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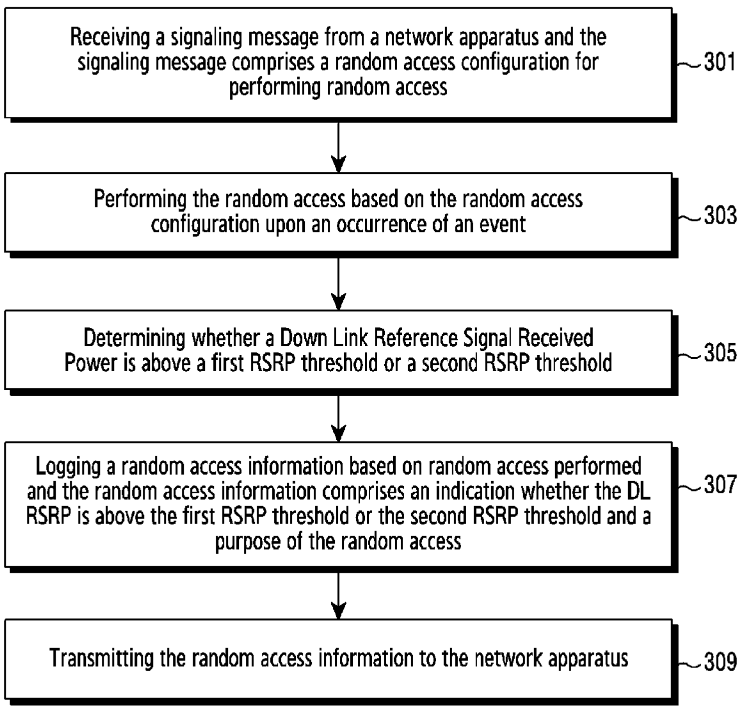
(54) **Title:** METHOD AND APPARATUS FOR HANDLING RANDOM ACCESS CHANNEL INFORMATION IN A WIRELESS COMMUNICATION SYSTEM



(57) **Abstract:** The disclosure relates to a 5G or 6G communication system for supporting a higher data transmission rate. Specifically, the disclosure related to method and apparatus for handling random access channel information for self-optimization network system. The UE receives a signaling message from network apparatus. The signaling message comprises a random access configuration for performing random access. Further, the UE performs the random access. Also, the UE determined whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold. Further, the UE logs random access information based on random access performed. The random access information includes an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and purpose of the random access. Further, the UE transmits the random access information to the network apparatus.

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Description

Title of Invention: METHOD AND APPARATUS FOR HANDLING RANDOM ACCESS CHANNEL INFORMATION IN A WIRELESS COMMUNICATION SYSTEM

Technical Field

[1] The present disclosure relates to generally to wireless communication systems and, more specifically, the present disclosure relates to method and apparatus for handling random access channel (RACH) information for self-organizing network (SON) system.

Background Art

[2] 5G mobile communication technologies define broad frequency bands such that high transmission rates and new services are possible, and can be implemented not only in “Sub 6GHz” bands such as 3.5GHz, but also in “Above 6GHz” bands referred to as mmWave including 28GHz and 39GHz. In addition, it has been considered to implement 6G mobile communication technologies (referred to as Beyond 5G systems) in terahertz (THz) bands (for example, 95GHz to 3THz bands) in order to accomplish transmission rates fifty times faster than 5G mobile communication technologies and ultra-low latencies one-tenth of 5G mobile communication technologies.

[3] At the beginning of the development of 5G mobile communication technologies, in order to support services and to satisfy performance requirements in connection with enhanced Mobile BroadBand (eMBB), Ultra Reliable Low Latency Communications (URLLC), and massive Machine-Type Communications (mMTC), there has been ongoing standardization regarding beamforming and massive MIMO for mitigating radio-wave path loss and increasing radio-wave transmission distances in mmWave, supporting numerologies (for example, operating multiple subcarrier spacings) for efficiently utilizing mmWave resources and dynamic operation of slot formats, initial access technologies for supporting multi-beam transmission and broadbands, definition and operation of BWP (BandWidth Part), new channel coding methods such as a LDPC (Low Density Parity Check) code for large amount of data transmission and a polar code for highly reliable transmission of control information, L2 pre-processing, and network slicing for providing a dedicated network specialized to a specific service.

[4] Currently, there are ongoing discussions regarding improvement and performance enhancement of initial 5G mobile communication technologies in view of services to be supported by 5G mobile communication technologies, and there has been physical layer standardization regarding technologies such as V2X (Vehicle-to-everything) for aiding driving determination by autonomous vehicles based on information regarding

positions and states of vehicles transmitted by the vehicles and for enhancing user convenience, NR-U (New Radio Unlicensed) aimed at system operations conforming to various regulation-related requirements in unlicensed bands, NR UE Power Saving, Non-Terrestrial Network (NTN) which is UE-satellite direct communication for providing coverage in an area in which communication with terrestrial networks is unavailable, and positioning.

[5] Moreover, there has been ongoing standardization in air interface architecture/protocol regarding technologies such as Industrial Internet of Things (IIoT) for supporting new services through interworking and convergence with other industries, IAB (Integrated Access and Backhaul) for providing a node for network service area expansion by supporting a wireless backhaul link and an access link in an integrated manner, mobility enhancement including conditional handover and DAPS (Dual Active Protocol Stack) handover, and two-step random access for simplifying random access procedures (2-step RACH for NR). There also has been ongoing standardization in system architecture/service regarding a 5G baseline architecture (for example, service based architecture or service based interface) for combining Network Functions Virtualization (NFV) and Software-Defined Networking (SDN) technologies, and Mobile Edge Computing (MEC) for receiving services based on UE positions.

[6] As 5G mobile communication systems are commercialized, connected devices that have been exponentially increasing will be connected to communication networks, and it is accordingly expected that enhanced functions and performances of 5G mobile communication systems and integrated operations of connected devices will be necessary. To this end, new research is scheduled in connection with eXtended Reality (XR) for efficiently supporting AR (Augmented Reality), VR (Virtual Reality), MR (Mixed Reality) and the like, 5G performance improvement and complexity reduction by utilizing Artificial Intelligence (AI) and Machine Learning (ML), AI service support, metaverse service support, and drone communication.

[7] Furthermore, such development of 5G mobile communication systems will serve as a basis for developing not only new waveforms for providing coverage in terahertz bands of 6G mobile communication technologies, multi-antenna transmission technologies such as Full Dimensional MIMO (FD-MIMO), array antennas and large-scale antennas, metamaterial-based lenses and antennas for improving coverage of terahertz band signals, high-dimensional space multiplexing technology using OAM (Orbital Angular Momentum), and RIS (Reconfigurable Intelligent Surface), but also full-duplex technology for increasing frequency efficiency of 6G mobile communication technologies and improving system networks, AI-based communication technology for implementing system optimization by utilizing satellites and AI (Artificial Intelligence) from the design stage and internalizing end-to-end AI support functions,

and next-generation distributed computing technology for implementing services at levels of complexity exceeding the limit of UE operation capability by utilizing ultra-high-performance communication and computing resources.

Disclosure of Invention

Technical Problem

[8] The present disclosure relates to wireless communication systems and, more specifically, the present disclosure relates to method and apparatus for handling random access channel (RACH) information for self-organizing network (son) system.

Solution to Problem

[9] In one aspect, the objectives are achieved by providing a method for handling RACH information for self-organizing network system. The method includes receiving, by the UE, a signaling message from a network apparatus, wherein the signaling message comprises a random access configuration for performing random access. The method includes performing, by the UE, the random access based on the random access configuration upon an occurrence of an event. Further, the method includes determining, by the UE, whether a Down Link Reference Signal Received Power (DL RSRP) is above a first RSRP threshold or a second RSRP threshold. The first RSRP threshold and the second RSRP threshold is indicated in the random access configuration. Further, the method includes logging, by the UE, a random access information based on random access performed. The random access information comprises an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the method includes transmitting, by the UE, the random access information to the network apparatus.

[10] In an embodiment, the first RSRP threshold is the rsrp-Threshold SSB and the random access configuration is a Feature Combination Preambles when a 4 step random access is performed.

[11] In an embodiment, the second RSRP threshold is a msgA-RSRP-Threshold SSB and the random access configuration is the Feature Combination Preambles when a 2 step random access is performed.

[12] In an embodiment, the occurrence of an event comprises of an initial connection establishment, a recovery from beam failure, a Loss of Up Link synchronisation, a reception of a LTM cell switch command, a service request failure, a Listen before transmission failure, LTM cell switch trigger after radio link failure or cell switch failure, Physical Downlink Control Channel (PDCCH) order from the network apparatus for synchronisation or early synchronisation of LTM candidate cells.

[13] In an embodiment, the indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold is provided using a Boolean RSRP above

threshold. The Boolean RSRP above threshold is included in at least one RA Report, Radio Link Failure report and Connection Establishment Failure report.

[14] In an embodiment, the purpose of the random access is a LTM cell switch when a LTM cell switch command or the LTM cell switch trigger is received after radio link failure or cell switch failure.

[15] In an embodiment, the method to transmit the random access information includes receiving, by the UE, a UE information request message from the network apparatus. Further, the method includes creating, by the UE, UE information response message by including the random access information. The random access information comprises at least one the indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and the purpose of the random access in the UE information. Further, the method includes transmitting, by the UE, the random access information in the UE information response to the network apparatus.

[16] Accordingly, the embodiment herein is to provide a method for handling RACH information for SON system. The method includes transmitting, by a network apparatus, a signaling message to a UE. The signaling message comprises at least one of a random access configuration for performing random access. Further, the method includes receiving, by the network apparatus, a random access information from the UE. The random access information comprises at least one of an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the method includes performing, by the network apparatus, resource optimization for random access based on the random access information.

[17] Accordingly, the embodiment herein is to provide a UE for handling random access channel (RACH) information for self-organizing network (SON) system. The UE comprises a processor and a SON random access controller coupled to the processor. The SON random access controller is configured to receive a signaling message from a network apparatus. The signaling message comprises a random access configuration for performing random access. Further, the SON random access controller performs the random access based on the random access configuration upon an occurrence of an event. Further, the SON random access controller determines whether a DL RSRP is above a first RSRP threshold or a second RSRP threshold. The first RSRP threshold and the second RSRP threshold is indicated in the random access configuration. Further, the SON random access controller logs a random access information based on random access performed. The random access information comprises an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the SON random access controller transmits the random access information to the network apparatus.

[18] Accordingly, the embodiment herein is to provide a network apparatus for handling RACH information for SON system. The network apparatus comprises a processor and a SON random access controller coupled to the processor. The SON random access controller is configured to transmit a signaling message to a UE. The signaling message comprises at least one of a random access configuration for performing random access. Further the SON random access controller receives a random access information from the UE. The random access information comprises at least one of an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the SON random access controller performs resource optimization for random access based on the random access information.

[19] These and other aspects of the embodiments herein will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following descriptions, while indicating preferred embodiments and numerous specific details thereof, are given by way of illustration and not of limitation. Many changes and modifications be made within the scope of the embodiments herein.

Brief Description of Drawings

[20] These and other features, aspects, and advantages of the present embodiments are illustrated in the accompanying drawings, throughout which like reference letters indicate corresponding parts in the various figures. The embodiments herein will be better understood from the following description with reference to the drawings, in which:

[21] FIG. 1 illustrates a sequence diagram of reporting feature specific random access channel information and LTM random access to network apparatus, according to the embodiment as disclosed herein;

[22] FIG. 2A is a block diagram that illustrates a UE for optimizing random access in telecommunication network, according to the embodiment as disclosed herein;

[23] FIG. 2B is a block diagram that illustrates a network apparatus for optimizing random access in telecommunication network, according to the embodiment as disclosed herein;

[24] FIG.3A is a flow diagram that illustrates a method for optimizing random access in telecommunication network, according to the embodiment as disclosed herein;

[25] FIG. 3B is a flow diagram that illustrates a method for performing random access for LTM in telecommunication network, according to the embodiment as disclosed herein;

[26] FIG. 3C is a flow diagram that illustrates a method for determining RSRP is above at a threshold for 2 step random access and 4-step random access, according to the em-

bodiment as disclosed herein;

[27] FIG.4 is a flow diagram that illustrates a method for optimizing random access in telecommunication network, according to the embodiment as disclosed herein;

[28] FIG. 5 illustrates a block diagram of a terminal (or a user equipment (UE), according to embodiments as disclosed herein; and

[29] FIG. 6 illustrates a block diagram of a base station, according to embodiment as disclosed herein.

[30] It may be noted that to the extent possible, like reference numerals have been used to represent like elements in the drawing. Further, those of ordinary skill in the art will appreciate that elements in the drawing are illustrated for simplicity and may not have been necessarily drawn to scale. For example, the dimension of some of the elements in the drawing may be exaggerated relative to other elements to help to improve the understanding of aspects of the invention. Furthermore, the elements may have been represented in the drawing by conventional symbols, and the drawings may show only those specific details that are pertinent to the understanding the embodiments of the invention so as not to obscure the drawing with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

Mode for the Invention

[31] The embodiments herein and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. Also, the various embodiments described herein are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments. The term “or” as used herein, refers to a non-exclusive or, unless otherwise indicated. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein can be practiced and to further enable those skilled in the art to practice the embodiments herein. Accordingly, the examples are not be construed as limiting the scope of the embodiments herein.

[32] As is traditional in the field, embodiments are described and illustrated in terms of blocks that carry out a described function or functions. These blocks, which referred to herein as managers, units, modules, hardware components or the like, are physically implemented by analog and/or digital circuits such as logic gates, integrated circuits, microprocessors, microcontrollers, memory circuits, passive electronic components, active electronic components, optical components, hardwired circuits and the like, and optionally be driven by firmware and software. The circuits, for example, be embodied

in one or more semiconductor chips, or on substrate supports such as printed circuit boards and the like. The circuits constituting a block be implemented by dedicated hardware, or by a processor (e.g., one or more programmed microprocessors and associated circuitry), or by a combination of dedicated hardware to perform some functions of the block and a processor to perform other functions of the block. Each block of the embodiments be physically separated into two or more interacting and discrete blocks without departing from the scope of the proposed method. Likewise, the blocks of the embodiments be physically combined into more complex blocks without departing from the scope of the proposed method.

[33] The accompanying drawings are used to help easily understand various technical features and it is understood that the embodiments presented herein are not limited by the accompanying drawings. As such, the proposed method is construed to extend to any alterations, equivalents and substitutes in addition to those which are particularly set out in the accompanying drawings. Although the terms first, second, etc. used herein to describe various elements, these elements are not be limited by these terms. These terms are generally used to distinguish one element from another.

[34] In a 5G wireless communication system, the Random Access (RA) feature is supported to achieve uplink (UL) time synchronization. The RA feature is used in various scenarios such as initial access, handover, radio resource control (RRC) connection re-establishment procedure, scheduling request transmission, secondary cell group (SCG) addition/modification, beam failure recovery, and data or control information transmission in the UL by a non-synchronized UE in a RRC CONNECTED state.

[35] Multiple types of random access procedures are supported in the 5G system to cater to different use cases and network requirements. These procedures include contention-based random access, non-contention-based random access, and hybrid random access.

[36] The RA feature is crucial for efficient and reliable communication in the 5G network. It helps to synchronize the UL transmission timing of the UE with the network, thereby reducing interference and improving network performance. Additionally, it enables the UE to access the network resources in a timely and efficient manner, ensuring smooth communication even in high traffic scenarios.

[37] Thus, it is desired to address the above-mentioned disadvantages or other shortcomings or at least provide a useful alternative.

[38] The principal object of the embodiments herein is to optimize random access in telecommunication network.

[39] Another object of the invention is to report random access information by UE to network apparatus for optimization.

[40] Another object of the invention is to perform random access optimization for Lower

Triggered Mobility (LTM).

[41] Another object of the invention is to perform a self-optimization of random access in the telecommunication network.

[42] Accordingly, the embodiments disclose a method for handling RACH information for self-organizing network system. The method includes receiving, by the UE, a signaling message from a network apparatus, wherein the signaling message comprises a random access configuration for performing random access. The method includes performing, by the UE, the random access based on the random access configuration upon an occurrence of an event. Further, the method includes determining, by the UE, whether a Downlink Reference Signal Received Power (DL RSRP) is above a first RSRP threshold or a second RSRP threshold. The first RSRP threshold and the second RSRP threshold is indicated in the random access configuration. Further, the method includes logging, by the UE, a random access information based on random access performed. The random access information comprises an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the method includes transmitting, by the UE, the random access information to the network apparatus.

[43] Accordingly, the embodiments disclose a method for handling RACH information for SON system. The method includes transmitting, by a network apparatus, a signaling message to a UE. The signaling message comprises at least one of a random access configuration for performing random access. The signaling message may be a system information message or a dedicated Radio Resource Control message. Further, the method includes receiving, by the network apparatus, a random access information from the UE. The random access information comprises at least one of an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the method includes performing, by the network apparatus, resource optimization for random access based on the random access information.

[44] Accordingly, the embodiments disclose a UE for handling random access channel (RACH) information for self-organizing network (SON) system. The UE comprises a processor and a SON random access controller coupled to the processor. The SON random access controller is configured to receive a signaling message from a network apparatus. The signaling message may be a system information message or a dedicated Radio Resource Control message. The signaling message comprises a random access configuration for performing random access. Further, the SON random access controller performs the random access based on the random access configuration upon an occurrence of an event. Further, the SON random access controller determines whether a DL RSRP is above a first RSRP threshold or a second RSRP threshold. The

first RSRP threshold and the second RSRP threshold is indicated in the random access configuration. Further, the SON random access controller logs a random access information based on random access performed. The random access information comprises an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the SON random access controller transmits the random access information to the network apparatus.

[45] Accordingly, the embodiments disclose a network apparatus for handling RACH information for SON system. The network apparatus comprises a processor and a SON random access controller coupled to the processor. The SON random access controller is configured to transmit a signaling message to a UE. The signaling message comprises at least one of a random access configuration for performing random access. Further the SON random access controller receives a random access information from the UE. The random access information comprises at least one of an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the SON random access controller performs resource optimization for random access based on the random access information.

[46] The proposed solution provides a method for optimizing random access in telecommunication network. The UE logs and reports the feature specific random access information and LTM random access information to the network apparatus for the optimization. Upon receiving, the report from the UE, the network apparatus optimizes the network performance with respect to the UE. Particularly, the proposed solution optimizes allocation of random access parameters. Upon the determination of whether the DL RSRP is above or below the threshold, the network apparatus can identify probability of beam failure or radio link failure. Further, when the probability is high the network apparatus can adjust RSRP threshold of a particular beam to ensure that UE selects the most suitable beam for random access.

[47] The random access (RACH) procedure is a mechanism in which the UE initiates a communication with the network apparatus. Particularly, there are two types of the RACH procedure that is a contention based random access (CBRA)and contention free random access (CFRA).

[48] In the CBRA, the UE first transmits Random Access preamble (also referred as Msg1) and then waits for Random access response (RAR) in a RAR window. The RAR is also referred as Msg2. The network apparatus transmits the RAR on a physical downlink shared channel (PDSCH). A Physical Downlink Control Channel (PDCCH) scheduling the PDSCH carrying RAR is addressed to a RA-radio network temporary identifier (RA-RNTI). The RA-RNTI identifies a time-frequency resource (also referred as physical RA channel (PRACH) occasion or PRACH transmission (TX) occasion or RA channel (RACH) occasion) in which the RA preamble is detected by

the network apparatus. If the RAR corresponding to its RA preamble transmission is received, the UE transmits a message 3 (Msg3) in uplink (UL) grant received in RAR. The Msg3 includes message such as RRC connection request, RRC connection re-establishment request, RRC handover confirm, scheduling request, SI request and the like. The Msg3 includes the UE identity (i.e. cell-radio network temporary identifier (C-RNTI) or system architecture evolution (SAE)-temporary mobile subscriber identity (S-TMSI) or a random number).

[49] After transmitting the Msg3, UE starts a contention resolution timer. While the contention resolution timer is running, if UE (101) receives a physical downlink control channel (PDCCH) addressed to C-RNTI included in Msg3, contention resolution is considered successful, contention resolution timer is stopped and RA procedure is completed. While a contention resolution timer is running, if the UE receives contention resolution MAC control element (CE) including the UE's contention resolution identity (first X bits of common control channel (CCCH) service data unit (SDU) transmitted in the Msg3), the contention resolution is considered successful, contention resolution timer is stopped and RA procedure is completed. If the contention resolution timer expires and the UE has not yet transmitted the RA preamble for a configurable number of times, the UE goes back to first step i.e. select random access resource (preamble/RACH occasion) and transmits the RA preamble. A backoff is applied before going back to first step.

[50] The CFRA procedure is used for scenarios such as the handover where low latency is required, timing advance establishment for secondary cell (Scell), etc. The network apparatus assigns to UE dedicated Random access preamble. The UE (101) transmits the dedicated RA preamble. Further, the UE transmits the RAR on PDSCH addressed to RA-RNTI. RAR conveys RA preamble identifier and timing alignment information. The RAR also includes a UL grant. The RAR is transmitted in the RAR window similar to the contention based RA (CBRA) procedure. The CFRA is considered successfully completed after receiving the RAR including RA preamble identifier (RAPID) of RA preamble transmitted by the UE. In case the RA is initiated for beam failure recovery, the CFRA is considered successfully completed if PDCCH addressed to C-RNTI is received in search space for beam failure recovery. If the RAR window expires and the RA is not successfully completed and the UE has not yet transmitted the RA preamble for a configurable (configured by gNB in RACH configuration) number of times, the UE retransmits the RA preamble.

[51] In a 2 step CBRA, the UE transmits the random access preamble on the PRACH and a payload (i.e. MAC PDU) on PUSCH. The random access preamble and payload transmission is also referred as MsgA. In the second step, after MsgA transmission, the UE monitors for a response from the network (i.e. gNB) within a configured window.

The response is also referred as MsgB. If CCCH SDU was transmitted in MsgA payload, UE performs contention resolution using the contention resolution information in MsgB. The contention resolution is successful if the contention resolution identity received in MsgB matches first 48 bits of CCCH SDU transmitted in MsgA. If C-RNTI was transmitted in MsgA payload, the contention resolution is successful if UE receives PDCCH addressed to C-RNTI. If contention resolution is successful, random access procedure is considered successfully completed. Instead of contention resolution information corresponding to the transmitted MsgA, MsgB includes fallback information corresponding to the random access preamble transmitted in MsgA. If the fallback information is received, the UE transmits Msg3 and performs contention resolution using Msg4 as in CBRA procedure. If contention resolution is successful, random access procedure is considered successfully completed. If contention resolution fails upon fallback (i.e. upon transmitting Msg3), UE retransmits MsgA. If configured window in which UE monitor network response after transmitting MsgA expires and UE has not received MsgB including contention resolution information or fallback information as explained above, the UE retransmits MsgA. If the random access procedure is not successfully completed even after transmitting the msgA configurable number of times, the UE fallbacks to 4 step RACH procedure i.e. UE only transmits the PRACH preamble.

[52] In 2 step CFRA, the network apparatus (102) assigns to UE dedicated Random access preamble (s) and PUSCH resource(s) for MsgA transmission. RACH Occasions RO(s) to be used for preamble transmission may also be indicated. In the first step, UE transmits random access preamble on PRACH and a payload on PUSCH using the contention free random access resources (i.e. dedicated preamble/PUSCH resource/RO). In the second step, after MsgA transmission, the UE monitors for a response from the network (i.e. gNB) within a configured window. If UE (101) receives PDCCH addressed to C-RNTI, random access procedure is considered successfully completed. If UE receives fallback information corresponding to its transmitted preamble, random access procedure is considered successfully completed.

[53] In NR release 17 further enhances RACH for various features like slicing, small data transmission, reduced capability UEs, coverage enhancements (msg3 repetitions) etc. A number of preambles from available RACH preambles and a number of RO may be partitioned for various features. The network apparatus may also allocate different available RACH occasions to different features as indicated in the system information. For slicing, different slices or slice groups may be allocated different RACH resources. For SDT, there could be separate preamble groups based on the size of data to be transmitted. For coverage enhancements, UE can be configured to repeat the msg3. For REDCAP, the msg1 resources allocated could be used to identify that the device is a

reduced capability device. In addition, for each feature, a number of RACH parameters which can be configured separately. The UE performs feature specific random access if it has performed random access using a feature or feature combination specific RACH configuration (which includes the feature or feature combination specific RACH partition configuration, the feature or feature combination specific RACH resources etc.). Also, the UE performs feature specific random access attempt if it has performed random access attempt using a feature or feature combination specific RACH configuration (which includes the feature or feature combination specific RACH partition configuration, the feature or feature combination specific RACH resources etc.).

[54] A Third generation Partnership Project (3gpp) TS 38.331 v17 defines feature groups and its characteristics is given below.

[55] Feature combination: An Information Element (IE) Feature Combination indicates a feature or a combination of features to be 15 associated with a set of Random Access resources (i.e. an instance of Feature Combination Preambles).

[56]

```
Feature Combination information element
-- ASN1START
-- TAG-FEATURECOMBINATION-START
FeatureCombination-r17::= SEQUENCE {
redCap-r17 ENUMERATED {true}
OPTIONAL, -- Need R
smallData-r17 ENUMERATED {true}
 OPTIONAL, -- Need R
sliceGroup-r17 SliceGroupList-r17
OPTIONAL, -- Need R
msg3-Repetitions-r17 ENUMERATED {true}
OPTIONAL, -- Need R
spare4 ENUMERATED {true}
OPTIONAL, -- Need R
spare3 ENUMERATED {true}
OPTIONAL, -- Need R
spare2 ENUMERATED {true}
OPTIONAL, -- Need R
spare1 ENUMERATED {true}
OPTIONAL -- Need R }
SliceGroupList-r17::= SEQUENCE (SIZE (1..ffsUpperLimit)) OF
SliceGroupID-r17
-- TAG-FEATURECOMBINATION-STOP
-- ASN1STOP
```

[57] The Feature Combination Indication field descriptions is defined as shown in below Table. 1:

[58]

***FeatureCombinationIndication* field descriptions**
redCap If present, this field indicates that RedCap is part of this feature combination.
smallData If present, this field indicates that Small Data is part of this feature combination.
sliceGroup If present, this field indicates slice group(s) that are part of this feature combination.
msg3-Repetitions If present, this field indicates that signalling of msg3 repetition is part of this feature combination. This field is not configured in a set of preambles that is configured with 2-step random-access type.

Table. 1

[59] Feature Combination Preambles: The IE Feature Combination Preambles associates a set of preambles with a feature combination. For parameters which can be provided in this IE, the UE applies this field value when performing Random Access using a preamble

[60]

```
-- ASN1START
-- TAG-FEATURECOMBINATIONPREAMBLES-START

FeatureCombinationPreambles-r17 ::=   SEQUENCE {
   featureCombination-r17              FeatureCombination-r17,
   startPreambleForThisPartition-r17     INTEGER (1..64),
   numberOfPreamblesPerSSB-ForThisPartition-r17 INTEGER (1..64),
   ssb-SharedRO-MaskIndex-r17          INTEGER (1..15)                          OPTIONAL,
-- Need S
groupBconfigured-r17               SEQUENCE {
      ra-SizeGroupA-r17                    ENUMERATED {b56, b144, b208, b256, b282, b480,
b640,
                                        b800, b1000, b72, spare6, spare5,spare4, spare3, spare2,
spare1},
      messagePowerOffsetGroupB          ENUMERATED { minusinfinity, dB0, dB5, dB8, dB10,
dB12, dB15, dB18},
      numberOfRA-PreamblesGroupA         INTEGER (1..64)
      }                                                    OPTIONAL, -- Need S
      separateMsgA-PUSCH-Config-r17                               MsgA-PUSCH-Config-r16
OPTIONAL, -- Cond MsgAConfigCommon
   msgA-RSRP-Threshold-r17            RSRP-Range
                  OPTIONAL, -- Need R
      rsrp-ThresholdSSB-r17             RSRP-Range                              OPTIONAL, --
Need R
deltaPreamble-r17                  INTEGER (-1..6)                          OPTIONAL,  -- Need
R
   ...
}

-- TAG-FEATURECOMBINATIONPREAMBLES-STOP
-- ASN1STOP
```

[61] The Feature Combination preambles field descriptions is defined as shown in below Table. 2:

[62]

***FeatureCombinationPreambles* field descriptions**
deltaPreamble Power offset between msg3 or msgA-PUSCH and RACH preamble transmission. If configured, this parameter overrides *msg3-DeltaPreamble* or *msgA-DeltaPreamble*, Actual value = field value * 2 [dB] (see TS 38.213 [13], clause 7.1). If *msgA-DeltaPreamble* is configured in *separateMsgA-PUSCH-Config-r17*, this field is absent.
featureCombination Indicates which combination of features that the preambles indicated by this IE are associated with. The UE ignores a RACH resource defined by this *FeatureCombinationPreambles* if any feature within the *featureCombination* is not supported by the UE or has an unknown value.
messagePowerOffsetGroupB Threshold for preamble selection. Value is in dB. Value *minusinfinity* corresponds to –infinity. Value *dB0* corresponds to 0 dB, *dB5* corresponds to 5 dB and so on (see TS 38.321 [3], clause 5.1.2).
msgA-RSRP-Threshold The UE selects 2-step random access type to perform random access based on this threshold (see TS 38.321 [3], clause 5.1.1). This field is only present if partition specific RSRP threshold for 2-step and 4-step RA type is configured for the BWP. If configured, this parameter overrides *msgA-RSRP-Threshold-r16*. If absent, the UE applies *msgA-RSRP-Threshold-r16*, if configured
numberOfPreamblesForThisPartition It determines how many consecutive preambles are associated to the Feature Combination starting from the starting preamble(s) per SSB.
numberOfRA-PreamblesGroupA It determines how many consecutive preambles per SSB are associated to Group A starting from the starting preamble(s). The remaining preambles associated to the Feature Combination are associated to Group B
ra-SizeGroupA Transport Blocks size threshold in bits below which the UE shall use a contention-based RA preamble of group A. (see TS 38.321 [3], clause 5.1.2). If this feature combination preambles are associated to a *RACH-ConfigCommon-twostepRA*, this field correspond to *ra-MsgA-SizeGroupA*, otherwise it corresponds to *ra-Msg3SizeGroupA*.
rsrp-ThresholdSSB L1-RSRP threshold used for determining whether a candidate beam may be used by the UE. If parameter is included in *FeatureCombinationPreambles* which is included in *RACH-ConfigCommonTwoStepRA*, it corresponds to *msgA-RSRP-ThresholdSSB*, as defined in TS 38.321 [3]. If this parameter is included in *FeatureCombinationPreambles* which is included in *RACH-ConfigCommon*, it it corresponds to *rsrp-ThresholdSSB*, as defined in TS 38.321 [3].
separateMsgA-PUSCH-Config If present it specifies how the 2-step RACH preambles identified by this *FeatureCombinationPreambles* are mapped to a PUSCH slot separate from the one defined in MsgA-ConfigCommon-r16. If the field is absent, the UE should apply the corresponding parameter in the *RACH-ConfigCommonTwoStepRA* of the BWP which includes the *FeatureCombinationPreambles IE*.

[63]

ssb-SharedRO-MaskIndex Mask index (see 38.321). Indicates a subset of ROs where preambles are allocated for this feature combination. If this field is configured within *FeatureCombinationPreambles* which is included in *RACH-ConfigCommonTwoStepRA*, it indicates a subset of ROs configured within this *RACH-ConfigCommonTwoStepRA*.This field is configured when there is more than one RO per SSB. If the field is absent, all ROs configured in *RACH-ConfigCommon* or *RACH-ConfigCommonTwoStepRA* containing this *FeatureCombinationPreambles* are shared.
startPreambleForThisPartition It defines the first preamble associated with the Feature Combination. If N<1 the first preamble in each PRACH occasion is the one having the same index indicated by this field. If N>=1 in each PRACH occasion N blocks of preambles associated with the Feature Combination are define, each having start index $n \cdot N_{\text{preamble}}^{\text{total}} / N$ + startPreambleForThisPartition (see 38.213).

Table. 2

[64] MsgA configuration common parameters are defined as shown in below Table. 3

[65]

Conditional Presence	Explanation
MsgAConfigCommon	The field is optionally present, Need S, if FeatureCombinationPreambles is included in RACH-ConfigCommonTwoStepRA. Otherwise, it is absent. If the field is absent in FeatureCombinationPreambles included in RACH-ConfigCommonTwoStepRA, the UE applies MsgA-PUSCH-Config included in the corresponding MsgA-ConfigCommon.

Table. 3

[66] Each of the features may be allocated a priority as specified below in TS 38.331 V17.0.0

[67]

```
featurePriorities-r17       SEQUENCE {
    redCapPriority-r17          FeaturePriority-r17                 OPTIONAL,
    slicingPriority-r17         FeaturePriority-r17                 OPTIONAL,
    msg3-Repetitions-Priority-r17       FeaturePriority-r17         OPTIONAL,
    sdt-Priority-r17            FeaturePriority-r17                 OPTIONAL
}
FeaturePriority-r17 ::= INTEGER (0..7)
```

[68] The above feature priorities indicates priorities for features, such as RedCap, Slicing, S+DT and MSG3-Repetitions for Coverage Enhancements. These priorities are used to determine which Feature Combination Preambles the UE shall use when a feature maps to more than one Feature Combination Preambles, as specified in TS 38.321 [3]. A lower value means a higher priority. The network does not signal the same priority for more than one feature. The network signals a priority for all feature that map to at least one Feature Combination Preambles.

[69] For different features, different criteria which decides whether the UE can select the feature specific RACH resources. In general, the criteria will be broadcasted by the gNB or configured through RRC release message. For slicing, the criteria will be based on the slice group or slice-id that triggers the msg1 transmission. For coverage en-

hancements, the criteria may be based on the measured RSRP (Reference Signal Received Power) at the time of msg3 repetitions.

[70] When feature specific RACH partitioning is used, UL BWP configuration can include additional RACH configuration as below from TS 38.331

[71]

```
BWP-UplinkCommon ::=            SEQUENCE {
   genericParameters            BWP,
   rach-ConfigCommon                        SetupRelease { RACH-ConfigCommon }
OPTIONAL,   -- Need M
   pusch-ConfigCommon                       SetupRelease { PUSCH-ConfigCommon }
OPTIONAL,   -- Need M
pucch-ConfigCommon                          SetupRelease { PUCCH-ConfigCommon }
OPTIONAL,   -- Need M
   ...,
[[
   rach-ConfigCommonIAB-r16                 SetupRelease { RACH-ConfigCommon }
OPTIONAL,   -- Need M
   useInterlacePUCCH-PUSCH-r16                           ENUMERATED    {enabled}
OPTIONAL,   -- Need R
   msgA-ConfigCommon-r16                    SetupRelease { MsgA-ConfigCommon-r16 }
OPTIONAL    -- Cond SpCellOnly2
   ]],
   [[
   enableRA-PrioritizationForSlicing-r17    BOOLEAN                     OPTIONAL,
-- Cond RAPrioSliceAI
   additionalRACH-ConfigCommon-r17    SEQUENCE (SIZE(0..maxAdditionalRACH-r17))
OF AdditionalRACH-ConfigCommon-r17 OPTIONAL -- Cond SpCellOnly3
   ]]

AdditionalRACH-ConfigCommon-r17 ::= SEQUENCE {

   rach-ConfigCommon-r17        RACH-ConfigCommon                   OPTIONAL,
-- Need R
   msgA-ConfigCommon-r17                               MsgA-ConfigCommon-r16
OPTIONAL,   -- Cond R
   ...
}
```

[72] RACH performed according to the above may be generally called feature specific RACH. When the applicable feature is slicing, it may be called slice specific RACH.

[73] Self-Optimisation in NR: A 5G NR (new radio) radio access network also known as NG-RAN (Next Generation Radio Network) comprises of a number of NR base stations knows as gNBs. The gNBs is connected to each other through Xn interface, and will be connected to various core network elements like AMF (Access and Mobility Management Function), UPF (User Plane Function) etc. Further gNBs can be divided into two physical entities named CU (Centralized Unit) and DU (Distributed Unit). CU provides support for the higher layers of the protocol stack such as SDAP (Session Data Application Protocol), PDCP (Packet Data Convergence Protocol) and RRC (Radio Resource Control) while DU provides support for the lower layers of the protocol stack such as RLC (Radio Link Control), MAC (Medium Access Control) and

Physical layer. Each gNB can have multiple cells serving many UEs (User Equipment). There are a large number of algorithms and configuration parameters used in NG-RAN. Especially, it is a very difficult task to identify the most optimal radio parameters and operators used to resort to manual techniques like drive tests to identify the parameters. However, such manual parameter tuning is a costly operation since it depends on a lot of factors like the number of users, number of neighbors, maximum throughput in the cell, average throughput in the cell etc. Further, whenever a neighbor gNB is installed or a new service is introduced, many of these manual operations need to be repeated. To resolve this problem, 3gpp has introduced Self-Organizing Networks (SON) techniques in the wireless technologies like NR. The SON is introduced in 3gpp release 9, in LTE. SON solutions can be divided into three categories: Self-Configuration, Self-Optimization and Self-Healing. The SON architecture can be a centralized, distributed or a hybrid solution.

[74] Self-optimization of RACH aims to minimize the number of attempts on the RACH. UE can report the detailed information about RACH in the RACH Report to the network and the network will optimize various parameters associated with RACH using the information. A List of information that the UE could report in RACH is given as below based on NR TS 38.331

[75]

```
RA-ReportList-r16::= SEQUENCE (SIZE (1..maxRAReport-r16)) OF RA-Report-r16
RA-Report-r16 ::=                SEQUENCE {
   cellId-r16                  CHOICE {
      cellGlobalId-r16               CGI-Info-Logging-r16,

      pci-arfcn-r16                SEQUENCE {
         physCellId-r16                PhysCellId,
         carrierFreq-r16               ARFCN-ValueNR
      }
   },
   ra-InformationCommon-r16          RA-InformationCommon-r16              OPTIONAL,
   raPurpose-r16                     ENUMERATED {accessRelated, beamFailureRecovery,
reconfigurationWithSync, ulUnSynchronized,
                                schedulingRequestFailure,        noPUCCHResourceAvailable,
requestForOtherSI,
                                spare9, spare8, spare7, spare6, spare5, spare4, spare3, spare2,
spare1},
   ...
}
RA-InformationCommon-r16 ::=       SEQUENCE {
   absoluteFrequencyPointA-r16       ARFCN-ValueNR,

   locationAndBandwidth-r16          INTEGER (0..37949),
   subcarrierSpacing-r16            SubcarrierSpacing,
   msg1-FrequencyStart-r16                  INTEGER (0..maxNrofPhysicalResourceBlocks-1)
OPTIONAL,
   msg1-FrequencyStartCFRA-r16             INTEGER (0..maxNrofPhysicalResourceBlocks-1)
OPTIONAL,
   msg1-SubcarrierSpacing-r16        SubcarrierSpacing                OPTIONAL,
   msg1-SubcarrierSpacingCFRA-r16     SubcarrierSpacing                OPTIONAL,
   msg1-FDM-r16                  ENUMERATED {one, two, four, eight}          OPTIONAL,
   msg1-FDMCFRA-r16               ENUMERATED {one, two, four, eight}          OPTIONAL,
   perRAInfoList-r16              PerRAInfoList-r16,
   ...,
   [[
perRAInfoListExt-v1660            PerRAInfoListExt-v1660               OPTIONAL
                      ]],
          [[
          msgA-FrequencyStart-r17            INTEGER (0..maxNrofPhysicalResourceBlocks-1)
OPTIONAL,
```

[76]

```
msgA-FrequencyStartCFRA-r17              INTEGER (0..maxNrofPhysicalResourceBlocks-1)
OPTIONAL,
        msgA-SubcarrierSpacing-r17          SubcarrierSpacing                    OPTIONAL,
        msgA-SubcarrierSpacingCFRA-r17      SubcarrierSpacing                    OPTIONAL,
        msgA-FDM-r17                        ENUMERATED {one, two, four, eight}
OPTIONAL,
        msgA-FDMCFRA-r17                    ENUMERATED {one, two, four, eight}
OPTIONAL,
        measuredDL-RSRP-r17                 RSRP-Range                           OPTIONAL,
                        msgA-TransMax-r17              ENUMERATED {n1, n2, n4, n6, n8,
n10, n20, n50, n100, n200}     OPTIONAL
msgA-MCS-r17                 INTEGER (0..15)                       OPTIONAL,
  nrofPRBs-PerMsgA-PO-r17            INTEGER (1..32)                      OPTIONAL,
  msgA-PUSCH-TimeDomainAllocation-r17          INTEGER      (1..maxNrofUL-Allocations)
OPTIONAL,
  frequencyStartMsgA-PUSCH-r17            INTEGER (0..maxNrofPhysicalResourceBlocks-1)
OPTIONAL,
  nrofMsgA-PO-FDM-r17            ENUMERATED {one, two, four, eight}            OPTIONAL,
  dlPathlossRSRP-r17             RSRP-Range                            OPTIONAL,
  intendedSIBs-r17                    SEQUENCE (SIZE (1..maxSIB)) OF SIB-Type-r17
OPTIONAL,
  ssbsForSI-Acquisition-r17           SEQUENCE (SIZE (1..maxNrofSSBs-r16)) OF SSB-Index
OPTIONAL,
  msgA-PUSCH-PayloadSize-r17          BIT STRING (SIZE (3))                OPTIONAL,
  onDemandSISuccess-r17            BOOLEAN                              OPTIONAL
]]
}
PerRAInfoList-r16 ::= SEQUENCE (SIZE (1..200)) OF PerRAInfo-r16
PerRAInfoListExt-v1660 ::= SEQUENCE (SIZE (1..200)) OF PerRACSI-RSInfoExt-v1660
PerRAInfo-r16 ::=               CHOICE {
  perRASSBInfoList-r16              PerRASSBInfo-r16,
  perRACSI-RSInfoList-r16            PerRACSI-RSInfo-r16
}
PerRASSBInfo-r16 ::=              SEQUENCE {
  ssb-Index-r16                    SSB-Index,
  numberOfPreamblesSentOnSSB-r16       INTEGER (1..200),
  perRAAttemptInfoList-r16           PerRAAttemptInfoList-r16
}

PerRACSI-RSInfo-r16 ::=            SEQUENCE {
  csi-RS-Index-r16                 CSI-RS-Index,
  numberOfPreamblesSentOnCSI-RS-r16    INTEGER (1..200)
}
PerRACSI-RSInfoExt-v1660 ::=        SEQUENCE {
  csi-RS-Index-v1660              INTEGER (1..96)               OPTIONAL
}
PerRAAttemptInfoList-r16 ::=        SEQUENCE (SIZE (1..200)) OF PerRAAttemptInfo-r16
PerRAAttemptInfo-r16 ::=           SEQUENCE {
```

[77]

```
  contentionDetected-r16          BOOLEAN          OPTIONAL,
  dlRSRPAboveThreshold-r16           BOOLEAN           OPTIONAL,
...,
[[
fallbackRAR-Received-r17          BOOLEAN          OPTIONAL
          ]]

}
```

[78] The UE sends the RACH reports to the network in RRC messages, for e.g. UE Information Response. On receiving the RACH report, a gNB CU sends it to a gNB DU or an OAM SON module or may directly use it for optimizing various parameters related to random access. For e.g. the number of preambles, configuration of group A and group B preambles, RACH prioritization information, contention resolution timer, number of RACH preambles for 2 step RACH, PUSCH related parameters for 2 step RACH etc. A detailed description of the various parameters that can be present in the random access report is given below:

[79] The RA-report field descriptions are provided in below table. 4

[80]

***RA-Report* field descriptions**
cellID This field indicates the CGI of the cell in which the associated random access procedure was performed.
contentionDetected This field is used to indicate that contention was detected for the transmitted preamble in the given random access attempt or not. This field is not included when the UE performs random access attempt is using contention free random-access resources or when the *raPurpose* is set to *requestForOtherSI* or when the RA attempt is a 2-step RA attempt and fallback to 4-step RA did not occur (i.e. *fallbackToFourStepRA* is not included).
csi-RS-Index, csi-RS-Index-v1660 This field is used to indicate the CSI-RS index corresponding to the random access attempt. If the random access procedure is for beam failure recovery, the field indicates the NZP-CSI-RS-ResourceId. For CSI-RS index larger than maxNrofCSI-RS-ResourcesRRM-1, the index value is the sum of csi-RS-Index (without suffix) and csi-RS-Index-v1660.
dlPathlossRSRP Measeured RSRP of the DL pathloss reference obtained at the time of *RA_Type* selection stage of the RA procedure as captured in TS 38.321 [3].
dlRSRPAboveThreshold In 4 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *rsrp-ThresholdSSB* in *beamFailureRecoveryConfig* in UL BWP configuration of UL BWP selected for random access procedure initiated for beam failure recovery; Otherwise, *rsrp-ThresholdSSB* in *rach-ConfigCommon* in UL BWP configuration of UL BWP selected for random access procedure. In 2 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *msgA-RSRP-ThresholdSSB* in *rach-ConfigCommonTwoStepRA* in UL BWP configuration of UL BWP selected for random access procedure.
fallbackToFourStepRA This field indicates if a fallback indication in MsgB is received (according to TS 38.321 [3]) for the 2-step random access attempt.
intendedSIBs This field indicates the SIB(s) the UE wanted to receive as a result of the on demand SI request (when the RA procedure is a used as a SI request) initiated by the UE. That is, it indicates the one(s) of the SIB(s) in the SI message(s) requested to be broadcast that the UE was interested in.
msg1-SCS-From-prach-ConfigurationIndex This field is set by the UE with the corresponding SCS for CBRA as derived from the *prach-ConfigurationIndex* in *RACH-ConfigGeneric* when the *msg1-SubcarrierSpacing* is absent; otherwise, this field is absent.
msg1-SCS-From-prach-ConfigurationIndexCFRA This field is set by the UE with the corresponding SCS for CFRA as derived from the *prach-ConfigurationIndex* in *RACH-ConfigGeneric* when the *msg1-SubcarrierSpacing* is absent; otherwise, this field is absent.
msgA-PUSCH-PayloadSize This field indicates the size of the overall payload available in the UE buffer at the time of initiating the 2 step RA procedure. The value refers to the index of TS 38.321 [3], table 6.1.3.1-1, corresponding to the UE buffer size.

[81]

msgA-RO-FDM This field indicates the number of msgA PRACH transmission occasions Frequency-Division Multiplexed in one time instance for the PRACH resources configured for 2-step CBRA..
msgA-RO-FDMCFRA This field indicates the number of msgA PRACH transmission occasions Frequency-Division Multiplexed in one time instance for the PRACH resources configured for 2-step CFRA.
msgA-RO-FrequencyStart This field indicates the lowest resource block of the contention based random-access resources for 2-step CBRA in the random-access procedure. The indication has the form of the offset of the lowest PRACH transmissions occasion with respect to PRB 0 in the frequency domain.
msgA-RO-FrequencyStartCFRA This field indicates the lowest resource block of the contention free random-access resources for the 2-step CFRA in the random-access procedure. The indication has the form of the offset of the lowest PRACH transmissions occasion with respect to PRB 0 in the frequency domain.
msgA-SCS-From-prach-ConfigurationIndex This field is set by the UE with the corresponding SCS as derived from the *msgA-PRACH-ConfigurationIndex* in *RACH-ConfigGenericTwoStepRA* (see tables Table 6.3.3.1-1, Table 6.3.3.1-2, Table 6.3.3.2-2 and Table 6.3.3.2-3, TS 38.211 [16]) when the *msgA-SubcarrierSpacing* is absent and when only 2-step random-access resources are available in the UL BWP used in the random-access procedure; otherwise, this field is absent.
numberOfPreamblesSentOnCSI-RS This field is used to indicate the total number of successive RA preambles that were transmitted on the corresponding CSI-RS.
numberOfPreamblesSentOnSSB This field is used to indicate the total number of successive RA preambles that were transmitted on the corresponding SS/PBCH block.
onDemandSISuccess This field is set to *true* when the RA report entry is included because of either msg1 based on demand SI request or msg3 based on demand SI request and if the on-demand SI request is successful. Otherwise, the field is absent.
perRAAttemptInfoList This field provides detailed information about a random access attempt.
perRACSI-RSInfoList This field provides detailed information about the successive random access attempts associated to the same CSI-RS.
perRASSBInfoList This field provides detailed information about the successive random access attempts associated to the same SS/PBCH block.
ra-InformationCommon This field is used to provide information on random access attempts. This field is mandatory present.

[82]

raPurpose This field is used to indicate the RA scenario for which the RA report entry is triggered. The RA accesses associated to Initial access from RRC_IDLE, RRC re-establishment procedure, transition from RRC-INACTIVE. The indicator *beamFailureRecovery* is used in case of successful beam failure recovery related RA procedure in the SpCell [3]. The indicator *reconfigurationWithSync* is used if the UE executes a reconfiguration with sync. The indicator *ulUnSynchronized* is used if the random access procedure is initiated in a SpCell by DL or UL data arrival during RRC_CONNECTED when the timeAlignmentTimer is not running in the PTAG or if the RA procedure is initiated in a serving cell by a PDCCH order [3]. The indicator *schedulingRequestFailure* is used in case of SR failures [3]. The indicator *noPUCCHResourceAvailable* is used when the UE has no valid SR PUCCH resources configured [3]. The indicator *requestForOtherSI* is used for MSG1 based on demand SI request. The indicator *msg3RequestForOtherSI* is used in case of MSG3 based SI request. The field can also be used for the SCG-related RA-Report when the *raPurpose* is set to *beamFailureRecovery*, *reconfigurationWithSync*, *ulUnSynchronized*, *schedulingRequestFailure* and *noPUCCHResourceAvailable*.
spCellID This field is used to indicate the CGI of the SpCell of the cell group associated to the SCell in which the associated random access procedure was performed. If the UE performs RA procedure on a SCell associated to the MCG, then this field is set to the CGI of the PCell and if the UE performs RA procedure on a SCell associated to the SCG, then this field is set to the CGI of the PSCell. If the CGI of the PSCell is not available at the UE for the RA procedure performed on a SCell associated to the SCG or for the RA procedure on the PSCell, this field is set to the CGI of the PCell. Otherwise, the field is absent.
ssb-Index This field is used to indicate the SS/PBCH index of the SS/PBCH block corresponding to the random access attempt.
ssbsForSI-Acquisition This field indicates the SSB(s) (in the form of SSB index(es)) that the UE used to receive the requested SI message(s). The field is present if the purpose of the random access procedure was to request on-demand SI (i.e. if the *raPurpose* is set to *requestForOtherSI* or *msg3RequestForOtherSI*). Otherwise, the field is absent.

Table. 4

[83] The 3gpp V17.4.0 version of TS 38.331, TS 38.321, TS 38.300 and TS 38.304 as relevant background for the proposed invention.

[84] In the 3gpp the optimization of RACH for feature specific random access is performed when the UE sends the feature or the combination of features that triggered the RACH as well as the used feature combination to the gNB for self-optimization purposes. The UE also includes NSAG ID when the applicable feature is slicing.

[85] Mobility and Lower Layers Triggered Mobility:

[86] In wireless technologies like 5G NR, devices can move across different cells. Mobility is performed using a procedure called cell reselection in RRC_IDLE mode. Till NR R17, mobility is performed using a procedure called handover in RRC_CONNECTED mode. Network controlled mobility applies to UEs in RRC_CONNECTED. It requires explicit RRC signalling to be triggered by the gNB in NR. Handover in NR usually consists of three steps: handover preparation, handover execution and handover completion. The gNB configures the UE to report measurements and based on the reported measurements or based on its own understanding

of the network topology, the gNB will send RRC Reconfiguration message to handover the UE to another cell called target cell from the source cell. UE accesses the target cell and sends RRC Reconfiguration complete message. In an alternative way introduced in 3gpp NR release 16, the gNB may configure the UE with the execution conditions for triggering handover and once the execution conditions are satisfied, the UE may move to target cell and sends the RRC Reconfiguration complete. 3gpp also introduced a new handover called DAPS handover in release 16. In all these methods, UE performs handover by sending layer 3 (RRC) messages which causes considerable signalling overhead and latency issues. The handover, and conditional handover (CHO) is referred to as layer 3 mobility. In case of dual connectivity, UE may perform PS Cell Change or Conditional PS Cell Change. In the context of dual connectivity, we can refer PS Cell Change or Conditional PS Cell Change also as layer 3 mobility. i.e. Handover, Conditional Handover, PS Cell Change, Conditional PS Cell Change etc. refers to L3 mobility. We can also refer PS Cell Change or Conditional PS Cell Change as SCG layer 3 mobility and the handover and CHO as MCG layer 3 mobility in the context of dual connectivity. UE may perform L3 mobility upon reception of the RRC reconfiguration message asking the UE to perform handover, or upon execution of the conditional reconfiguration (CHO, CPA (Conditional PS Cell Addition) or CPC).

[87] The 3gpp release 18 is considering Lower Layers (L1/L2 layers) Triggered Mobility, also known as LTM to solve the problem related to latency, signalling overhead etc. associated with layer 3 mobility. The 3gpp, the goal of LTM is to enable a serving cell change via L1/L2 signalling, in order to reduce the latency, overhead and interruption time. Network (gNB) may configure the UE with multiple candidate cells to allow fast application of configurations for candidate cells. Network may further send MAC CE or L1 signalling to dynamically switch the UE from a source cell to one of the configured candidate cells. Further, LTM is triggered based on L1 measurements rather than L3 measurements.

[88] The 3gpp performs LTM, without reset of lower layers like MAC to avoid data loss and to reduce the additional delay of data recovery wherever it is possible.

[89] The gNB provides LTM Candidate Configuration, i.e. configure LTM candidate cells through one RRC Reconfiguration message for a candidate target cell or through one Cell Group Config for each candidate target cell or through any similar RRC structure or IE containing the similar fields (for e.g. a new IE LTM-Candidate Config can be defined as ASN.1 sequence containing Cell Group Config and some other information elements in the RRC Reconfiguration). The gNB may further release or modify the candidate configurations. A UE may store the LTM configuration of other candidate cells even after moving to a candidate cell through LTM. gNB also may provide the

UE with configuration for performing LTM measurements for different candidate frequencies and candidate cells and reporting based on the performed LTM measurements.

[90] In an embodiment, during the LTM measurements, the UE can be configured by the gNB with different measurement configurations for both layer 3 mobility (for e.g. using Meas Config IE in R17 NR) and LTM. A UE which has been configured with measurement configurations for layer3 mobility (Measurements configured/ performed/reported for layer 3 mobility for e.g. configured through R17 Meas Config IE, is here in after referred as L3 measurements) and LTM (Measurements configured/ performed/reported for LTM is here in after referred as LTM measurements), performs both L3 measurements and LTM measurements. LTM measurements are L1 measurements.

[91] There are multiple ways by which L1 measurements for LTM can be provided to the UE. For e.g. 3gpp is considering three different ways for providing L1 measurements to the UE as below.

[92] 1) Configurations for L1 measurement RS is provided under Serving Cell Config for the serving cells.

[93] 2) Configurations for L1 measurement RS is provided separately from Serving Cell Config for the serving cells and Cell Group Config for the candidate cells.

[94] 3) Configurations for L1 measurement RS is provided under Cell Group Config for the candidate cells.

[95] L1 measurement report for LTM is reported as periodic report on PUCCH, semi-persistent report on PUCCH/PUSCH, and aperiodic report on PUSCH. Further, L1 measurements can be reported using MAC CE. This reports may be scheduled by gNB or initiated by UE. It is also possible that gNB can decide for LTM through UL measurements.

[96] In an embodiment, in the cell Switch command, the gNB instructs the UE to perform LTM, i.e. to move to a target candidate cell through a Downlink (DL) MAC CE or through L1 signaling. MAC CE triggering of the cell switch carries LTM related information for cell switch including the cell identifier. A procedure of triggering change of cells via the LTM feature is called cell switch. Both RACH-based (CFRA, CBRA) and RACH-less procedures for cell switch is supported. RACH-less cell switch may be used if the UE doesn't need to acquire TA during the cell switch. RACH resource for CFRA for cell switch can be provided in RRC configuration to the UE.

[97] The LTM cell switch is supervised by a timer. The UE arrival in the target cell will be indicated to the network by uplink signaling, either MAC signaling or RRC signaling. The timer which is referred as Tcellswitch is started when the UE receives cell switch command and is stopped once the cell switch is completed. In an option,

Tcellswitch is defined as a new timer. In another option, existing NR RRC R17 timer T304 can be used for supervising LTM cell switch and all the embodiments for Tcellswitch in this invention are applicable for T304 when it is used for LTM, such as supervising LTM cell switch. Cell switch is completed once the UE successfully completes random access for RACH based cell switch. For RACH less cell switch, cell switch may be completed once a UL transmission is successful (for e.g. the UL transmission for indicating the in the target cell. UE also may perform random access without Random Access Response for LTM, if configured by the network. In Release 18 NR, LTM is supported in dual connectivity, NR-DC also.

[98] The 3gpp specifications such as TS38.300, TS38.331, TS 38.321 V17.4.0 as relevant background.

[99] FIG. 1 illustrates a sequence diagram of reporting feature specific random access channel information and LTM random access to network apparatus, according to the embodiment as disclosed herein. As shown in Fig. 1, UE (101) communicates with network apparatus (102) for optimization of random access procedure. The UE (101) is an end user device in a telecommunication network. For example, the UE is at least one of a mobile phone, tablet, computer, laptop, and smart watch. Further, the network apparatus (102) communicates with the UE (101) to provide network services. The network apparatus (102) is at least one of a base station, and server. At step S1, the UE (101) logs the feature specific RACH information and LTM RACH information. Further at step S2, the network apparatus (102) transmits a UE information request to the UE (101). The network apparatus (102) transmits the UE information request for optimizing the random access procedure. The UE information request comprises at least one of a Random Access (RA) report request, Radio Link Failure (RLF) report request and Connection Establishment Failure (CEF) report request. The UE information request is transmitted for self-optimization of random access in telecommunication network. The self optimization at the network apparatus (102) can be performed for minimization of drive tests. The telecommunication network is a group of nodes that are interconnected to exchange the messages between the nodes. The nodes in the telecommunication network can be at least one of the UE (101) and the network apparatus (102). Further, at step S3, the UE (101) performs the random acsees procedure with the network apparatus (102). Further at step S4, the UE (101) includes the random access information and the LTM RACH information in the at least one of the RA report, the RLF report and the CEF report.. Further, at step S5 the UE (101) transmits the UE information response to the network apparatus (102). The UE information response includes at least one of the RA report, the RLF report and the CEF report. The UE information response can be transmitted through the Radio Resource Control (RRC) message.

[100] FIG. 2A is a block diagram that illustrates a UE for handling random access channel information for self-organizing network system, according to the embodiment as disclosed herein.

[101] The User Equipment (UE) (101) includes a processor (201), a memory (203), an I/O interface (205) and a SON random access controller (207). The UE (101) can be an end-user device that connects with the network apparatus (102) to access services. For example, the UE (101) can include, but not limited to a mobile phone, a smart phone, tablets, laptops, Internet of Things (IoT) devices. Further, the processor (201) of the UE (101) communicates with the memory (203), the I/O interface (205) and the SON random access controller (207). The processor (201) is configured to execute instructions stored in the memory (203) and to perform various processes. The processor (201) can include one or a plurality of processors, can be a general-purpose processor, such as a central processing unit (CPU), an application processor (AP), or the like, a graphics-only processing unit such as a graphics processing unit (GPU), a visual processing unit (VPU), and/or an Artificial intelligence (AI) dedicated processor such as a neural processing unit (NPU).

[102] Further, the memory (203) of the UE (101) includes storage locations to be addressable through the processor (201). The memory (203) is not limited to a volatile memory and/or a non-volatile memory. Further, the memory (203) can include one or more computer-readable storage media. The memory (203) can include non-volatile storage elements. For example, non-volatile storage elements can include magnetic hard discs, optical discs, floppy discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories. The memory (203) can store the media streams such as audios stream, video streams, haptic feedbacks and the like. Also, the memory (203) of the UE (101) can store several information received the at least one of the network apparatus (102). For example, the memory can store several information such as random access configurations for performing the random access.

[103] The I/O interface (205) transmits the information between the memory (203) and external peripheral devices. The peripheral devices are the input-output devices associated with the UE (101). The I/O interface (205) receives several information from the network apparatus (102). The several information received from the network apparatus (102) can include but not limited to random access configurations for performing the random access.

[104] The SON random access controller (207) communicates with the I/O interface (205) and memory (203 handling random access channel (RACH) information for SON system. The SON random access controller (207) is an innovative hardware that is realized through the physical implementation of both analog and digital circuits,

including logic gates, integrated circuits, microprocessors, microcontrollers, memory circuits, passive and active electronic components, as well as optical components. The SON random access controller optimizer (207) of the UE (101) receives a signaling message from the network apparatus (102). The signaling message comprises the random access configuration for performing random access. Further, the SON random access controller optimizer (207) performs the random access based on the random access configuration upon an occurrence of an event. Further, the SON random access controller optimizer (207) determines whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold. The first RSRP threshold or the second RSRP threshold is indicated in the received random access configuration. Further, the SON random access controller optimizer (207) logs the random access information based random access performed. The random access information includes an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and the purpose of the random access. Particularly, the indication is provided using a Boolean RSRP above threshold. The purpose of the random access is provided as the LTM cell switch when the LTM cell switch command or LTM cell switch trigger is received from the network apparatus (102). Further, the SON random access controller optimizer (207) transmits the random access information to the network apparatus (102). The network apparatus (102) can use the random access information for self-optimizing the various network parameters and configurations.

[105] In an embodiment, the purpose of the random access is logged while performing the random access upon receiving the random access configuration. The random access configuration can be at least one of the release-17 random access configuration or the release-18 random access configuration.

[106] In an embodiment, the UE (101) which has performed random access logs and report the preamble Trans Max used for the random access to the network apparatus (102). In an embodiment, this information is logged in RA-Information Common. In an embodiment, this information is logged is RA_Report, RLF report and CEF report.

[107] In an embodiment, the UE (101) which has performed random access logs and report the power Ramping Step used for the random access to the network apparatus (102). In an embodiment, this information is logged in RA-Information Common. In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[108] In an embodiment, the UE (101) which has performed random access logs and report the preamble Received Target Power used for the random access to the network apparatus (102). In an embodiment, this information is logged in RA-InformationCommon. In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[109] In an embodiment, the UE (101) which has performed random access logs and report

the preamble Trans Max used for the random access to the network apparatus (102), if it has performed feature specific random access. In an embodiment, this information is logged in RA-Information Common. In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[110] In an embodiment, the UE (101) which has performed random access logs and report the power Ramping Step used for the random access to the gNB, if it has performed feature specific random access. In an embodiment,this information is logged in RA-Information Common.In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[111] In an embodiment, the UE (101) which has performed random access logs and report the preamble Received Target Power used for the random access to the network apparatus (102), if it has performed feature specific random access. In an embodiment, this information is logged in RA-InformationCommon. In an embodiment, this information is logged is RA_Report, RLF report and CEF report.

[112] In an embodiment, the UE (101) which has performed random access logs and report the preamble Trans Max used for the random access to the network apparatus (102), if it has performed feature specific random access and has used preamble Trans Max configured for the used feature combination. In an embodiment, this information is logged in RA-InformationCommon. In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[113] In an embodiment, the UE (101) which has performed random access logs and report the power Ramping Step used for the random access to the network apparatus (102), if it has performed feature specific random access and has used power Ramping Step configured for the used feature combination. In an embodiment, this information is logged in RA-Information Common. In an embodiment, this information is logged is RA_Report,RLF report and CEF report.

[114] In an embodiment, the UE which has performed random access logs and report the preamble Received Target Power used for the random access to the network apparatus (102), if it has performed feature specific random access and has used preamble Received Target Power configured for the used feature combination. In an embodiment, this information is logged in RA-Information Common. In an embodiment, this information is logged is RA_Report, RLF report and CEF report.

[115] In an embodiment, the UE (101) which has performed feature specific random access or the UE (101) for which feature specific random access was triggered and one of those features were slicing, includes the NSAGs associated with the S-NSSAI(s) triggering the access attempt (e.g. as informed by UE NAS to UE RRC) which are not included in SIB16, in the RA-Information Common and stores/reports to the network in RACH report, RLF report, CEF report. In an embodiment, the UE (101) which has

performed feature specific random access or the UE (101) for which feature specific random access was triggered and one of those features were slicing, excludes any NSAG associated with the S-NSSAI(s) triggering the access attempt (e.g. as informed by UE NAS to UE RRC) which are included in SIB16 and are not included in SIB1, in the RA-Information Common and stores/reports to the network in RACH report, RLF report, CEF report. In an embodiment, these NSAGs are reported as the NSAGs that has triggered RACH.

[116] In an alternate embodiment, the UE (101) which has performed feature specific random access or a UE (101) for which feature specific random access was triggered and one of those features were slicing, includes the NSAGs associated with the S-NSSAI(s) triggering the access attempt (e.g. as informed by UE NAS to UE RRC), in the RA-Information Common and stores/reports to the network in RACH report, RLF report, CEF report. In an embodiment, these NSAGs are reported as the NSAGs that has triggered RACH. In an embodiment, a gNB which receives such a RACH report, RLF report or CEF report including the NSAGs as in the above embodiment, filters out the NSAGs which are not applicable for RACH (i.e. filters in the NSAGs that are applicable for cell reselection) from the list of NSAGs.

[117] In an embodiment, the UE (101) which has performed random access due to Lower Layer Triggered Mobility (e.g. due to reception of cell switch command) informs the network apparatus (102) that a random access is performed due to LTM (i.e. due to cell switch command). In an embodiment, UE (101) informs network apparatus (102) that the random access is due to LTM as in the above embodiment through raPurpose field in RA-Report. A NR UE sets the ra-purpose-r16 to cellswitch (or any other value which communicates that the random access is performed for LTM or due to cellswitch command). In an embodiment, UE (101) uses a spare value in the ra-purpose-r16 IE to inform the gNB that random access is performed for cellswitch (LTM). Random access performed by LTM may use the feature specific configuration or non-feature specific configuration.

[118] In an embodiment, if the UE (101) has performed random access for LTM in SCG (i.e. cellswitch for SCG received from SN), the UE (101) stores the random access related information in RA-Report and informs the network apparatus (102) that it has performed random access due to LTM (cellswitchcommand). UE (101) sets RA-Purpose as cellswitch command or any equivalent value.

[119] In an embodiment, the above leads to below example changes in TS 38.331

[120]

```
RA-Report-r16 ::=              SEQUENCE {
   cellId-r16                  CHOICE {
      cellGlobalId-r16            CGI-Info-Logging-r16,
      pci-arfcn-r16               PCI-ARFCN-NR-r16
   },
  ra-InformationCommon-r16       RA-InformationCommon-r16              OPTIONAL,
   raPurpose-r16                   ENUMERATED {accessRelated, beamFailureRecovery,
reconfigurationWithSync, ulUnSynchronized,
                               schedulingRequestFailure,        noPUCCHResourceAvailable,
requestForOtherSI,
                               msg3RequestForOtherSI-r17,    cellswitch , spare7,    spare6,
spare5, spare4, spare3,
                               spare2, spare1},
   ...,
   [[
   spCellID-r17              CGI-Info-Logging-r16                 OPTIONAL
   ]]
}
```

[121] RA purpose is field is used to indicate the RA scenario for which the RA report entry is triggered. The RA accesses associated to Initial access from RRC_IDLE, RRC re-establishment procedure, transition from RRC-INACTIVE. The indicator beam Failure Recovery is used in case of successful beam failure recovery related RA procedure in the SpCell [3]. The indicator reconfigurationWithSync is used if the UE (101) executes a reconfiguration with sync. The indicator ulUnSynchronized is used if the random access procedure is initiated in a SpCell by DL or UL data arrival during RRC_CONNECTED when the time Alignment Timer is not running in the PTAG or if the RA procedure is initiated in a serving cell by a PDCCH order [3]. The indicator schedulingRequestFailure is used in case of SR failures [3]. The indicator noPUC-CHResourceAvailable is used when the UE has no valid SR PUCCH resources configured [3]. The indicator requestForOtherSI is used for MSG1 based on demand SI request. The indicator msg3RequestForOtherSI is used in case of MSG3 based SI request. The field can also be used for the SCG-related RA-Report when the raPurpose is set to beamFailureRecovery, reconfigurationWithSync, ulUnSynchronized, schedul-ingRequestFailure noPUCCHResourceAvailable and cellswitch. RA purpose cellswitch used if randomaccess is performed due to cell switch.

[122] In an embodiment, a NR UE which has performed a 4 step feature specific random access attempts logs and reports whether DL RSRP was above a threshold (field dlRSRPAboveThreshold in RA-InformationCommon-r16) based on whether the UE has received rsrp-ThresholdSSB-r17 in Feature Combination Preambles used for the same feature specific random access. If the NR UE has received rsrp-ThresholdSSB-r17 in the IE Feature Combination Preambles used for the feature specific random access attempt, UE logs and reports whether DL beam (SSB) quality

associated to the random access attempt was above or below this rsrp-ThresholdSSB-r17 to the network. This information will be logged in PerRAAttemptInfo-r16 IE in the PerRAAttemptInfoList-r16 IE and will be logged in RA-InformationCommon-r16 and included in RA-Report,RLF report and CEF report. The received rsrp-ThresholdSSB-r17 could have been used by UE for the random access operation. Alternatively, rsrp-ThresholdSSB-r17was not used by the UE, for e.g. when the random access is performed due to PDCCH order for uplink synchronization or due to early synchronization of LTM candidate cells. When rsrp-ThresholdSSB-r17 was not used by the UE, the reported field dlRSRPAboveThreshold helps in proactive optimisations. i.e. if the random access were used for some other random access purpose, the value could have been used, hence network uses the received parameters for proactive optimizations. dlRSRPAboveThreshold information in scenarios such as PDCCH order and LTM early synchronisation where the rsrp-ThresholdSSB-r17is not used also helps the network to identify the synchronization patterns.

[123] In an embodiment, a NR UE which has performed a 2 step feature specific random access attempts logs and reports whether DL RSRP was above a threshold (field dlRSRPAboveThreshold in RA-InformationCommon-r16) based on whether the UE has msgA-RSRP-Threshold-r17 in Feature Combination Preambles used for the feature specific random access. If the NR UE has received msgA-RSRP-Threshold-r17 in the IE Feature Combination Preambles used for the feature specific random access attempt, UE logs and reports whether DL beam (SSB) quality associated to the random access attempt was above or below this msgA-RSRP-Threshold-r17 to the network. This information will be logged in PerRAAttemptInfo-r16 IE in the PerRAAttemptInfoList-r16 IE and will be logged in RA-InformationCommon-r16 and included in RA-Report,RLF report and CEF report. The received msgA-RSRP-Threshold-r17 could have been used by UE for the random access operation. Alternatively, msgA-RSRP-Threshold-r17 was not used by the UE, for e.g. when the random access is performed due to PDCCH order for uplink synchronization or due to early synchronization of LTM candidate cells.When msgA-RSRP-Threshold-r17 was not used by the UE, the reported field dlRSRPAboveThreshold helps in proactive optimisations. i.e. if the random access were used for some other random access purpose, the value could have been used, hence network uses the received parameters for proactive optimizations. dlRSRPAboveThreshold information in scenarios such as PDCCH order and LTM early synchronisation where the msgA-RSRP-Threshold-r17 is not used also helps the network to identify the synchronization patterns.

[124] In an embodiment, RRC specification (TS 38.331) may include the below changes according to the above embodiments.

[125]

4> if the random-access attempt is performed on the contention based random-access resource; or 4> if the random-access attempt is performed on the contention free random-access resource and if the random-access procedure was initiated due to the PDCCH ordering: 5> if the random access attempt is a 4-step random access attempt and the SS/PBCH block RSRP of the SS/PBCH block corresponding to the random-access resource used in the random-access attempt is above rsrp-ThresholdSSB or rsrp-ThresholdSSB-r17 which is used for the selection of SSB ; or 5> if the random access attempt is a 2-step random access attempt and the SS/PBCH block RSRP of the SS/PBCH block corresponding to the random-access resource used in the random-access attempt is above *msgA-RSRP-ThresholdSSB* or msgA-rsrp-ThresholdSSB-r17 which is used (or could have been used if the random access was performed for operations other than PDCCH order RACH and LTM early synchronization) for the selection of SSB ; or : 6> set the dlRSRPAboveThreshold to true; 5> else: 6> set the dlRSRPAboveThreshold to false;

[126] The RA-InformationCommon field descriptions is provided in below Table. 5:

[127]

RA-InformationCommon **field descriptions**
absoluteFrequencyPointA This field indicates the absolute frequency position of the reference resource block (Common RB 0).
locationAndBandwidth Frequency domain location and bandwidth of the bandwidth part associated to the random-access resources used by the UE.
perRAInfoList, perRAInfoList-v1660 This field provides detailed information about each of the random access attempts in the chronological order of the random access attempts. If *perRAInfoList-v1660* is present, it shall contain the same number of entries, listed in the same order as in *perRAInfoList-r16*.
subcarrierSpacing Subcarrier spacing used in the BWP associated to the random-access resources used by the UE.

Table 5

[128] The RA-Report field descriptions is provided in below Table. 6 and Table. 7:

[129]

***RA-Report* field descriptions**
cellID This field indicates the CGI of the cell in which the associated random access procedure was performed.
contentionDetected This field is used to indicate that contention was detected for the transmitted preamble in the given random access attempt or not. This field is not included when the UE performs random access attempt is using contention free random-access resources or when the *raPurpose* is set to *requestForOtherSI* or when the RA attempt is a 2-step RA attempt and fallback to 4-step RA did not occur (i.e. *fallbackToFourStepRA* is not included).
csi-RS-Index, csi-RS-Index-v1660 This field is used to indicate the CSI-RS index corresponding to the random access attempt. If the random access procedure is for beam failure recovery, the field indicates the NZP-CSI-RS-ResourceId. For CSI-RS index larger than maxNrofCSI-RS-ResourcesRRM-1, the index value is the sum of csi-RS-Index (without suffix) and csi-RS-Index-v1660.
dlPathlossRSRP Measeured RSRP of the DL pathloss reference obtained at the time of *RA_Type* selection stage of the RA procedure as captured in TS 38.321 [3].
dlRSRPAboveThreshold In 4 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *rsrp-ThresholdSSB* in *beamFailureRecoveryConfig* in UL BWP configuration of UL BWP selected for random access procedure initiated for beam failure recovery; Otherwise, *if the UE has received* rsrp-ThresholdSSB-r17 in *FeatureCombinationPreambles used for the feature specific random access, the field is used to indicate whether* DL beam (SSB) quality associated to the random access attempt was above or below this rsrp-ThresholdSSB-r17, else *rsrp-ThresholdSSB* in *rach-ConfigCommon* in UL BWP configuration of UL BWP selected for random access procedure In 2 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *msgA-RSRP-ThresholdSSB* in *rach-ConfigCommonTwoStepRA* in UL BWP configuration of UL BWP selected for random access procedure or *if the UE has received* msgA-RSRP-Threshold-r17 in *FeatureCombinationPreambles used for the feature specific random access, the field is used to indicate whether* DL beam (SSB) quality associated to the random access attempt was above or below this msgA-RSRP-Threshold-r17

Table. 6

[130]

***RA-Report* field descriptions**
cellID This field indicates the CGI of the cell in which the associated random access procedure was performed.
contentionDetected This field is used to indicate that contention was detected for the transmitted preamble in the given random access attempt or not. This field is not included when the UE performs random access attempt is using contention free random-access resources or when the *raPurpose* is set to *requestForOtherSI* or when the RA attempt is a 2-step RA attempt and fallback to 4-step RA did not occur (i.e. *fallbackToFourStepRA* is not included).
csi-RS-Index, csi-RS-Index-v1660 This field is used to indicate the CSI-RS index corresponding to the random access attempt. If the random access procedure is for beam failure recovery, the field indicates the NZP-CSI-RS-ResourceId. For CSI-RS index larger than maxNrofCSI-RS-ResourcesRRM-1, the index value is the sum of csi-RS-Index (without suffix) and csi-RS-Index-v1660.
dlPathlossRSRP Measeured RSRP of the DL pathloss reference obtained at the time of *RA_Type* selection stage of the RA procedure as captured in TS 38.321 [3].
dlRSRPAboveThreshold In 4 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *rsrp-ThresholdSSB* in *beamFailureRecoveryConfig* in UL BWP configuration of UL BWP selected for random access procedure initiated for beam failure recovery; Otherwise, ***if the UE has received* rsrp-ThresholdSSB-r17 in *FeatureCombinationPreambles used for the feature specific random access, the field is used to indicate whether* DL beam (SSB) quality associated to the random access attempt was above or below this rsrp-ThresholdSSB-r17, else** *rsrp-ThresholdSSB* in *rach-ConfigCommon* in UL BWP configuration of UL BWP selected for random access procedure In 2 step random access procedure, this field is used to indicate whether the DL beam (SSB) quality associated to the random access attempt was above or below the threshold *msgA-RSRP-ThresholdSSB* in *rach-ConfigCommonTwoStepRA* in UL BWP configuration of UL BWP selected for random access procedure **or *if the UE has received* msgA-RSRP-Threshold-r17 in *FeatureCombinationPreambles used for the feature specific random access, the field is used to indicate whether* DL beam (SSB) quality associated to the random access attempt was above or below this msgA-RSRP-Threshold-r17**
fallbackToFourStepRA This field indicates if a fallback indication in MsgB is received (according to TS 38.321 [3]) for the 2-step random access attempt.
intendedSIBs This field indicates the SIB(s) the UE wanted to receive as a result of the on demand SI request (when the RA procedure is a used as a SI request) initiated by the UE. That is, it indicates the one(s) of the SIB(s) in the SI message(s) requested to be broadcast that the UE was interested in.
msg1-SCS-From-prach-ConfigurationIndex This field is set by the UE with the corresponding SCS for CBRA as derived from the *prach-ConfigurationIndex* in *RACH-ConfigGeneric* used for the random access when the *msg1-SubcarrierSpacing* is absent; otherwise, this field is absent.
msg1-SCS-From-prach-ConfigurationIndexCFRA This field is set by the UE with the corresponding SCS for CFRA as derived from the *prach-ConfigurationIndex* in *RACH-ConfigGeneric* used for the random access when the *msg1-SubcarrierSpacing* is absent; otherwise, this field is absent.

[131]

msgA-PUSCH-PayloadSize This field indicates the size of the overall payload available in the UE buffer at the time of initiating the 2 step RA procedure. The value refers to the index of TS 38.321 [3], table 6.1.3.1-1, corresponding to the UE buffer size.
msgA-RO-FDM This field indicates the number of msgA PRACH transmission occasions Frequency-Division Multiplexed in one time instance for the PRACH resources configured for 2-step CBRA..
msgA-RO-FDMCFRA This field indicates the number of msgA PRACH transmission occasions Frequency-Division Multiplexed in one time instance for the PRACH resources configured for 2-step CFRA.
msgA-RO-FrequencyStart This field indicates the lowest resource block of the contention based random-access resources for 2-step CBRA in the random-access procedure. The indication has the form of the offset of the lowest PRACH transmissions occasion with respect to PRB 0 in the frequency domain.
msgA-RO-FrequencyStartCFRA This field indicates the lowest resource block of the contention free random-access resources for the 2-step CFRA in the random-access procedure. The indication has the form of the offset of the lowest PRACH transmissions occasion with respect to PRB 0 in the frequency domain.
msgA-SCS-From-prach-ConfigurationIndex This field is set by the UE with the corresponding SCS as derived from the *msgA-PRACH-ConfigurationIndex* in *RACH-ConfigGenericTwoStepRA* (see tables Table 6.3.3.1-1, Table 6.3.3.1-2, Table 6.3.3.2-2 and Table 6.3.3.2-3, TS 38.211 [16]) when the *msgA-SubcarrierSpacing* is absent and when only 2-step random-access resources are available in the UL BWP used in the random-access procedure; otherwise, this field is absent.
numberOfPreamblesSentOnCSI-RS This field is used to indicate the total number of successive RA preambles that were transmitted on the corresponding CSI-RS.
numberOfPreamblesSentOnSSB This field is used to indicate the total number of successive RA preambles that were transmitted on the corresponding SS/PBCH block.
onDemandSISuccess This field is set to *true* when the RA report entry is included because of either msg1 based on demand SI request or msg3 based on demand SI request and if the on-demand SI request is successful. Otherwise, the field is absent.
perRAAttemptInfoList This field provides detailed information about a random access attempt.
perRACSI-RSInfoList This field provides detailed information about the successive random access attempts associated to the same CSI-RS.
perRASSBInfoList This field provides detailed information about the successive random access attempts associated to the same SS/PBCH block.
ra-InformationCommon This field is used to provide information on random access attempts. This field is mandatory present.

[132]

raPurpose This field is used to indicate the RA scenario for which the RA report entry is triggered. The RA accesses associated to Initial access from RRC_IDLE, RRC re-establishment procedure, transition from RRC-INACTIVE. The indicator *beamFailureRecovery* is used in case of successful beam failure recovery related RA procedure in the SpCell [3]. The indicator *reconfigurationWithSync* is used if the UE executes a reconfiguration with sync. The indicator *ulUnSynchronized* is used if the random access procedure is initiated in a SpCell by DL or UL data arrival during RRC_CONNECTED when the timeAlignmentTimer is not running in the PTAG or if the RA procedure is initiated in a serving cell by a PDCCH order [3]. The indicator *schedulingRequestFailure* is used in case of SR failures [3]. The indicator *noPUCCHResourceAvailable* is used when the UE has no valid SR PUCCH resources configured [3]. The indicator *requestForOtherSI* is used for MSG1 based on demand SI request. The indicator *msg3RequestForOtherSI* is used in case of MSG3 based SI request. The field can also be used for the SCG-related RA-Report when the *raPurpose* is set to *beamFailureRecovery*, *reconfigurationWithSync*, *ulUnSynchronized*, *schedulingRequestFailure* and *noPUCCHResourceAvailable*.
spCellID This field is used to indicate the CGI of the SpCell of the cell group associated to the SCell in which the associated random access procedure was performed. If the UE performs RA procedure on a SCell associated to the MCG, then this field is set to the CGI of the PCell and if the UE performs RA procedure on a SCell associated to the SCG, then this field is set to the CGI of the PSCell. If the CGI of the PSCell is not available at the UE for the RA procedure performed on a SCell associated to the SCG or for the RA procedure on the PSCell, this field is set to the CGI of the PCell. Otherwise, the field is absent.
ssb-Index This field is used to indicate the SS/PBCH index of the SS/PBCH block corresponding to the random access attempt.
ssbsForSI-Acquisition This field indicates the SSB(s) (in the form of SSB index(es)) that the UE used to receive the requested SI message(s). The field is present if the purpose of the random access procedure was to request on-demand SI (i.e. if the *raPurpose* is set to *requestForOtherSI* or *msg3RequestForOtherSI*). Otherwise, the field is absent.

Table. 7

[133] 5.7.10.5 RA information determination

[134] The UE shall set the content in ra-InformationCommon as follows:

[135]

<some text not relevant to the invention>
4> if the random-access attempt is performed on the contention based random-access resource; or
4> if the random-access attempt is performed on the contention free random-access resource and if the random-access procedure was initiated due to the PDCCH ordering:
5> if the random access attempt is a 4-step random access attempt and the SS/PBCH block RSRP of the SS/PBCH block corresponding to the random-access resource used (or could have been used if the random access was performed for operations other than PDCCH order RACH and LTM early synchronization) in the random-access attempt is above rsrp-ThresholdSSB or rsrp-ThresholdSSB-r17 which is used for the selection of SSB ; or
5> if the random access attempt is a 2-step random access attempt and the SS/PBCH block RSRP of the SS/PBCH block corresponding to the random-access resource used (or could have been used if the random access was performed for operations other than PDCCH order RACH and LTM early synchronization) in the random-access attempt is above msgA-RSRP-ThresholdSSB or msgA-rsrp-ThresholdSSB-r17 which is used for the selection of SSB; or
:
6> set the dlRSRPAboveThreshold to true;
5> else:
6> set the dlRSRPAboveThreshold to false;

[136] In an embodiment, a NR UE which has received both additional RACH configuration list and RACH configuration including RACH-ConfigGeneric and has performed random access using feature specific random access using RACH-ConfigGeneric in the additional RACH Configuration, sets the msg1-SCS-From-prach-ConfigurationIndex with the corresponding SCS for CBRA as derived from the prach-ConfigurationIndex in RACH-ConfigGeneric within the additional RACH configuration list when the msg1-SubcarrierSpacing is absent and when the RACH-ConfigGeneric includes prach-ConfigurationIndex.

[137] In an embodiment, the NR UE which has received both additional RACH configuration list and RACH configuration including RACH-ConfigGeneric and has performed random access using feature specific random access using RACH-ConfigGeneric in the additional RACH Configuration, sets the field msg1-SCS-From-prach-ConfigurationIndexCFRA with the corresponding SCS for CBRA as derived from the prach-ConfigurationIndex in RACH-ConfigGeneric within the additional RACH configuration list when the msg1-SubcarrierSpacing is absent and when the RACH-ConfigGeneric includes prach-ConfigurationIndex.

[138] In an embodiment, the NR UE which has received both additional RACH configuration list and RACH configuration including RACH-ConfigGeneric and has

performed random access using feature specific random access using RACH-ConfigGeneric in the additional RACH Configuration, sets the field msgA-SCS-From-prach-ConfigurationIndex with the corresponding SCS for CBRA as derived from the msgA-PRACH-ConfigurationIndex in RACH-ConfigGeneric within the additional RACH configuration list when the msg1-SubcarrierSpacing is absent and when the RACH-ConfigGeneric includes prach-ConfigurationIndex

[139] In an embodiment, the UE (101) logs and reports whether the random access is performed without Random Access Response. In an embodiment, the UE (101) logs and reports whether the random access is performed without Random Access Response, when the random access attempt is for PDCCH ordered-RACH for candidate cells in LTM. In an embodiment, the UE (101) logs and reports whether the reception of RAR is configured or indicated for the logged and reported random access. In an embodiment, UE (101) logs and reports the information in above embodiments in RA-Report or RLF report or CEF report. In an embodiment, UE (101) logs and reports the information in above embodiments in reports for providing information about Successful Handover or Successful PSCell Addition or Change.

[140] In an embodiment, the UE (101) logs and reports the number of retransmissions performed for the PRACH when reception of RAR is not configured/indicated. In an embodiment, UE (101) logs and reports the number of preambles transmitted for a single random access procedure when the reception of RAR is not configured/indicated. In an embodiment, UE logs and reports the power ramping step performed for each subsequent random access attempt.

[141] In an embodiment, the UE (101) logs and reports to the network apparatus (102), in all the above embodiments, also mean the network apparatus (102) receives from the UE (101). Reception is performed by the network apparatus (102) CU through RRC message.

[142] FIG. 2B is a block diagram that illustrates a network apparatus for optimizing random access in telecommunication network, according to the embodiment as disclosed herein.

[143] The network apparatus (102) includes a processor (209), a memory (211), an I/O interface (213) and a SON random access controller (215). The network apparatus (102) communicates with the UE (101) for self-optimization when random access procedure is performed. For example, the network apparatus (102) can include, but not limited to a base station access point, a central server, or similar equipment. Further, the processor (209) of the network apparatus (102) communicates with the memory (211), the I/O interface (213) and the SON random access controller (215). The processor (209) is configured to execute instructions stored in the memory (211) and to perform various processes. The processor (209) can include one or a plurality of

processors, can be a general-purpose processor, such as a central processing unit (CPU), an application processor (AP), or the like, a graphics-only processing unit such as a graphics processing unit (GPU), a visual processing unit (VPU), and/or an Artificial intelligence (AI) dedicated processor such as a neural processing unit (NPU).

[144] Further, the memory (211) of the UE (102) includes storage locations to be addressable through the processor (209). The memory (211) is not limited to a volatile memory and/or a non-volatile memory. Further, the memory (211) can include one or more computer-readable storage media. The memory (211) can include non-volatile storage elements. For example, non-volatile storage elements can include magnetic hard discs, optical discs, floppy discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories. The memory (203) can store the media streams such as audios stream, video streams, haptic feedbacks and the like. Also, the memory (211) of the network apparatus (102) can store several information received from the UE (101). For example, the memory (211) can store several information such as UE information response that further includes RA report, RLF report and CEF report and the like.

[145] The I/O interface (213) transmits the information between the memory (211) and external peripheral devices. The peripheral devices are the input-output devices associated with the network apparatus (102). The I/O interface (213) receives several information from the network apparatus (102). The several information received from the UE (101) can include but not limited to the RA report, RLF report and CEF report in the UE information response.

[146] The SON random access controller (215) communicates with the I/O interface (213) and memory (211) for handling RACH information for SON system. The SON random access controller (215) is an innovative hardware that is realized through the physical implementation of both analog and digital circuits, including logic gates, integrated circuits, microprocessors, microcontrollers, memory circuits, passive and active electronic components, as well as optical components. The SON random access controller (215) of the network apparatus (102) transmits a signaling message to the UE (101) wherein the signaling message comprises at least one of a random access configuration for performing random access. Further, the SON random access controller (215) receives a random access information from the UE (101). The random access information comprises at least one of an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access. Further, the SON random access controller (215) performs resource optimization for random access based on the random access information.

[147] In an embodiment, the network apparatus (102) CU which receives the new information as in all the above embodiments, optimizes the random access related pa-

rameters itself and also transfers the information to network apparatus DU and Operation, Administration and Management (OAM) modules.

[148] In an embodiment, the signaling message can be at least one of the RRC message. RRC message could be a system information message or a dedicated message such as RRCReconfiguration message. On receiving the RRC message including the details of feature specific random access resource selection, a gNB RRC in gNB CU may forward it to gNB DU and to the SON module, for e.g. OAM. SON module in CU/DU or SON module outside gNB can identify if the amount of resources allocated for a particular feature or a particular scenario within the feature (for e.g. resources for a particular slice-group) is optimum based on the received information. Further, the resources allocated per feature or per slice-group could be increased or decreased based on the received information. A Self-optimization module in the network may also adapt the criteria for using the feature specific random access resources and other RACH parameters based on the received information from the UE (101). Further Self optimization module optimizes the LTM related aspects including whether UE can perform random access without RAR, whether UE (101) can retransmit random access without RAR and so using the received information.

[149] An example of some of the parameters which may be optimized based on the methods specified are given below.

[150] 1. SSB selection related parameters, i.e., rsrp-ThresholdSSB, msgA-RSRP-ThresholdSSB.

[151] 2. Power control related parameters, i.e., preambleReceivedTargetPower/ gA-PreambleReceivedTargetPower, powerRampingStep/ msgA-PreamblePowerRampingStep, msg3-DeltaPreamble/msgA-DeltaPreamble.

[152] 3. Preamble group related parameters, i.e., msg3-DeltaPreamble/msgA-DeltaPreamble, messagePowerOffsetGroupB for 2-step RA and 4-step RA.

[153] 4. ra-Msg3SizeGroupA, messagePowerOffsetGroupB and numberOfRA-PreamblesGroupA when Preamble Group B, msg3 repetitions etc.

[154] Slicegroup or msg3 repetition specific parameters like scalingFactorBI and powerRampingStepHighPriority for slicing or enableRA-PrioritizationForSlicing.

[155] FIG.3A is a flow diagram that illustrates a method for optimizing random access in telecommunication network, according to the embodiment as disclosed herein;

[156] At block 301, the SON random access controller (207) receives a signaling message from the network apparatus (102). The signaling message comprises a random access configuration for performing random access. The random access configuration can be at least one of the release-17 random access configuration or the release-18 random access configuration.

[157] At block 303, the SON random access controller (207) performs the random access based on the received random access configuration upon occurrence of the event. Particularly, the random access is performed when an event occurs. The events can be one of the initial connection establishment, the recovery from beam failure, the loss of Uplink synchronisation, the reception of a LTM cell switch command, the service request failure, the Listen before Transmission failure, the LTM cell switch trigger after radio link failure or cell switch failure, the PDCCH order from the network apparatus (102) for synchronisation or early synchronisation of LTM candidate cells or others.

[158] At block 305, the SON random access controller (207) determines whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold. The first RSRP threshold is the RSRP-thresholdSSB when the 4 step random access is performed. Similarly, the second RSRP threshold is the msgA-RSRP-ThresholdSSB when the 2 step random access is performed.

[159] At block 307, the SON random access controller (207) logs the random access information based on the random access performed. The random access information includes an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and the purpose of the random access. Particularly, when the random access is performed due to the LTM cell switch event, then the purpose of the random access is mentioned as cell switch in the random access information.

[160] At block 309, the SON random access controller (207) transmits the random access information to the network apparatus (102), so that the network apparatus (102) can utilize the random access information for the self-optimization.

[161] FIG. 3B is a flow diagram that illustrates a method for performing random access for LTM in telecommunication network, according to the embodiment as disclosed herein.

[162] At block 311, the SON random access controller (207) receives a signaling message from the network apparatus (102). The signaling message comprises a random access configuration for performing random access. The random access configuration can be at least one of the release-17 random access configuration or the release-18 random access configuration.

[163] At block 313, the SON random access controller (207) performs the random access based on the received random access configuration upon receiving a trigger for LTM.

[164] At block 315, the SON random access controller (207) logs the random access information based on the random access performed. The random access information includes an the purpose of the random access is due to the LTM cell switch event.

[165] At block 317, the SON random access controller (207) transmits the random access information to the network apparatus (102), so that the network apparatus (102) can utilize the random access information for the self-optimization

[166] FIG. 3C is a flow diagram that illustrates a method for determining RSRP is above at a threshold for 2 step random access and 4-step random access, according to the embodiment as disclosed herein.

[167] At block 321, the SON random access controller (207) receives a signaling message from the network apparatus (102). The signaling message comprises a random access configuration for performing random access. The random access configuration can be at least one of the release-17 random access configuration or the release-18 random access configuration.

[168] At block 323, the SON random access controller (207) determines whether the DL RSRP is above the RSRP-thresholdSSB when 4 step random access or msgA-RSRP-ThresholdSSB when the 2 step random access the is performed.

[169] At block 325, the SON random access controller (207) logs the random access information based on the random access performed. The random access information includes an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold.

[170] At block 327, the SON random access controller (207) transmits the random access information to the network apparatus (102), so that the network apparatus (102) can utilize the random access information for the self-optimization.

[171] FIG.4 is a flow diagram that illustrates a method for optimizing random access in telecommunication network, according to the embodiment as disclosed herein.

[172] At block 401, the SON random access controller (215) transmits the signaling message to the UE (101). The signaling message includes the random access configuration for the UE (101) to perform the random access.

[173] At block 403, the SON random access controller (215) receives a random access information from the UE (101). The random access information includes the indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and the purpose of the random access. The indication provided is a Boolean value. The indication can be set at least one of TRUE or FALSE.

[174] At block 405, the SON random access controller (215) forwards the received random information to at least one of the DU, OAM and the other CU.

[175] At block 407, the SON random access controller (215) performs self -optimization for the random access based on the random access information. The SON random access controller (215) can optimize the LTM related aspects such as whether the UE (101) can perform random access without RAR.

[176] FIG. 5 illustrates a block diagram of a terminal (or a user equipment (UE)), according to embodiments of the present disclosure. FIG. 5 corresponds to the example of the UE of FIG. 2a.

[177] As shown in FIG. 5, the UE according to an embodiment may include a transceiver

510, a memory 520, and a processor 530. The transceiver 510, the memory 520, and the processor 530 of the UE may operate according to a communication method of the UE described above. However, the components of the UE are not limited thereto. For example, the UE may include more or fewer components than those described above. In addition, the processor 530, the transceiver 510, and the memory 520 may be implemented as a single chip. Also, the processor 530 may include at least one processor.

[178] The transceiver 510 collectively refers to a UE receiver and a UE transmitter, and may transmit/receive a signal to/from a base station or a network entity. The signal transmitted or received to or from the base station or a network entity may include control information and data. The transceiver 510 may include a RF transmitter for up-converting and amplifying a frequency of a transmitted signal, and a RF receiver for amplifying low-noise and down-converting a frequency of a received signal. However, this is only an example of the transceiver 510 and components of the transceiver 510 are not limited to the RF transmitter and the RF receiver.

[179] Also, the transceiver 510 may receive and output, to the processor 530, a signal through a wireless channel, and transmit a signal output from the processor 530 through the wireless channel.

[180] The memory 520 may store a program and data required for operations of the UE. Also, the memory 520 may store control information or data included in a signal obtained by the UE. The memory 520 may be a storage medium, such as read-only memory (ROM), random access memory (RAM), a hard disk, a CD-ROM, and a DVD, or a combination of storage media.

[181] The processor 530 may control a series of processes such that the UE operates as described above. For example, the transceiver 510 may receive a data signal including a control signal transmitted by the base station or the network entity, and the processor 530 may determine a result of receiving the control signal and the data signal transmitted by the base station or the network entity.

[182] FIG. 6 illustrates a block diagram of a base station, according to embodiments of the present disclosure. FIG. 6 corresponds to the example of the gNB of FIG. 2b.

[183] As shown in FIG. 6, the base station according to an embodiment may include a transceiver 610, a memory 620, and a processor 630. The transceiver 610, the memory 620, and the processor 630 of the base station may operate according to a communication method of the base station described above. However, the components of the base station are not limited thereto. For example, the base station may include more or fewer components than those described above. In addition, the processor 630, the transceiver 610, and the memory 620 may be implemented as a single chip. Also, the processor 630 may include at least one processor.

[184] The transceiver 610 collectively refers to a base station receiver and a base station

transmitter, and may transmit/receive a signal to/from a terminal or a network entity. The signal transmitted or received to or from the terminal or a network entity may include control information and data. The transceiver 610 may include a RF transmitter for up-converting and amplifying a frequency of a transmitted signal, and a RF receiver for amplifying low-noise and down-converting a frequency of a received signal. However, this is only an example of the transceiver 610 and components of the transceiver 610 are not limited to the RF transmitter and the RF receiver.

[185] Also, the transceiver 610 may receive and output, to the processor 630, a signal through a wireless channel, and transmit a signal output from the processor 630 through the wireless channel.

[186] The memory 620 may store a program and data required for operations of the base station. Also, the memory 620 may store control information or data included in a signal obtained by the base station. The memory 620 may be a storage medium, such as read-only memory (ROM), random access memory (RAM), a hard disk, a CD-ROM, and a DVD, or a combination of storage media.

[187] The processor 630 may control a series of processes such that the base station operates as described above. For example, the transceiver 610 may receive a data signal including a control signal transmitted by the terminal, and the processor 630 may determine a result of receiving the control signal and the data signal transmitted by the terminal.

[188] In the afore-described embodiments of the present disclosure, elements included in the present disclosure are expressed in a singular or plural form according to the embodiments. However, the singular or plural form is appropriately selected for convenience of explanation and the present disclosure is not limited thereto. As such, an element expressed in a plural form may also be configured as a single element, and an element expressed in a singular form may also be configured as plural elements.

[189] The various actions, acts, blocks, steps, or the like in the method is performed in the order presented, in a different order or simultaneously. Further, in some embodiments, some of the actions, acts, blocks, steps, or the like are omitted, added, modified, skipped, or the like without departing from the scope of the proposed method.

[190] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred

embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the scope of the embodiments as described herein.

Claims

[Claim 1] A method performed by a user equipment (UE) in a wireless communication system, the method comprising:
receiving, from a base station (BS), configuration information for a feature specific random access (RA), the configuration information including a first threshold and a second threshold;
performing the feature specific RA based on the first threshold and the second threshold; and
transmitting, to the BS, RA information associated with the feature specific RA, the RA information including information indicating whether a quality of synchronization signal/physical broadcast channel block (SSB) for the feature specific RA is above the second threshold.

[Claim 2] The method of claim 1,
wherein the first threshold is for selecting a type of the feature specific RA as 2-step RA or 4-step RA.

[Claim 3] The method of claim 2,
wherein the second threshold is a reference signal received power (RSRP) threshold for selecting the SSB associated with the 2-step RA or the 4-step RA, and
wherein the RSRP threshold is for identifying whether a RSRP of the SSB is above in the 2-step RA or the 4-step RA.

[Claim 4] The method of claim 1,
wherein the feature specific RA is for a lower layer triggered mobility (LTM),
wherein the RA information further includes information indicating that the feature specific RA is performed for the LTM.

[Claim 5] A method performed by a base station (BS) in a wireless communication system, the method comprising:
transmitting, to a user equipment (UE), configuration information for a feature specific random access (RA), the configuration information including a first threshold and a second threshold; and
receiving, from the UE, RA information indicating whether a quality of synchronization signal/physical broadcast channel block (SSB) associated with the feature specific RA is above or below the second threshold.

[Claim 6] The method of claim 5,
wherein the first threshold is for a type of the feature specific RA as

2-step RA or 4-step RA.

[Claim 7] The method of claim 6,
wherein the second threshold is a reference signal received power (RSRP) threshold for he SSB associated with the 2-step RA or the 4-step RA.

[Claim 8] The method of claim 5,
wherein the feature specific RA is for a lower layer triggered mobility (LTM),
wherein the RA information further includes information indicating that the feature specific RA is performed for the LTM.

[Claim 9] A user equipment (UE) in a wireless communication system, the UE comprising:
a transceiver, and
a controller coupled with the transceiver and configured to:
receive, from a base station (BS), configuration information for a feature specific random access (RA), the configuration information including a first threshold and a second threshold;
perform the feature specific RA based on the first threshold and the second threshold; and
transmit, to the BS, RA information associated with the feature specific RA, the RA information including information indicating whether a quality of synchronization signal/physical broadcast channel block (SSB) for the feature specific RA is above the second threshold.

[Claim 10] The UE of claim 9,
wherein the first threshold is for selecting a type of the feature specific RA as 2-step RA or 4-step RA.

[Claim 11] The UE of claim 10,
wherein the second threshold is a reference signal received power (RSRP) threshold for selecting the SSB associated with the 2-step RA or the 4-step RA, and
wherein the RSRP threshold is for identifying whether a RSRP of the SSB is above in the 2-step RA or the 4-step RA.

[Claim 12] The UE of claim 9,
wherein the feature specific RA is for a lower layer triggered mobility (LTM),
wherein the RA information further includes information indicating that the feature specific RA is performed for the LTM.

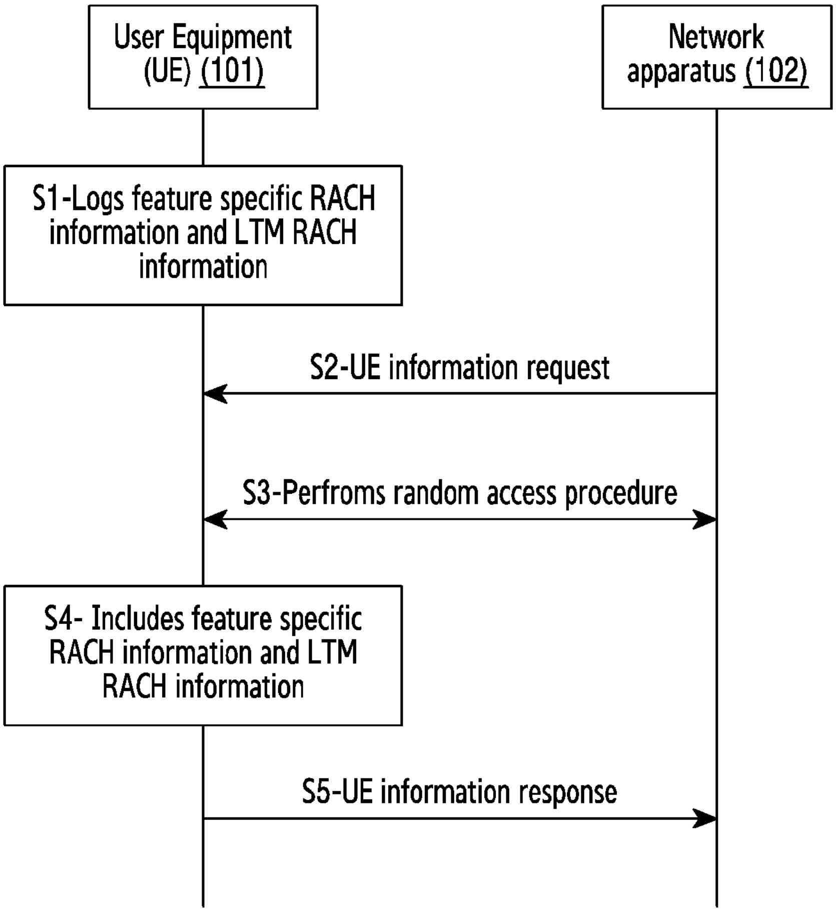
[Claim 13] A base station (BS) in a wireless communication system, the BS

comprising:
a transceiver, and
a controller coupled with the transceiver and configured to:
transmit, to a user equipment (UE), configuration information for a feature specific random access (RA), the configuration information including a first threshold and a second threshold; and
receive, from the UE, RA information indicating whether a quality of synchronization signal/physical broadcast channel block (SSB) associated with the feature specific RA is above or below the second threshold.

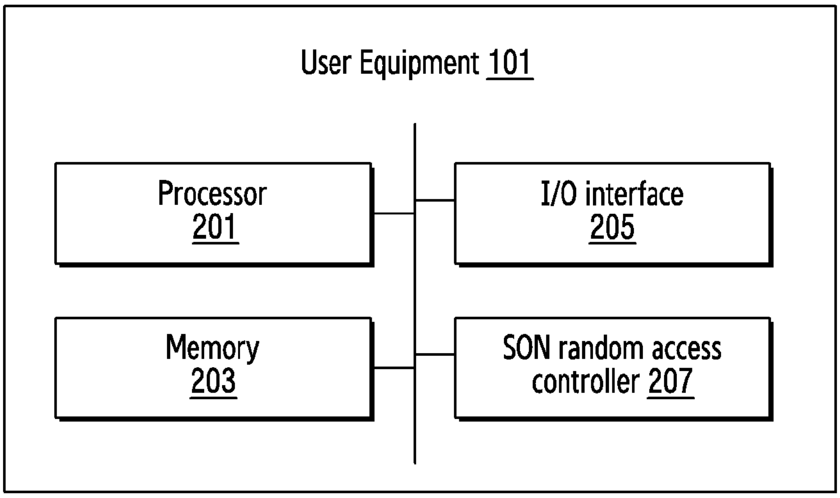
[Claim 14] The BS of claim 13,
wherein the first threshold is for a type of the feature specific RA as 2-step RA or 4-step RA.

[Claim 15] The BS of claim 14,
wherein the second threshold is a reference signal received power (RSRP) threshold for the SSB associated with the 2-step RA or the 4-step RA.

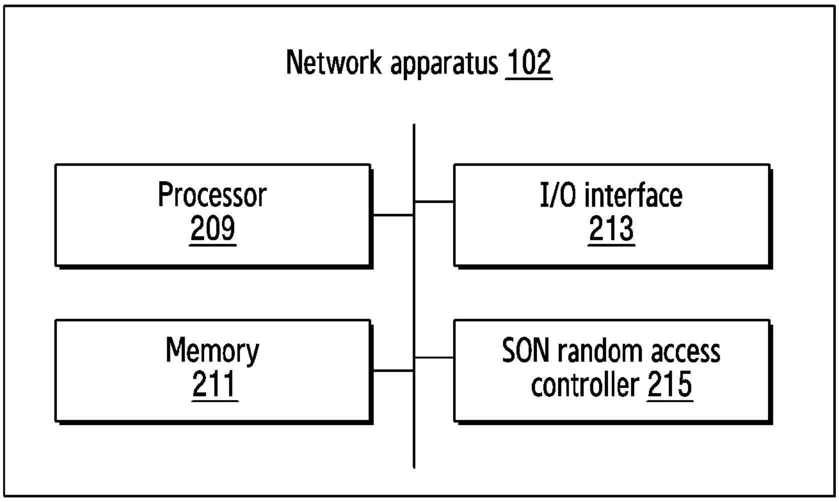
[Fig. 1]


User Equipment (UE) (101)
Network apparatus (102)
S1-Logs feature specific RACH information and LTM RACH information
S2-UE information request
S3-Perfroms random access procedure
S4- Includes feature specific RACH information and LTM RACH information
S5-UE information response

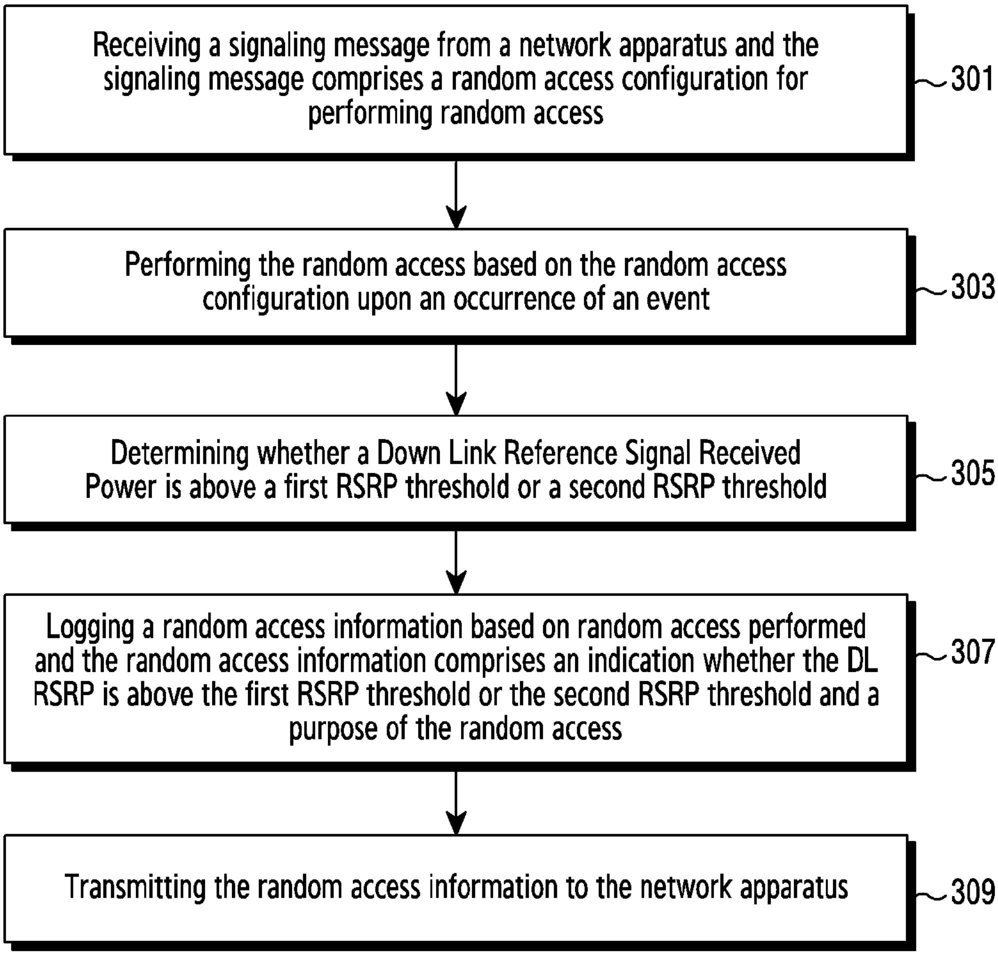
[Fig. 2A]


User Equipment 101
Processor 201
I/O interface 205
Memory 203
SON random access controller 207

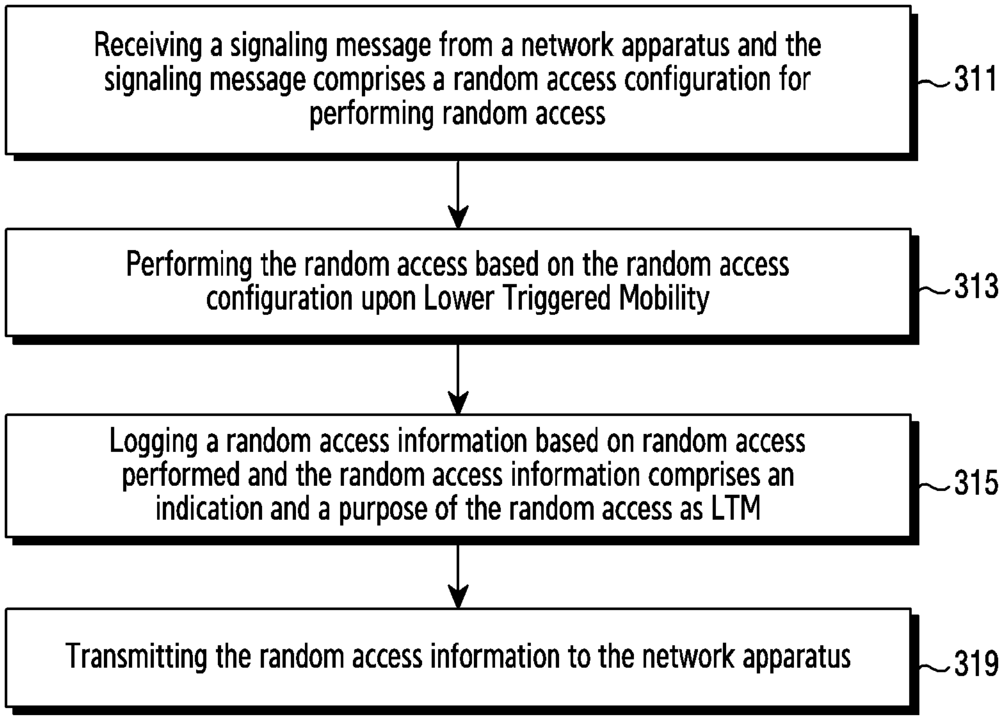
[Fig. 2B]


Network apparatus 102
Processor 209
I/O interface 213
Memory 211
SON random access controller 215

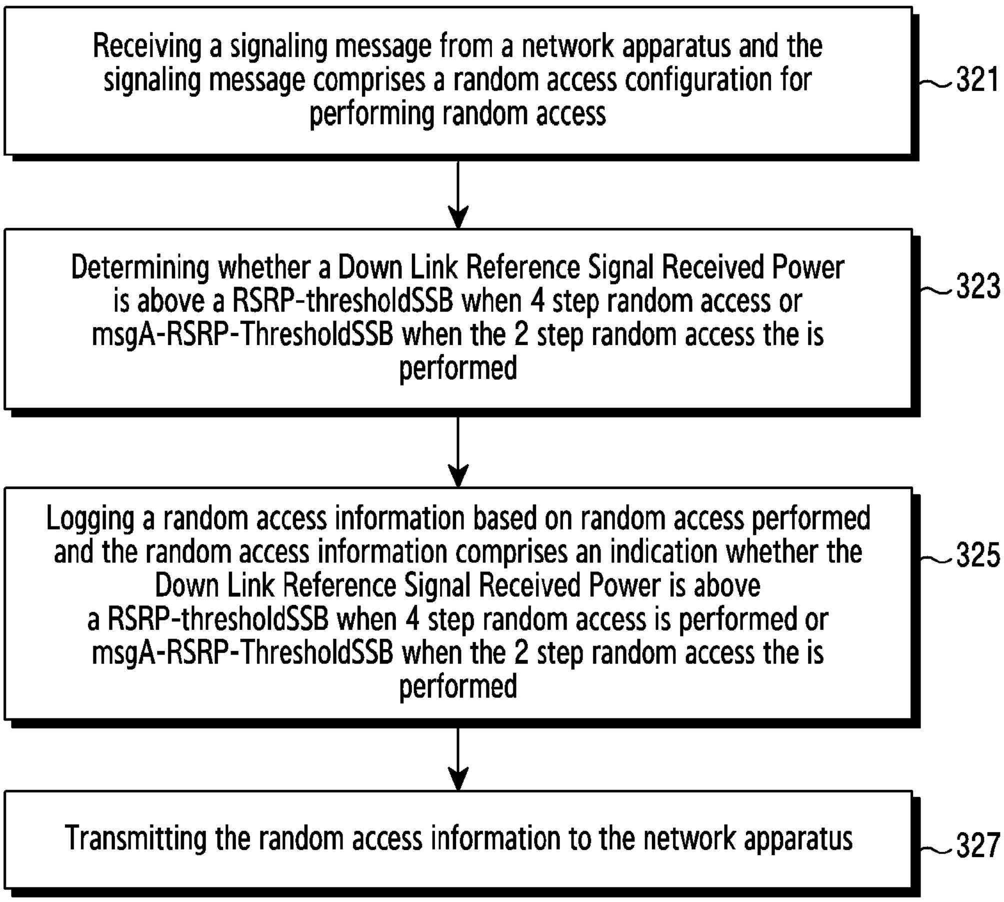
[Fig. 3A]


Receiving a signaling message from a network apparatus and the signaling message comprises a random access configuration for performing random access
301
Performing the random access based on the random access configuration upon an occurrence of an event
303
Determining whether a Down Link Reference Signal Received Power is above a first RSRP threshold or a second RSRP threshold
305
Logging a random access information based on random access performed and the random access information comprises an indication whether the DL RSRP is above the first RSRP threshold or the second RSRP threshold and a purpose of the random access
307
Transmitting the random access information to the network apparatus
309

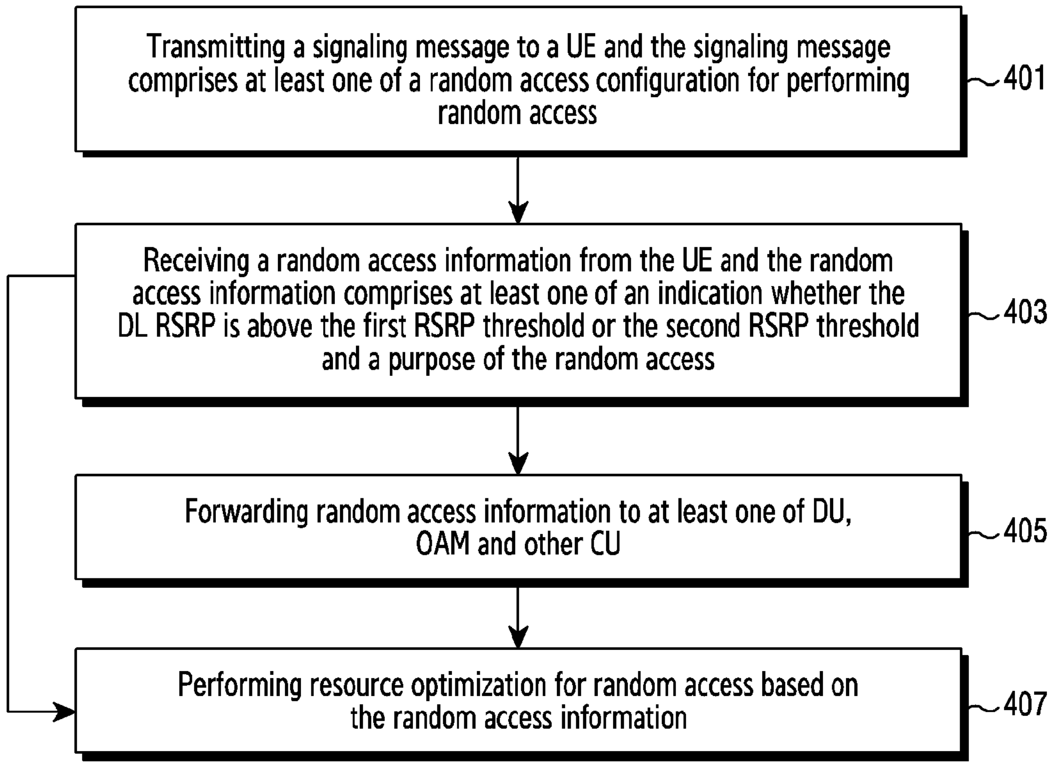
[Fig. 3B]


Receiving a signaling message from a network apparatus and the signaling message comprises a random access configuration for performing random access
311
Performing the random access based on the random access configuration upon Lower Triggered Mobility
313
Logging a random access information based on random access performed and the random access information comprises an indication and a purpose of the random access as LTM
315
Transmitting the random access information to the network apparatus
319

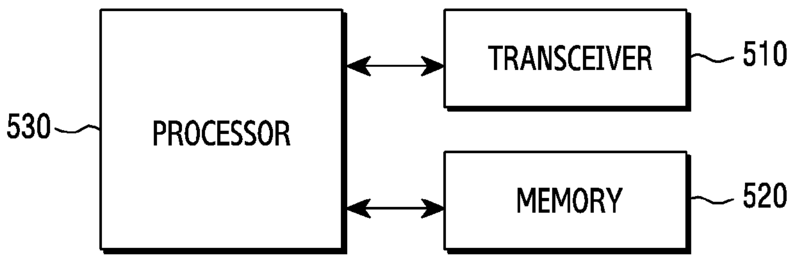
[Fig. 3C]


Receiving a signaling message from a network apparatus and the signaling message comprises a random access configuration for performing random access
321
Determining whether a Down Link Reference Signal Received Power is above a RSRP-thresholdSSB when 4 step random access or msgA-RSRP-ThresholdSSB when the 2 step random access the is performed
323
Logging a random access information based on random access performed and the random access information comprises an indication whether the Down Link Reference Signal Received Power is above a RSRP-thresholdSSB when 4 step random access is performed or msgA-RSRP-ThresholdSSB when the 2 step random access the is performed
325
Transmitting the random access information to the network apparatus
327

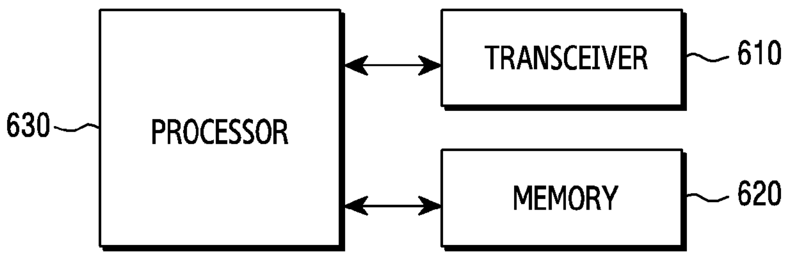
[Fig. 4]



[Fig. 5]



[Fig. 6]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/004840

A. CLASSIFICATION OF SUBJECT MATTER

H04W 36/00(2009.01)i; **H04W 36/30**(2009.01)i; **H04B 17/318**(2015.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 36/00(2009.01); H04L 5/00(2006.01); H04W 24/00(2009.01); H04W 24/10(2009.01); H04W 74/08(2009.01); H04W 76/20(2018.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: first threshold, second threshold, feature specific random access (RA) configuration , SSB quality, above, RA information

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
DX DA	`3GPP; TSG RAN; NR; Radio Resource Control (RRC) protocol specification (Release 17)', 3GPP TS 38.331 V17.4.0, 30 March 2023 pages 268-275, 446, 511-514, 602-606, 777-784; and figure 5.7.10.1-1	1-3,5-7,9-11,13-15 4,8,12
A	WO 2023-012705 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 09 February 2023 (2023-02-09) paragraphs [0051]-[0079]; and figures 1-3	1-15
A	WO 2022-141438 A1 (LENOVO (BEIJING) LIMITED) 07 July 2022 (2022-07-07) paragraphs [0074]-[0078]; and figure 4	1-15
A	US 2023-0077603 A1 (ZTE CORPORATION) 16 March 2023 (2023-03-16) paragraphs [0024]-[0063]; and figure 3	1-15
A	EP 4120725 A1 (SAMSUNG ELECTRONICS CO., LTD.) 18 January 2023 (2023-01-18) paragraphs [0062]-[0069]; and figures 10A-12	1-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 July 2024	**25 July 2024**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/004840

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				EP	4381884	A1	12 June 2024
WO	2022-141438	A1	07 July 2022	US	2024-0121832	A1	11 April 2024
US	2023-0077603	A1	16 March 2023	CN	115399052	A	25 November 2022
				EP	4118918	A1	18 January 2023
				EP	4118918	A4	10 May 2023
				WO	2021-109388	A1	10 June 2021
EP	4120725	A1	18 January 2023	KR	10-2021-0125941	A	19 October 2021
				US	2023-0217485	A1	06 July 2023
				WO	2021-206487	A1	14 October 2021