRACH transmissions respectively are possible. The preamble may be sent in the RO group within a certain duration of time and within a same beam. The certain duration of time may be referred as a set of consecutive OFDM symbols, slots, or sub-frames, or frames, or SSB-to-RO association periods, or SSB-to-RO

association pattern period, or configuration period of a multi-PRACH transmissions which can be configured by a gNB.

[77] A set of preambles may be configured based on *N* SSBs and *K* options for the numbers of multiple PRACH transmissions. Based on the one or more multiple PRACH transmissions, a UE may determine a RO group and a preamble from the set of preambles to be sent in the RO group with a same beam (e.g., the preamble and RO group being sent within the same/one SSB based beam instead of across multiple SSB based beams) according to a mapping between the preamble, the RO group, and an SSB index. The preamble may be considered as a RO group-specific preamble for one or more multiple PRACH transmissions with the same SSB beam. The mapping may be realized based on one of the following solutions. In a Solution 1, the mapping is based on a rule. In a Solution 2, the mapping is based on an explicit indication by a gNB.

[78] For example, referring to illustration 800 of Fig. 8A, the determination may be made within a time period 802 of 10 ms, and the set of preambles may be used for other purposes during the remaining time period 804 of 20ms. In another example, referring to illustration 806 of Fig. 8B, the determination may be made within a time period 808 of 30ms. In Fig. 8A, within the time period 802 of 10 ms, it allows a shorter transmission period of a multi-PRACH transmission in one PRACH attempt that can reduce the latency of initial access as compared with eventual distribution of preamble resource over a longer period. For the case of Fig. 8B having a longer time period 808 of 30ms, it can be suitable for a high number of multiple PRACH transmissions. Advantageously, it is possible to adjust the period of time to achieve better flexibility of configuration of preamble for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

[79] In an implementation, from the determined RO group or from the determined number of PRACH transmissions and the SSB index, the UE determines a preamble to be sent in the RO group to a gNB based on the mapping. The SSB index may be a best SSB index or a SSB index which meets a condition (e.g., above a threshold). The RO group or the mapping may be determined based on *K* options for one or more multiple PRACH transmissions. After that, the UE monitors to receive a random access response (RAR) of the multi-PRACH transmission.

[80] In an implementation, the gNB may configure one or more sets of preambles, *N* SSBs, and *K* options for a number of multiple PRACH transmissions for a multi-PRACH transmission (e.g., *K* being an index associated with one or more multiple PRACH transmissions that indicates a number of options that are available for the one or more multiple PRACH transmissions). The gNB may generate a DCI to schedule PDSCH carrying a RAR, and transmits the RAR as a response to the multi-PRACH transmission (e.g., received from the UE) to the UE.

[81] In an implementation, wherein a set of preambles may be configured based on *N* SSBs and *K* options for one or more multiple PRACH transmissions (e.g., *K* being an index associated with one or more multiple PRACH transmissions that indicates a number of options that are available for the one or more multiple PRACH transmissions). For example, *K*=1 (e.g., the index indicates 1) may denote 2, 4 or 8 PRACH transmissions (e.g., 1 multiple PRACH transmission comprising 2, 4 or 8 PRACH transmissions), *K*=2 (e.g., the index indicates 2) may denote 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions (e.g., 2 multiple PRACH transmissions comprising 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions), and *K*=3 (e.g., the index indicates 3) may denote 2, 4, and 8 PRACH transmissions (e.g., 3 multiple PRACH transmissions comprising 2, 4, and 8 PRACH transmissions). It may be *N*>=1 and 1<=*K*<=3. The index *K* may not be limited to 3 options, and expanded options may be applicable to embodiments with more than 8 PRACH transmissions e.g., embodiments where *K* = 4, 5, 6 may be associated with 16, 32 or 64 PRACH transmissions respectively are possible. For example, referring to illustration 900 of Fig. 9, a set of preambles 902 consisting of *N***K* preambles may be required for *N* SSBs and *K* options for the one or more multiple PRACH transmissions. The *K* options for one or more multiple PRACH transmissions may be indicated from a base station by control information such as a higher layer signalling. A set of preambles and the one or more multiple PRACH transmissions may be mapped closely in time but not overlapping in time-domain, which advantageously results a shorter transmission period of the multi-PRACH transmission in one PRACH attempt. It will be appreciated that a multi-PRACH transmission may be referred to herein as a multiple PRACH transmission, or a RO group, or one PRACH attempt.

[82] Fig. 10A shows an exemplary illustration 1000 of determining a preamble per RO group for a 2-PRACH transmission according to the current technical

specifications. A RO group#0 (e.g., comprising two ROs RO#*i* and RO#*j*) and two preambles (e.g., preamble#*a* and preamble#*b*) are determined for 2 PRACHs based on the current TS within two SSB-to-RO association periods 1002 and 1004. Fig. 10B shows an exemplary illustration 1006 of determining a preamble per RO group for a 2-PRACH transmission according to various embodiments of the present disclosure. In contrast to the example of Fig. 10A, a RO group#0 (e.g., comprising two ROs RO#*i* and RO#*j*) and a preamble (e.g., preamble#*a*) are determined for 2 PRACHs within one SSB-to-RO association period 1008.

[83] In the present solution, a preamble is indicated per RO group (for one or more multiple PRACH transmissions) per SSB, e.g., it can be considered as a preamble-to-RO group-to-SSB mapping to provide a RO group-specific preamble. Further, based on a number of multiple PRACH transmissions, a UE may determine a RO group and a preamble to be sent in the RO group, for example with a same beam according to a mapping between the preamble, the RO group, and an SSB index. In the present solution. Up to *N*K* preambles are required for *N* SSBs. In addition, a short transmission period of a multi-PRACH transmission in one PRACH attempt can reduce latency of initial access, e.g., as shown in Fig. 10B. It can achieve better flexibility of preamble configuration for a multi-PRACH transmission, and can improve provision of preamble resources for other purposes. Further, it can support different levels of PRACH coverage enhancements in different sectors/directions. For example, beams in different sectors/directions (e.g., *N* SSBs) covering different areas may have different coupling loss due to the outdoor to indoor penetration and tree/building/obstacles penetration, thus requiring different values of *N* and *K*.

[84] Examples of how preamble resource may be determined based on the present solution are as follows. If *N*=8, *K*=1 in a FR1 case based on the present solution, at most 8 preambles may be required to support 2 PRACH transmissions. If based on the current TS, it may require at least (1+1+1)*8= 24 preambles. If *N*=8, *K*=2 in a FR1 case based on the present solution, at most 16 preambles may be required to support 2 and 4 PRACH transmissions. If based on the current TS, it may require at least (1+1+1)*8= 24 preambles. Further, if *N*=8, *K*=3 in a FR1 case based on the present solution, at most 24 preambles may be required to support 2, 4 and 8 PRACH transmissions. If based on the current TS, it may require

at least (1+1+1)*8= 24 preambles. Advantageously, the present solution is more suitable for a multiple PRACH transmission case compared to the current SSB-to-RO mapping which was mainly designed for single PRACH transmission. Further, for a scenario in which K = 1 or 2, less preamble resources are required.

[85] In the present disclosure, it may be assumed that a gNB may configure K options for one or more multiple PRACH transmissions (e.g., K being an index associated with the one or more multiple PRACH transmissions that indicates a number of options that are available for the one or more multiple PRACH transmissions) in a serving cell, where K=1 denotes 2 PRACH transmissions, K=2 denotes 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions, and K=3 denotes 2, 4, and 8 PRACH transmissions. The index K may not be limited to 3 options, and expanded options may be applicable to embodiments with more than 8 PRACH transmissions e.g., embodiments where K = 4, 5, 6 may be associated with 16, 32 or 64 PRACH transmissions respectively are possible. The gNB may also configure N SSBs. The gNB may also configure a set of preambles separately (e.g., the set can include up to $N*K$ preambles as a separate configuration). The preambles in the set may be arranged in a sequential order (e.g., ascending/descending order of preamble indexes). Based on the index associated with the one or more multiple PRACH transmissions, a UE may determine a RO group and a preamble to be sent in the RO group according to a mapping between the preamble and the RO group. The mapping may further be between the preamble, the RO group and an SSB index. The UE may further determine a set of RO groups based on the configurable N SSBs and the index associated with the one or more multiple PRACH transmissions. Each RO group from the set of RO groups (e.g., $N*K$ RO groups) corresponds to a number of PRACH transmissions (e.g., in a multiple PRACH transmission) and associates with a SSB index from the N SSBs.

[86] The mapping between the preamble, the RO group, and the SSB index may be based on a rule, the rule being one of a sequential mapping or a cyclic mapping. Fig. 11 shows an exemplary illustration 1100 of determining a preamble per RO group per SSB index according to a sequential mapping for a multi-PRACH transmission according to various embodiments of the present disclosure. It is assumed in illustration 1100 that N=3 SSBs, K=2, and a set of $N*K$ preambles 1102 are used. Each preamble of the set of preambles 1102 may be mapped to each RO group from the set of RO groups 1104 sequentially. Based on the

mapping, and as shown in illustration 1200 of Fig. 12, each preamble may be transmitted in a respectively mapped RO group in multi-PRACH transmission 1202 within a configuration period 1204 of 10ms.

[87] Further, Fig. 13 shows an exemplary illustration 1300 of determining a preamble per RO group per SSB index according to a cyclic mapping for a multi-PRACH transmission according to various embodiments of the present disclosure. It is assumed for illustration 1300 that N=3 SSBs, K=2, and a set of $N*K$ preambles are configured. A UE may determine a preamble per RO group (corresponding to a number of multiple PRACH transmissions) per SSB index according to a cyclical mapping. In a first step, a first preamble (e.g., preamble#0) of a set of preambles 1302 may be mapped to a first RO group (e.g., RO group#0) of a set of RO groups 1304 associated with a lowest SSB index (e.g., SSB#0). In a second step, a second preamble (e.g., preamble#1) of the set of preambles 1302 may be mapped to a second RO group (e.g., RO group#3) associated with the lowest SSB index (e.g., SSB#0). Thereafter, in a third step, the first and second steps may be repeated for the remaining SSB indexes (e.g., SSB indexes SSB#1 and SSB#2).

[88] In an implementation, the rule may be specified in a TS, or configured by a gNB or a UE, or other similar implementations. In an implementation where the rule may be specified in a TS, there is advantageously no need of signalling for the mapping.

[89] In an implementation, one or more sets of preambles may be used for one or more multiple PRACH transmissions in time-domain. For example, referring to illustrations 1400, 1500 and 1600 of Figs. 14, 15 and 16 respectively, it is assumed K=2 and N=3. 2 sets of preambles 1402 and 1502 are sequentially mapped to a set of RO groups 1404 in two different durations of time 1602 and 1604, respectively. For example, the set of preambles 1402 are transmitted in the set of RO groups 1404 within the duration of time 1602, and the set of preambles 1502 are transmitted in the set of RO groups 1404 within the duration of time 1604. In an implementation, the preambles of the one or more sets of preambles may be same or different from each other. For example, preamble set 1502 comprises preamble#0, preamble#1, preamble#2 and preamble#3 that are also included in preamble set 1402. Advantageously, this implementation makes it possible for a gNB to flexibly configure preamble resources based on actual usage of the multi-PRACH transmission or other purposes in time-domain when needed. The one or

more sets of preambles may be configured by control information such as a higher layer signalling, downlink control information (DCI) and so on. Although 2 sets of preambles are illustrated, it will be appreciated that two or more mappings between two or more sets of preambles and the set of RO groups 1404 are possible, and each of the two or more sets of preambles may be mapped to the set of the RO groups, for example in time domain sequentially, cyclically, or other similar mapping configuration.

[90] In an implementation, a total number of sets of preambles that are mapped to a set of RO groups may be different based on the index associated with one or more multiple PRACH transmissions. For example, a set of preambles may be mapped to a set of RO groups when the index is '1' (e.g., K = 1), 2 sets of preambles may be mapped to a set of RO groups when the index is '2' (e.g., K = 2), or other possible variations may be implemented. The total number of the sets of preambles may also be different among each SSB of N SSBs. In this implementation, when the index is low, e.g., K=1, a lower number of preambles may be required, and thus one set of preambles may be sufficient for mapping to the set of RO groups. This frees up PRACH resources for the gNB to allocate for other purposes. When the index is high, e.g., K=3, a higher number of preambles may be required, and thus more sets of preambles may be configured to map to the set of RO groups to enable the multiple PRACH transmission. Advantageously, it is possible to configure the total number of sets of preambles so that a gNB can prioritize to allocate more PRACH preamble resources for other purposes when needed, enabling more flexibility.

[91] In an implementation, there may be a different number of preambles in a set of preambles from RO groups in the set of RO groups. If the number of preambles is greater than the number of RO groups, the leftover preambles (e.g., which are not mapped to any RO group) may be left unused. If the number of preambles is lesser than the number of RO groups, the one or more leftover RO groups (e.g., which are not mapped to any preamble) may be allocated for other transmissions or left unused. Advantageously, a gNB can prioritize to allocate more PRACH resources (e.g., the leftover RO groups) for other purposes when needed.

[92] In an implementation, wherein a set of preambles (e.g., a first set of preambles) is mapped to a set of RO groups, and there are less numbers of preambles in the set

of preambles than RO groups in the set of RO groups, one or more leftover RO groups (e.g., which are not mapped to any preamble in the first set of preambles) in the set of RO groups may be mapped to one or more preambles of a subsequent set of preambles (e.g., a second set of preambles) if the subsequent set is determined or configured. This advantageously overcomes a limitation of a small set of preambles (e.g., in a case where the number of preambles in a set of preambles is lesser than the number of RO groups in a set of RO groups) for supporting all possibilities of RO groups associated with their own SSB indexes.

[93] In an implementation, two table-based indications may be used to indicate one or more sets of preambles (e.g., table 1700 of Fig. 17), as well as the set of RO groups (e.g., a multi-PRACH table as shown in table 1702 of Fig. 17), respectively, based on a configurable *N* SSBs and *K* options for a number of PRACH transmissions (e.g., *K* being an index associated with one or more multiple PRACH transmissions). Table 1700 indicates one or more sets of preambles to be used in time-domain. It may be implicitly determined or configured e.g., by a gNB. Multi-PRACH table 1702 may also be implicitly determined or configured e.g., by a gNB. Each row of the table 1702 indicates an association between a SSB index and a RO group, starting from a lowest SSB index (e.g., SSB#0) from *N* SSBs (e.g., each row corresponds to a RO group), and each column indicates indexes of PRACH transmissions for different RO groups. The number of columns may depend on the index (e.g., 2 columns for *K*=1, 4 columns for *K*=2, and 8 columns for *K*=3). Further, each entry in the table 1702 indicates an association between a SSB index and a RO from a RO group (e.g., SSB#*i*, RO#*i*).

[94] For example, in Fig. 17, *N*=3 and *K*=2 are assumed, and the tables 1700 and 1702 indicate possible PRACH resources (e.g., preamble and RO) for 2 & 4 PRACH transmissions (since index=*K*=2). There may be 6 rows to show 6 possible associations between SSBs and RO groups for 2 & 4 PRACH transmissions. For 2 PRACH transmissions, 2 columns in the multi-PRACH transmissions are sufficient to indicate PRACH resources. For 4 PRACH transmissions, 4 columns in the multi-PRACH transmissions are sufficient to indicate PRACH resources. Accordingly, each preamble from the one or more sets of preambles (e.g., a first set of preambles 1706 and a second set of preambles 1708 as shown in Table 1700) is mapped to each row of the multi-PRACH table (e.g., each row of table 1702 indicating a RO group of a set of RO groups). Referring to illustration 1800 of Fig. 18, the mapped preambles in the first set of preambles 1706 may be

transmitted in a time duration 1802, and the mapped preambles in the second set of preambles 1708 may be transmitted in a time duration 1804. It will be appreciated that there can be other possibilities to show the one or more sets of preambles and the multi-PRACH table, and tables 1700 and 1702 are just two of such possibilities.

[95] In an implementation, the preambles in the set of preambles may be same or different from that of another set of preambles. One or more ROs in a RO group #A for a number of PRACH transmissions may be included in a RO group #B for a same number or different number of PRACH transmissions. Different preambles from the set may be mapped to the RO group #A and the RO group #B, respectively. For example, for 2 PRACH transmissions, a preamble#0 may be mapped to a RO group #0 (e.g., consisting of RO#*i* and RO#(*i*+1)) for a UE#0, while a preamble#1 may be mapped to a RO group#1 (e.g., consisting of RO#*i*, RO#(*i*+1)) for a UE#1. A gNB may be configured to distinguish the RO group#0 and RO group#1 sent by UE#0 and UE#1 based on a detection of different preamble#0 and preamble#1. In another example, a preamble#0 may be mapped to a RO group #0 (consisting of RO#*i* and RO#(*i*+1)) for 2 PRACH transmissions for a UE#0, while a preamble#1 may be mapped to a RO group#1 (e.g., consisting of RO#*i*, RO#(*i*+1), RO#(*i*+4), and RO#(*i*+5)) for 4 PRACH transmissions for a UE#1. Further, in an implementation, a number of preambles used for a small number of PRACH transmissions may be lesser (or greater) than a number of preambles used for a large number of PRACH transmissions depending on an ordering of the mapping, if the number of preambles in the set is less than *N*K* (e.g., in preamble set 1708 in Fig. 17, 3 preambles (preamble #0, preamble #1, preamble #2) may be used for 2 PRACH transmissions and 1 preamble (preamble #3) may be used for 4 PRACH transmissions).

[96] In an implementation, each preamble from a set of preambles may be mapped to more than one RO groups in a set of RO groups in a FDM (frequency division multiplexing) scheme. Each RO group from the set of RO groups can be differentiated from one another at frequency-domain, e.g., multiple FDMed RO groups. Mapping may be implemented based on the following options: in an option a, if there is only one preamble in the set of preambles, it is mapped to all rows of the multi-PRACH table; in an option b, if there are more than one preambles in the set of preambles, sequential mapping or cyclical mapping (e.g., as implemented in Figs. 11 and 13 respectively) may be used in a repeated manner. For example, in

the case of a sequential mapping, the preambles in the set of preambles may be arranged in a sequential order, and the sequential order may be repeated multiple times to meet the size of the set of RO groups. Referring to illustration 1900 of Fig. 19, sequential mapping is used in a repeated manner between a set of preambles 1902 comprising 2 preambles (preamble#0 and preamble#1) and a set of RO groups 1904 comprising 6 RO groups, under an assumption of 2 preambles, N=3 SSBs, and index=K=2. For example, in illustration 1900, preamble#0 and preamble#1 are mapped to RO group#0 and RO group#1, RO group#2 and RO group#3, as well as RO group#4 and RO group#5 respectively. Advantageously, this implementation enables less PRACH preamble usage.

[97] Alternatively, a gNB may determine a number of preambles for each of K options and corresponding preambles, and indicates them to the UE. For example, in a case K=3, a number of preambles and corresponding preambles are determined for each of 2, 4 and 8 PRACH transmissions. Then, the gNB and/or UE may determine a mapping between a set of preambles and a set of RO groups. The corresponding preambles may be mapped to each of RO groups (e.g., $N*K$ RO groups). Some of the corresponding preambles may be mapped to more than one RO groups, or some of the RO groups may be mapped to more than one corresponding preambles. The corresponding preambles of a first multiple PRACH transmission (e.g., comprising 2 PRACH transmissions) may be a larger number or smaller number than that of a second multiple PRACH transmission (e.g., comprising 4 PRACH transmissions).

[98] In an implementation, it may be assumed that a gNB may configure a number of N SSBs and K options for one or more multiple PRACH transmissions (e.g., K being an index associated with the one or more multiple PRACH transmissions) in a serving cell, where K=1 denotes 2, 4 or 8 PRACH transmissions, K=2 denotes 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions, and K=3 denotes 2, 4, and 8 PRACH transmissions. The index K may not be limited to 3 options, and expanded options may be applicable to embodiments with more than 8 PRACH transmissions e.g., embodiments where K = 4, 5, 6 may be associated with 16, 32 or 64 PRACH transmissions respectively are possible. Based on a number of multiple PRACH transmissions, a UE may determine a RO group and a preamble to be sent in the RO group with a same beam according to a mapping between the preamble, the RO group, and an SSB index.

[99] The mapping may be based on an explicit indication. In an implementation, in a random access (RA) without a PDCCH order, a mapping may be between a preamble, a RO group and a SSB index, the mapping being an explicit indication from one or a combination of a master information block (MIB), a system information block (SIB), a higher layer parameter, and a downlink control information (DCI). The UE may determine the preamble based on the number of multiple PRACH transmissions. Further, in a case for RA with a PDCCH order, the explicit indication may indicate directly a preamble (from the set of preambles) for the multiple PRACH transmissions in a DCI. In another implementation, a multi-PRACH table such as table 2000 of Fig. 20 may be configured (e.g., in MIB or SIB) based on *N* SSBs and *K* options (e.g., K being an index associated with the one or more multiple PRACH transmissions). The explicit indication (e.g., it can be included in MIB or SIB in a RA without PDCCH order, or an indication field in a DCI in a RA with PDCCH order) may indicate a row in a multi-PRACH table. Each row in table 2000 indicates a preamble from a set of preambles and its mapping with a RO group that is associated with a SSB index. Advantageously, this implementation can provide greater flexibility (as compared to configuring a table or list of preambles that are separate from one or more sets of RO groups) from a gNB perspective.

[100] In an implementation, a UE may receive an explicit indication (e.g., from a gNB) to determine a preamble to be sent in a RO group with a same beam according to a mapping between the preamble, the RO group, and a SSB index in a FDM scheme. Each RO group of a set of RO groups may be differentiated from one another at frequency-domain, e.g., according to multiple FDMed RO groups. Further, a preamble may be mapped to more than one RO groups in the set of RO groups in a FDM scheme (e.g., mapped to more than one rows in a multi-PRACH table). For example, table 2100 of Fig. 21 is generated under an assumption of 2 preambles in a set of preambles (e.g., the set of preambles comprising preamble#0 and preamble#1), N=3 SSBs, and K=2. In table 2100, preamble#0 and preamble#1 are mapped to respective RO groups in a repeated manner e.g., preamble#0 is mapped to RO groups in rows 2102 and preamble#1 is mapped to RO groups in rows 2104. Advantageously, this implementation enables less PRACH preamble usage.

[101] In an implementation, for example referring to illustration 1900 of Fig. 19, if there are two preambles (e.g., a first preamble preamble#0 and a second preamble preamble#1) in the set of preambles 1902, the first preamble and the second

preamble may be mapped to a first-half of RO group indexes (e.g., from RO group index#0 to RO group index #((*N***K*/2)-1) and a second-half of RO group indexes (e.g., from RO group index #(*N***K*/2) to RO group index#(*N***K*-1)) in the set of RO groups 1904.

[102] It will be appreciated that all the implementations disclosed herein may be applied to a case of CSI-RS based beams instead of SSB-based beams, and may also be applied to a case in which a RO group consists of shared ROs with separate preamble(s), or a case in which a RO group consists of separate ROs.

[103] The mappings discussed in the implementations disclosed herein ensures that only mapped preamble(s) are sent in a multi-PRACH transmission from a UE in a code division multiplexing (CDM) scheme, FDM scheme, spatial division multiplexing (SDM) scheme, or other similar schemes where applicable. In a CDM scheme (e.g., which may be applicable to implementations according to Figs. 11-18 and 20), preambles in a set of preambles are differentiated in code domain (e.g., preamble domain). In a FDM scheme (e.g., which may be applicable to implementations according to Figs. 19 and 21), a set of RO groups may be determined or configured for multiple values of the number of PRACH transmissions. Each RO group of the set of RO groups may be differentiated from one another at frequency-domain. Each preamble from the set of preambles may be mapped to more than one RO group for a same number of PRACH transmissions. Further, in a SDM scheme, different sets of preambles may be configured for different Transmission Reception Points (TRPs), different cells, different sets of beams, or other similar entities. For example, each set of preambles may be applied to each TRP, each cell, or each set of beams where applicable.

[104] It will be appreciated that the implementations disclosed herein may be implemented for a multi-PRACH transmission with a same beam, as well as for a multi-PRACH transmission with different beams. Further, for a number of multiple PRACH transmissions, a RO group may be divided into 2 or more sub-RO groups, such that the mapping may be between a preamble, a sub-RO group, and a SSB index. Likewise, the multiple PRACH transmissions may be transmitted with a same beam or with different beams.

[105] Fig. 22 shows a flow chart 2200 for a UE according to various embodiments of the present disclosure. In a step 2202, a UE may determine or be configured with one or more sets of preambles, *N* SSBs, and *K* options for a number of multiple PRACH transmissions for a multi-PRACH transmission (e.g., *K* being an index associated with one or more multiple PRACH transmissions). In step 2204, the UE may determine a preamble per RO group per SSB index implicitly or explicitly (e.g., according to the implementations discussed herein). In step 2206, based on a SSB-RSRP measurement(s) and a corresponding threshold(s), the UE may determine or select a RO group with the corresponding preamble determined in step 2204 to send a multi-PRACH transmission. In step 2208, the UE may monitor to receive a random access response (RAR) of the multi-PRACH transmission, e.g., from a gNB.

[106] Fig. 23 shows a flow chart 2300 for a gNB according to various embodiments of the present disclosure. In step 2302, a gNB may configure one or more sets of preambles, *N* SSBs, and *K* options for a number of multiple PRACH transmissions for a multi-PRACH transmission (e.g., *K* being an index associated with one or more multiple PRACH transmissions). In step 2304, a gNB may configure a multi-PRACH table and/or a preamble mapping (e.g., according to an implementation of an explicit indication based on Fig. 20). It will be appreciated that this step 2304 may be skipped for an implementation based on Figs. 11-18. In step 2306, the gNB may generate a DCI to schedule PDSCH carrying a RAR, and transmits the RAR as a response to the multi-PRACH transmission (e.g., received from a UE) to the UE.

[107] In an implementation, the gNB may be configured to generate a mapping between a preamble and a RO group based on one or more sets of preambles, a number of SSBs, and an index associated with one or more multiple PRACH transmissions, and the gNB may signal the mapping to a UE.

[108] Fig. 24 shows an exemplary illustration 2400 of a flow of interaction between a UE 2402 and a gNB 2404 in a 4-step RACH procedure according to various embodiments of the present disclosure. In phase 2406, the gNB 2404 may configure one or more sets of preambles, *N* SSBs, and *K* options for a number of multiple PRACH transmissions for a multi-PRACH transmission (e.g., *K* being an index associated with one or more multiple PRACH transmissions). In phase 2408, the UE 2402 may determine a preamble per RO group per SSB index implicitly or

explicitly (e.g., according to the implementations discussed herein). In phase 2410, the UE 2402 may transmit a multi-PRACH transmission (e.g., Msg1) based on a RO group with the corresponding preamble determined in phase 2408, and monitor to receive a RAR of the multi-PRACH transmission from the gNB 2404. In phase 2412, the gNB 2404 may generate a DCI to schedule PDSCH carrying a RAR, and transmit the RAR as a response to the multi-PRACH transmission (e.g., Msg2) to the UE 2402. In phase 2414, the UE 2402 may transmit a scheduled transmission (e.g., Msg4) to the gNB 2404, and the gNB 2404 may send a Msg4 to the UE 2402 for contention resolution.

[109] Fig. 25 shows a flow chart 2500 illustrating a communication method according to various embodiments of the present disclosure. At step 2502, a Random Access Channel Occasion (RO) group is determined based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission. In step 2504, a preamble to be used for the RO group is determined based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs. In step 2506, the preamble is transmitted.

[110] Fig. 26 shows a schematic, partially sectioned view of the communication apparatus 2600 that can be implemented for in accordance with various embodiments and examples as shown in Figs. 1 to 25. The communication apparatus 2600 may be implemented as a UE or base station according to various embodiments.

[111] Various functions and operations of the communication apparatus 2600 are arranged into layers in accordance with a hierarchical model. In the model, lower layers report to higher layers and receive instructions therefrom in accordance with 3GPP technical specifications. For the sake of simplicity, details of the hierarchical model are not discussed in the present disclosure.

[112] As shown in Fig. 26, the communication apparatus 2600 may include circuitry 2614, at least one radio transmit (Tx) chain 2602 (also referred to herein as transmitter 2602), at least one radio receive (Rx) chain 2604 (also referred to herein as receiver 2604), and at least one antenna 2612 (for the sake of simplicity, only one antenna is depicted in Fig. 26 for illustration purposes). The circuitry 2614 may include at least one controller 2606 for use in software and hardware aided

execution of tasks that the at least one controller 2606 is designed to perform, including control of communications with one or more other communication apparatuses in a wireless network. The circuitry 2614 may furthermore include at least one transmission signal generator 2608 and at least one receive signal processor 2610. The at least one controller 2606 may control the at least one transmission signal generator 2608 for generating signals to be sent through the at least one radio transmitter 2602 to one or more other communication apparatuses and the at least one receive signal processor 2610 for processing signals received through the at least one radio receiver 2604 from the one or more other communication apparatuses under the control of the at least one controller 2606. The at least one transmission signal generator 2608 and the at least one receive signal processor 2610 may be stand-alone modules of the communication apparatus 2600 that communicate with the at least one controller 2606 for the above-mentioned functions as shown in Figs. 1-25. Alternatively, the at least one transmission signal generator 1408 and the at least one receive signal processor 2610 may be included in the at least one controller 2606. It is appreciable to those skilled in the art that the arrangement of these functional modules is flexible and may vary depending on the practical needs and/or requirements. The data processing, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets. In various embodiments, when in operation, the at least one radio transmitter 2602, at least one radio receiver 2604, and at least one antenna 2612 may be controlled by the at least one controller 2606. It will be appreciated that the communication apparatus 2600 may include a plurality of antennas, for example as shown in communication apparatus 2700 of Fig. 27 which includes a plurality of antennas 2712. Each of the plurality of antennas 2712 can be connected to a corresponding Tx chain 2702 and Rx chain 2704 through a switcher or switch point. Alternatively, each of the plurality of antennas 2712 can be connected to a corresponding Tx chain or Rx chain.

[113] The communication apparatus 2600, when in operation, provides functions required for resource assignment for multi-PRACH transmissions. For example, the communication apparatus 2600 may be a UE, and the circuitry 2614 may, in operation, determine a Random Access Channel Occasion (RO) group based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission, and determine a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO

groups, the RO group comprising one or more ROs. The transmitter 2602 may, in operation, transmit the preamble.

[114] The circuitry 2614 may be configured to determine the one or more RO groups and the one or more preambles based on a number of synchronization signal blocks (SSBs) and based on an index associated with one or more multiple PRACH transmissions, each of the one or more RO groups being associated with a synchronization signal block (SSB) index of the SSBs. There may be greater numbers of preambles in the one or more preambles than RO groups in the one or more RO groups, and there may be one or more leftover preambles that are not mapped and left unused. The index may be 1 to denote 2, 4 or 8 PRACH transmissions, 2 to denote 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions, and 3 to denote 2, 4 and 8 PRACH transmissions.

[115] The mapping may be applicable for a duration of time, the duration of time being a set of consecutive OFDM symbols, slots, sub-frames, frames, synchronization signal block (SSB) to Random Access Channel Occasions (SSB-to-RO) association periods, or SSB-to-RO association pattern period, and the transmitter 2402 may transmit the preamble in the RO group within the duration of time. The one or more preambles may be sequentially or cyclically mapped to the one or more RO groups in the mapping. One preamble of the one or more preambles may be mapped to one RO group of the one or more RO groups. Each of the one or more RO groups may be mapped with a same preamble or a different preamble from one another. A total number of the one or more preambles in the mapping or a total number of the one or more RO groups in the mapping may be different based on a number of synchronization signal blocks (SSBs) and an index associated with one or more multiple PRACH transmissions.

[116] There may be a different number of preambles in the one or more preambles from RO groups in the one or more RO groups, and one or more leftover RO groups in the one or more RO groups that are not mapped to the one or more preambles may be allocated for other transmissions or left unused. A first set of preambles comprising the one or more preambles may be mapped to a set of RO groups comprising the one or more RO groups, and there may be less numbers of preambles in the first set of preambles than RO groups in the set of RO groups, and the circuitry 2614 may be configured to map one or more preambles of a second set of preambles to one or more leftover RO groups in the set of RO groups.

[117] The one or more preambles may be a first set of preambles, the mapping between the first set of preambles and the one or more RO groups may be a first mapping and there may be at least a second mapping between at least a second set of one or more preambles and the one or more RO groups, the at least second set of one or more preambles being the same or different from the first set of preambles, and each set of preambles may be sequentially or cyclically mapped to the one or more RO groups in time domain. The one or more preambles may be a first set of preambles, the mapping between the first set of preambles and the one or more RO groups may be a first mapping and there may be at least a second mapping between at least a second set of one or more preambles and the one or more RO groups, and a total number of preambles to be mapped to the one or more RO groups in the first mapping may be different from that in the second mapping. Each set of the first set and the at least second set of preambles may be assigned for each of one or more transmission reception points, or each of one or more cells, or each of one or more of sets of beams.

[118] There may be one or more multiple PRACH transmissions, and each RO group of the one or more RO groups may be associated with one of the one or more multiple PRACH transmissions. The RO group may be determined from the one or more RO groups based on a synchronization signal block (SSB) index of a number of SSBs.

[119] The mapping may be in a form of a first table indicating one or more sets of preambles to be used in time domain and a second table indicating a set of RO groups based on an index associated with one or more multiple PRACH transmissions and a number of SSBs, and the circuitry 2614 may be configured to determine the RO group and the preamble based on the first and second tables. The mapping may indicate that each preamble of a set of preambles comprising the one or more preambles is mapped to more than one RO groups in a frequency division multiplexing (FDM) scheme.

[120] The mapping may be further between the preamble, the RO group and a SSB index, the mapping being an explicit indication from one or a combination of a master information block (MIB), a system information block (SIB), a higher layer parameter, and a downlink control information (DCI).

[121] Each of the one or more RO groups may comprise a plurality of sub-RO groups, and the mapping further being between the preamble, a sub-RO group of the one or more RO groups, and a synchronization signal block (SSB) index. The mapping may further be between the preamble, a RO group of the one or more RO groups, and a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and an index associated with one or more multiple PRACH transmissions

[122] The communication apparatus 2600 may be a base station, and the circuitry 2614 may, in operation, determine a mapping between one or more preambles and one or more Random Access Channel Occasions (RO) groups based on an index associated with one or more multiple physical Random Access Channel (PRACH) transmissions. The transmitter 2602 may, in operation, signal the mapping to a communication apparatus.

[123] The mapping may further be between a preamble of the one or more preambles, a RO group of the one or more RO groups, and (1) a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and the index associated with the one or more multiple PRACH transmissions, or (2) a synchronization signal block (SSB) index based on a number of SSBs and the index associated with the one or more multiple PRACH transmissions.

(Control Signals)

[124] In the present disclosure, the downlink control signal (information) related to the present disclosure may be a signal (information) transmitted through PDCCH of the physical layer or may be a signal (information) transmitted through a MAC Control Element (CE) of the higher layer or the RRC. The downlink control signal may be a pre-defined signal (information).

[125] The uplink control signal (information) related to the present disclosure may be a signal (information) transmitted through PUCCH of the physical layer or may be a signal (information) transmitted through a MAC CE of the higher layer or the RRC. Further, the uplink control signal may be a pre-defined signal (information). The uplink control signal may be replaced with uplink control information (UCI), the first stage sidelink control information (SCI) or the second stage SCI.

(Base Station)

[126] In the present disclosure, the base station may be a Transmission Reception Point (TRP), a cluster head, an access point, a Remote Radio Head (RRH), an eNodeB (eNB), a gNodeB (gNB), a Base Station (BS), a Base Transceiver Station (BTS), a base unit or a gateway, for example. Further, in sidelink communication, a terminal may be adopted instead of a base station. The base station may be a relay apparatus that relays communication between a higher node and a terminal. The base station may be a roadside unit as well.

(Uplink/Downlink/Sidelink)

[127] The present disclosure may be applied to any of uplink, downlink and sidelink.

[128] The present disclosure may be applied to, for example, uplink channels, such as PUSCH, PUCCH, and PRACH, downlink channels, such as PDSCH, PDCCH, and PBCH, and side link channels, such as Physical Sidelink Shared Channel (PSSCH), Physical Sidelink Control Channel (PSCCH), and Physical Sidelink Broadcast Channel (PSBCH).

[129] PDCCH, PDSCH, PUSCH, and PUCCH are examples of a downlink control channel, a downlink data channel, an uplink data channel, and an uplink control channel, respectively. PSCCH and PSSCH are examples of a sidelink control channel and a sidelink data channel, respectively. PBCH and PSBCH are examples of broadcast channels, respectively, and PRACH is an example of a random access channel.

(Data Channels/Control Channels)

[130] The present disclosure may be applied to any of data channels and control channels. The channels in the present disclosure may be replaced with data channels including PDSCH, PUSCH and PSSCH and/or control channels including PDCCH, PUCCH, PBCH, PSCCH, and PSBCH.

(Reference Signals)

[131] In the present disclosure, the reference signals are signals known to both a base station and a mobile station and each reference signal may be referred to as a Reference Signal (RS) or sometimes a pilot signal. The reference signal may be any of a DMRS, a Channel State Information – Reference Signal (CSI-RS), a Tracking Reference Signal (TRS), a Phase Tracking Reference Signal (PTRS), a Cell-specific Reference Signal (CRS), and a Sounding Reference Signal (SRS).

(Time Intervals)

[132] In the present disclosure, time resource units are not limited to one or a combination of slots and symbols, and may be time resource units, such as frames, superframes, subframes, slots, time slot subslots, minislots, or time resource units, such as symbols, Orthogonal Frequency Division Multiplexing (OFDM) symbols, Single Carrier-Frequency Division Multiplexing Access (SC-FDMA) symbols, or other time resource units. The number of symbols included in one slot is not limited to any number of symbols exemplified in the embodiment(s) described above, and may be other numbers of symbols.

(Frequency Bands)

[133] The present disclosure may be applied to any of a licensed band and an unlicensed band.

(Communication)

[134] The present disclosure may be applied to any of communication between a base station and a terminal (Uu-link communication), communication between a terminal and a terminal (Sidelink communication), and Vehicle to Everything (V2X) communication. The channels in the present disclosure may be replaced with PSCCH, PSSCH, Physical Sidelink Feedback Channel (PSFCH), PSBCH, PDCCH, PUCCH, PDSCH, PUSCH, and PBCH.

[135] In addition, the present disclosure may be applied to any of a terrestrial network or a network other than a terrestrial network (NTN: Non-Terrestrial Network) using a satellite or a High Altitude Pseudo Satellite (HAPS). In addition, the present disclosure may be applied to a network having a large cell size, and a

terrestrial network with a large delay compared with a symbol length or a slot length, such as an ultra-wideband transmission network.

(Antenna Ports)

[136] An antenna port refers to a logical antenna (antenna group) formed of one or more physical antenna(s). That is, the antenna port does not necessarily refer to one physical antenna and sometimes refers to an array antenna formed of multiple antennas or the like. For example, it is not defined how many physical antennas form the antenna port, and instead, the antenna port is defined as the minimum unit through which a terminal is allowed to transmit a reference signal. The antenna port may also be defined as the minimum unit for multiplication of a precoding vector weighting.

[137] As described above, the embodiments of the present disclosure provide an advanced communication system, communication methods and communication apparatuses that advantageously perform resource assignment for multi-PRACH transmissions.

[138] The present disclosure can be realized by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be partly or entirely realized by an LSI such as an integrated circuit, and each process described in each embodiment may be controlled partly or entirely by the same LSI or a combination of LSIs. The LSI may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. The LSI may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit, a general-purpose processor, or a special-purpose processor. In addition, a FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuit cells disposed inside the LSI can be reconfigured may be used. The present disclosure can be realized as digital processing or analogue processing. If future integrated circuit technology replaces LSIs as a result of the advancement of semiconductor technology or other

derivative technology, the functional blocks could be integrated using the future integrated circuit technology. Biotechnology can also be applied.

[139] The present disclosure can be realized by any kind of apparatus, device or system having a function of communication, which is referred as a communication apparatus.

[140] Some non-limiting examples of such communication apparatus include a phone (e.g., cellular (cell) phone, smart phone), a tablet, a personal computer (PC) (e.g., laptop, desktop, netbook), a camera (e.g., digital still/video camera), a digital player (e.g., digital audio/video player), a wearable device (e.g., wearable camera, smart watch, tracking device), a game console, a digital book reader, a telehealth/telemedicine (e.g., remote health and medicine) device, and a vehicle providing communication functionality (e.g., automotive, airplane, ship), and various combinations thereof.

[141] The communication apparatus is not limited to be portable or movable, and may also include any kind of apparatus, device or system being non-portable or stationary, such as a smart home device (e.g., an appliance, lighting, smart meter, control panel), a vending machine, and any other “things” in a network of an “Internet of Things (IoT)”.

[142] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[143] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication device performing a function of communication described in the present disclosure. For example, the communication apparatus may comprise a controller or a sensor that generates control signals or data signals which are used by a communication device performing a communication function of the communication apparatus.

[144] The communication apparatus also may include an infrastructure facility, such as a base station, an access point, and any other apparatus, device or system that communicates with or controls apparatuses such as those in the above non-limiting examples.

[145] It will be understood that while some properties of the various embodiments have been described with reference to a device, corresponding properties also apply to the methods of various embodiments, and vice versa.

[146] The present disclosure may refer to the following statements:

Statement 1. A communication apparatus comprising:
circuitry, which in operation, determines a Random Access Channel Occasion (RO) group based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission, and determines a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and
a transmitter, which in operation, transmits the preamble.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

Statement 2. The communication apparatus of Statement 1, wherein the circuitry is configured to determine the one or more RO groups and the one or more preambles based on a number of synchronization signal blocks (SSBs) and based on an index associated with one or more multiple PRACH transmissions, each of the one or more RO groups being associated with a synchronization signal block (SSB) index of the SSBs.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

Statement 3. The communication apparatus of Statement 1, wherein the mapping is applicable for a duration of time, the duration of time being a set of consecutive OFDM symbols, slots, sub-frames, frames, synchronization signal block (SSB) to Random Access Channel Occasion (SSB-to-RO) association periods, or SSB-to-RO association pattern period, and the transmitter transmits the preamble in the RO group within the duration of time.

Advantageously, it is possible to enable a shorter transmission period of a multi-PRACH transmission in one PRACH attempt to reduce the latency of initial access,

as compared with eventual distribution of preamble resource over a longer period as required in the current technical specification.

Statement 4. The communication apparatus of Statement 1, wherein there are one or more multiple PRACH transmissions, and each RO group of the one or more RO groups is associated with one of the one or more multiple PRACH transmissions.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

Statement 5. The communication apparatus of Statement 4, wherein the RO group is determined from the one or more RO groups based on a synchronization signal block (SSB) index of a number of SSBs.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

Statement 6. The communication apparatus of Statement 1, wherein the one or more preambles is sequentially or cyclically mapped to the one or more RO groups in the mapping.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 7. The communication apparatus of Statement 1, wherein one preamble of the one or more preambles is mapped to one RO group of the one or more RO groups.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 8. The communication apparatus of Statement 1, wherein the one or more preambles is a first set of preambles, the mapping between the first set of preambles and the one or more RO groups is a first mapping and there is at least a second mapping between at least a second set of one or more preambles and the one or more

RO groups, the at least second set of one or more preambles being the same or different from the first set of preambles, and each set of preambles is sequentially or cyclically mapped to the one or more RO groups in time domain.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 9. The communication apparatus of Statement 1, wherein the one or more preambles is a first set of preambles, the mapping between the first set of preambles and the one or more RO groups is a first mapping and there is at least a second mapping between at least a second set of one or more preambles and the one or more RO groups, and a total number of preambles to be mapped to the one or more RO groups in the first mapping is different from that in the second mapping.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 10. The communication apparatus of Statement 1, wherein each of the one or more RO groups is mapped with a same preamble or a different preamble from one another.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 11. The communication apparatus of Statement 1, wherein a total number of the one or more preambles in the mapping or a total number of the one or more RO groups in the mapping is different based on a number of synchronization signal blocks (SSBs) and an index associated with one or more multiple PRACH transmissions.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 12. The communication apparatus of Statement 8 or 9, wherein each set of the first set and the at least second set of preambles is assigned for each of one or more transmission reception points, or each of one or more cells, or each of one or more of sets of beams.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 13. The communication apparatus of Statement 1, wherein there is a different number of preambles in the one or more preambles from RO groups in the one or more RO groups, and one or more leftover RO groups in the one or more RO groups that are not mapped to the one or more preambles are allocated for other transmissions or left unused.

This advantageously overcomes a limitation of a small set of preambles for supporting all possibilities of RO groups associated with, for example, their own SSB indexes or CSI-RS indexes.

Statement 14. The communication apparatus of Statement 1, wherein a first set of preambles comprising the one or more preambles is mapped to a set of RO groups comprising the one or more RO groups, and there are less numbers of preambles in the first set of preambles than RO groups in the set of RO groups, and the circuitry is configured to map one or more preambles of a second set of preambles to one or more leftover RO groups in the set of RO groups.

This advantageously overcomes a limitation of a small set of preambles for supporting all possibilities of RO groups associated with, for example, their own SSB indexes or CSI-RS indexes.

Statement 15. The communication apparatus of Statement 2, wherein there are greater numbers of preambles in the one or more preambles than RO groups in the one or more RO groups, and there are one or more leftover preambles that are not mapped and left unused.

It is possible to achieve better flexibility of configuration of preambles for a multi-PRACH transmission, hence improving provision of PRACH resources for other purposes.

Statement 16. The communication apparatus of Statement 1, wherein the mapping is in a form of a first table indicating one or more sets of preambles to be used in time domain and a second table indicating a set of RO groups based on an index associated with one or more multiple PRACH transmissions and a number of SSBs, and the circuitry is configured to determine the RO group and the preamble based on the first and second tables.

Advantageously, the mapping provides greater flexibility for a gNB.

Statement 17. The communication apparatus of Statement 1, wherein the mapping indicates that each preamble of a set of preambles comprising the one or more preambles is mapped to more than one RO groups in a frequency division multiplexing (FDM) scheme.

Advantageously, less PRACH preamble usage is required.

Statement 18. The communication apparatus of Statement 1, wherein the mapping is further between the preamble, the RO group and a SSB index.

Advantageously, the mapping ensures that the preamble is transmitted in the RO group by using a same SSB beam so that gNB can perform a combined detection of preamble to achieve a combined gain.

Statement 19. The communication apparatus of Statement 18, wherein the mapping is an explicit indication from one or a combination of a master information block (MIB), a system information block (SIB), a higher layer parameter, and a downlink control information (DCI).

Advantageously, the mapping provides greater flexibility for a gNB when configuring a multi-PRACH table.

Statement 20. The communication apparatus of Statement 18, wherein the preamble is further mapped to more than one RO group in a frequency division multiplexing (FDM) scheme.

Advantageously, less PRACH preamble usage is required.

Statement 21. The communication apparatus of Statement 2, wherein the index is 1 to denote 2, 4 or 8 PRACH transmissions, 2 to denote 2 and 4, 2 and 8, or 4 and 8 PRACH transmissions, and 3 to denote 2, 4 and 8 PRACH transmissions.

Advantageously, it is possible to enable a shorter transmission period of a multi-PRACH transmission in one PRACH attempt to reduce the latency of initial access, as compared with eventual distribution of preamble resource over a longer period as required in the current technical specification.

Statement 22. The communication apparatus of Statement 1, wherein the RO group comprises a plurality of sub-RO groups, and the mapping further being between the preamble, a sub-RO group of the one or more RO groups, and a synchronization signal block (SSB) index.

Advantageously, the mapping provides greater flexibility for a gNB when configuring a multi-PRACH table.

Statement 23. The communication apparatus of Statement 1, wherein the mapping is further being between the preamble, a RO group of the one or more RO groups, and a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and an index associated with one or more multiple PRACH transmissions.

Advantageously, the mapping applies for a case where SSB index is not applicable and CSI-RS index is used instead.

Statement 24. A base station comprising:

circuitry, which in operation, determines a mapping between one or more preambles and one or more Random Access Channel Occasion (RO) groups based on an index associated with one or more multiple physical Random Access Channel (PRACH) transmissions; and

a transmitter, which in operation, signals the mapping to a communication apparatus.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

Statement 25. The base station of Statement 24, wherein the mapping is further being between a preamble of the one or more preambles, a RO group of the one or more RO groups, and (1) a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and the index associated with the one or more multiple PRACH transmissions, or (2) a synchronization signal block (SSB) index based on a number of SSBs and the index associated with the one or more multiple PRACH transmissions.

Advantageously, the mapping provides greater flexibility for a gNB when configuring a multi-PRACH table for SSB or CSI-RS cases.

Statement 26. A communication method comprising:
determining a Random Access Channel Occasion (RO) group based on a number of multiple physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission;
determining a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and
transmitting the preamble in the RO group.

Advantageously, it is possible to improve a usage of preambles used for the multiple PRACH transmission.

[147] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present disclosure as shown in the specific embodiments without departing from the spirit or scope of the disclosure as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

CLAIMS

1. A communication apparatus comprising:

circuitry, which in operation, determines a Random Access Channel Occasion (RO) group based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission, and determines a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and

a transmitter, which in operation, transmits the preamble.

2. The communication apparatus of claim 1, wherein the circuitry is configured to determine the one or more RO groups and the one or more preambles based on a number of synchronization signal blocks (SSBs) and based on an index associated with one or more multiple PRACH transmissions, each of the one or more RO groups being associated with a synchronization signal block (SSB) index of the SSBs.

3. The communication apparatus of claim 1, wherein the mapping is applicable for a duration of time, the duration of time being a set of consecutive OFDM symbols, slots, sub-frames, frames, synchronization signal block (SSB) to Random Access Channel Occasions (SSB-to-RO) association periods, or SSB-to-RO association pattern period, and the transmitter transmits the preamble in the RO group within the duration of time.

4. The communication apparatus of claim 1, wherein the RO group is determined from the one or more RO groups based on a synchronization signal block (SSB) index of a number of SSBs.

5. The communication apparatus of claim 1, wherein one preamble of the one or more preambles is mapped to one RO group of the one or more RO groups.

6. The communication apparatus of claim 1, wherein the one or more preambles is a first set of preambles, the mapping between the first set of preambles and the one or more RO groups is a first mapping and there is at least a second mapping between at least a second set of one or more preambles and the one or more RO groups, the at least second set of one or more preambles

being the same or different from the first set of preambles, and each set of preambles is sequentially or cyclically mapped to the one or more RO groups in time domain.

7. The communication apparatus of claim 1, wherein each of the one or more RO groups is mapped with a same preamble or a different preamble from one another.

8. The communication apparatus of claim 1, wherein a total number of the one or more preambles in the mapping or a total number of the one or more RO groups in the mapping is different based on a number of synchronization signal blocks (SSBs) and an index associated with one or more multiple PRACH transmissions.

9. The communication apparatus of claim 6, wherein each set of the first set of preambles and the at least second set of preambles is assigned for each of one or more transmission reception points, or each of one or more cells, or each of one or more of sets of beams.

10. The communication apparatus of claim 1, wherein the mapping is in a form of a first table indicating one or more sets of preambles to be used in time domain and a second table indicating a set of RO groups based on an index associated with one or more multiple PRACH transmissions and a number of SSBs, and the circuitry is configured to determine the RO group and the preamble based on the first and second tables.

11. The communication apparatus of claim 1, wherein the mapping is further between the preamble, the RO group and a SSB index.

12. The communication apparatus of claim 1, wherein the mapping is further being between the preamble, a RO group of the one or more RO groups, and a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and an index associated with one or more multiple PRACH transmissions.

13. A base station comprising:

circuitry, which in operation, determines a mapping between one or more preambles and one or more Random Access Channel Occasion (RO) groups based on an index associated with one or more multiple physical Random Access Channel (PRACH) transmissions; and

a transmitter, which in operation, signals the mapping to a communication apparatus.

14. The base station of claim 13, wherein the mapping is further being between a preamble of the one or more preambles, a RO group of the one or more RO groups, and (1) a channel state information reference signal (CSI-RS) index based on a number of CSI-RSs and the index associated with the one or more multiple PRACH transmissions, or (2) a synchronization signal block (SSB) index based on a number of SSBs and the index associated with the one or more multiple PRACH transmissions.

15. A communication method comprising:

determining a Random Access Channel Occasion (RO) group based on a number of multiple physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission;

determining a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs; and

transmitting the preamble in the RO group.