## Description

# Title of Invention: RO GROUP RESOURCE FOR MULTI-PRACH TRANSMISSIONS

## TECHNICAL FIELD

[1] The present disclosure relates to communication apparatuses and communication methods for Random Access Channel (RACH) occasion (RO) Group Resource for multi-physical RACH (Multi-PRACH) Transmissions.

## BACKGROUND

[2] A new working item (WI) for further New Radio (NR) coverage enhancement (CovEnh) has been approved in Release (Rel.) 18, where one of the main objectives is to specify PRACH coverage enhancements (RAN1, RAN2), including multiple PRACH transmissions with same beams for 4-step RACH procedure, as well as study, and if justified, specify PRACH transmissions with different beams for 4-step RACH procedure. It has been agreed that at least ROs located at different time instances can be utilized for the multiple PRACH transmissions and the multiple PRACH transmissions can be differentiated from single PRACH transmission in the latest RAN agreements.

[3] However, there has still been no discussion on communication apparatuses and methods for RO group resource for multi-PRACH transmissions to improve performance gain of coverage.

[4] There is thus a need for communication apparatuses and methods that provide feasible technical solutions for RO group resource for multi-PRACH transmissions to achieve better performance gain of coverage due to achievable gain of combining detection of preamble by utilizing time diversity and/or frequency diversity. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

**SUMMARY**

[5] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and methods for RO group resource for multi-PRACH transmissions.

[6] According to a first embodiment of the present disclosure, there is provided a communication apparatus comprising: circuitry, which in operation, determines at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-physical RACH (PRACH) transmission from the communication apparatus; and a transmitter, which in operation, transmits a preamble in each of the plurality of ROs of the at least one first RO group.

[7] According to a second embodiment of the present disclosure, there is provided a base station, comprising: circuitry, which in operation, generates a signal comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus; a transmitter, which in operation, transmits the signal to the communication apparatus; a receiver, which in operation, receives at least one multi-PRACH transmission from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group; and the circuitry detects a preamble in each of the at least one multi-PRACH transmission.

[8] According to a third embodiment of the present disclosure, there is provided a communication method comprising: determining at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-PRACH transmission from a communication apparatus; and transmitting a preamble in each of the plurality of ROs of the at least one first RO group.

[9] 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.

[10] 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**

[11] 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:

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

[13] 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.

[14] 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.

[15] 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.

[16] 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.

[17] Fig. 6 shows an example illustration of different Random Access Channel (RACH) occasion (RO) user equipment (UE) groups according to various embodiments of the present disclosure.

[18] Fig. 7 shows a table providing an exemplary list of possible embodiments according to the present disclosure.

[19] Fig. 8 shows an example illustration of determination of different RO UE groups for different number of PRACH transmissions in which only separate ROs are assumed to be used for multi-PRACH transmissions according to various embodiments of the present disclosure.

[20] Fig. 9 shows an example illustration of determination of different RO UE groups for different number of PRACH transmissions in which both separate and shared ROs are assumed to be used for multi-PRACH transmissions according to various embodiments of the present disclosure.

[21] Fig. 10 shows an example illustration of an explicit indication in Master Information Block or System Information Block (MIB/SIB) according to various embodiments of the present disclosure.

[22] Fig. 11 shows an example illustration of an explicit indication in a table form according to various embodiments of the present disclosure.

[23] Fig. 12 shows an example illustration of an explicit indication in another table form according to various embodiments of the present disclosure.

[24] Fig. 13 shows an example illustration of determination of multiple RO cell groups by clustering one or more ROs located closely in time-domain according to various embodiments of the present disclosure.

[25] Fig. 14 shows an example illustration of determination of multiple RO cell groups by clustering one or more ROs located in a same unit of time according to various embodiments of the present disclosure.

[26] Fig. 15 shows an example illustration of determination of multiple RO cell groups by clustering one or more ROs located closely in frequency-domain according to various embodiments of the present disclosure.

[27] Fig. 16 shows an example illustration of determination of multiple RO cell groups by clustering one or more ROs located at a same frequency resource allocation in frequency-domain according to various embodiments of the present disclosure.

[28] Fig. 17 shows an example illustration of determination of multiple RO cell groups by clustering one or more ROs located closely in frequency and time domain according to various embodiments of the present disclosure.

[29] Fig. 18 shows an example illustration of (pre-)configured RO cell groups according to various embodiments of the present disclosure

[30] Fig. 19 shows a flow chart for a UE according to various embodiments of the present disclosure.

[31] Fig. 20 shows a flow chart illustrating a communication method according to various embodiments.

[32] Fig. 21 shows a schematic block diagram of an example communication apparatus in accordance with various embodiments.

[33] Fig. 22 shows a schematic block diagram of another example communication apparatus in accordance with various embodiments.

[34] 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**

[35] 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.

[36] 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).

[37] 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).

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

[39] 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).

[40] 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).

[41] Therefore, the orthogonal frequency-division multiplexing (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 $\Delta f$ 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.

[42] 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).

[43] 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).

[44] 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.

[45] 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.

[46] 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.

[47] 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.

[48] 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.

[49] 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.

[50] 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 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).

[51] 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.

[52] 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.

[53] 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.

[54] 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.

[55] 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.

[56] 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.

[57] 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 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).

[58] 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.

[59] 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.

[60] 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.

[61] 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.

[62] While it has been agreed that at least ROs located at different time instances can be utilized for the multiple PRACH transmissions and the multiple PRACH transmissions can be differentiated with single PRACH transmission in the latest RAN agreements, there are still many points for further study (FFS). In RAN1#110-bis-e, it is agreed that for multiple PRACH transmissions with a same beam, at least ROs located at different time instances can be utilized for the transmissions. Whether or how the starting resource block (RB) of ROs can be different at different time instances for multiple PRACH transmissions, as well as whether or how multiple PRACH transmissions can be located in the same time instance, e.g., for UEs with multiple transmission (Tx) chains, are still FFS. Further, in RAN1#111, it is agreed that for multiple PRACH transmissions with a same Tx beam, to differentiate the multiple PRACH transmissions with single PRACH transmission, one or multiple of the following options may be considered. In a first option, multiple PRACH may be transmitted with separate preamble on shared ROs. In a second option, multiple PRACH may be transmitted on separate ROs. In a third option, a portion of the multiple PRACHs may be transmitted with separate preamble on shared ROs, while the other multiple PRACHs may be transmitted on separate ROs. Other options are not precluded. A shared or separate RO/preamble means that the RO/preamble is shared with or separated from single PRACH transmission respectively.

[63] It is not specified how multiple RACH occasions (ROs) for a specific number of multi-PRACH transmissions can be determined, considering at least one of the following conditions: (1) multi-PRACH transmissions can be performed on separate ROs and/or with separate preamble on shared ROs, where the shared or separate RO/preamble means that the RO/preamble is shared with or separated from single PRACH transmission; (2) Frequency domain resource allocations of the multiple ROs can be the same or different; (3) multiple ROs located at different time instances can be utilized.

[64] In the present disclosure, a UE may be configured to determine at least one RO UE group including number of ROs for a specific *N* number of PRACH transmissions which may be sent in, for example, one PRACH attempt, where *N* is equal to or greater than 1. One preamble may be sent in each of the *N* ROs of the at least one RO UE group. The at least one RO UE group can be associated with one or more Synchronization Signal Block (SSB) indices, or associated with at least two SSB indices. For example, referring to illustration 600 of Fig. 6 depicting different RO UE groups 602, 604, 606, 608, 610 and 612, each RO UE group can include 2 or 4 ROs for specific 2 or 4 PRACH transmissions respectively, which are sent in one PRACH attempt. The RO UE group 602 is associated with a SSB#2, RO UE group 604 is associated with a SSB#0, RO UE group 606 is associated with SSB#2, RO UE group 608 is associated with SSB#0, RO UE group 610 is associated with a SSB#1 and a SSB#3, as well as RO UE group 612 is associated with SSB#1 and SSB#3. Moreover, the at least one RO UE group can also be associated with one or more channel state information reference signal (CSI-RS) indices when CSI-RS based beam(s) are used to transmit the preamble in each of the *N* ROs of the at least one RO UE group. The CSI-RS based beam(s) are configured to the UE by gNB. The RO UE group may be defined corresponding to a multi-PRACH transmission from a UE and comprising a plurality of ROs that correspond to a plurality of PRACH transmissions in the multi-PRACH transmission. The plurality of ROs in the RO UE group may be same or different from a plurality of ROs included in another RO UE group used by another communication apparatus. It will be appreciated that “RO UE group” may also be referred to herein as “RO communication apparatus group”, “first RO group”, “RO bundle” or “RO bundling”.

[65] The *N* ROs can be separate or shared ROs that are separated from or shared with single PRACH transmission respectively. The current SSB-to-RO mapping for the *N* ROs can be reused, or a new sequence of SSB-to-RO mapping for the *N* ROs can also be used (e.g., cyclic shift mapping for *L* SSBs to *N* ROs, where *L* is equal to or greater than 1, or SSB-to-RO UE group mapping). Advantageously, better performance gain of coverage can be achieved due to achievable gain from combining detection of preamble by utilizing time diversity and/or frequency diversity. For the current SSB-to-RO mapping, it can be configured by a higher layer parameter *ssb-perRACH-OccasionAndCB-PreamblesPerSSB* which conveys the information about the number of SSBs mapped to each RO and the number of random access preambles mapped to each SSB.

[66] A UE may be configured to determine the at least one RO UE group including *N* number of ROs based on the following operations. For example, the at least one RO UE group may be determined from *M* number of RO cell group(s) to utilize time diversity and/or frequency diversity based on one of the following options, where *M* is equal to or greater than 1, (e.g., determination of the at least one RO UE group): in a first option, random selection is used; in a second option, explicit indication is used; in a third option, implicit indication via a rule is used. In an implementation, the UE may be configured to determine the at least one RO UE group from a plurality of ROs (e.g., from a pool of ROs that are available for use for the multiple PRACH transmissions) without any regard to RO cell group(s), for example when no RO cell groups are defined. A RO cell group may comprise one or more ROs that are for use among one or more UEs or communication apparatuses. One or more RO cell groups may be commonly determined in a serving cell. It will be appreciated that “RO cell group” may also be referred to herein as “second RO group”. The RO cell group is a kind of cell-specific group in a serving cell, while the at least one RO UE group is a kind of UE-specific group in the serving cell.

[67] Furthermore, the at least one RO UE group may be determined by using ROs that are located at same or different time instances. It may also be determined by using ROs that are located at same or different frequency allocation indexes. Alternatively, it may be determined by using ROs that are located at different time and frequency indexes as well.

[68] For determining RO cell group(s), when $M$=1, one RO cell group can be determined by including all possible ROs that can be used for the multiple PRACH transmissions. When $M$>1, each of the M RO cell groups can be determined based on one of the following methods 1-5: (method 1) by clustering one or more ROs located closely in time-domain; (method 2) by clustering one or more ROs located in a same unit of time, including a same slot/sub-frame/frame, or a same periodicity of configuration for a specific number of multiple PRACH transmissions; (method 3) by clustering one or more ROs located closely in frequency-domain; (method 4) by clustering one or more ROs located at a same frequency resource allocation; and (method 5) by clustering one or more ROs located closely in frequency and time domains. The one or more ROs can be separate or shared ROs that are separated from or shared with single PRACH transmission respectively. Each of the one or more ROs in the above-mentioned methods 1-5 may have certain time and frequency resource allocations. At the gNB side, a gNB may be configured to receive the $N$ PRACH transmissions to perform a combining detection of preamble. The above-mentioned methods 1-5 will be further explained in the Figs. 8-18 of the present disclosure.

[69] Fig. 7 shows a table 700 providing an exemplary list of possible embodiments according to the present disclosure. For example, when $M$=1 (see table entries 702), an embodiment may be based on one of the above-mentioned 3 options for determination of the at least one RO UE group (e.g., in the first option, random selection is used; in the second option, explicit indication is used; in the third option, implicit indication via a rule is used). In Fig. 6, only one RO cell group ($M$=1) is assumed. When $M$>1 (see table entries 704), an embodiment will be a combination of an option for determination of the at least one RO UE group (e.g., one of the 3 options described above) and a method for determination of RO cell group (e.g., methods 1-5 as described above) which will be further described in Figs. 8-18 of the present disclosure.

[70] There can be a lot of possibilities when combining 1 option for determination of the at least one RO UE group and 1 method for determination of a RO cell group. Fig. 8 shows an example illustration 800 of determination of different RO UE groups (e.g., RO UE groups 802, 804, 806, 808, 810 and 812) for different number of PRACH transmissions, in which only separate ROs are assumed to be used for multi-PRACH transmissions. In this example, each RO cell group (e.g., RO UE cell groups 814, 816, 818 and 820) may be determined by using either clustering one

or more ROs located closely in time-domain (e.g., method 1 with frequency division multiplexed (FDMed) ROs located at one time instance), or clustering one or more ROs located in the same slot via method 2. In illustration 900 of Fig. 9, determination of different RO UE groups for different number of PRACH transmissions are depicted in which both separate ROs (e.g., ROs indicated by reference 902) and shared ROs (e.g., ROs indicated by reference 904) are assumed to be used for multi-PRACH transmissions, wherein multiple PRACHs are transmitted with separate preamble on the shared ROs.

[71] A UE may be configured to determine at least one RO UE group including *N* ROs for the specific *N* PRACH transmissions which are sent in one PRACH attempt, for example based on one of the three options as described above. *N* PRACH transmissions may be referred as a multiple PRACH transmissions, a multi-PRACH transmission, or one PRACH attempt. When a UE is capable of multi-PRACH transmission, the UE can send *N* PRACH transmissions based on $N$ ROs in the RO UE group in one PRACH attempt, where the one PRACH attempt may be referred to a process of sending *N* PRACH transmissions. At gNB side, gNB can receive *N* PRACH transmissions to perform a combining detection of preamble. In the first option, the at least one RO UE group may include N ROs that are determined from *M* RO cell group(s) by the UE based on a random selection to utilize time diversity and/or frequency diversity. For the *M* RO cell group(s), there may be two cases: (Case 1) there is a common understanding of *M* RO cell group(s) between UEs in a serving cell, then gNB receives the N PRACH transmissions and needs to do blind detection of preamble; (Case 2) there is no common understanding of the *M* RO cell group(s) between UEs in the serving cell, then gNB also receives the N PRACH transmissions and needs to do a blind detection of preamble from the N PRACH transmissions, but it requires more effort from gNB perspective, compared to Case 1. Since UE can randomly determine the *N* ROs from *M* RO cell group(s), a plurality of RO UE groups can be introduced such that it is beneficial to increase the random perspective from a random-access procedure point of view.

[72] In the second option, the at least one RO UE group may include *N* ROs that are determined from *M* RO cell group(s) by the UE based on an explicit indication under a consideration of achieving time diversity gain and/or frequency diversity gain. The explicit indication may be a higher-layer parameter that can be included in a Master Information Block (MIB) or System Information Block (SIB). For

example, referring to MIB/SIB illustration 1000 of Fig. 10, *Multi_PRACH_transmission_R18* (see reference 1002) is included in MIB/SIB to indicate preamble format, *RO_UE_Group* for 2/4/6/8 PRACH transmissions (see reference 1004), a start slot (see reference 1006) of *RO_UE_Group*, as well as positions and lengths of ROs in *RO_UE_Group* in time and frequency domains (see reference 1008).

[73] Alternatively, the explicit indication may be a table-based indication. A new table or the existing table for random-access configurations (e.g., Table 6.3.3.2-3 of TS 38.211) with new added entries can be used to indicate the at least one RO UE group for multi-PRACH transmissions. If a new table is used, a new higher-layer parameter may be introduced to indicate a row of the table which corresponds to the at least one RO UE group including *N* ROs. The new table can be configured or pre-configured. Fig. 11 shows an example illustration of a new table 1100 for explicitly indicating different RO UE groups for different number of multi-PRACH transmissions (*N*). The input of *N* ROs is based on Fig. 6.

[74] If the existing table with new added entries is used, current higher-layer parameter *prach-ConfiguationIndex* can be reused to indicate a row of the table which corresponds to the at least one RO UE group including *N* ROs. Fig. 12 shows an example table 1200 which is Table 6.3.3.2-3 of TS 38.211 that is enhanced by adding new entries to indicate ROs for multi-PRACH transmissions (see reference 1202 indicating ROs for *N*=2 and *N*=4 multi-PRACH transmissions). The existing table with new added entries can be configured or pre-configured.

[75] Further, in the third option, the at least one RO UE group may include *N* ROs that are determined from *M* RO cell group(s) by the UE based on an implicit indication to utilize time diversity and/or frequency diversity. The implicit indication may be based on a cyclic shift or sequence ordering. In an example, a UE may be configured to perform selection via sequence ((*i* mode *M*) = *k*) and take a RO from RO cell group #*k* from *M* RO cell group(s) (0<=*i*<*N*, 0<=*k*<*M*). In another example, the implicit indication is that UE determines the (*i*+1)-th RO (0<=*i*<*N)* in the at least one RO UE group which is associated with the logical (*i*+1)-th index of time/frequency resource of PRACHs from *M* RO cell group(s) within a resource pool, wherein the resource pool consists of contiguous physical resource blocks (PRBs) and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions (e.g., determined before mapping to physical resources).

The logical ($i$+1)-th index of time/frequency resource of PRACHs can be defined based on the following order: first, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions; second, in increasing order of time resource indexes for time multiplexed PRACH occasions within a logical PRACH slot; and third, in increasing order of indexes for logical PRACH slots. It will be appreciated that equations for implicit indication are not limited to the equations described in the above examples, and other variations are possible.

[76] In another example, the implicit indication is that UE determines the($i$+1)-th RO ($0<=i<N$) in the at least one RO UE group which is associated with the same logical index of preamble from $M$ RO cell group(s) within a resource pool, wherein the resource pool consists of contiguous PRBs and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions (e.g., before mapping to physical resources). If a number of ROs with the same logical index of preamble $K$ is less than $N$, where $K$ is equal to or greater than 1, a partitioning method may be used as follows: firstly, the $K$ ROs are determined such that they are associated with the first logical index of preamble; secondly, the $(N-K)$ ROs are determined such that they are associated with the second logical index of preamble. For example, assuming that $M$=1 RO cell group which includes 4 ROs (RO#0 to RO#3) associated with a first logical index of preamble and 5 ROs (RO#4 toRO#8) associated with a 2nd logical index of preamble before mapping to physical resources, a UE may be indicated to send 2 PRACHs transmissions in which the UE determines 2 ROs (RO#0, RO#1) associated with the 1st logical index of preamble to send 2 PRACH transmissions, or 6 PRACHs transmissions in which the UE determines 4 ROs (RO#0-RO#3) associated with the first logical index of preamble and 2 ROs (RO#4, RO#5) associated with the 2nd logical index of preamble to send 6 PRACH transmissions (in this case, 2 different preambles can be used). Advantageously, this avoids an increase in signalling overhead.

[77] Fig. 13 shows an example illustration 1300 for determination of 2 RO cell groups (e.g., RO cell groups 1302 and 1304) by clustering one or more ROs located closely in time-domain (e.g., based on method 1 in which each of $M$ RO cell group(s) can be determined by clustering one or more ROs located closely in time-domain) according to various embodiments of the present disclosure. 4 RO UE groups (e.g., RO UE groups 1306, 1308, 1310 and 1312) may be obtained by one of the options 1, 2 or 3. The one or more ROs can be FDMed ROs at one time instance or located closely within a time duration of $Z$ ms, e.g., $Z$=1 ms in Fig. 13.

Within a RO cell group, the one or more ROs can have different frequency resource allocations. Advantageously, this method is suitable for the case when densities of overall ROs are different in time-domain. Time diversity gain can be utilized when the RO UE group includes *N* ROs from different RO cell groups.

[78] Fig. 14 shows an example illustration 1400 for determination of 4 RO cell groups (e.g., RO cell groups 1402, 1404, 1406 and 1408) by clustering one or more ROs located in a same unit of time (e.g., based on method 2 in which each of *M* RO cell group(s) can be determined by clustering one or more ROs located in a same unit of time, including a same slot/sub-frame/frame, or a same periodicity of configuration for a specific number of multiple PRACH transmissions) according to various embodiments of the present disclosure. Within a RO cell group, the one or more ROs can have different radio resource allocations. Further, 4 RO UE groups (e.g., RO UE groups 1410, 1412, 1414 and 1416) may be obtained by one of the options 1, 2 or 3.

[79] Fig. 15 shows an example illustration 1500 for determination of 2 RO cell groups (e.g., RO cell groups 1502 and 1504) by clustering one or more ROs located closely in frequency-domain (e.g., based on method 3 in which each of *M* RO cell group(s) can be determined by clustering one or more ROs located closely in frequency-domain) according to various embodiments of the present disclosure. The one or more ROs may be located closely within a set of physical resource blocks (PRBs) in frequency-domain, e.g., a set 1514 of 2 PRBs (e.g., PRB#0 and PRB#1) for RO cell group 1502 and a set 1516 of 2 PRBs (e.g., PRB#15 and PRB#16) for RO cell group 1504. Within each of the RO cell groups 1502 and 1504, the one or more ROs can have different radio resource allocations. Further, 4 RO UE groups (e.g., RO UE groups 1506, 1508, 1510 and 1512) may be obtained by one of the options 1, 2 or 3. RO 1518 (e.g., RO#10 with SSB#3) in RO cell group 1606 is included in both RO UE group 1614 and 1616. This method is suitable for the case when the densities of overall ROs are different in frequency-domain. Frequency hopping gain may be utilized when a RO UE group includes *N* ROs from different RO cell groups.

[80] Fig. 16 shows an example illustration for determination of 4 RO cell groups (e.g., RO cell groups 1602, 1604, 1606 and 1608) by clustering one or more ROs located at a same frequency resource allocation in frequency-domain (e.g., based on method 4 in which each of *M* RO cell group(s) can be determined by clustering

one or more ROs located at a same frequency resource allocation in frequency-domain) according to various embodiments of the present disclosure. Within each of the RO cell groups 1602, 1604, 1606 and 1608, the one or more ROs can have different time resource allocations. Further, 4 RO UE groups (e.g., RO UE groups 1610, 1612, 1614 and 1616) may be obtained by one of the options 1, 2 or 3. RO 1518 (e.g., RO#9 with SSB#1) in RO cell group 1502 is included in both RO UE group 1508 and 1512. Advantageously, frequency hopping gain can be utilized when the RO UE group includes *N* ROs from different RO cell groups.

[81] Fig. 17 shows an example illustration 1700 for determination of 4 RO cell groups (e.g., RO cell groups 1702, 1704, 1706 and 1708) by clustering one or more ROs located closely in frequency and time domain (e.g., based on method 5 in which each of *M* RO cell group(s) can be determined by clustering one or more ROs located closely in frequency and time domains) according to various embodiments of the present disclosure. For example, each of the RO cell groups 1702, 1704, 1706 and 1708 is formed as a cluster or box (of 4 ROs) with a size of *Z* ms in time-domain and a set of physical resource blocks (PRBs) in frequency-domain. Further, 4 RO UE groups (e.g., RO UE groups 1710, 1712, 1714 and 1716) may be obtained by one of the options 1, 2 or 3. Advantageously, if multiple RO cell groups can be obtained, it is possible to provide gain of time diversity and frequency diversity when the at least one RO UE group includes ROs from different RO cell groups.

[82] In an implementation, a UE may be configured to duplicate one or more sets of *M* numbers of RO cell group(s) to meet the required number of ROs (e.g., *N* number of ROs) if *N* is greater than a total number of ROs of the M RO cell group(s). For example, assuming 2 RO cell groups and each of them has 1 RO, a UE has to duplicate 1 additional set of the 2 RO cell groups for 4 PRACH transmissions.

[83] In an implementation, RO UE preamble group may be used to replace UE cell group. A RO UE preamble group is defined as a group of dedicated one or more preambles for a UE that can be sent in multi-PRACH transmissions in one PRACH attempt by the UE. The UE determines *N* ROs for multi-PRACH transmissions that are associated with the dedicated one or more preambles, where each of the dedicated one or more preambles is associated with at least one RO. Different RO UE preamble groups cannot be used for multi-PRACH

transmissions in one PRACH attempt by the UE. It will be appreciated that “RO UE preamble group” may also be termed as “RO communication apparatus preamble group”.

[84] In an implementation, for a UE equipped with multiple transmit (Tx) chains, the UE may be configured to determine at least one RO UE group for a specific number of multi-PRACH transmissions (e.g., *N* numbers of multi-PRACH transmissions) which are sent in one PRACH attempt for each of the multiple Tx chains, for example based on one of the embodiments as shown in table 700 of Fig. 7. Each of the multiple Tx chains can be connected with one or more antennas depending on a design of radio frequency chain of a UE vendor (e.g., Fig. 22 shows one of the possibilities of the design).

[85] In an implementation, each of *M* RO cell group(s) may be (pre-)configured to be dedicated for the specific number of multi-PRACH transmissions (e.g., *N* numbers of multi-PRACH transmissions). A UE may be configured to determine at least one RO UE group including *N* ROs from the corresponding dedicated RO cell group. Referring to illustration 1800 of Fig. 18, it is assumed to have a dedicated RO cell group 1802 for 2 PRACH transmissions and a dedicated RO cell group 1804 for 4 PRACH transmissions. Thus, for 2 PRACH transmissions, the UE determines 2 ROs from the corresponding dedicated RO cell group 1802. Similarly, for 4 PRACH transmissions, the UE determines 4 ROs from the corresponding dedicated RO cell group 1804.

[86] In an implementation, *M* RO cell group(s) may be determined based on a cell-specific (pre-)configuration. Frequency hopping may be utilized between ROs, which are taken from different RO cell groups (e.g., as shown in Figs. 8, 14 and 15) or from the same RO cell group (e.g., Fig. 16), in a RO UE group.

[87] In an implementation, there may be separate use cases in all embodiments (e.g., as shown in table 700 of Fig. 7) as follows: (use case 1) a RO can be included in only one RO UE group, e.g., as shown in Figs. 6, 8, 9, 13, 14, and 17; and (use case 2) a RO can be included in more than one RO UE group, e.g., as shown in Figs. 15 and 16. The number of RO UE groups may be increased to improve the random perspective from a random-access procedure point of view.

[88] In an implementation, a same or different preamble may be sent in each of N ROs of at least one RO UE group.

[89] In an implementation, all embodiments (e.g., as shown in table 700 of Fig. 7) are applicable for both same beam and different beam cases. For a same beam case, a UE may be configured to use the same beam to send the specific number of multi-PRACH transmissions (e.g., *N* numbers of multi-PRACH transmissions). For a different beam case, a UE may be configured to use different beams to send the specific number of multi-PRACH transmissions (e.g., *N* numbers of multi-PRACH transmissions). Moreover, all embodiments are also applicable for both 2-step RACH and 4-step RACH procedures.

[90] In an implementation, for all embodiments (e.g., as shown in table 700 of Fig. 7), in a RO UE group including *N* ROs, the RO UE group may be associated with one or more SSB indices. For example, based on a scenario that a SSB#0 is mapped to a set of ROs {RO#0, RO#1, R0#2, RO#3) while a SSB#1 is mapped to another set of ROs {RO#4, RO#5, RO#6, RO#7}, UE may be configured to determine, for 2 PRACH transmissions, a RO UE group#0 including ROs {RO#0, RO#1} or a RO UE group#1 including ROs {RO#0, RO#4}. Accordingly, the RO UE group#0 is associated with SSB#0, while the RO UE group#1 is associated with SSB#0 and SSB#1.

[91] Fig. 19 shows a flow chart 1900 for a UE according to various embodiments of the present disclosure. At step 1902, a UE determines *M* RO cell group(s). At step 1904, the UE determines, from the *M* RO cell group(s) based on one of the options 1-3 as described in the present disclosure, at least one RO UE group including *N* numbers of ROs which correspond to *N* numbers of multi-PRACH transmissions. At step 1906, the UE sends one preamble in each of the *N* ROs of the at least one RO UE group, for example in one PRACH attempt by using a same beam or different beams.

[92] Fig. 20 shows a flow diagram 2000 illustrating a communication method according to various embodiments. In step 2002, at least one first Random Access Channel (RACH) occasion (RO) group may be determined, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-PRACH transmission from a communication apparatus. In step 2004, a preamble may be transmitted in each of the plurality of ROs of the at least one first RO group.

[93] In an implementation, a signal may be generated comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus; the signal may be transmitted to the communication apparatus; at least one multi-PRACH transmission may be received from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group; and a preamble may be detected in each of the at least one multi-PRACH transmission.

[94] Fig. 21 shows a schematic, partially sectioned view of the communication apparatus 2100 that can be implemented for in accordance with various embodiments and examples as shown in Figs. 1 to 20. The communication apparatus 2100 may be implemented as a UE or base station according to various embodiments.

[95] Various functions and operations of the communication apparatus 2100 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.

[96] As shown in Fig. 21, the communication apparatus 2100 may include circuitry 2114, at least one radio transmit (Tx) chain 2102 (also referred to herein as transmitter 2102), at least one radio receive (Rx) chain 2104 (also referred to herein as receiver 2104), and at least one antenna 2112 (for the sake of simplicity, only one antenna is depicted in Fig. 21 for illustration purposes). The circuitry 2114 may include at least one controller 2106 for use in software and hardware aided execution of tasks that the at least one controller 2106 is designed to perform, including control of communications with one or more other communication apparatuses in a wireless network. The circuitry 2114 may furthermore include at least one transmission signal generator 2108 and at least one receive signal processor 2110. The at least one controller 2106 may control the at least one transmission signal generator 2108 for generating signals (for example, a signal indicating a geographical zone) to be sent through the at least one radio transmitter 2102 to one or more other communication apparatuses and the at least one receive signal processor 2110 for processing signals (for example, a signal

indicating a geographical zone) received through the at least one radio receiver 2104 from the one or more other communication apparatuses under the control of the at least one controller 2106. The at least one transmission signal generator 2108 and the at least one receive signal processor 2110 may be stand-alone modules of the communication apparatus 2100 that communicate with the at least one controller 2106 for the above-mentioned functions, as shown in Fig. 21. Alternatively, the at least one transmission signal generator 2108 and the at least one receive signal processor 2110 may be included in the at least one controller 2106. 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 2102, at least one radio receiver 2104, and at least one antenna 2112 may be controlled by the at least one controller 2106. It will be appreciated that the communication apparatus 2100 may include a plurality of antennas, for example as shown in communication apparatus 2200 of Fig. 22 which includes a plurality of antennas 2212. Each of the plurality of antennas 2212 can be connected to a corresponding Tx chain 2202 and Rx chain 2204 through a switcher or switch point. Alternatively, each of the plurality of antennas 2212 can be connected to a corresponding Tx chain or Rx chain.

[97] The communication apparatus 2100, when in operation, provides functions required for RO group resource for multi-PRACH transmissions. For example, the communication apparatus 2100 may be a UE, and the circuitry 2114 may, in operation, determine at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-physical RACH (PRACH) transmission from the communication apparatus. The transmitter 2102 may, in operation, transmit a preamble in each of the plurality of ROs of the at least one first RO group.

[98] The plurality of ROs included in the first RO group may be same or different from a plurality of ROs included in another RO group used by another communication apparatus. The circuitry 2114 may be configured to determine the at least one first RO group based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer

parameter, or a table-based indication. The circuitry 2114 may be configured to determine one or more second RO groups based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer parameter, or a table-based indication, each of the one or more second RO groups comprising one or more ROs that are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell. The circuitry 2114 may be configured to determine the at least one first RO group based on a random selection from the one or more second RO groups. The circuitry 2114 may be configured to determine the at least one first RO group based on an implicit indication through a cyclic shift or sequence ordering rule from the one or more second RO groups. The circuitry 2114 may be configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and logical indexes of time or frequency resources from the one or more second RO groups within a resource pool, wherein the resource pool consists of contiguous physical resource blocks (PRBs) and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions. The circuitry 2114 may be configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and the same logical index of preamble from the one or more second RO groups within a resource pool, wherein the resource pool consists of contiguous PRBs and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions. The circuitry 2114 may be further configured to duplicate one or more sets of the one or more second RO groups when the plurality of ROs in the at least one first RO group exceed a total number of ROs of the one or more second RO groups. The circuitry 2114 may be further configured to determine the at least one first RO group from the one or more second RO groups, each of the one or more second RO groups being dedicated for a specific number of multi-PRACH transmissions.

[99] The circuitry 2114 may be further configured to: determine one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell based on clustering one or more ROs located in close proximity to one another in time domain or frequency domain, or in both time and frequency domains; and the plurality of ROs in the first RO group being determined from the one or more second RO groups; and determines the one or more RA-

RNTI candidates based on an association between at least one of the plurality of ROs in the first RO group and the one or more second RO groups.

[100] The circuitry 2114 may be further configured to cluster one or more frequency division multiplexed (FDMed) ROs at one time instance, and determine the at least one first RO group based on the clustered one or more ROs. The circuitry 2114 may be further configured to cluster one or more ROs located at a same unit of time, and determine the at least one first RO group based on the clustered one or more ROs. The unit of time may be a slot, sub-frame, frame, or a same periodicity of configuration for a specific number of multiple PRACH transmissions. The circuitry 2114 may be further configured to cluster one or more ROs located at a same frequency resource allocation, and determine the at least one first RO group based on the clustered one or more ROs. The clustered one or more ROs may form a second RO group of one or more second RO groups, such that the clustered one or more ROs are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell.

[101] Each of the at least one first RO group may be associated with two or more synchronization signal block (SSB) indices. Each of the at least one first RO group may be associated with one or more channel state information reference signal (CSI-RS) indices. The plurality of ROs may comprise separate ROs that are separated from single PRACH transmission, or shared ROs that are shared with single PRACH transmission. The circuitry 2114 may be further configured to determine a RO communication apparatus preamble group based on dedicated one or more preambles for the communication apparatus, and determine the at least one first RO group from the RO communication apparatus preamble group. The transmitter 2102 may be further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using a same beam. The transmitter 2102 may be further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using different beams. The transmitter 2102 may be further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using frequency hopping. The circuitry 2114 may be configured to include a same RO in more than one first RO group.

[102] The circuitry 2114 may be further configured to determine, from the at least one first RO group, a first RO group for each of a plurality of transmit (Tx) chains

of the communication apparatus; and the transmitter is further configured to transmit the preamble in each of the first RO group for each of the plurality of transmit (Tx) chains.

[103] The communication apparatus 2100 may be a base station, and the circuitry 2114 may, in operation, generate a signal comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus. The transmitter 2102 may, in operation, transmit the signal to the communication apparatus. The receiver 2104 may, in operation, receive at least one multi-PRACH transmission from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group. The circuitry 2114 may detect a preamble in each of the at least one multi-PRACH transmission.

[104] The circuitry 2114 may be further configured to generate a signal comprising information of at least one first RO group and one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell; and the transmitter 2102 may be configured to transmit the signal to the communication apparatus.

(Control Signals)

[105] 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).

[106] 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)

[107] 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)

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

[109] 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).

[110] 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)

[111] 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)

[112] 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)

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)

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

(Communication)

[114] 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.

[115] 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)

[116] 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.

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

[118] 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.

[119] 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.

[120] 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.

[121] 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)”.

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

[123] 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.

[124] 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.

[125] 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.

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

Statement 1. A communication apparatus, comprising:

circuitry, which in operation, determines at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-physical RACH (PRACH) transmission from the communication apparatus; and

a transmitter, which in operation, transmits a preamble in each of the plurality of ROs of the at least one first RO group.

Statement 2. The communication apparatus of Statement 1, wherein the plurality of ROs included in the first RO group are same or different from a plurality of ROs included in another RO group used by another communication apparatus.

Statement 3. The communication apparatus of Statement 1 or 2, wherein the circuitry is configured to determine the at least one first RO group based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer parameter, or a table-based indication.

Statement 4. The communication apparatus of Statement 1 or 2, wherein the circuitry is configured to determine one or more second RO groups based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer parameter, or a table-based indication, each of the one or more second RO groups comprising one or more ROs that are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell.

Statement 5. The communication apparatus of Statement 4, wherein the circuitry is configured to determine the at least one first RO group based on a random selection from the one or more second RO groups.

Statement 6. The communication apparatus of Statement 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication through a cyclic shift or sequence ordering rule from the one or more second RO groups.

Statement 7. The communication apparatus of Statement 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and logical indexes of time or frequency resources from the one or more second RO groups within a resource pool , wherein the resource pool consists of contiguous physical resource blocks (PRBs) and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions.

Statement 8. The communication apparatus of Statement 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and the same logical index of preamble from the one or more second RO groups within a resource pool, wherein the resource pool consists of contiguous PRBs and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions.

Statement 9. The communication apparatus of Statement 1 or 2, wherein the circuitry is further configured to: determine one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell based on clustering one or more ROs located in close proximity to one another in time domain or frequency domain, or in both time and frequency domains; and the plurality of ROs in the first RO group being determined from the one or more second RO groups; and determines the one or more RA-RNTI candidates based on an association between at least one of the plurality of ROs in the first RO group and the one or more second RO groups.

Statement 10.The communication apparatus of Statement 1 or 2, wherein the circuitry is further configured to cluster one or more frequency division multiplexed (FDMed) ROs at one time instance, and determine the at least one first RO group based on the clustered one or more ROs.

Statement 11.The communication apparatus of Statement 1 or 2, wherein the circuitry is further configured to cluster one or more ROs located at a same unit of time, and determine the at least one first RO group based on the clustered one or more ROs.

Statement 12.The communication apparatus of Statement 11, wherein the unit of time is a slot, sub-frame, frame, or a same periodicity of configuration for a specific number of multiple PRACH transmissions.

Statement 13.The communication apparatus of Statement 1 or 2, wherein the circuitry is further configured to cluster one or more ROs located at a same frequency resource allocation, and determine the at least one first RO group based on the clustered one or more ROs.

Statement 14.The communication apparatus of Statements 10-13, wherein the clustered one or more ROs form a second RO group of one or more second RO groups, such that the clustered one or more ROs are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell.

Statement 15.The communication apparatus of Statement 4, wherein the circuitry is further configured to duplicate one or more sets of the one or more second RO groups when the plurality of ROs in the at least one first RO group exceed a total number of ROs of the one or more second RO groups.

Statement 16.The communication apparatus of Statement 4, wherein the circuitry is further configured to determine the at least one first RO group from the one or more second RO groups, each of the one or more second RO groups being dedicated for a specific number of multi-PRACH transmissions.

Statement 17.The communication apparatus of Statement 1 or 2, wherein each of the at least one first RO group is associated with two or more synchronization signal block (SSB) indices.

Statement 18.The communication apparatus of Statement 1 or 2, wherein each of the at least one first RO group is associated with one or more channel state information reference signal (CSI-RS) indices.

Statement 19.The communication apparatus of Statement 1 or 2, wherein the plurality of ROs comprise separate ROs that are separated from single PRACH transmission, or shared ROs that are shared with single PRACH transmission.

Statement 20. The communication apparatus of Statement 1 or 2, wherein the circuitry is further configured to determine a RO communication apparatus preamble group based on dedicated one or more preambles for the communication apparatus, and determine the at least one first RO group from the RO communication apparatus preamble group.

Statement 21. The communication apparatus of Statement 1 or 2, wherein the transmitter is further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using a same beam.

Statement 22.The communication apparatus of Statement 1 or 2, wherein the transmitter is further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using different beams.

Statement 23.The communication apparatus of Statement 1 or 2, wherein the transmitter is further configured to transmit a preamble in each of the plurality of ROs of the at least one first RO group using frequency hopping.

Statement 24.The communication apparatus of any one of Statements 1-23, wherein the circuitry is further configured to determine, from the at least one first RO group, a first RO group for each of a plurality of transmit (Tx) chains of the communication apparatus; and the transmitter is further configured to transmit the preamble in each of the first RO group for each of the plurality of transmit (Tx) chains.

Statement 25. The communication apparatus of Statement 1 or 2, wherein the circuitry is configured to include a same RO in more than one first RO group.

Statement 26. A base station comprising:

circuitry, which in operation, generates a signal comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus;

a transmitter, which in operation, transmits the signal to the communication apparatus;

a receiver, which in operation, receives at least one multi-PRACH transmission from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group; and

the circuitry detects a preamble in each of the at least one multi-PRACH transmission.

Statement 27. The base station of Statement 26, wherein the circuitry is further configured to generate a signal comprising information of at least one first RO group and one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell; and the transmitter is configured to transmit the signal to the communication apparatus.

Statement 28. A communication method, comprising:

determining at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-PRACH transmission from a communication apparatus; and

transmitting a preamble in each of the plurality of ROs of the at least one first RO group.

Statement 29. A communication method, comprising:

generating a signal comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus;

transmitting the signal to the communication apparatus;

receiving at least one multi-PRACH transmission from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group; and

detecting a preamble in each of the at least one multi-PRACH transmission.

[127] 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 at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-physical RACH (PRACH) transmission from the communication apparatus; and

a transmitter, which in operation, transmits a preamble in each of the plurality of ROs of the at least one first RO group.

2. The communication apparatus of claim 1, wherein the plurality of ROs included in the first RO group are same or different from a plurality of ROs included in another RO group used by another communication apparatus.

3. The communication apparatus of claim 1 or 2, wherein the circuitry is configured to determine the at least one first RO group based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer parameter, or a table-based indication.

4. The communication apparatus of claim 1 or 2, wherein the circuitry is configured to determine one or more second RO groups based on an explicit indication from a System Information Block (SIB), Master Information Block (MIB), or a higher layer parameter, or a table-based indication, each of the one or more second RO groups comprising one or more ROs that are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell.

5. The communication apparatus of claim 4, wherein the circuitry is configured to determine the at least one first RO group based on a random selection from the one or more second RO groups.

6. The communication apparatus of claim 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication through a cyclic shift or sequence ordering rule from the one or more second RO groups.

7. The communication apparatus of claim 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and logical indexes of time or frequency resources from the one or more second RO groups within a resource pool, wherein the resource pool consists of contiguous physical resource blocks (PRBs) and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions.

8. The communication apparatus of claim 4, wherein the circuitry is configured to determine the at least one first RO group based on an implicit indication, wherein the implicit indication is an association between the at least one first RO group and the same logical index of preamble from the one or more second RO groups within a resource pool, wherein the resource pool consists of contiguous PRBs and contiguous or non-contiguous logical slots for a plurality of multi-PRACH transmissions.

9. The communication apparatus of claim 1 or 2, wherein the circuitry is further configured to: determine one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell based on clustering one or more ROs located in close proximity to one another in time domain or frequency domain, or in both time and frequency domains; and the plurality of ROs in the first RO group being determined from the one or more second RO groups; and determines the one or more RA-RNTI candidates based on an association between at least one of the plurality of ROs in the first RO group and the one or more second RO groups.

10. The communication apparatus of claim 1 or 2, wherein the circuitry is further configured to cluster one or more frequency division multiplexed (FDMed) ROs at one time instance, and determine the at least one first RO group based on the clustered one or more ROs.

11. The communication apparatus of claim 1 or 2, wherein the circuitry is further configured to cluster one or more ROs located at a same unit of time, and determine the at least one first RO group based on the clustered one or more ROs.

12. The communication apparatus of claim 11, wherein the unit of time is a slot, sub-frame, frame, or a same periodicity of configuration for a specific number of multiple PRACH transmissions.

13. The communication apparatus of claim 1 or 2, wherein the circuitry is further configured to cluster one or more ROs located at a same frequency resource allocation, and determine the at least one first RO group based on the clustered one or more ROs.

14. The communication apparatus of claims 10-13, wherein the clustered one or more ROs form a second RO group of one or more second RO groups, such that the clustered one or more ROs are for use among one or more communication apparatuses, the one or more second RO groups being commonly determined in a serving cell.

15. The communication apparatus of claim 4, wherein the circuitry is further configured to duplicate one or more sets of the one or more second RO groups when the plurality of ROs in the at least one first RO group exceed a total number of ROs of the one or more second RO groups.

16. The communication apparatus of claim 4, wherein the circuitry is further configured to determine the at least one first RO group from the one or more second RO groups, each of the one or more second RO groups being dedicated for a specific number of multi-PRACH transmissions.

17. The communication apparatus of claim 1 or 2, wherein each of the at least one first RO group is associated with two or more synchronization signal block (SSB) indices.

18. A base station comprising:

circuitry, which in operation, generates a signal comprising information of at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of multi-physical RACH (PRACH) transmissions in a multi-PRACH transmission from a communication apparatus;

a transmitter, which in operation, transmits the signal to the communication apparatus;

a receiver, which in operation, receives at least one multi-PRACH transmission from the communication apparatus, the at least one multi-PRACH transmission corresponding to the at least one first RO group; and

the circuitry detects a preamble in each of the at least one multi-PRACH transmission.

19. The base station of claim 18, wherein the circuitry is further configured to generate a signal comprising information of at least one first RO group and one or more second RO groups, the one or more second RO groups being commonly determined in a serving cell; and the transmitter is configured to transmit the signal to the communication apparatus.

20. A communication method, comprising:

determining at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-PRACH transmission from a communication apparatus; and

transmitting a preamble in each of the plurality of ROs of the at least one first RO group.