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(54) **USER EQUIPMENT APPARATUS, BASE STATION APPARATUS, AND COMMUNICATION METHOD**

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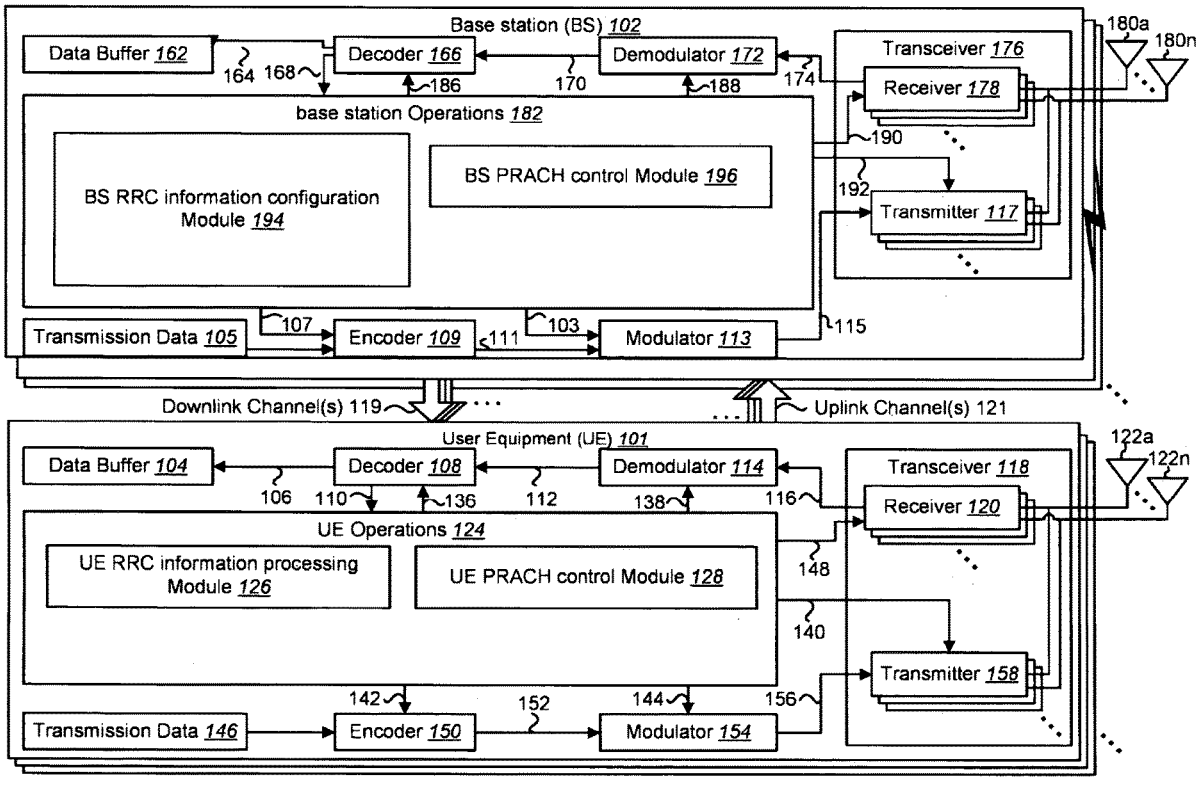
(57) **ABSTRACT**

A UE includes reception circuitry configured to receive PRACH configuration information comprising a first RSRP threshold and a first list of preamble index ranges, and control circuitry configured to, if one of one or more SSBs with SS-RSRP above the first RSRP threshold is available, select an SSB with SS-RSRP above the first RSRP threshold; else select any SSB, wherein in a first case that the PRACH configuration information further provides a second list of preamble index ranges, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in second list, in a second case that the PRACH configuration information does not provide the second list, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list.



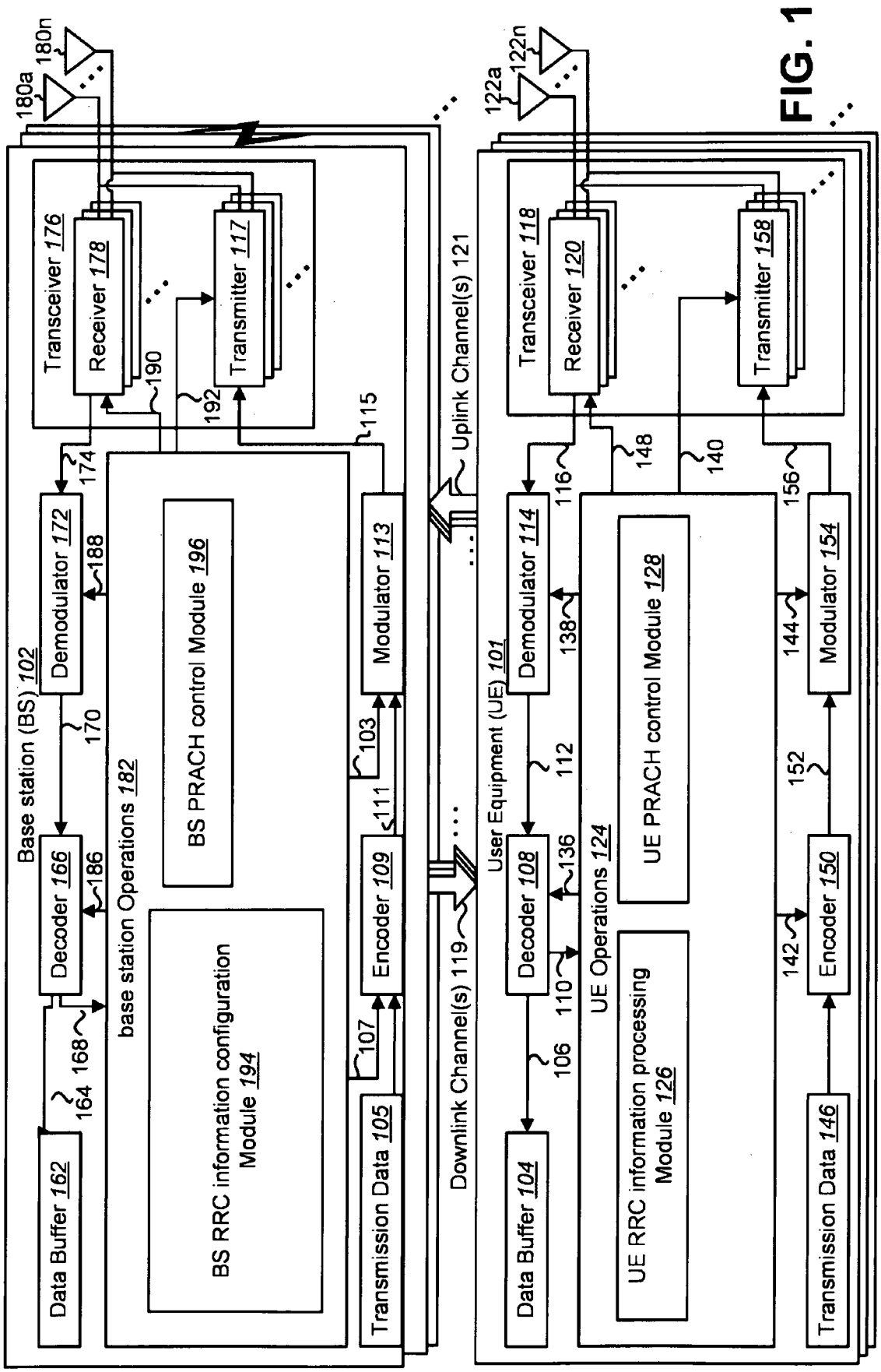

Base station (BS) 102
Transceiver 176
Receiver 178
Transmitter 117
Demodulator 172
Decoder 166
Data Buffer 162
base station Operations 182
BS PRACH control Module 196
BS RRC information configuration Module 194
Modulator 113
Encoder 109
Transmission Data 105
Uplink Channel(s) 121
Downlink Channel(s) 119
User Equipment (UE) 101
Transceiver 118
Receiver 120
Transmitter 158
Demodulator 114
Decoder 108
Data Buffer 104
UE Operations 124
UE PRACH control Module 128
UE RRC information processing Module 126
Modulator 154
Encoder 150
Transmission Data 146
180a
180n
122a
122n
190
192
115
174
188
170
186
168
164
103
111
107
116
148
140
156
138
112
136
110
106
144
152
142

FIG. 1

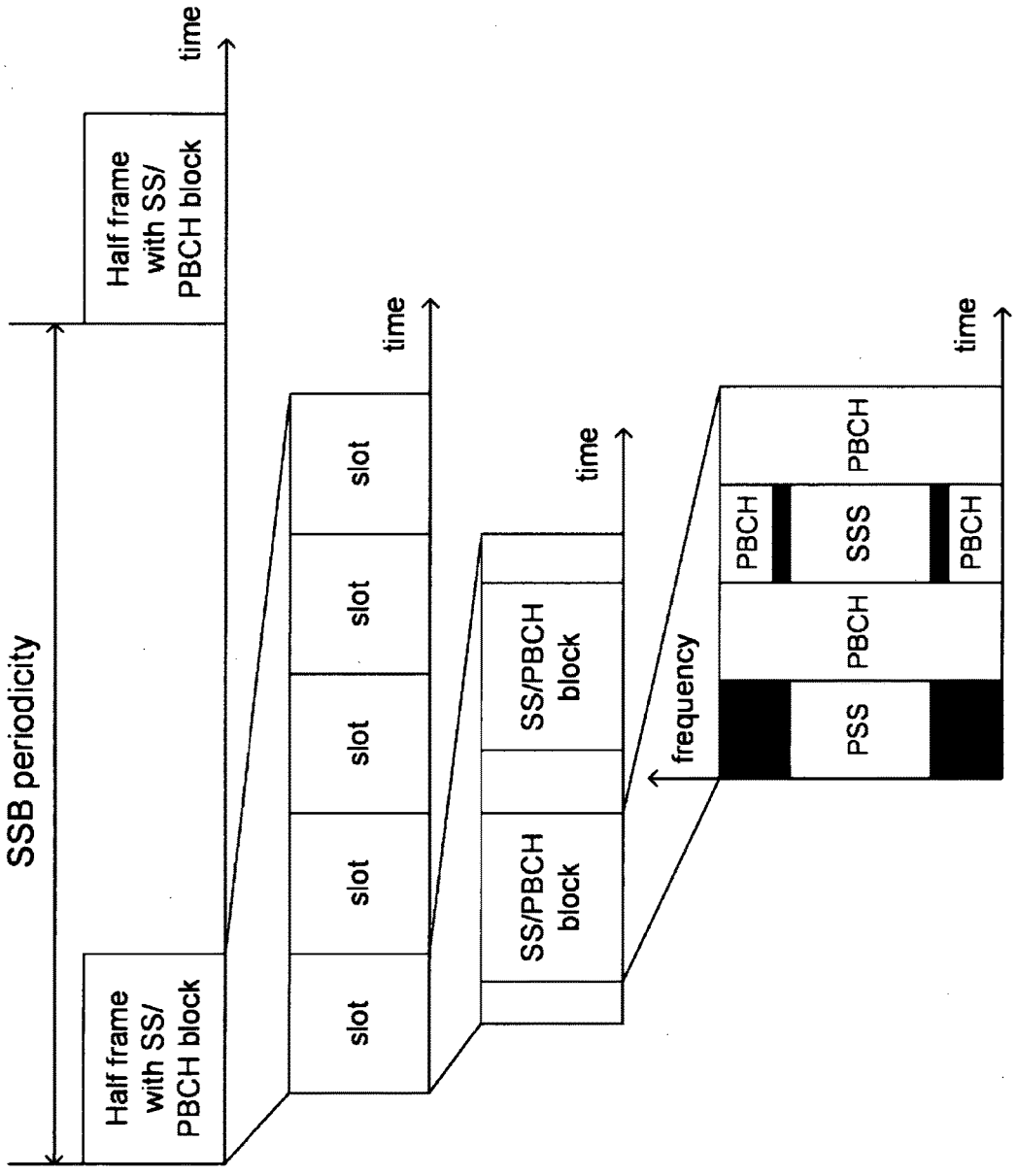

SSB periodicity
Half frame with SS/ PBCH block
Half frame with SS/ PBCH block
time
slot
slot
slot
slot
slot
time
SS/PBCH block
SS/PBCH block
time
frequency
PSS
PBCH
SSS
PBCH
PBCH
PBCH
time

FIG. 2

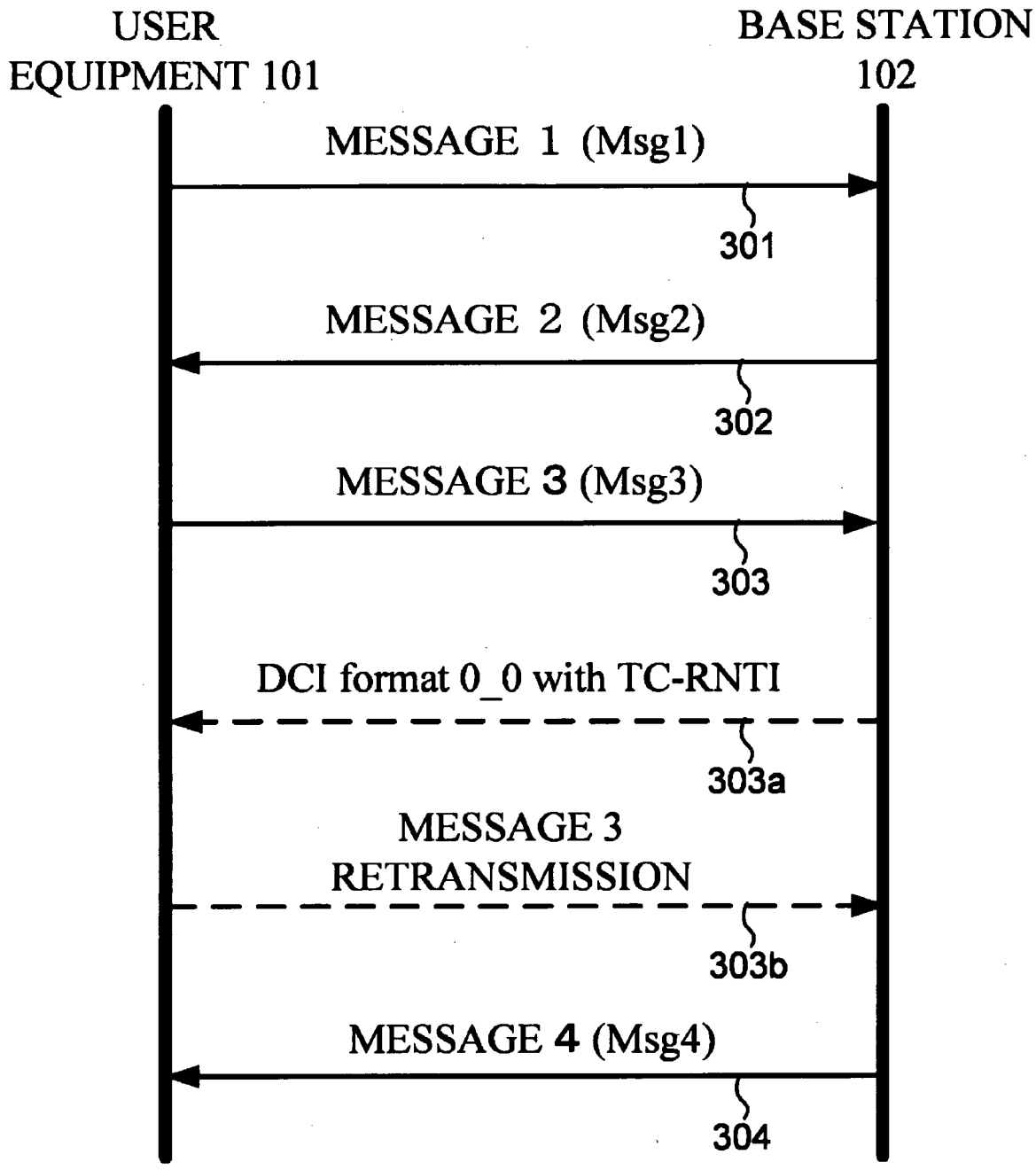

USER EQUIPMENT 101
BASE STATION 102
MESSAGE 1 (Msg1)
301
MESSAGE 2 (Msg2)
302
MESSAGE 3 (Msg3)
303
DCI format 0_0 with TC-RNTI
303a
MESSAGE 3 RETRANSMISSION
303b
MESSAGE 4 (Msg4)
304

FIG. 3

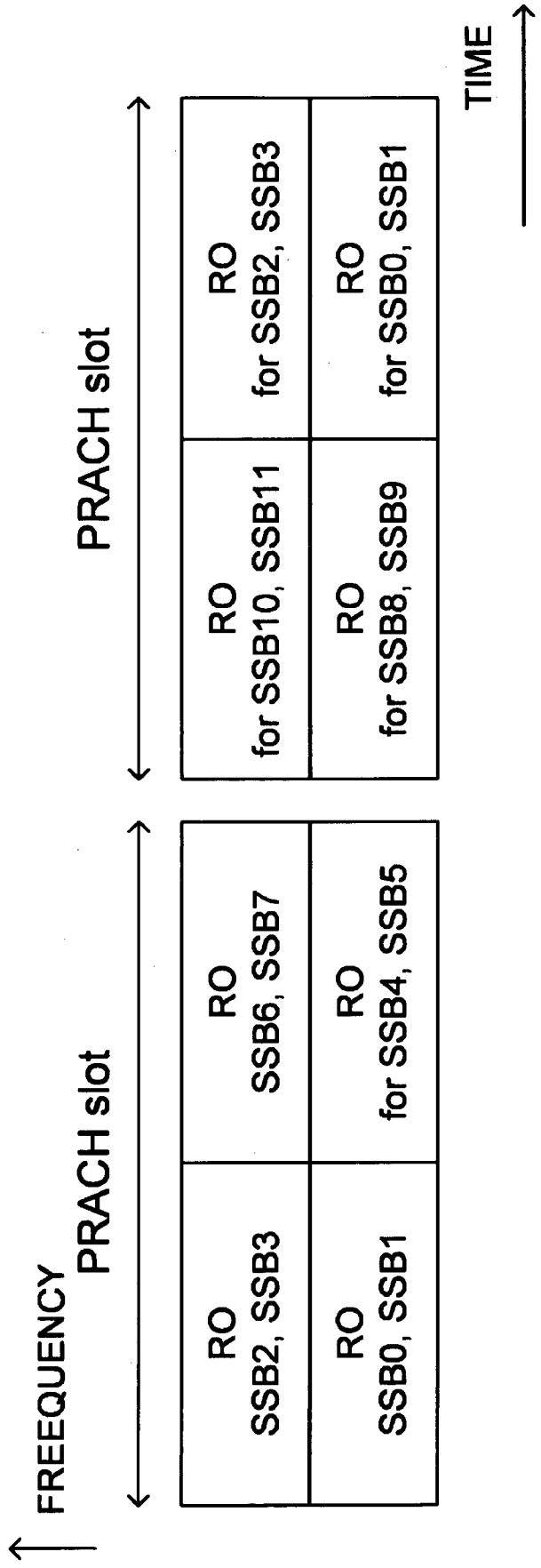

FREEQUENCY
TIME
PRACH slot
PRACH slot
RO
SSB2, SSB3
RO
SSB0, SSB1
RO
SSB6, SSB7
RO
for SSB4, SSB5
RO
for SSB10, SSB11
RO
for SSB8, SSB9
RO
for SSB2, SSB3
RO
for SSB0, SSB1

FIG. 4

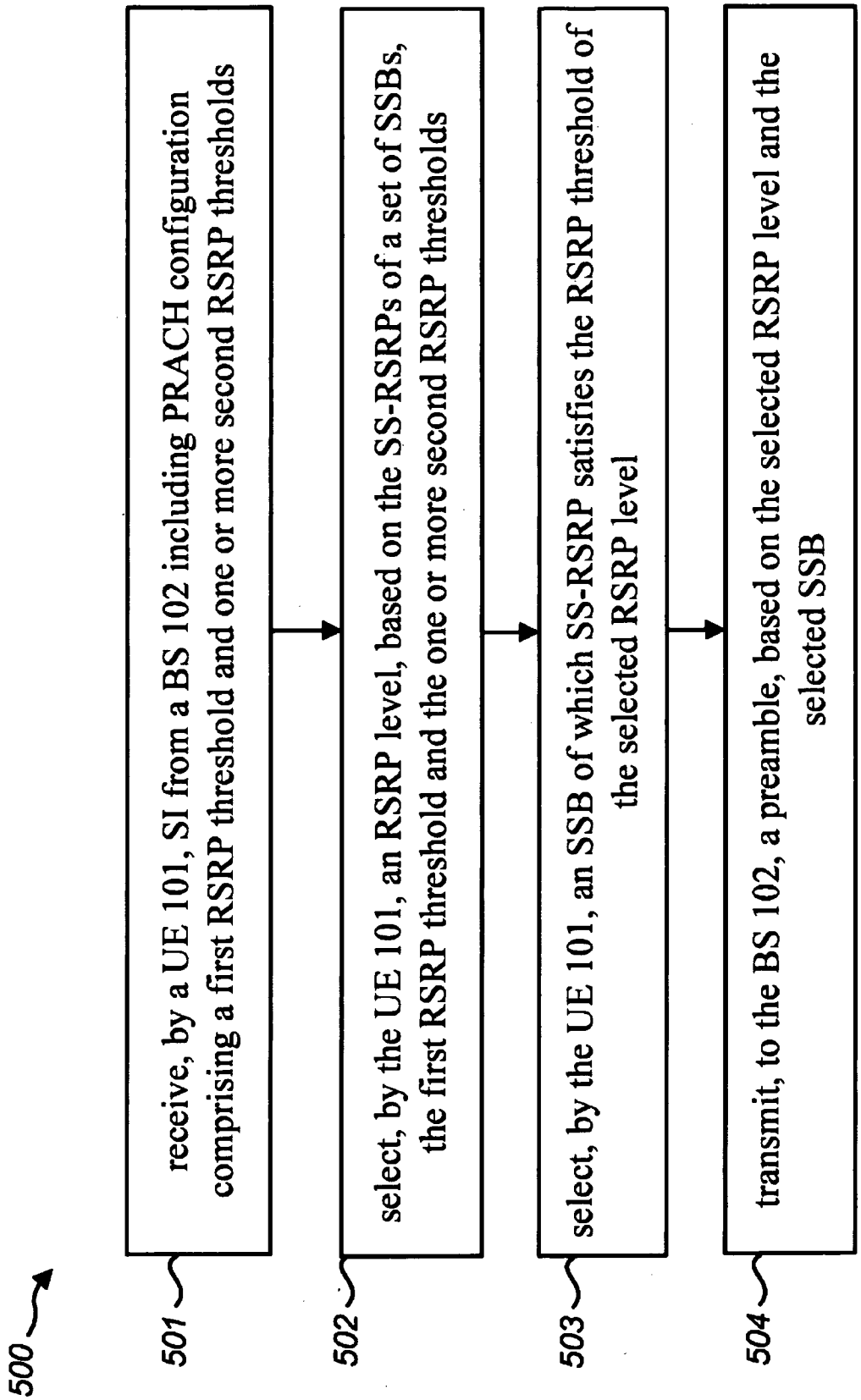

500
501
receive, by a UE 101, SI from a BS 102 including PRACH configuration comprising a first RSRP threshold and one or more second RSRP thresholds
502
select, by the UE 101, an RSRP level, based on the SS-RSRPs of a set of SSBs, the first RSRP threshold and the one or more second RSRP thresholds
503
select, by the UE 101, an SSB of which SS-RSRP satisfies the RSRP threshold of the selected RSRP level
504
transmit, to the BS 102, a preamble, based on the selected RSRP level and the selected SSB

FIG. 5

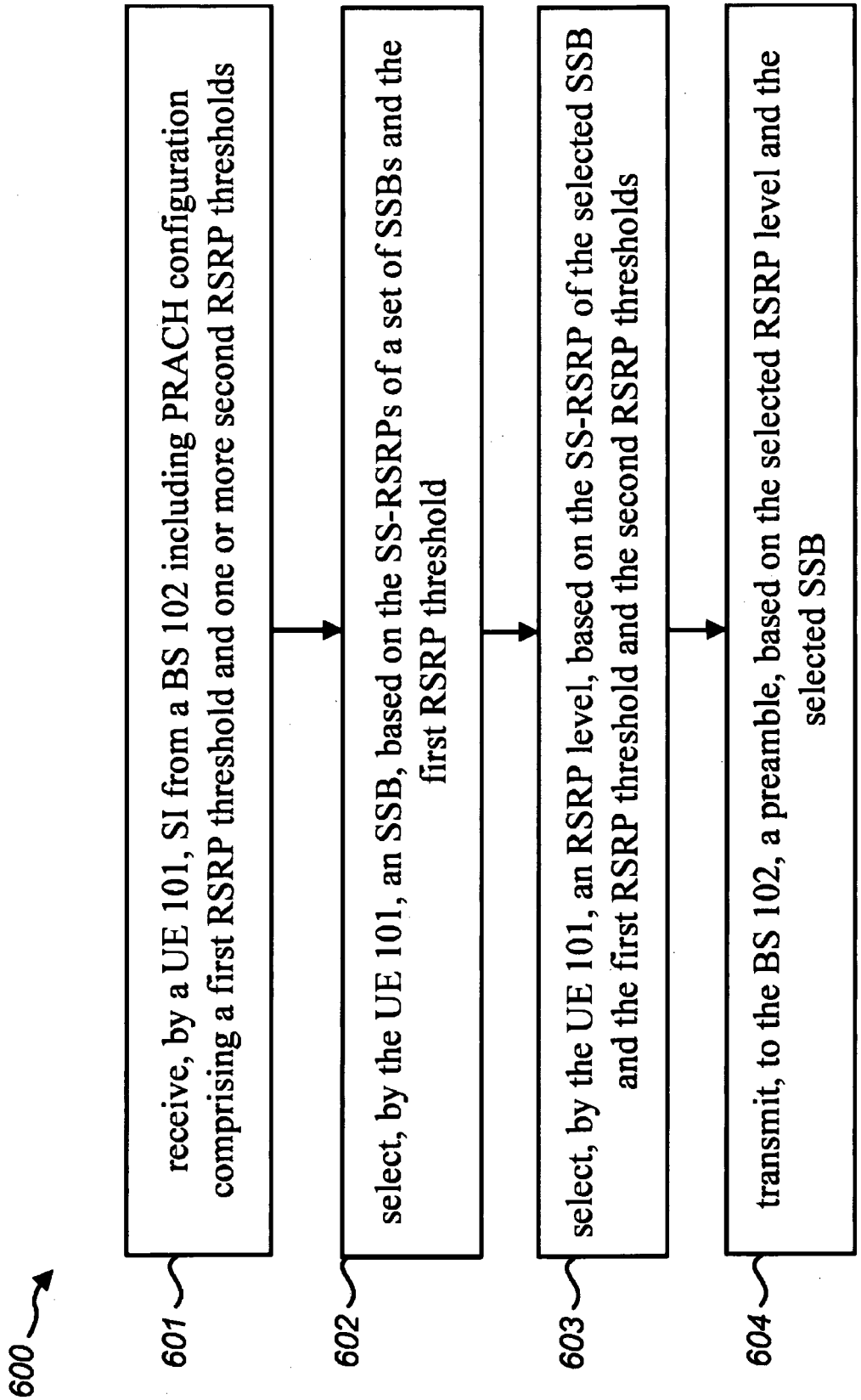

600
601
receive, by a UE 101, SI from a BS 102 including PRACH configuration comprising a first RSRP threshold and one or more second RSRP thresholds
602
select, by the UE 101, an SSB, based on the SS-RSRPs of a set of SSBs and the first RSRP threshold
603
select, by the UE 101, an RSRP level, based on the SS-RSRP of the selected SSB and the first RSRP threshold and the second RSRP thresholds
604
transmit, to the BS 102, a preamble, based on the selected RSRP level and the selected SSB

FIG. 6

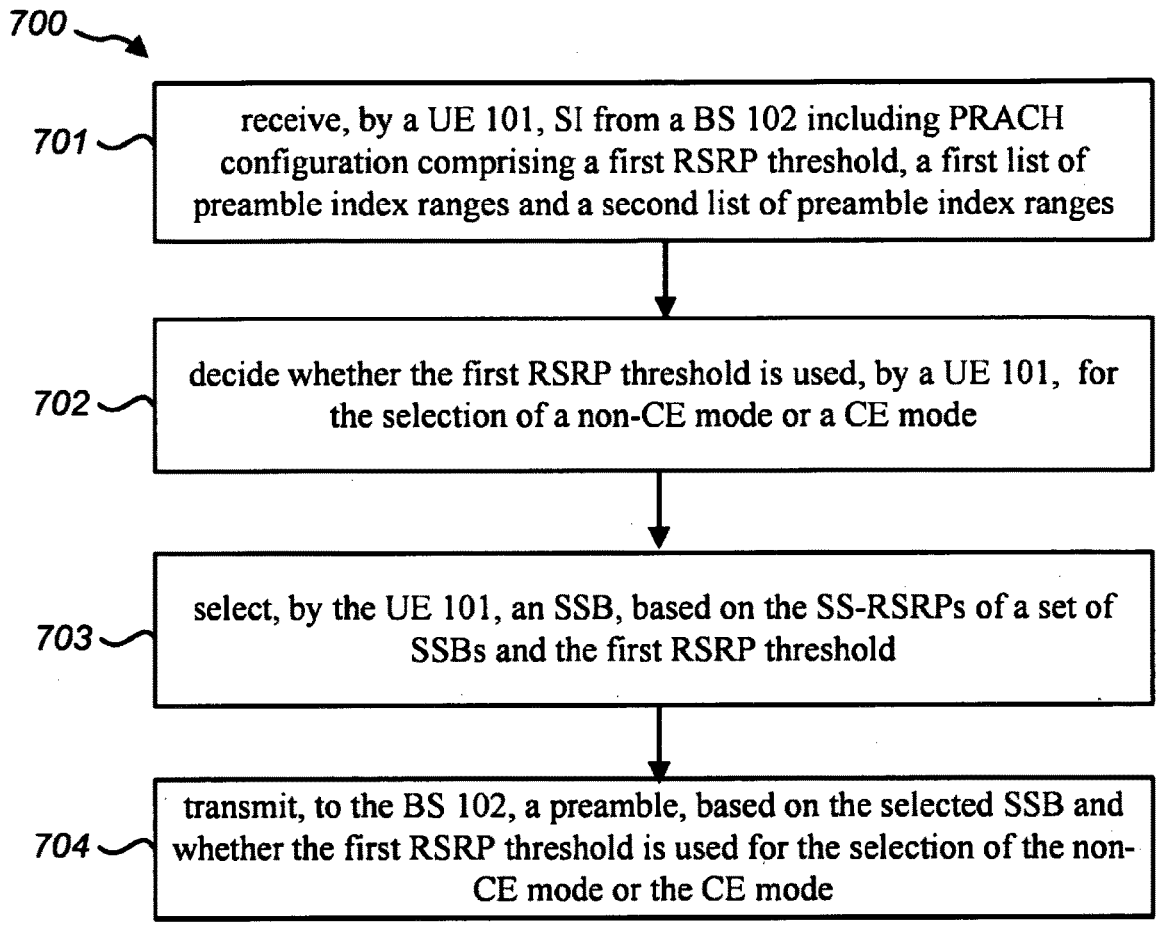

700
701
receive, by a UE 101, SI from a BS 102 including PRACH configuration comprising a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges
702
decide whether the first RSRP threshold is used, by a UE 101, for the selection of a non-CE mode or a CE mode
703
select, by the UE 101, an SSB, based on the SS-RSRPs of a set of SSBs and the first RSRP threshold
704
transmit, to the BS 102, a preamble, based on the selected SSB and whether the first RSRP threshold is used for the selection of the non-CE mode or the CE mode

FIG. 7

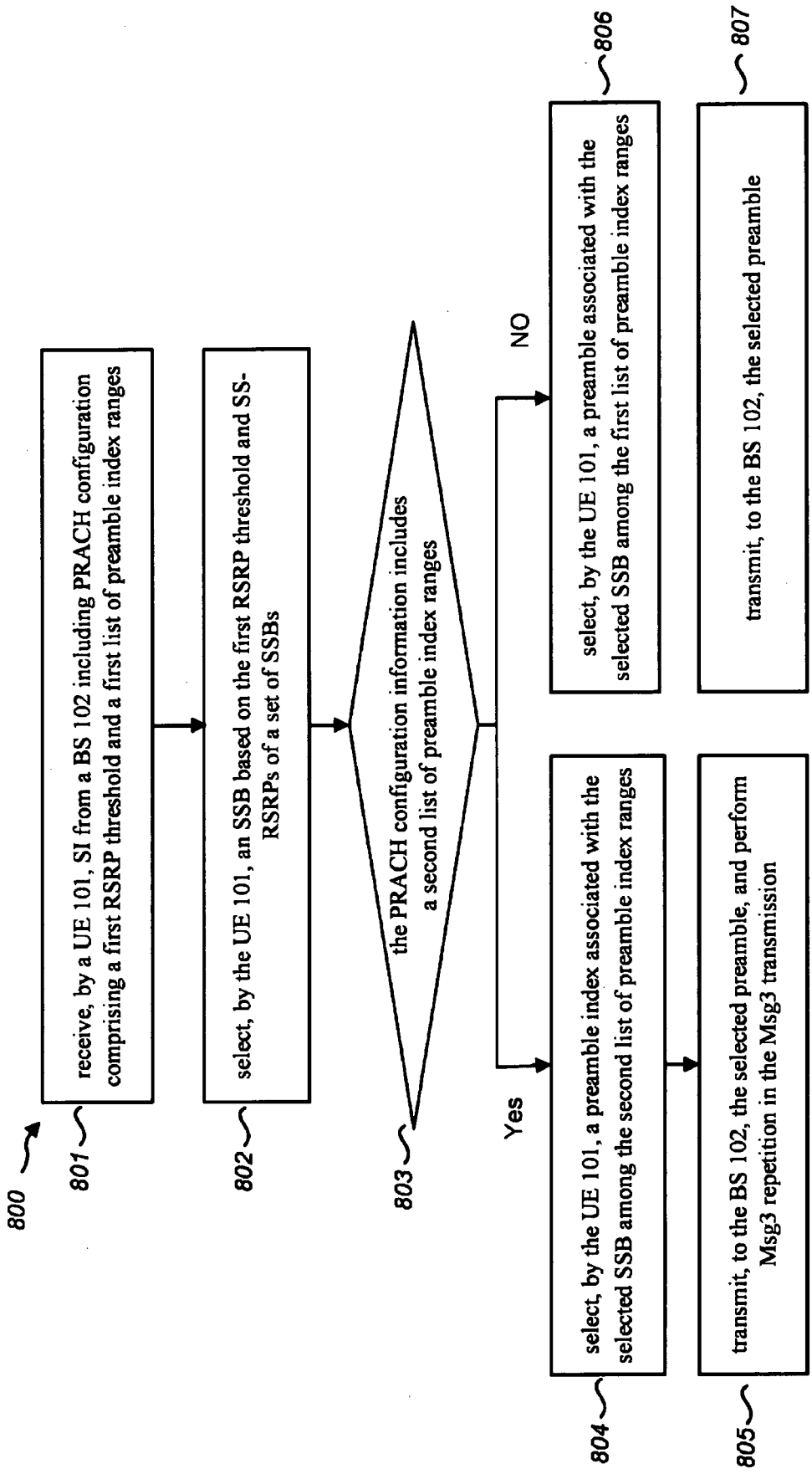

800
801
receive, by a UE 101, SI from a BS 102 including PRACH configuration comprising a first RSRP threshold and a first list of preamble index ranges
802
select, by the UE 101, an SSB based on the first RSRP threshold and SS-RSRPs of a set of SSBs
803
the PRACH configuration information includes a second list of preamble index ranges
Yes
NO
804
select, by the UE 101, a preamble index associated with the selected SSB among the second list of preamble index ranges
805
transmit, to the BS 102, the selected preamble, and perform Msg3 repetition in the Msg3 transmission
806
select, by the UE 101, a preamble associated with the selected SSB among the first list of preamble index ranges
807
transmit, to the BS 102, the selected preamble

FIG. 8

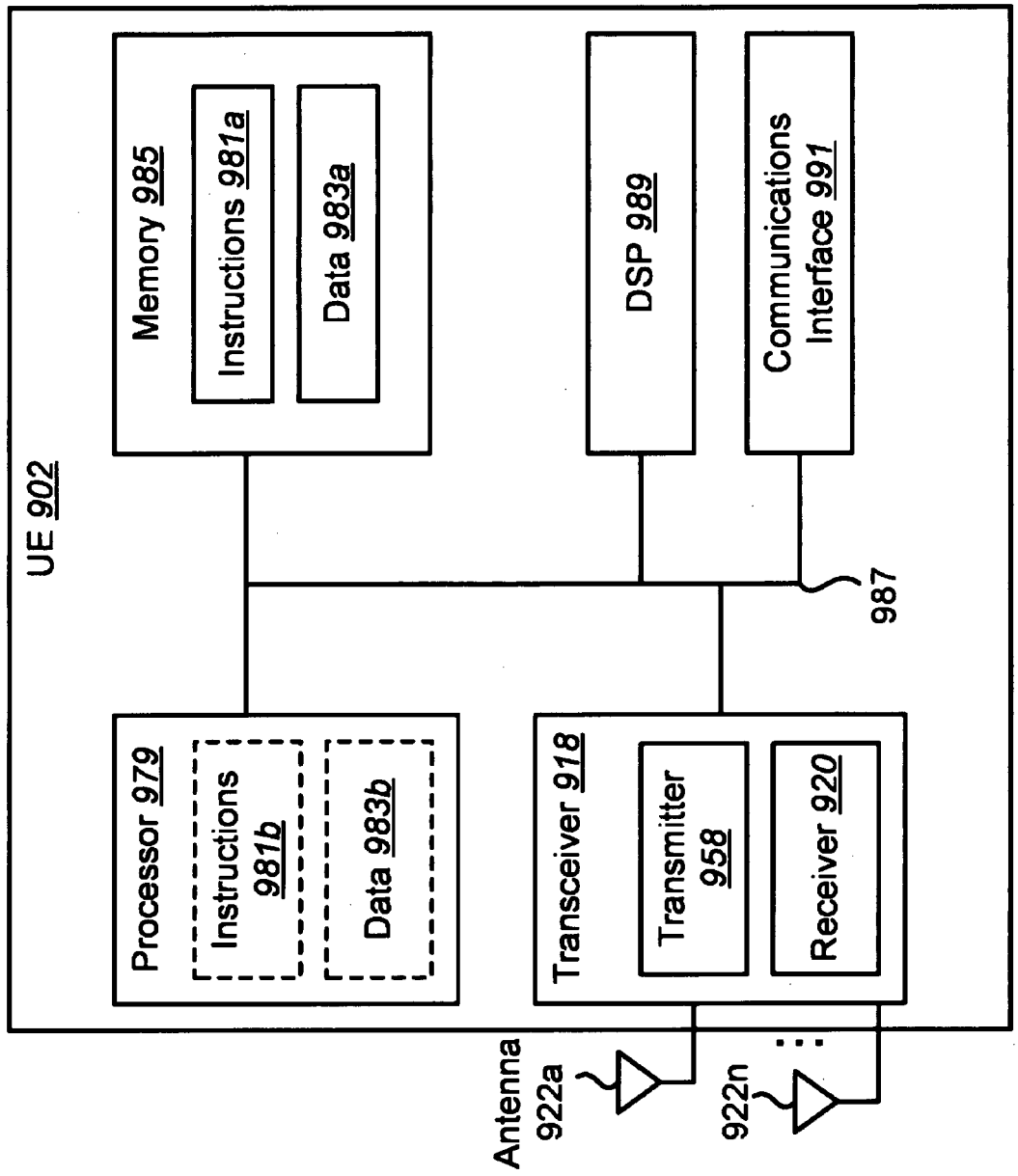

UE 902
Memory 985
Instructions 981a
Data 983a
DSP 989
Communications Interface 991
987
Processor 979
Instructions 981b
Data 983b
Transceiver 918
Transmitter 958
Receiver 920
Antenna 922a
922n

FIG. 9

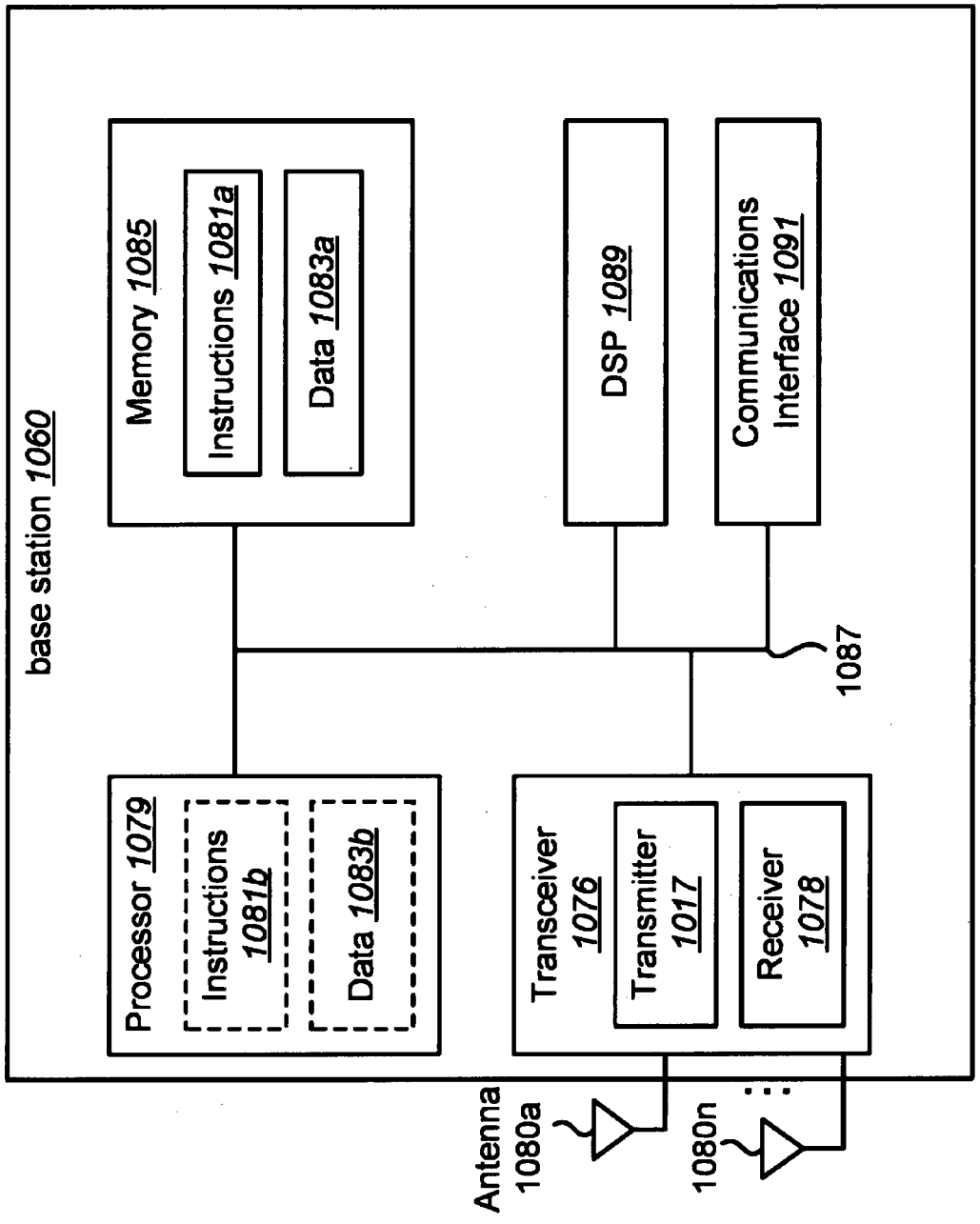

base station 1060
Memory 1085
Instructions 1081a
Data 1083a
DSP 1089
Communications Interface 1091
1087
Processor 1079
Instructions 1081b
Data 1083b
Transceiver 1076
Transmitter 1017
Receiver 1078
Antenna 1080a
1080n

FIG. 10

USER EQUIPMENT APPARATUS, BASE STATION APPARATUS, AND COMMUNICATION METHOD

TECHNICAL FIELD

[0001] The present disclosure relates to a user equipment, a base station and a communication method.

BACKGROUND ART

[0002] Recently, new wireless network technologies are being developed for the fifth generation (5G) cellular system. The related technical investigations are conducted to drive a standard evolution from the standards of Long Term Evolution (LTE) to the LTE-Advanced Pro (LTE-A Pro) and New Radio (NR) in the 3rd Generation Partnership Project (3GPP).

[0003] In 5G cellular systems, three main services are focused on, including the enhanced mobile broadband (eMBB) for achieving a high-speed and large-volume transmission, ultra-reliable and low latency communication (URLLC) for achieving a low-latency and high-reliability communication, and massive machine type communication (mMTC) for achieving a large connection of machine type devices such as Internet of Things (IoT). To supporting other 5G applications which may have less strict quality-of-service (QoS) requirements, techniques and standards for reduced-capability user equipment (UE) are also under discussion.

[0004] For 5G UEs, initial random access plays an important role in fulfilling the latency requirements. However, for some cell-edge UEs, delay may occur due to the poor connectivity in the random access procedure. To extend the coverage of 5G services, techniques for enhanced coverage UEs are studied. As one of the study items, early identification of UE types through physical random access channel (PRACH) resources is widely considered, where the reference signal received power (RSRP) values of the synchronization signal and physical broadcasting channel blocks (SSBs) are based on.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is a block diagram illustrating configurations of one or more user equipment (UE) **101** and one or more base stations (BSs) **102**, where modules and methods for physical random access may be implemented.

[0006] FIG. **2** is a diagram illustrating examples of one or more SSBs according to the present disclosure.

[0007] FIG. **3** is a diagram illustrating an example of a random access procedure according to the present disclosure.

[0008] FIG. **4** is a diagram illustrating an example of allocation of SSB indexes to PRACH occasions according to the present disclosure.

[0009] FIG. **5** is a flow diagram illustrating one implementation of a method **500** for determining an RSRP level, an SSB, and a preamble index for a UE **101**.

[0010] FIG. **6** is a flow diagram illustrating one implementation of a method **600** for determining an SSB, an RSRP level, and a preamble index for a UE **101**.

[0011] FIG. **7** is a flow diagram illustrating one implementation of a method **700** for determining an SSB and a preamble index for a UE **101**.

[0012] FIG. **8** is a flow diagram illustrating one implementation of a method **800** for determining an SSB and a preamble index for a UE **101**.

[0013] FIG. **9** illustrates various components that may be utilized in a UE **902**;

[0014] FIG. **10** illustrates various components that may be utilized in a BS **1060**;

DESCRIPTION OF EMBODIMENTS

[0015] A method by a user equipment (UE) is described. The method includes receiving, from a base station, system information including physical random access channel (PRACH) configuration information, for a serving cell, wherein the PRACH configuration information includes a first reference signal received power (RSRP) threshold, one or more second RSRP thresholds and a list of preamble index ranges, where each of the preamble index ranges is associated with an synchronization signal and physical broadcasting channel block (SSB) from one or more SSBs, where each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, and selecting, if at least one of the one or more SSBs with synchronization signal (SS)-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and RSRP level 0; else, if no SSB with SS-RSRP above the second RSRP threshold A is available, selecting RSRP level 2, and any SSB; else, selecting RSRP level 1, and any SSB with SS-RSRP above the second RSRP threshold A; and selecting a preamble from a sub-range associated with the selected RSRP level and the selected SSB.

[0016] A method by a user equipment (UE) is described. The method includes receiving, from a base station, system information including physical random access channel (PRACH) configuration information, for a serving cell, wherein the PRACH configuration information includes a first reference signal received power (RSRP) threshold, one or more second RSRP thresholds and a list of preamble index ranges, where each of the preamble index ranges is associated with an synchronization signal and physical broadcasting channel block (SSB) from one or more SSBs, where each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, and selecting, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and RSRP level 0; else, selecting an SSB with the largest SS-RSRP, and if the SS-RSRP of the selected SSB is not above the second RSRP threshold A, selecting RSRP level 2; else, selecting RSRP level 1; and selecting a preamble from a sub-range associated with the selected RSRP level and the selected SSB.

[0017] A method by a user equipment (UE) is described. The method includes receiving, from a base station, system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, wherein the first list is associated with a non-CE mode, the second list is associated with a CE mode, each of the preamble index ranges in the first list is associated with an SSB from one or more SSBs, and each of the preamble

index ranges in the second list is associated with an SSB from one or more SSBs; and selecting, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold and a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list; else, selecting any SSB and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list.

[0018] A method by a user equipment (UE) is described. The method includes receiving, from a base station, system information including PRACH configuration information comprising a first RSRP threshold and a first list of preamble index ranges, for a serving cell, and selecting, if at least one of one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold; else, selecting any SSB, wherein in a first case that the PRACH configuration information further provides a second list of preamble index ranges, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list, in a second case that the PRACH configuration information does not provide the second list of preamble index ranges, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list, wherein each of the preamble index ranges in the first list is associated with an SSB from the one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from the one or more SSBs. The method further includes performing Msg3 transmission with repetitions in the first case and performing Msg3 transmission without repetitions in the second case.

[0019] A method by a base station (BS) is described. The method includes transmitting, transmitting, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, where each of the preamble index ranges is associated with an SSB from one or more SSBs, where each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, wherein the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP level 2, and select any SSB; else, select RSRP level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and receiving, from the UE, the preamble.

[0020] A method by a base station (BS) is described. The method includes transmitting, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, where each of the preamble index ranges is associated with an SSB from one or more SSBs, where each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, wherein the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, select an SSB with the largest SS-RSRP, and if the SS-RSRP of the selected SSB is not above the second RSRP threshold A, select RSRP level 2; else, select RSRP level 1; and select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and receiving, from the UE, the preamble.

[0021] A method by a base station (BS) is described. The method includes transmitting, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, wherein the first list is associated with a non-CE mode, the second list is associated with a CE mode, each of the preamble index ranges in the first list is associated with an SSB from one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from one or more SSBs, wherein the first RSRP threshold, the first list of preamble index ranges and the second list of preamble index ranges are used for the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold and a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list; else, select any SSB and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list; and receiving, from the UE, the preamble.

[0022] A method by a base station (BS) is described. The method includes transmitting, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, for a serving cell, wherein the first RSRP threshold, the first list of preamble index ranges and the second list of preamble index ranges are used for the UE to select, if at least one of one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold; else, select any SSB; and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list, wherein each of the preamble index ranges in the first list is associated with an SSB from the one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from the one or more SSBs; and receiving, from the UE, the preamble. The method further comprises receiving Msg3 transmission with repetitions.

[0023] A UE is described. The UE includes reception circuitry configured to receive, from a base station, system information including physical random access channel (PRACH) configuration information, for a serving cell,

wherein the PRACH configuration information includes a first reference signal received power (RSRP) threshold, one or more second RSRP thresholds and a list of preamble index ranges, wherein each of the preamble index ranges is associated with an synchronization signal and physical broadcasting channel block (SSB) from one or more SSBs, wherein each of the preamble index ranges comprises one or more preamble index sub-ranges, wherein each of the preamble index sub-ranges is associated with an RSRP level, and control circuitry configured to, if at least one of the one or more SSBs with synchronization signal (SS)-RSRP above the first RSRP threshold is available, select an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP level 2, and select any SSB; else, select RSRP level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and select a preamble from a sub-range associated with the selected RSRP level and the selected SSB.

[0024] A UE is described. The UE includes reception circuitry configured to receive, from a base station, system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, wherein each of the preamble index ranges is associated with an SSB from one or more SSBs, wherein each of the preamble index ranges comprises one or more preamble index sub-ranges, wherein each of the preamble index sub-ranges is associated with an RSRP level, and control circuitry configured to, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, select an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, select an SSB with the largest SS-RSRP, and if the SS-RSRP of the selected SSB is not above the second RSRP threshold A, select RSRP level 2; else, select RSRP level 1; and select a preamble from a sub-range associated with the selected RSRP level and the selected SSB.

[0025] A UE is described. The UE includes reception circuitry configured to receive, from a base station, system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, wherein the first list is associated with a non-CE mode, the second list is associated with a CE mode, each of the preamble index ranges in the first list is associated with an SSB from one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from one or more SSBs; and control circuitry configured to, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, select an SSB with SS-RSRP above the first RSRP threshold, and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list; else select any SSB and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list.

[0026] A UE is described. The UE includes reception circuitry configured to receive, from a base station, system information including PRACH configuration information comprising a first RSRP threshold and a first list of preamble index ranges, for a serving cell, and control circuitry configured to, if at least one of one or more SSBs with SS-RSRP above the first RSRP threshold is available, select an SSB with SS-RSRP above the first RSRP threshold; else select any SSB, wherein in a first case that the PRACH configuration information further provides a second list of preamble index ranges, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list, in a second case that the PRACH configuration information does not provide the second list of preamble index ranges, the control circuitry is further configured to select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list, wherein each of the preamble index ranges in the first list is associated with an SSB from the one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from the one or more SSBs. The control circuitry is further configured to perform Msg3 transmission with repetitions in the first case, and the control circuitry is further configured to perform Msg3 transmission without repetitions in the second case.

[0027] ABS is described. The BS includes transmitting circuitry configured to transmit, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, wherein each of the preamble index ranges is associated with an SSB from one or more SSBs, wherein each of the preamble index ranges comprises one or more preamble index sub-ranges, wherein each of the preamble index sub-ranges is associated with an RSRP level, wherein the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP level 2, and select any SSB; else, select RSRP level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and reception circuitry configured to receive, from the UE, the preamble.

[0028] A BS is described. The BS includes transmitting circuitry configured to transmit, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, wherein each of the preamble index ranges is associated with an SSB from one or more SSBs, wherein each of the preamble index ranges comprises one or more preamble index sub-ranges, wherein each of the preamble index sub-ranges is associated with an RSRP level, wherein the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP level 0; else, select an SSB with the largest SS-RSRP, and if the SS-RSRP of the selected SSB is not above the second RSRP threshold A, select RSRP level 2; else, select RSRP

level 1; and select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and reception circuitry configured to receive, from the UE, the preamble.

[0029] ABS is described. The BS includes transmitting circuitry configured to transmit, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, wherein the first list is associated with a non-CE mode, the second list is associated with a CE mode, each of the preamble index ranges in the first list is associated with an SSB from one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from one or more SSBs, wherein the first RSRP threshold, the first list of preamble index ranges and the second list of preamble index ranges are used for the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold and a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the first list; else, select any SSB and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list; and reception circuitry configured to receive, from the UE, the preamble.

[0030] ABS is described. The BS includes transmitting circuitry configured to transmit, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein the PRACH configuration information includes a first RSRP threshold, a first list of preamble index ranges and a second list of preamble index ranges, for a serving cell, wherein the first RSRP threshold, the first list of preamble index ranges and the second list of preamble index ranges are used for the UE to select, if at least one of one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB with SS-RSRP above the first RSRP threshold; else, select any SSB; and select a preamble from the preamble index range associated with the selected SSB among the preamble index ranges in the second list, wherein each of the preamble index ranges in the first list is associated with an SSB from the one or more SSBs, and each of the preamble index ranges in the second list is associated with an SSB from the one or more SSBs; and reception circuitry configured to receive, from the UE, the preamble. The reception circuitry is further configured to receive Msg3 transmission with repetitions

[0031] 3GPP Long Term Evolution (LTE) is the name given to a project to improve the Universal Mobile Telecommunications System (UMTS) mobile phone or device standard to cope with future requirements. In one aspect, UMTS has been modified to provide support and specification for the Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN). 3GPP NR (New Radio) is the name given to a project to improve the LTE mobile phone or device standard to cope with future requirements. In one aspect, LTE has been modified to provide support and specification (TS 38.331, 38.321, 38.300, 37.300, 38.211, 38.212, 38.213, 38.214, etc) for the New Radio Access (NR) and Next generation—Radio Access Network (NG-RAN).

[0032] At least some aspects of the systems and methods disclosed herein may be described in relation to the 3GPP LTE, LTE-Advanced (LTE-A), LTE-Advanced Pro, New Radio Access (NR), and other 3G/4G/5G standards (e.g., 3GPP Releases 8, 9, 10, 11, 12, 13, 14, and/or 15, and/or Narrow Band-Internet of Things (NB-IoT)). However, the scope of the present disclosure should not be limited in this regard. At least some aspects of the systems and methods disclosed herein may be utilized in other types of wireless communication systems.

[0033] A wireless communication device may be an electronic device used to communicate voice and/or data to a base station, which in turn may communicate with a network of devices (e.g., public switched telephone network (PSTN), the Internet, etc.). In describing systems and methods herein, a wireless communication device may alternatively be referred to as a mobile station (MS), a user equipment (UE), an access terminal, a terminal apparatus, a subscriber station, a mobile terminal, a remote station, a user terminal, a terminal, a subscriber unit, a mobile device, a relay node, etc. Examples of wireless communication devices include cellular phones, smart phones, personal digital assistants (PDAs), laptop computers, netbooks, e-readers, wireless modems, etc. In 3GPP specifications, a wireless communication device is typically referred to as a UE. However, as the scope of the present disclosure should not be limited to the 3GPP standards, the terms "UE" and "wireless communication device" may be used interchangeably herein to mean the more general term "wireless communication device."

[0034] In 3GPP specifications, a base station (BS) is typically referred to as a Node B, an eNB, a next generation NB (gNB), a transmission and reception point (TRP), an evolved Node B (HeNB) or other terminologies. As the scope of the disclosure should not be limited to 3GPP standards, the terms "Node B", "eNB", "gNB", "TRP" and "HeNB" may be used interchangeably herein to indicate a more general meaning of the BS. Furthermore, one example of a BS is an access point. An access point may be an electronic device that provides access to a network (e.g., Local Area Network (LAN), the Internet, etc.) for wireless communication devices. The term "communication device" may be used to denote both a wireless communication device and/or a base station.

[0035] It should be noted that as used herein, a "cell" may be any communication channel that is specified by standardization or regulatory bodies to be used for International Mobile Telecommunications-Advanced (IMT-Advanced), IMT-2020 (5G) and all of it or a subset of it may be adopted by 3GPP as licensed bands (e.g., frequency bands) to be used for communication between a base station and a UE. It should also be noted that in NR, NG-RAN, E-UTRA and E-UTRAN overall description, as used herein, a "cell" may be defined as "combination of downlink and optionally uplink resources." The linking between the carrier frequency of the downlink resources and the carrier frequency of the uplink resources may be indicated in the system information transmitted on the downlink resources.

[0036] "Configured cells" are those cells of which the UE is aware and is allowed by a base station to transmit or receive information. "Configured cell(s)" may be serving cell(s). The UE may receive system information and perform the required measurements on configured cells. "Configured cell(s)" for a radio connection may consist of a primary cell and/or no, one, or more secondary cell(s). "Activated cells" are those configured cells on which the UE is transmitting

and receiving. That is, activated cells are those cells for which the UE monitors the physical downlink control channel (PDCCH) and in the case of a downlink transmission, those cells for which the UE decodes a physical downlink shared channel (PDSCH). "Deactivated cells" are those configured cells that the UE is not monitoring the transmission PDCCH. It should be noted that a "cell" may be described in terms of differing dimensions. For example, a "cell" may have temporal, spatial (e.g., geographical) and frequency characteristics.

[0037] The base stations may be connected by the NG interface to the 5G-core network (5G-CN). 5G-CN may be called as to NextGen core (NGC), or 5G core (5GC). The BSs may also be connected by the S1 interface to the evolved packet core (EPC). For instance, the BSs may be connected to a NextGen (NG) mobility management function by the NG-2 interface and to the NG core User Plane (UP) functions by the NG-3 interface. The NG interface supports a many-to-many relation between NG mobility management functions, NG core UP functions and the BSs. The NG-2 interface is the NG interface for the control plane and the NG-3 interface is the NG interface for the user plane. For instance, for EPC connection, the BSs may be connected to a mobility management entity (MME) by the S1-MME interface and to the serving gateway (S-GW) by the S1-U interface. The S1 interface supports a many-to-many relation between MMEs, serving gateways and the BSs. The S1-MME interface is the S1 interface for the control plane and the S1-U interface is the S1 interface for the user plane. The UE interface is a radio interface between the UE and the BS for the radio protocol.

[0038] The radio protocol architecture may include the user plane and the control plane. The user plane protocol stack may include packet data convergence protocol (PDCP), radio link control (RLC), medium access control (MAC) and physical (PHY) layers. A DRB (Data Radio Bearer) is a radio bearer that carries user data (as opposed to control plane signaling). For example, a DRB may be mapped to the user plane protocol stack. The PDCP, RLC, MAC and PHY sublayers (terminated at the BS on the network) may perform functions (e.g., header compression, ciphering, scheduling, ARQ and HARQ) for the user plane. PDCP entities are located in the PDCP sublayer. RLC entities may be in the RLC sublayer. MAC entities may be located in the MAC sublayer. The PHY entities may be in the PHY sublayer.

[0039] The control plane may include a control plane protocol stack. The PDCP sublayer (terminated in BS on the network side) may perform functions (e.g., ciphering and integrity protection) for the control plane. The RLC and MAC sublayers (terminated in BS on the network side) may perform the same functions as for the user plane. The Radio Resource Control (RRC) (terminated in BS on the network side) may perform the following functions. The RRC may perform broadcast functions, paging, RRC connection management, radio bearer (RB) control, mobility functions, UE measurement reporting and control. The Non-Access Stratum (NAS) control protocol (terminated in MME on the network side) may perform, among other things, evolved packet system (EPS) bearer management, authentication, evolved packet system connection management (ECM)-IDLE mobility handling, paging origination in ECM-IDLE and security control.

[0040] Signaling Radio Bearers (SRBs) are Radio Bearers (RB) that may be used only for the transmission of RRC and NAS messages. Three SRBs may be defined. SRB0 may be used for RRC messages using the common control channel (CCCH) logical channel. SRB1 may be used for RRC messages (which may include a piggybacked NAS message) as well as for NAS messages prior to the establishment of SRB2, all using the dedicated control channel (DCCH) logical channel. SRB2 may be used for RRC messages which include logged measurement information as well as for NAS messages, all using the DCCH logical channel. SRB2 has a lower-priority than SRB1 and may be configured by a network (e.g., BS) after security activation. A broadcast control channel (BCCH) logical channel may be used for broadcasting system information. Some of BCCH logical channel may convey system information which may be sent from the network to the UE via BCH (Broadcast Channel) transport channel. BCH may be sent on a physical broadcast channel (PBCH). Some of BCCH logical channel may convey system information which may be sent from the network to the UE via DL-SCH (Downlink Shared Channel) transport channel. Paging may be provided by using paging control channel (PCCH) logical channel.

[0041] For example, the DL-DCCH logical channel may be used (but not limited to) for an RRC reconfiguration message, an RRC reestablishment message, an RRC release, a UE Capability Enquiry message, a DL Information Transfer message or a Security Mode Command message. UL-DCCH logical channel may be used (but not limited to) for a measurement report message, a RRC Reconfiguration Complete message, a RRC Reestablishment Complete message, an RRC Setup Complete message, a Security Mode Complete message, a Security Mode Failure message, a UE Capability Information, message, a UL Handover Preparation Transfer message, a UL Information Transfer message, a Counter Check Response message, a UE Information Response message, a Proximity Indication message, a RN (Relay Node) Reconfiguration Complete message, an MBMS Counting Response message, an inter Frequency RSTD Measurement Indication message, a UE Assistance Information message, an In-device Coexistence Indication message, an MBMS Interest Indication message, an SCG Failure Information message. DL-CCCH logical channel may be used (but not limited to) for an RRC Connection Reestablishment message, an RRC Reestablishment Reject message, an RRC Reject message, or an RRC Setup message. UL-CCCH logical channel may be used (but not limited to) for an RRC Reestablishment Request message, or an RRC Setup Request message.

[0042] System information may be divided into a MasterInformationBlock (MIB) and one or more SystemInformationBlocks (SIBs).

[0043] The UE may receive one or more RRC messages from the BS to obtain RRC configurations or parameters. The RRC layer of the UE may configure RRC layer and/or lower layers (e.g., PHY layer, MAC layer, RLC layer, PDCP layer) of the UE according to the RRC configurations or parameters which may be configured by the RRC messages, broadcasted system information, and so on. The BS may transmit one or more RRC messages to the UE to cause the UE to configure RRC layer and/or lower layers of the UE according to the RRC configurations or parameters which may be configured by the RRC messages, broadcasted system information, and so on.

[0044] FIG. **1** is a block diagram illustrating a configuration of one or more user equipment (UE) **101** and one or more BSs **102** (e.g., eNB, gNB etc.), where modules and methods for random access may be implemented.

[0045] The one or more UEs **101** may communicate with one or more BSs **102** using one or more antennas **122***a-n*. For example, a UE **101** transmits electromagnetic signals to the BS **102** and receives electromagnetic signals from the BS **102** using the one or more antennas **122***a-n*. The BS **102** may communicate with the UE **101** using one or more antennas **180***a-n*.

[0046] It should be noted that, the multiple UEs **101** described herein may be replaced by a single UE in some scenarios. Additionally, or alternatively, the multiple BSs **102** described herein may be replaced by a single BS in some scenarios. Therefore, in the context of FIG. **1**, modules and methods described for a single UE may be also implemented to multiple UEs **101**. Additionally, or alternatively, modules and methods described for a single BS may be also implemented to multiple BSs **102**.

[0047] The UE **101** and the BS **102** may use one or more channels **119**, **121** to communicate with each other. For example, a UE **101** may transmit information or data to the BS **102** using one or more uplink (UL) channels **121** and signals. Examples of uplink channels **121** include a physical uplink control channel (PUCCH) and a physical uplink shared channel (PUSCH), etc. Examples of uplink signals include a demodulation reference signal (DMRS) and a sounding reference signal (SRS), etc. The one or more BSs **102** may also transmit information or data to the one or more UEs **101** using one or more downlink (DL) channels **119** and signals, for instance. Examples of downlink channels **119** include a PDCCH, a PDSCH, etc. A PDCCH can be used to schedule DL transmissions on PDSCH and UL transmissions on PUSCH, where the Downlink Control Information (DCI) on PDCCH includes downlink assignment and uplink scheduling grants. The PDCCH is used for transmitting DCI in a case of downlink radio communication (radio communication from the BS to the UE). Here, one or more DCIs (may be referred to as DCI formats) are defined for transmission of downlink control information. Information bits are mapped to one or more fields defined in a DCI format. Examples of downlink signals include a primary synchronization signal (PSS), a secondary synchronization signal (SSS), a cell-specific reference signal (CRS), a non-zero power channel state information reference signal (NZP CSI-RS), and a zero power channel state information reference signal (ZP CSI-RS), etc. Other kinds of channels or signals may be used.

[0048] Each of the one or more UEs **101** may include one or more transceivers **118**, one or more demodulators **114**, one or more decoders **108**, one or more encoders **150**, one or more modulators **154**, one or more data buffers **104** and one or more UE operations modules **124**. For example, one or more reception and/or transmission paths may be implemented in the UE **101**. For convenience, only a single transceiver **118**, decoder **108**, demodulator **114**, encoder **150** and modulator **154** are illustrated in the UE **101**, though multiple parallel elements (e.g., transceivers **118**, decoders **108**, demodulators **114**, encoders **150** and modulators **154**) may be implemented.

[0049] The transceiver **118** may include one or more receivers **120** and one or more transmitters **158**. The one or more receivers **120** may receive signals (e.g., downlink channels, downlink signals) from the BS **102** using one or more antennas **122***a*—n. For example, the receiver **120** may receive and convert signals to produce one or more received signals **116**. The one or more received signals **116** may be provided to a demodulator **114**. The one or more transmitters **158** may transmit signals (e.g., uplink channels, uplink signals) to the BS **102** using one or more antennas **122***a*—n. For example, the one or more transmitters **158** may upconvert and transmit one or more modulated signals **156**.

[0050] The demodulator **114** may demodulate the one or more received signals **116** to produce one or more demodulated signals **112**. The one or more demodulated signals **112** may be provided to the decoder **108**. The UE **101** may use the decoder **108** to decode signals. The decoder **108** may produce one or more decoded signals **106**, **110**. For example, a first UE-decoded signal **106** may comprise received payload data, which may be stored in a data buffer **104**. A second UE-decoded signal **110** may comprise overhead data and/or control data. For example, the second UE-decoded signal **110** may provide data that may be used by the UE operations module **124** to perform one or more operations.

[0051] As used herein, the term "module" may mean that an element or a component may be implemented in hardware, software or a combination of hardware and software. For example, the UE operations module **124** may be implemented in hardware, software or a combination of them.

[0052] In general, the UE operations module **124** may enable the UE **101** to communicate with the one or more BSs **102**. The UE operations module **124** may include a UE RRC information processing module **126**. The UE operations module **124** may include a PRACH control module **128**. In some implementations, the UE operations module **124** may include physical (PHY) entities, Medium Access Control (MAC) entities, Radio Link Control (RLC) entities, packet data convergence protocol (PDCP) entities, and a Radio Resource Control (RRC) entity. For example, the UE RRC information processing module **126** may process RRC parameters received from the BS **102** for random access configurations. The UE PRACH control module **128** may determine PRACH resources for the random access, based on the processing output from the UE RRC information processing module **126**. The UE PRACH control module **128** may select an RSRP level from a set of RSRP levels configured, based on the processing output from the UE RRC information processing module **126**. The UE PRACH control module **128** may select a non-CE mode or a CE mode from a set of CE modes configured, based on the processing output from the UE RRC information processing module **126**. The UE PRACH control module **128** may select an SSB from a set of SSBs, based on the processing output from the UE RRC information processing module **126**. In this case, the measured synchronization signal (SS)-RSRP values of the set of SSBs may be compared with one or more RSRP thresholds which are included in the received RRC parameters by the UE **101**.

[0053] The UE PRACH control module **128** may determine one or more consecutive preamble indexes associated with the selected SSB, based on the processing output from the UE RRC information processing module **126**. The one or more consecutive preamble indexes associated with an SSB can be referred to as a preamble index range in the present disclosure. The UE PRACH control module **128** may further determine one or more preamble index sub-ranges from the preamble index range associated with the selected SSB and

the selected RSRP level (or from the selected non-CE mode or from the selected CE mode), based on the processing output from the UE RRC information processing module **126**. The UE PRACH control module **128** may further separate the one or more preamble indexes associated with the selected SSB into one or more sets (or one or more sub-sets) according to the selected RSRP level (or from the selected non-CE mode or from the selected CE mode), based on the processing output from the UE RRC information processing module **126**. The UE PRACH control module **128** may determine a preamble from the determined preamble index sub-range for Msg1/MsgA transmission.

[0054] The UE operations module **124** may provide the benefit of performing UE random access efficiently. The UE operations module **124** may provide information **148** to the one or more receivers **120**. For example, the UE operations module **124** may inform the receiver(s) **120** when or when not to receive transmissions based on the Radio Resource Control (RRC) message (e.g, broadcasted system information, RRC reconfiguration message), MAC control element, and/or the DCI (Downlink Control Information). The UE operations module **124** may provide information **148**, including the PDCCH monitoring occasions and DCI format size, to the one or more receivers **120**. The UE operation module **124** may inform the receiver(s) **120** when or where to receive/monitor the PDCCH candidate for DCI formats with which DCI size.

[0055] The UE operations module **124** may provide information **138** to the demodulator **114**. For example, the UE operations module **124** may inform the demodulator **114** of a modulation pattern anticipated for transmissions from the BS **102**.

[0056] The UE operations module **124** may provide information **136** to the decoder **108**. For example, the UE operations module **124** may inform the decoder **108** of an anticipated encoding for transmissions from the BS **102**. For example, the UE operations module **124** may inform the decoder **108** of an anticipated PDCCH candidate encoding with which DCI size for transmissions from the BS **102**.

[0057] The UE operations module **124** may provide information **142** to the encoder **150**. The information **142** may include data to be encoded and/or instructions for encoding. For example, the HE operations module **124** may instruct the encoder **150** to encode transmission data **146** and/or other information **142**.

[0058] The encoder **150** may encode transmission data **146** and/or other information **142** provided by the UE operations module **124**. For example, encoding the data **146** and/or other information **142** may involve error detection and/or correction coding, mapping data to space, time and/or frequency resources for transmission, multiplexing, etc. The encoder **150** may provide encoded data **152** to the modulator **154**.

[0059] The UE operations module **124** may provide information **144** to the modulator **154**. For example, the UE operations module **124** may inform the modulator **154** of a modulation type (e.g., constellation mapping) to be used for transmissions to the BS **102**. The modulator **154** may modulate the encoded data **152** to provide one or more modulated signals **156** to the one or more transmitters **158**.

[0060] The UE operations module **124** may provide information **140** to the one or more transmitters **158**. This information **140** may include instructions for the one or more transmitters **158**. For example, the UE operations module **124** may instruct the one or more transmitters **158** when to transmit a signal to the BS **102**. The one or more transmitters **158** may upconvert and transmit the modulated signal(s) **156** to one or more BSs **102**.

[0061] The BS **102** may include one or more transceivers **176**, one or more demodulators **172**, one or more decoders **166**, one or more encoders **109**, one or more modulators **113**, one or more data buffers **162** and one or more BS operations modules **182**. For example, one or more reception and/or transmission paths may be implemented in a BS **102**. For convenience, only a single transceiver **176**, decoder **166**, demodulator **172**, encoder **109** and modulator **113** are illustrated in the BS **102**, though multiple parallel elements (e.g., transceivers **176**, decoders **166**, demodulators **172**, encoders **109** and modulators **113**) may be implemented.

[0062] The transceiver **176** may include one or more receivers **178** and one or more transmitters **117**. The one or more receivers **178** may receive signals (e.g., uplink channels, uplink signals) from the UE **101** using one or more antennas **180***a-n*. For example, the receiver **178** may receive and downconvert signals to produce one or more received signals **174**. The one or more received signals **174** may be provided to a demodulator **172**. The one or more transmitters **117** may transmit signals (e.g., downlink channels, downlink signals) to the UE **101** using one or more antennas **180***a-n*. For example, the one or more transmitters **117** may upconvert and transmit one or more modulated signals **115**.

[0063] The demodulator **172** may demodulate the one or more received signals **174** to produce one or more demodulated signals **170**. The one or more demodulated signals **170** may be provided to the decoder **166**. The BS **102** may use the decoder **166** to decode signals. The decoder **166** may produce one or more decoded signals **164**, **168**. For example, a first BS-decoded signal **164** may comprise received payload data, which may be stored in a data buffer **162**. A second BS-decoded signal **168** may comprise overhead data and/or control data. For example, the second BS-decoded signal **168** may provide data (e.g., PUSCH transmission data) that may be used by the BS operations module **182** to perform one or more operations.

[0064] In general, the BS operations module **182** may enable the BS **102** to communicate with the one or more UEs **101**. The BS operations module **182** may include a BS RRC information configuration module **194**. The BS operations module **182** may include a BS PRACH control module **196**. The BS operations module **182** may include PHY entities, MAC entities, RLC entities, PDCP entities, and an RRC entity.

[0065] The BS PRACH control module **196** may determine, for respective UE **101**, the PRACH resources for random access. The BS PRACH control module **196** may determine, for respective UE **101**, one or more thresholds for the selection of SSB from a set of SSBs. The BS PRACH control module **196** may determine, for respective UE **101**, one or more thresholds for the selection of RSRP levels. The BS PRACH control module **196** may determine, for respective UE **101**, one or more thresholds for the selection of a non-CE mode or one or more CE modes. The BS PRACH control module **196** may determine, for respective UE **101**, a number of SSBs per PRACH occasion. The BS PRACH control module **196** may determine, for respective UE **101**, one or more preamble indexes (or a preamble index range) associated with an SSB. The BS PRACH control module **196** may determine, for respective UE **101**, one or more sets

of one or more preamble indexes (or one or more sub-sets of one or more preamble indexes, or one or more preamble index sub-ranges) from the one or more preambles associated with each SSB, according to the RSRP levels (or the non-CE mode or the CE modes).

[0066] The BS PRACH control module **196** may input the determined information to the BS RRC information configuration module **194**. The BS RRC information configuration module **194** may generate RRC parameters, for respective UE **101**, with regard to the PRACH resources, based on the output from the BS PRACH control module **196**.

[0067] The BS operations module **182** may provide the benefit of performing PDCCH candidate search and monitoring efficiently.

[0068] The BS operations module **182** may provide information **190** to the one or more receivers **178**. For example, the BS operations module **182** may inform the receiver(s) **178** when or when not to receive transmissions based on the RRC message (e.g, broadcasted system information, RRC reconfiguration message), MAC control element, and/or the DCI (Downlink Control Information).

[0069] The BS operations module **182** may provide information **188** to the demodulator **172**. For example, the BS operations module **182** may inform the demodulator **172** of a modulation pattern anticipated for transmissions from the UE(s) **101**.

[0070] The BS operations module **182** may provide information **186** to the decoder **166**. For example, the BS operations module **182** may inform the decoder **166** of an anticipated encoding for transmissions from the UE(s) **101**.

[0071] The BS operations module **182** may provide information **107** to the encoder **109**. The information **107** may include data to be encoded and/or instructions for encoding. For example, the BS operations module **182** may instruct the encoder **109** to encode transmission data **105** and/or other information **107**.

[0072] In general, the BS operations module **182** may enable the BS **102** to communicate with one or more network nodes (e.g., a NG mobility management function, a NG core UP functions, a mobility management entity (MIME), serving gateway (S-GW), gNBs). The BS operations module **182** may also generate an RRC reconfiguration message to be signaled to the UE **101**.

[0073] The encoder **109** may encode transmission data **105** and/or other information **107** provided by the BS operations module **182**. For example, encoding the data **105** and/or other information **107** may involve error detection and/or correction coding, mapping data to space, time and/or frequency resources for transmission, multiplexing, etc. The encoder **109** may provide encoded data **111** to the modulator **113**. The transmission data **105** may include network data to be relayed to the UE **101**.

[0074] The BS operations module **182** may provide information **103** to the modulator **113**. This information **103** may include instructions for the modulator **113**. For example, the BS operations module **182** may inform the modulator **113** of a modulation type (e.g., constellation mapping) to be used for transmissions to the UE(s) **101**. The modulator **113** may modulate the encoded data **111** to provide one or more modulated signals **115** to the one or more transmitters **117**.

[0075] The BS operations module **182** may provide information **192** to the one or more transmitters **117**. This information **192** may include instructions for the one or more transmitters **117**. For example, the BS operations module **182** may instruct the one or more transmitters **117** when to (or when not to) transmit a signal to the UE(s) **101**. The BS operations module **182** may provide information **192**, including the PDCCH monitoring occasions and DCI format size, to the one or more transmitters **117**. The BS operation module **182** may inform the transmitter(s) **117** when or where to transmit the PDCCH candidate for DCI formats with which DCI size. The one or more transmitters **117** may upconvert and transmit the modulated signal(s) **115** to one or more UEs **101**.

[0076] It should be noted that one or more of the elements or parts thereof included in the BSs **102** and UEs **101** may be implemented in hardware. For example, one or more of these elements or parts thereof may be implemented as a chip, circuitry or hardware components, etc. It should also be noted that one or more of the functions or methods described herein may be implemented in and/or performed using hardware. For example, one or more of the methods described herein may be implemented in and/or realized using a chipset, an application-specific integrated circuit (ASIC), a large-scale integrated circuit (LSI) or integrated circuit, etc.

[0077] A BS may generate an RRC message including the one or more RRC parameters and transmit the RRC message to a UE. A UE may receive, from a BS, an RRC message including one or more RRC parameters. The term 'RRC parameter(s)' in the present disclosure may be alternatively referred to as 'RRC information element(s)'. An RRC parameter may further include one or more RRC parameter (s). In the present disclosure, an RRC message may include system information. an RRC message may include one or more RRC parameters. An RRC message may be sent on a broadcast control channel (BCCH) logical channel, a common control channel (CCCH) logical channel or a dedicated control channel (DCCH) logical channel.

[0078] In the present disclosure, a description "a BS may configure a UE to" may also imply/refer to "a BS may transmit, to a UE, an RRC message including one or more RRC parameters". Additionally, or alternatively, "RRC parameter configure a UE to" may also refer to "a BS may transmit, to a UE, an RRC message including one or more RRC parameters". Additionally, or alternatively, "a UE is configured to" may also refer to "a UE may receive, from a BS, an RRC message including one or more RRC parameters".

[0079] A BS may transmit an RRC message including one or more RRC parameters related to bandwidth part (BWP) configuration to a UE. A UE may receive the RRC message including one or more RRC parameters related to BWP configuration from a BS. For each cell, the BS may configure at least an initial DL BWP and one initial uplink bandwidth parts (initial UL BWP) to the UE. Furthermore, the BS may configure additional UL and DL BWPs to the UE for a cell.

[0080] An RRC parameters initialDownlinkBWP may indicate the initial downlink BWP (initial DL BWP) configuration for a serving cell (e.g., a SpCell and Scell). The BS may configure the RRC parameter locationAndBandwidth included in the initialDownlinkBWP so that the initial DL BWP contains the entire CORESET 0 of this serving cell in the frequency domain. The locationAndBandwidth may be used to indicate the frequency domain location and bandwidth of a BWP. An RRC parameter initialUplinkBWP

may indicate the initial uplink BWP (initial UL BWP) configuration for a serving cell (e.g., a SpCell and Scell). The BS may transmit initialDownlinkBWP and/or initialUplinkBWP which may be included in SIB1, RRC parameter ServingCellConfigCommon, or RRC parameter ServingCellConfig to the UE.

[0081] SIB1, defined as a cell-specific system information block (SystemInformationBlock, SIB), may contain information for determining if a UE is allowed to access a cell and define the scheduling of other system information. SIB1 may also contain radio resource configuration information that is common for all UEs and barring information applied to the unified access control. The RRC parameter ServingCellConfigCommon is used to configure cell specific parameters of a UE's serving cell. The RRC parameter ServingCellConfig is used to configure (add or modify) the UE with a serving cell, which may be the SpCell or an SCell of an MCS or SCG. The RRC parameter ServingCellConfig herein are mostly UE specific but partly also cell specific.

[0082] The BS may configure the UE with an RRC parameter BWP-Downlink and a RRC parameter BWP-Uplink. The RRC parameter BWP-Downlink can be used to configure an additional DL BWP. The RRC parameter BWP-Uplink can be used to configure an additional UL BWP. The BS may transmit the BWP-Downlink and the BWP-Uplink which may be included in RRC parameter ServingCellConfig to the UE.

[0083] If a UE is not configured (provided) initialDownlinkBWP from a BS, an initial DL BWP is defined by a location and number of contiguous physical resource blocks (PRBs), starting from a PRB with the lowest index and ending at a PRB with the highest index among PRBs of a CORESET for Type0-PDCCH common search space (CSS) set (i.e., CORESET 0), and a subcarrier spacing (SCS) and a cyclic prefix for PDCCH reception in the CORESET for Type0-PDCCH CSS set. If a UE is configured (provided) initialDownlinkBWP from a BS, the initial DL BWP is provided by initialDownlinkBWP. If a UE is configured (provided) initialUplinkBWP from a BS, the initial UL BWP is provided by initialUplinkBWP.

[0084] The UE **101** may be configured by the BS **102**, at least one initial BWP and up to 4 additional BWP(s). One of the initial BWP and the configured additional BWP(s) may be activated as an active BWP. The UE may monitor DCI format, and/or receive PDSCH in the active DL BWP. The UE may not monitor DCI format, and/or receive PDSCH in a DL BWP other than the active DL BWP. The UE may transmit PUSCH and/or PUCCH in the active UL BWP. The UE may not transmit PUSCH and/or PUCCH in a BWP other than the active UL BWP.

[0085] As above-mentioned, a UE may monitor DCI format in the active DL BWP. To be more specific, a UE may monitor a set of PDCCH candidates in one or more CORESETs on the active DL BWP on each activated serving cell configured with PDCCH monitoring according to corresponding search space set where monitoring implies decoding each PDCCH candidate according to the monitored DCI formats.

[0086] A set of PDCCH candidates for a UE to monitor is defined in terms of PDCCH search space sets. A search space set can be a CSS set or a UE-specific search space (USS) set. A UE may monitor a set of PDCCH candidates in one or more of the following search space sets

[0087] a Type0-PDCCH CSS set configured by pdcch-ConfigSIB1 in MIB or by searchSpaceSIB1 in PDCCH-ConfigCommon or by searchSpaceZero in PDCCH-ConfigCommon for a DCI format with CRC scrambled by a SI-RNTI on the primary cell of the MCG

[0088] a Type0A-PDCCH CSS set configured by searchSpaceOtherSystemInformation in PDCCH-ConfigCommon for a DCI format with CRC scrambled by a SI-RNTI on the primary cell of the MCG

[0089] a Type1-PDCCH CSS set configured by ra-SearchSpace in PDCCH-ConfigCommon for a DCI format with CRC scrambled by a RA-RNTI or a Temporary C-RNTI (TC-RNTI) on the primary cell

[0090] a Type2-PDCCH CSS set configured by paging-SearchSpace in PDCCH-ConfigCommon for a DCI format with CRC scrambled by a P-RNTI on the primary cell of the MCG

[0091] a Type3-PDCCH CSS set configured by SearchSpace in PDCCH-Config with searchSpaceType=common for DCI formats with CRC scrambled by INT-RNTI, SFI-RNTI, TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, or TPC-SRS-RNTI and, only for the primary cell, C-RNTI, MCS-C-RNTI, or CS-RNTI(s), and

[0092] a USS set configured by SearchSpace in PDCCH-Config with searchSpaceType=ue-Specific for DCI formats with CRC scrambled by C-RNTI, MCS-C-RNTI, SP-CSI-RNTI, or CS-RNTI(s).

[0093] For a DL BWP, if a UE is configured (provided) one above-described search space set, the UE may determine PDCCH monitoring occasions for a set of PDCCH candidates of the configured search space set. PDCCH monitoring occasions for monitoring PDCCH candidates of a search space set s is determined according to the search space set s configuration and a CORESET configuration associated with the search space set s. In other words, a UE may monitor a set of PDCCH candidates of the search space set in the determined (configured) PDCCH monitoring occasions in one or more configured control resource sets (CORESETs) according to the corresponding search space set configurations and CORESET configuration. A BS may transmit, to a UE, information to specify one or more CORESET configuration and/or search space configuration. The information may be included in MIB and/or SIBs broadcasted by the BS. The information may be included in RRC configurations or RRC parameters. A BS may broadcast system information such as MIB, SIBs to indicate CORESET configuration or search space configuration to a UE. Or the BS may transmit an RRC message including one or more RRC parameters related to CORESET configuration and/or search space configuration to a UE.

[0094] FIG. **2** is a diagram illustrating an example of one or more SSBs during a half frame SS/PBCH block in an SSB periodicity. The wording "SSBs", "synchronization signal blocks", "SS blocks" and "SS/PBCH blocks" can be also interchanged with each other in all implementations of the present disclosure. The wording "SSB", "synchronization signal block", "SS block" and "SS/PBCH block" can be also interchanged with each other in all implementations of the present disclosure. In the time domain, an SSB consists of 4 OFDM symbols, numbered in increasing order from 0 to 3.

In the frequency domain, an SSB consists of 240 contiguous subcarriers with the subcarriers numbered in increasing order from 0 to 239.

[0095] The SSB is a unit block including at least synchronization signals (PSS, SSS) and/or the PBCH. The PBCH may include DMRS for demodulating the PBCH. Transmission of the signals/channel included in the SSB will be expressed as transmission of the SSB. In a case that the BS **102** transmits the synchronization signals and/or the PBCH using one or a plurality of SSBs in the half frame, the BS **102** may use a downlink transmission beam independent for each SSB.

[0096] In FIG. **2**, the PSS, the SSS, and the PBCH are time/frequency-multiplexed in one SSB. However, the order that the PSS, the SSS, and/or the PBCH are multiplexed in time domain may differ from the one in the example illustrated in FIG. **2**.

[0097] A UE can be provided per serving cell by ssb-periodicityServingCell a periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell. If the UE is not configured a periodicity of the half frames for receptions of the SS/PBCH blocks, the UE assumes a periodicity of a half frame. A UE assumes that the periodicity is same for all SS/PBCH blocks in the serving cell. For initial cell selection, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames. For operation without shared spectrum channel access, an SS/PBCH block index is same as a candidate SS/PBCH block index.

[0098] For operation with shared spectrum channel access, when a UE is provided a SS/PBCH block index by ssb-Index, the UE is expected to perform radio link monitoring using SS/PBCH block(s) in the discovery burst transmission window, where the SS/PBCH block(s) have candidate SS/PBCH block index(es) corresponding to SS/PBCH block index provided by ssb-Index.

[0099] An SSB index (which may also be referred to as an SSB/PBCH block index) is allocated to the SSB in accordance with a temporal position in the half frame. The UE **101** calculates the SSB index based on information of the PBCH and/or information of the reference signals included in the detected SSB.

[0100] The number of SSBs (which may also be referred to as the number of SS blocks) may be defined as the number of SSBs in the periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell. Also, the number of SSBs may indicate the number of beam groups for selecting a cell in the half frame periodicity, the half frame with SS/PBCH block, or the SSB periodicity. Here, the beam groups may be defined as the number of different SSBs or the number of different beams included in the periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell.

[0101] The reference signals described below in the present embodiment include a downlink reference signal, a synchronization signal, an SSB, a downlink DMRS, a CSI-RS, an uplink reference signal, an SRS, and/or an uplink DMRS. For example, the downlink reference signal, the synchronization signal, and/or the SSB may be referred to as reference signals. The reference signals used in the downlink include a downlink reference signal, a synchronization signal, an SSB, a downlink DMRS, a CSI-RS, and the like. The reference signals used in the uplink include an uplink reference signal, an SRS, an uplink DMRS, and/or the like.

[0102] In addition, the reference signal may also be used for Radio Resource Measurement (RRM). The reference signal may also be used for beam management.

[0103] The beam management may be a procedure performed by the BS **102** and/or the UE **101** to match directionality between an analog and/or digital beam in a transmission apparatus (the BS **102** in the case of the downlink, or the UE **101** in the case of the uplink) and an analog and/or digital beam of a reception apparatus (the UE **101** in the case of the downlink, or the BS **102** in the case of the uplink) and acquire a beam gain.

[0104] Note that the following procedures may be included as a procedure of configuring, configuration, or establishing beam pairing.

[0105] Beam selection

[0106] Beam refinement

[0107] Beam recovery

[0108] For example, the beam selection may be a procedure for selecting a beam in communication between the BS **102** and the UE **101**. Also, the beam refinement may be a procedure of selecting a beam having a higher gain or changing a beam to an optimum beam between the BS **102** and the UE **101** according to the movement of the UE **101**. The beam recovery may be a procedure of re-selecting the beam in a case that the quality of a communication link is degraded due to blockage caused by a blocking object, passing of a person, or the like in communication between the BS **102** and the UE **101**.

[0109] The beam selection and the beam refinement may be included in the beam management. The beam recovery may include the following procedures.

[0110] Detection of beam failure

[0111] Discovery of new beam

[0112] Transmission of beam recovery request

[0113] Monitoring of response to beam recovery request

[0114] For example, a Reference Signal Received Power (RSRP) of the SSS included in the CSI-RS or the SSB may be used, or the CSI may be used, in a case that a transmission beam for the BS **102** is selected in the UE **101**. In addition, a CSI-RS Resource Index (CRI) may be used as a report to the BS **102**, or an index indicated by a sequence of demodulation reference signals (DMRS) used for demodulating the PBCH and/or the PBCH included in the SSB may be used.

[0115] Also, the BS **102** indicates a time index of the CRI or the SS/PBCH in a case that a beam is indicated for the UE **101**, and the UE **101** performs reception based on the indicated time index of the CRI or the SS/PBCH. At this time, the UE **101** may configure a space filter based on the indicated time index of the CRI or the SS/PBCH and may perform reception. In addition, the UE **101** may perform reception using the assumption of a Quasi Co-Location (QCL). An expression that a certain signal (such as an antenna port, a synchronization signal, or a reference signal) is "QCL" with another signal (such as an antenna port, a synchronization signal, or a reference signal) or an expression that "an assumption of QCL is used" can be interpreted as having a meaning that the certain signal is associated with another signal.

[0116] In a case that a Long Term Property of a channel on which a certain symbol in a certain antenna port is carried can be estimated from a channel on which a certain symbol in the other antenna port is carried, it is possible to state that the two antenna ports are QCL. The Long Term Property of

the channel includes one or a plurality of delay spread, Doppler spread, Doppler shift, an average gain, and an average delay. In a case that an antenna port 1 and an antenna port 2 are QCL in regard to an average delay, for example, this means that a reception timing for the antenna port 2 can be estimated from a reception timing for the antenna port 1.

[0117] The QCL can also be expanded to beam management. For this purpose, spatially expanded QCL may be newly defined. For example, the Long term property of a channel on the assumption of QCL in the space domain may be an arrival angle in a radio link or the channel (such as an Angle of Arrival (AoA) or a Zenith angle of Arrival (ZoA)) and/or an angle spread (for example, Angle Spread of Arrival (ASA) or a Zenith angle Spread of Arrival (ZSA)), a transmission angle (such as AoD or ZoD) or an angle spread of the transmission angle (for example, an Angle Spread of Departure (ASD) or a Zenith angle Spread of Departure (ZSD)), Spatial Correlation, or a reception space parameter.

[0118] In a case that the antenna port 1 and the antenna port 2 can be regarded as being QCL in regard to the reception space parameter, for example, this means that a reception beam for receiving a signal from the antenna port 2 can be estimated from a reception beam (reception space filter) for receiving a signal from the antenna port 1.

[0119] As QCL types, combinations of long term properties that may be QCL may be defined. For example, the following types may be defined.

[0120] Type A: Doppler shift, Doppler spread, average delay, delay spread

[0121] Type B: Doppler shift, Doppler spread

[0122] Type C: Average delay, Doppler shift

[0123] Type D: Receiving space parameter

[0124] For the aforementioned QCL types, an assumption of QCL between one or two reference signals and the PDCCH or the PDSCH DMRS in the RRC and/or the MAC layer and/or the DCI may be configured and/or indicated as a Transmission Configuration Indication (TCI). In a case that an index #2 of the SSB and a QCL type A+QCL type B are configured and/or indicated as one state of the TCI in a case that the UE **101** receives the PDCCH, for example, the UE **101** may receive the DMRS of the PDCCH by regarding it as Doppler shift, Doppler spread in a case of receiving the index #2 of the SSB, an average delay, delay spread, a reception space parameter, and a channel long term property and may perform synchronization and carrier path estimation, in a case that the UE **101** receives the PDCCHDMRS. At this time, a reference signal (the SSB in the aforementioned example) indicated by the TCI may be referred to as a source reference signal, and a reference signal (the PDCCH DMRS in the aforementioned example) affected by a long term property estimated from the long term property of the channel in a case that the source reference signal is received may be referred to as a target reference signal. Also, one or a plurality of TCI states and a combination of a source reference signal and a QCL type for each state may be configured with the RRC, and the TCI may be indicated in the MAC layer or the DCI for the UE **101**.

[0125] Operations of the BS **102** and the UE **101** equivalent to the beam management may be defined through assumption of QCL in the space domain and with a radio resource (time and/or frequency) as beam management and beam indication/report by this method.

[0126] Hereinafter, the subframe will be described. The subframe referred in the present disclosure may also be referred to as a resource unit, a radio frame, a time section, a time interval, or the like.

[0127] FIG. **3** is a diagram illustrating an example of a random access procedure of the UE **101** according to the present disclosure.

[0128] Random access procedure may include the transmission of random access preamble (Msg1 or Message 1) in a PRACH, the reception of random access response (RAR) message with a PDCCH and/or a PDSCH (Msg2, Message 2), the transmission of a PUSCH scheduled by a RAR UL grant (e.g., Msg3, Message 3), and the reception of PDSCH for contention resolution

[0129] In **301**, the UE **101** transmits a random access preamble to the BS **102** via a PRACH. The transmitted random access preamble may be referred to as a message 1 (Msg1). The transmission of the random access preamble will also be referred to as PRACH transmission. The random access preamble is configured to notify information to the BS **102** using one sequence among a plurality of sequences. For example, 64 types (the numbers of random access preamble indexes range from 1 to 64) of sequences are prepared. In a case that 64 types of sequences are prepared, it is possible to indicate 6-bit information (which may be ra-PreambleIndex or a preamble index) for the BS **102**. The information may be indicated as a random access preamble identifier (Random Access Preamble Identifier, RAPID).

[0130] In a case of a contention-based random access procedure, an index of a random access preamble is randomly selected by the UE **101** itself. In the contention-based random access procedure, the UE **101** selects an SSB of which synchronization signal-RSRP (SS-RSRP) exceeds a configured RSRP threshold value and selects one or a plurality of consecutive preamble indexes configured for the selected SSB. The one or a plurality of consecutive preamble indexes configured for the selected SSB may be referred to as a preamble index range in various implementations of the present disclosure.

[0131] In a case that a relationship between the SSB and the preamble index range has been configured, the UE **101** randomly selects ra-PreambleIndex from the preamble range associated with the selected SSB and sets the selected ra-PreambleIndex to the preamble index (PREAMBLE INDEX). Also, the selected preamble index range associated with the selected SSB may be divided into two groups, e.g., group A and group B, based on the transmission size of the Msg3. For example, the UE **101** may randomly select a preamble index from group A corresponding to a small transmission size of the Msg3 **303** in a case that the transmission size of the Msg3 **303** is small, or may randomly select a preamble index from the group B corresponding to a large transmission size of the Msg3 **303** in a case that the transmission size of the Msg3 **303** is large. The preamble index group corresponding to a small message size may be used when properties of the transmission path are poor (or the distance between the UE **101** and the BS **102** is far), and the preamble index group corresponding to a large message size may be used when properties of the transmission path are good (or the distance between the UE **101** and the BS **102** is close).

[0132] In a case of the non-contention-based random access procedure (i.e. contention free random access procedure), an index of the random access preamble is selected

based on information received by the UE **101** from the BS **102**. Here, the information received by the UE **101** from the BS **102** may be included in the PDCCH. In a case that all the values of bits of the information received from the BS **102** are 0, the contention-based random access procedure is executed by the UE **101**, and the index of the random access preamble is selected by the UE **101** itself.

[0133] Next, the BS **102** that has received the Msg1 **301** may generate an RAR message including an uplink grant (Random Access Response Grant, RAR UL grant) for indicating transmission for the UE **101** and transmits a random access response including the generated RAR message to the UE **101** in DL-SCH in **302**. In other words, the BS **102** transmits, in the PDSCH in a primary cell, the random access response including the RAR message corresponding to the random access preamble transmitted in **301**. The PDSCH corresponds to a PDCCH including RA-RNTI. This Ra-RNTI is calculated by RA-RNTI=1+s_id+14×t_id+14×80×f_id+14×80×8×ul_carrier_id. Here, s_id is an index of the first OFDM symbol in the transmitted PRACH and is a value of 0 to 13. t_id is an index of the first slot of the PRACH in the system frame and is a value of 0 to 79. f_id is an index of the PRACH in the frequency domain and is a value of 0 to 7. ul_carrier_id is an uplink carrier used for Msg1 transmission. ul_carrier_id for the NUL carrier is 0 while ul_carrier_id for the SUL carrier is 1.

[0134] The random access response may be referred to as a message 2 (Msg2) **302**. Also, the BS **102** includes, in the Msg2, a random access preamble identifier corresponding to the received random access preamble and an RAR message (MAC RAR) corresponding to the identifier. The BS **102** calculates a deviation in transmission timing between the UE **101** and the BS **102** from the received random access preamble and includes, in the RAR message, transmission timing adjustment information (Timing Advance (TA) command) for adjusting the deviation. The RAR message includes at least a random access response grant field mapped to the uplink grant, a Temporary Cell Radio Network Temporary Identifier (C-RNTI) field to which Temporary C-RNTI is mapped, and a Timing Advance (TA) command. The UE **101** adjusts the timing of the PUSCH transmission based on the TA command. The timing of the PUSCH transmission may be adjusted for each cell group. The BS **102** includes, in the Msg2 **302**, the random access preamble identifier corresponding to the received random access preamble.

[0135] In order to respond to PRACH transmission, the UE **101** detects (monitors) the DCI format 1_0 to which CRC parity bits scrambled with the corresponding RA-RNTI is added, during a time period of a random access response window. The time period of the random access response window (window size) is provided by a higher layer parameter ra-ResponseWindow. The window size is the number of slots based on the subcarrier spacing of the Type1-PDCCH common search space.

[0136] In a case that the UE **101** detects the DCI format 1_0 to which the CRC scrambled with RA-RNTI is added and the PDSCH including one DL-SCH transport block in the time period of the window, then the UE **101** passes the transport block to the higher layer. The higher layer analyzes the transport block for the random access preamble identifier (RAPID) related to the PRACH transmission. In a case that the higher layer identifies RAPID included in the RAR message of the DL-SCH transport block, the higher layer indicates the uplink grant for the physical layer. The identification means that RAPID included in the received random access response and RAPID corresponding to the transmitted random access preamble are the same. The uplink grant will be referred to as a random access response uplink grant (RAR UL grant) in the physical layer. In other words, the UE **101** can specify the RAR message (MAC RAR) dedicated to itself from the BS **102**, by monitoring the random access response (contained in Msg2 **302**) corresponding to the random access preamble identifier.

[0137] In a case that the UE **101** does not detect the DCI format 1_0 to which CRC scrambled with RA-RNTI is added in the time period of the window, or (ii) in a case that the UE **101** does not properly receive the DL-SCH transport block in the PDSCH in the time period of the window, or (iii) in a case that the higher layer does not identify RAPID related to the PRACH transmission, the higher layer provides an indication to transmit the PRACH to the physical layer.

[0138] In a case that the random access preamble identifier corresponding to the transmitted random access preamble is included in the received random access response, and the random access preamble has been selected based on the information received by the UE **101** from the BS **102**, the UE **101** regards the non-contention-based random access procedure as having successfully been completed and transmits the PUSCH based on the uplink grant included in the random access response.

[0139] In a case that the random access preamble identifier corresponding to the transmitted random access preamble is included in the received random access response, and the random access preamble has been selected by the UE **101** itself, TC-RNTI is set to the value of the TC-RNTI field included in the received random access response, and the random access Msg3 **303** is transmitted in the PUSCH based on the uplink grant included in the random access response. The PUSCH corresponding to the uplink grant included in the random access response is transmitted in a serving cell in which the corresponding preamble has been transmitted in the PRACH. The transmission of PUSCH through Msg3 **303** may include an initial transmission scheduled by RAR and/or one or more re-transmissions scheduled by a DCI format 0_0 with CRC scrambled by TC-RNTI.

[0140] The random access process described in FIG. **3** is regarded as a 4-step random access type, which requires two round round-trip transmissions between the UE **101** and the BS **102**. To further reduce the latency of the random access process, a 2-step random access may be considered.

[0141] For the 2-step random access type, the preamble (Msg1) and the scheduled PUSCH transmission (Msg3) defined in the 4-step type are combined into a single message MsgA. The RAR (Msg2) and the contention resolution message (Msg4) are combined into a single message MsgB.

[0142] The MsgA PRACH preambles are separated from the 4-step random access preambles but can be transmitted in the same PRACH Occasions (ROs) as the preambles of 4-step random access type, or in separate ROs. The PUSCH transmissions are organized into PUSCH Occasions (POs) which span multiple symbols and PRBs with optional guard periods and guard bands between consecutive POs. Each PO consists of multipleDMRS ports and DMRS sequences, with each DMRS port/DMRS sequence pair known as PUSCH resource unit (PRU). The 2-step random access type sup-

ports at least one-to-one and multiple-to-one mapping between the preambles and PRUs.

[0143] FIG. **4** is a diagram illustrating an example of allocation of SSB indexes to PRACH occasions according to the present disclosure. FIG. **4** illustrates an example of a case in which two PRACH slots are present in a certain time period, two ROs in the time direction and two ROs in the frequency direction are present in one PRACH slot, and SSB indexes 0 to 11 are present. Two SSB indexes are mapped to one PRACH occasion, the SSB indexes are mapped in accordance with the aforementioned rules (1) to (4), and the SSB indexes are mapped from the SSB index 0 again from the seventh PRACH occasion.

[0144] In a case that although the SSB indexes are mapped to each PRACH occasion, all the SSB indexes (all SSBs transmitted by the BS **102**) are not mapped even in a case that all the PRACH occasions in a PRACH configuration period specified by prach-ConfigIndex are used, the SSB indexes may be mapped over a plurality of PRACH configuration periods. However, the entire number of SSBs transmitted by the BS **102** may be indicated by a higher layer parameter. For example, the BS **102** may indicate, to the UE **101**, a set of SSBs that are transmitted by the BS **102** by a higher layer parameter included in SIB **1**. The period at which the PRACH configuration period is repeated a predetermined number of times such that all the SSB indexes are mapped at least once will be referred to as an association period. As the number of times the PRACH configuration period configuring the association period is repeated, a minimum value that satisfies the conditions, as mentioned before, in a predefined set of a plurality of values may be used. The predefined set of a plurality of values may be defined for each PRACH configuration period. However, in a case that all the SSB indexes are mapped to the PRACH occasions in the association period, and the number of remaining PRACH occasions is greater than the number of SSBs, the SSB indexes may be mapped again. However, in a case that all the SSB indexes are mapped to the PRACH occasions in the association period, and the number of remaining PRACH occasions is smaller than the number of SSBs, the SSB indexes may not be mapped to the remaining PRACH occasions. A cycle at which the PRACH occasions are allocated to all the SSB indexes once will be referred to as an SSB index allocation cycle. In a case that SSB-perRACH-Occasion is equal to or greater than 1, each of the SSB indexes is mapped to one PRACH occasion in one SSB index allocation cycle. In a case that SSB-perRACH-Occasion is a value that is smaller than 1, each SSB index is mapped to 1/SSB-perRACH-Occasion PRACH occasions in one SSB index allocation cycle. The UE **101** may specify the association period based on the PRACH configuration period indicated by the PRACH configuration index and the number of SSBs specified by the higher parameter provided by the higher layer (higher layer signal).

[0145] Each of one or a plurality of random access preamble range included in random access configuration information may be associated for each reference signal (for example, an SSB, a CSI-RS, or a downlink transmission beam). The UE **101** may select a random access preamble range based on the received reference signal (for example, the SSB, the CSI-RS, or the downlink transmission beam).

[0146] However, the random access preamble range associated with each SSB may be specified by one or a plurality of parameters notified from the higher layer. The one parameter or one of the plurality of parameters may be one index (for example, a start index) of one or a plurality of available preambles. The one parameter or the one of the plurality of parameters may be the number of preambles that can be used for a contention-based random access per SSB. The one parameter or the one of the plurality of parameters may be a total of the number of preambles that can be used for the contention-based random access per SSB and the number of preambles that can be used for the non-contention-based random access. The one parameter or the one of the plurality of parameters may be the number of SSBs associated with one PRACH occasion.

[0147] However, the UE **101** may receive one or a plurality of downlink signals, each of which is transmitted using one downlink transmission beam, receive random access configuration information associated with one of the downlink signals, and perform the random access procedure based on the received random access configuration information. The UE **101** may receive one or a plurality of SSBs in the periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell, receive random access configuration information associated with one of the SSBs, and perform the random access procedure based on the received random access configuration information. The UE **101** may receive one or a plurality of CRI-RSs, receive random access configuration information associated with one of the CRI-RSs, and perform the random access procedure based on the received random access configuration information.

[0148] One or a plurality of pieces of random access configuration information may include one random access channel configuration (RACH-Config) and/or one physical random access channel configuration (PRACH-Config).

[0149] Parameters related to the random access for each reference signal may be included in the random access channel configuration.

[0150] Parameters (such as an index of PRACH configuration, a PRACH occasion, and the like) related to the physical random access channel for each reference signal may be included in the physical random access channel configuration.

[0151] One piece of random access configuration information may indicate parameters related to a random access corresponding to one reference signal, and a plurality of pieces of random access configuration information may indicate parameters related to a plurality of random accesses corresponding to a plurality of reference signals.

[0152] One piece of random access configuration information may indicate parameters related to a physical random access corresponding to one reference signal, and may indicate parameters related to a plurality of random accesses corresponding to a plurality of reference signals.

[0153] Random access configuration information corresponding to a reference signal (random access channel configuration corresponding to the reference signal, physical random access channel configuration corresponding to the reference signal) may be selected in response to selection of the corresponding reference signal.

[0154] However, the UE **101** may receive one or a plurality of pieces of random access configuration information from a BS **102** that transmits the random access preamble and/or a BS **102** that is different from the transmission reception points **4** and/or the transmission reception points **4**. For example, the UE **101** may transmit the random access

preamble to a second BS **102** based on at least one piece of random access configuration information received from a first BS **102**.

[0155] However, the BS **102** may determine the downlink transmission beam to be applied in a case that the downlink signal is transmitted to the UE **101**, by receiving the random access preamble transmitted by the UE **101**. The UE **101** may transmit the random access preamble using a PRACH occasion indicated by the random access configuration information associated with a certain downlink transmission beam. The BS **102** may determine the downlink transmission beam to be applied in a case that the downlink signal is transmitted to the UE **101**, based on the random access preamble received from the UE **101** and/or the PRACH occasion in which the random access preamble is received.

[0156] The BS **102** transmits an RRC parameter including one or a plurality of pieces of random access configuration information (which may include random access resources) as an RRC message to the UE **101**.

[0157] The UE **101** may select one or a plurality of available random access preambles and/or one or a plurality of available PRACH occasions used for the random access procedure based on properties of a transmission path with the BS **102**.

[0158] The UE **101** may select one or a plurality of available random access preambles and/or one or a plurality of PRACH occasions used for the random access procedure based on properties of the transmission path (which may be an RSRP, for example) measured by a reference signal (an SS/PBCH bock and/or a CSI-RS, for example) received from the BS **102**.

[0159] FIG. **5** is a flow diagram illustrating one implementation of a method **500** for determining an RSRP level, an SSB, and a preamble index for a UE **101**.

[0160] In the implementation of the present disclosure, the UE **101** may receive **501** system information which is broadcast by the BS **102**. The system information may include PRACH configuration information. The PRACH configuration information may contain one or more RRC parameters.

[0161] The RRC parameter "rsrp-ThresholdSSB" may be used for the UE to select an SSB from one or more SSBs and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "rsrp-ThresholdSSB". The RRC parameter "rsrp-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "rsrp-ThresholdSSB" may be used in the 4-step random access type. The RRC parameter "rsrp-ThresholdSSB" may be considered as a parameter indicating an RSRP threshold to determine one or more RSRP levels.

[0162] The RRC parameter "msgA-RSRP-ThresholdSSB" may be used for the UE to select an SSB from one or more SSBs and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "msgA-RSRP-ThresholdSSB". The RRC parameter "msgA-RSRP-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "msgA-RSRP-ThresholdSSB" may be used in the 2-step random access type. The RRC parameter "msgA-RSRP-ThresholdSSB" may be considered as a parameter indicating an RSRP threshold to determine one or more RSRP levels.

[0163] The one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" included in the PRACH configuration information may be RRC parameters indicating one or more RSRP thresholds. The RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may be referred to as a first RSRP threshold, i.e. the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" indicates a first RSRP threshold. The one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" included in the PRACH configuration information may be referred to as one or more second RSRP thresholds, i.e. the one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" indicates the one or more second RSRP thresholds. That is, an RRC parameter may include a list of entries wherein the first entry in the list indicates the first RSRP threshold, the entries other than first entry indicate the one or more second RSRP thresholds.

[0164] The first RSRP threshold may be larger than the one or more second RSRP thresholds. The first RSRP threshold and the one or more second RSRP thresholds may be provided by independent RRC parameters. Alternatively, or additionally, the first RSRP threshold may be included in an RRC parameter indicating the one or more second RSRP thresholds.

[0165] The one or more RSRP thresholds may be used for determining one or more RSRP levels for the UE **101**. The descriptions of the one or more RRC parameters, i.e., the first RSRP threshold and the one or more second RSRP thresholds above may be also applied to other implementations of the present disclosure.

[0166] The RSRP level described above may also indicate an enhanced coverage level, a coverage enhancement (CE) level, a repetition level (or repetition number), a CE mode or a CE sub-mode in this implementation, and other various implementations of the present disclosure. Therefore, the wording "RSRP level" is interchangeable with "enhanced coverage level", "CE level", "repetition level (or repetition number)", "CE mode", or "CE sub-mode" in this implementation and other various implementations of the present disclosure.

[0167] The RSRP level may be associated with one, more, or all of a number of PUSCH repetitions, a number of PUCCH repetitions, a number of PDCCH repetitions, a number of PDSCH repetitions, a number of PRACH repetitions and etc. The RSRP level may be associated with a number of PUSCH transmissions of a transmission block (TB) within a bundle of a dynamic grant or configured grant. Different RSRP levels can be associated with different number of PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, and PRACH repetitions. The PUSCH repetitions may be PUSCH repetitions for Msg3. The PUCCH repetitions may be the PUCCH repetitions for Msg4. The repetition may be applied to both initial transmission of PUSCH and retransmission of PUSCH. For example, RSRP level 0 may imply a single transmission of PUSCH and/or PUCCH without repetition. For another example, RSRP levels other than RSRP level 0 may imply transmissions of PUSCH and/or PUCCH with R repetitions, where R is associated with each RSRP level. The repetition number R can be a predefined number or can be indicated by the broadcasted system information (e.g., MIB, SIB1, or other SIBs), RRC message, MAC control element, DCI format and so on. For example, a set of repetition numbers

$\{r_0, r_1\}$ and a set of RSRP levels {RSRP level 0, RSRP level 1} may be configured for the UE **101**. The UE **101** may perform r_0 repetitions (PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, or PRACH repetitions) if RSRP level 0 is selected. The UE **101** may perform r_1 repetitions (PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, or PRACH repetitions) if RSRP level 1 is selected.

[0168] In the present disclosure, the BS **102** may indicate, to the UE **101**, one or more SSBs (or a set of SSBs) that are transmitted by the BS **102** via the broadcast system information (e.g. SIB1). The UE **101** may measure the SS-RSRPs of the one or more SSBs indicated by the broadcasted system information (e.g. SIB1). In this implementation, an RSRP level may be selected **502**, by the UE **101**, based on SS-RSRPs of the one or more SSBs, the first RSRP threshold and the one or more second RSRP thresholds. Then, an SSB may be selected **503**, by the UE **101**, if the SS-RSRP of the SSB satisfies the threshold of the selected RSRP level.

[0169] In an example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2, to select. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., a second RSRP threshold A. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **502** RSRP level 0, and select **503** an SSB with SS-RSRP above (above or equal to) the first RSRP threshold; else, if no SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A is available, the UE **101** may select **502** RSRP level 2, and select **503** any SSB; else, the UE **101** may select **502** RSRP level 1, and select **503** an SSB with SS-RSRP above (above or equal to) the second RSRP threshold A.

[0170] In another example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2, to select. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., a second RSRP threshold A. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **502** RSRP level 0, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold; else, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A is available, the UE **101** may select **502** RSRP level 1, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A; else, the UE **101** may select **502** RSRP level 2, and select **503** any SSB.

[0171] In another example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., the second RSRP threshold A. In this example, if all the one or more SSBs are with SS-RSRPs less than the second RSRP threshold A, the UE **101** may select **502** RSRP level 2, and select **503** any SSB; else, if all the one or more SSBs are with SS-RSRPs less than the first RSRP threshold, the UE **101** may select **502** RSRP level 1, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A; else, the UE **101** may select **502** RSRP level 0, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold.

[0172] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, for select, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold A**1** and a second RSRP threshold A**2**. The second RSRP threshold A**1** may be larger than the second RSRP threshold A**2**. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **502** RSRP level 0, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold; else, if no SSB with SS-RSRP above (above or equal to) the second RSRP threshold A**2** is available, the UE **101** may select **502** RSRP level 2, and select **503** any SSB; else, the UE **101** may select **502** RSRP level 1, and if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**1** is available, the UE **101** may select **502** RSRP level 1a, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**1**; else, the UE **101** may select **502** RSRP level 1b, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**2**.

[0173] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, to select, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold A**1** and a second RSRP threshold A**2**. The second RSRP threshold A**1** may be larger than the second RSRP threshold A**2**. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **502** RSRP level 0, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold; else, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**1** is available, the UE **101** may select **502** RSRP level 1a, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**1**; else, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**2** is available, the UE **101** may select **502** RSRP level 1b, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**2**; else, the UE **101** may select **502** RSRP level 2, and select **503** any SSB.

[0174] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold A**1** and a second RSRP threshold A**2**. The second RSRP threshold A**1** may be larger than the second RSRP threshold A**2**. In this example, if all of the one or more SSBs are with SS-RSRPs less than the second RSRP threshold A**2**, the UE **101** may select **502** RSRP level 2, and select **503** any SSB; else, if all of the one or more SSBs are with SS-RSRPs less than the second RSRP threshold A**1**, the UE **101** may select

502 RSRP level 1b, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**2**; else, if all of the one or more SSBs are with SS-RSRPs less than the first RSRP threshold, the UE **101** may select **502** RSRP level 1a, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the second RSRP threshold A**1**; else, the UE **101** may select **502** RSRP level 0, and select **503** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold.

[0175] Each SSB from the one or more SSBs is associated with a set of one or more preambles with consecutive indexes. A list of the sets of the one or more preambles may be indicated explicitly by one or more RRC parameters included in the PRACH configuration information. Alternatively, or additionally, a list of the sets of the one or more preambles may be indicated implicitly by one or more RRC parameters included in the PRACH configuration information. For example, preamble indexes in each set of the one or more preambles with consecutive indexes associated with an SSB may be determined based on the number of SSBs per RACH occasion and the number of preambles per SSB. Furthermore, each of the sets of the one or more preambles may comprise one or more sub-sets of one or more preambles. Each sub-set of the one or more preambles is associated with one of the configured RSRP levels. The BS **102** may configure, to the UE **101**, a number of the sub-sets of the one or more preambles included in each set of the one or more preambles being equal to the number of the configured RSRP levels. The BS **102** may configure, to the UE **101**, one or more explicit RRC parameters to indicate the indexes in each sub-set of the one or more preambles from each set of the one or more preambles. Alternatively, or additionally, the BS **102** may configure, to the UE **101**, one or more implicit RRC parameters to indicate the indexes in each sub-set of the one or more preambles from each set of the one or more preambles. For example, the first index in each sub-set of the one or more preambles may be indicated by one or more RRC parameters configured by the BS **102**, and the last index in each sub-set of the one or more preambles may be determined by adding up the first index and the number of the preambles configured in each sub-set and subtracting one. The number of the preambles configured in each sub-set may be configured by other one or more RRC parameters by the BS **102**. For another example, the indexes in each sub-set of the one or more preambles may be determined by a predefined equation, which at least contains the indexes of the set of the one or more preambles where the sub-set is included and the number of the sub-set (or the number of the RSRP levels) configured.

[0176] Additionally, or alternatively, the set of the one or more preambles with consecutive indexes associated with each SSB may be referred to as a preamble index range in this implementation, as well as in other various implementations of the present disclosure. A list of the preamble index ranges associated with the one or more SSBs respectively may be indicated explicitly by one or more RRC parameters included in the PRACH configuration information. Alternatively, or additionally, a list of the preamble index ranges associated with the one or more SSBs respectively may be indicated implicitly by one or more RRC parameters included in the PRACH configuration information. For example, preambles in each preamble index range associated with an SSB may be determined based on the number of SSBs per RACH occasion and the number of preambles per SSB. Furthermore, each preamble index range from the list of preamble index ranges may comprise one or more preamble index sub-ranges. Each preamble index sub-range from the one or more preamble index sub-ranges is associated with one of the configured RSRP levels. The BS **102** may configure, to the UE **101**, a number of the preamble index sub-ranges included in each preamble index range being equal to the number of the RSRP levels. The BS **102** may configure, to the UE **101**, one or more explicit RRC parameters to indicate the indexes in each preamble sub-range of each preamble range. Alternatively, or additionally, the BS **102** may configure, to the UE **101**, one or more implicit RRC parameters to indicate the indexes in each preamble sub-range of each preamble range. For example, the first index in each preamble sub-range may be indicated by one or more RRC parameters configured by the BS **102**, and the last index in each preamble sub-range may be determined by adding up the first index and the number of the preambles configured in each preamble sub-range and subtracting one. The number of the preambles configured in each preamble sub-range may be configured by other one or more RRC parameters by the BS **102**. For another example, the indexes in each preamble sub-range may be determined by a predefined equation, which at least contains the indexes of the preamble range where the sub-range is included and the number of the preamble sub-ranges (or the number of the RSRP levels) configured.

[0177] The one or more preambles with consecutive indexes (or the set of one or more preambles, or the preamble index range) associated with each SSB may be used for contention-based random access and/or contention-free random access.

[0178] In an example, there are 64 preambles (with consecutive index {0, 1, 2, . . . , 63}) in total, 4 SSBs (including SSB0, SSB1, SSB2 and SSB3) and 2 RSRP levels (RSRP level 0 and RSRP level 1) configured by the BS **102** in the serving cell. In this case, SSB0 may be associated with 16 preambles with consecutive indexes {0, 1, 2, . . . , 15}, SSB1 may be associated with 16 preambles with consecutive indexes {16, 17, 18, . . . , 31}, SSB2 may be associated with 16 preambles with consecutive indexes {32, 33, 34, . . . , 47}, SSB3 may be associated with 16 preambles with consecutive indexes {48, 49, 50, . . . , 63}. The consecutive indexes {0, 1, 2, . . . , 15} associated with SSB0 may be separated as {{0, 1, 2, . . . , 7}, {8, 9, 10, . . . 15}}, where {0, 1, 2, . . . , 7} may be associated with RSRP level 0 and {8, 9, 10, . . . 15} may be associated with RSRP level 1. In this case, {0, 1, 2, . . . , 7} and {8, 9, 10, . . . 15} may be referred to as two sub-sets of the preamble indexes of the set {0, 1, 2, . . . , 15} associated with SSB0. In other words, {0, 1, 2, . . . , 7} and {8, 9, 10, . . . 15} may be referred to as two preamble index sub-ranges of the preamble index range {0, 1, 2, . . . , 15} associated with SSB0.

[0179] The UE **101** may select a preamble from the one or more preambles (or from the preamble index sub-range, or from the sub-set of the one or more preamble indexes) associated with the selected RSRP level and the selected SSB, and transmit **504** it through Msg1 **301** to the BS **102** during a 4-step random access procedure, or alternatively or additionally, transmit it through MsgA to the BS **102** during a 2-step random access procedure. That is, the UE **101** may randomly select a preamble from the one or more preambles (or from the preamble index sub-range, or from the sub-set

of the one or more preamble indexes) associated with the selected RSRP level and the selected SSB in a PRACH occasion. The PRACH occasion is associated with the selected SSB and/or the selected RSRP level.

[0180] FIG. **6** is a flow diagram illustrating one implementation of a method **600** for determining an SSB, an RSRP level, and a preamble index for a UE **101**.

[0181] In the implementation of the present disclosure, the UE **101** may receive **601** system information which is broadcast by the BS **102**. The system information may include PRACH configuration information. The PRACH configuration information may contain one or more RRC parameters.

[0182] The RRC parameter "rsrp-ThresholdSSB" may be used for the UE to select an SSB and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "rsrp-ThresholdSSB". The RRC parameter "rsrp-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "rsrp-ThresholdSSB" may be used in the 4-step random access type. The RRC parameter "rsrp-ThresholdSSB" may be considered as a parameter indicating an RSRP threshold to determine one or more RSRP levels.

[0183] The RRC parameter "msgA-RSRP-ThresholdSSB" may be used for the UE to select an SSB and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "msgA-RSRP-ThresholdSSB". The RRC parameter "msgA-RSRP-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "msgA-RSRP-ThresholdSSB" may be used in the 2-step random access type. The RRC parameter "msgA-RSRP-ThresholdSSB" may be considered as a parameter indicating an RSRP threshold to determine one or more RSRP levels.

[0184] The one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" included in the PRACH configuration information may be RRC parameters indicating one or more second RSRP thresholds. The RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may be referred to as a first RSRP threshold, i.e. the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" indicates a first RSRP threshold. The one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" included in the PRACH configuration information may be referred to as one or more second RSRP thresholds, i.e. the one or more RRC parameters other than "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" indicates the one or more second RSRP thresholds.

[0185] The first RSRP threshold may be larger than the one or more second RSRP thresholds. The first RSRP threshold and the one or more second RSRP thresholds may be provided by independent RRC parameters. Alternatively, or additionally, the first RSRP threshold may be included in an RRC parameter indicating the one or more second RSRP thresholds. That is, an RRC parameter may include a list of entries wherein the first entry in the list indicates the first RSRP threshold, the entries other than first entry indicate the one or more second RSRP thresholds.

[0186] The one or more RSRP thresholds may be used for determining one or more RSRP levels for the UE **101**. The descriptions of the one or more RRC parameters, i.e., the first RSRP threshold and the one or more second RSRP thresholds above, may be also applied to other implementations of the present disclosure.

[0187] An SSB may be selected **602**, by the UE **101**, based on the SS-RSRPs of a set of SSBs and the first RSRP threshold. Then, an RSRP level may be selected **603**, by the UE **101**, based on the SS-RSRP of the selected SSB and the first RSRP threshold or the one or more second RSRP threshold.

[0188] The RSRP level described above may also indicate an enhanced coverage level, a coverage enhancement (CE) level, a repetition level (or repetition number), a CE mode or a CE sub-mode in this implementation, and other various implementations of the present disclosure. Therefore, the wording "RSRP level" is interchangeable with "enhanced coverage level", "CE level", "repetition level (or repetition number)", "CE mode", or "CE sub-mode" in this implementation and other various implementations of the present disclosure.

[0189] The RSRP level may be associated with one, more, or all of a number of PUSCH repetitions, a number of PUCCH repetitions, a number of PDCCH repetitions, a number of PDSCH repetitions, a number of PRACH repetitions and etc. The RSRP level may be associated with a number of PUSCH transmissions of a transmission block (TB) within a bundle of a dynamic grant or configured grant. Different RSRP levels can be associated with different number of PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, and PRACH repetitions. The PUSCH repetitions may be PUSCH repetitions for Msg3. The PUCCH repetitions may be the PUCCH repetitions for Msg4. The repetition may be applied to both initial transmission of PUSCH and retransmission of PUSCH. For example, RSRP level 0 may imply a single transmission of PUSCH and/or PUCCH without repetition. For another example, RSRP levels other than RSRP level 0 may imply transmissions of PUSCH and/or PUCCH with R repetitions, where R is associated with each RSRP level. The repetition number R can be a predefined number or can be indicated by the broadcasted system information (e.g., MIB, SIB1, or other SIBs), RRC message, MAC control element, DCI format and so on. For example, a set of repetition numbers $\{r_0, r_1\}$ and a set of RSRP levels {RSRP level 0, RSRP level 1} may be configured for the UE **101**. The UE **101** may perform r_0 repetitions (PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, or PRACH repetitions) if RSRP level 0 is selected. The UE **101** may perform r_1 repetitions (PUSCH repetitions, PUCCH repetitions, PDCCH repetitions PDSCH repetitions, or PRACH repetitions) if RSRP level 1 is selected.

[0190] In an example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2, to select. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., the second RSRP threshold A. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is less

than the second RSRP threshold A, the UE **101** may select **603** RSRP level 2; else, the UE **101** may select **603** RSRP level 1.

[0191] In another example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2, to select. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., the second RSRP threshold A. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is above (above or equal to) the second RSRP threshold A, the UE **101** may select **603** RSRP level 1; else, the UE **101** may select **603** RSRP level 2.

[0192] In another example, three RSRP levels are configured for the UE **101**, i.e., RSRP level 0, RSRP level 1 and RSRP level 2, to select. Meanwhile, the one or more second RSRP thresholds are assumed to contain a single element, i.e., the second RSRP threshold A. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is less than the second RSRP threshold A, the UE **101** may select **603** RSRP level 2; else, the UE **101** may select **603** RSRP level 1.

[0193] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold **A1** and a second RSRP threshold **A2**. The second RSRP threshold **A1** may be larger than the second RSRP threshold **A2**. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is less than the second RSRP threshold **A2**, the UE **101** may select **603** RSRP level 2; else, the UE **101** may select **603** RSRP level 1, and if the SS-RSRP of the selected SSB is above (above or equal to) the second RSRP threshold **A1**, the UE **101** may select **603** RSRP level 1a; else, the UE **101** may select **603** RSRP level 1b.

[0194] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold **A1** and a second RSRP threshold **A2**. The second RSRP threshold **A1** may be larger than the second RSRP threshold **A2**. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is above (above or equal to) the second RSRP threshold **A1**, the UE **101** may select **603** RSRP level 1a; else, if the SS-RSRP of the selected SSB is above (above or equal to) the second RSRP threshold **A2**, the UE **101** may select **603** RSRP level 1b; else, the UE **101** may select **603** RSRP level 2.

[0195] In another example, the UE **101** is configured with RSRP level 0, RSRP level 1 and RSRP level 2, where RSRP level 1 may further include two sub-levels, i.e., RSRP level 1a and RSRP level 1b. Meanwhile, the one or more second RSRP thresholds may contain a second RSRP threshold **A1** and a second RSRP threshold **A2**. The second RSRP threshold **A1** may be larger than the second RSRP threshold **A2**. In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **602** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and select **603** RSRP level 0; else, the UE **101** may select **602** an SSB with the largest SS-RSRP, or select **602** any SSB, and then if the SS-RSRP of the selected SSB is less than the second RSRP threshold **A2**, the UE **101** may select **603** RSRP level 2; else, if the SS-RSRP of the selected SSB is less than the second RSRP threshold **A1**, the UE **101** may select **603** RSRP level 1b; else, the UE **101** may select **603** RSRP level 1a.

[0196] Each SSB from the one or more SSBs is associated with a set of one or more preambles with consecutive indexes. A list of the sets of the one or more preambles may be indicated explicitly by one or more RRC parameters included in the PRACH configuration information. Alternatively, or additionally, a list of the sets of the one or more preambles may be indicated implicitly by one or more RRC parameters included in the PRACH configuration information. For example, preamble indexes in each set of the one or more preambles with consecutive indexes associated with an SSB may be determined based on the number of SSBs per RACH occasion and the number of preambles per SSB. Furthermore, each of the sets of the one or more preambles may comprise one or more sub-sets of one or more preambles. Each sub-set of the one or more preambles is associated with one of the configured RSRP levels. The BS **102** may configure, to the UE **101**, a number of the sub-sets of the one or more preambles included in each set of the one or more preambles being equal to the number of the configured RSRP levels. The BS **102** may configure, to the UE **101**, one or more explicit RRC parameters to indicate the indexes in each sub-set of the one or more preambles from each set of the one or more preambles. Alternatively, or additionally, the BS **102** may configure, to the UE **101**, one or more implicit RRC parameters to indicate the indexes in each sub-set of the one or more preambles from each set of the one or more preambles. For example, the first index in each sub-set of the one or more preambles may be indicated by one or more RRC parameters configured by the BS **102**, and the last index in each sub-set of the one or more preambles may be determined by adding up the first index and the number of the preambles configured in each sub-set and subtracting one. The number of the preambles configured in each sub-set may be configured by other one or more RRC parameters by the BS **102**. For another example, the indexes in each sub-set of the one or more preambles may

be determined by a predefined equation, which at least contains the indexes of the set of the one or more preambles where the sub-set is included and the number of the sub-set (or the number of the RSRP levels) configured.

[0197] Additionally, or alternatively, the set of the one or more preambles with consecutive indexes associated with each SSB may be referred to as a preamble index range in this implementation, as well as in other various implementations of the present disclosure. A list of the preamble index ranges associated with the one or more SSBs respectively may be indicated explicitly by one or more RRC parameters included in the PRACH configuration information. Alternatively, or additionally, a list of the preamble index ranges associated with the one or more SSBs respectively may be indicated implicitly by one or more RRC parameters included in the PRACH configuration information. For example, preambles in each preamble index range associated with an SSB may be determined based on the number of SSBs per RACH occasion and the number of preambles per SSB. Furthermore, each preamble index range from the list of preamble index ranges may comprise one or more preamble index sub-ranges. Each preamble index sub-range from the one or more preamble index sub-ranges is associated with one of the configured RSRP levels. The BS **102** may configure, to the UE **101**, a number of the preamble index sub-ranges included in each preamble index range being equal to the number of the RSRP levels. The BS **102** may configure, to the UE **101**, one or more explicit RRC parameters to indicate the indexes in each preamble sub-range of each preamble range. Alternatively, or additionally, the BS **102** may configure, to the UE **101**, one or more implicit RRC parameters to indicate the indexes in each preamble sub-range of each preamble range. For example, the first index in each preamble sub-range may be indicated by one or more RRC parameters configured by the BS **102**, and the last index in each preamble sub-range may be determined by adding up the first index and the number of the preambles configured in each preamble sub-range and subtracting one. The number of the preambles configured in each preamble sub-range may be configured by other one or more RRC parameters by the BS **102**. For another example, the indexes in each preamble sub-range may be determined by a predefined equation, which at least contains the indexes of the preamble range where the sub-range is included and the number of the preamble sub-ranges (or the number of the RSRP levels) configured.

[0198] The one or more preambles with consecutive indexes (or the set of one or more preambles, or the preamble index range) associated with each SSB may be used for contention-based random access and/or contention-free random access.

[0199] In an example, there are 64 preambles (with consecutive index $\{0, 1, 2, \ldots, 63\}$) in total, 4 SSBs (including SSB0, SSB1, SSB2 and SSB3) and 2 RSRP levels (RSRP level 0 and RSRP level 1) configured by the BS **102** in the serving cell. In this case, SSB0 may be associated with 16 preambles with consecutive indexes $\{0, 1, 2, \ldots, 15\}$, SSB1 may be associated with 16 preambles with consecutive indexes $\{16, 17, 18, \ldots, 31\}$, SSB2 may be associated with 16 preambles with consecutive indexes $\{32, 33, 34, \ldots, 47\}$, SSB3 may be associated with 16 preambles with consecutive indexes $\{48, 49, 50, \ldots, 63\}$. The consecutive indexes $\{0, 1, 2, \ldots, 15\}$ associated with SSB0 may be separated as $\{\{0, 1, 2, \ldots, 7\}, \{8, 9, 10, \ldots 15\}\}$, where $\{0, 1, 2, \ldots, 7\}$ may be associated with RSRP level 0 and $\{8, 9, 10, \ldots 15\}$ may be associated with RSRP level 1. In this case, $\{0, 1, 2, \ldots, 7\}$ and $\{8, 9, 10, \ldots 15\}$ may be referred to as two sub-sets of the preamble indexes of the set $\{0, 1, 2, \ldots, 15\}$ associated with SSB0. In other words, $\{0, 1, 2, \ldots, 7\}$ and $\{8, 9, 10, \ldots 15\}$ may be referred to as two preamble index sub-ranges of the preamble index range $\{0, 1, 2, \ldots, 15\}$ associated with SSB0.

[0200] The UE **101** may select a preamble from the one or more preambles (or from the preamble index sub-range, or from the sub-set of the one or more preamble indexes) associated with the selected RSRP level and the selected SSB, and transmit **604** it through Msg1 **301** to the BS **102** during a 4-step random access procedure, or alternatively or additionally, transmit it through MsgA to the BS **102** during a 2-step random access procedure. That is, the UE **101** may randomly select a preamble from the one or more preambles (or from the preamble index sub-range, or from the sub-set of the one or more preamble indexes) associated with the selected RSRP level and the selected SSB in a PRACH occasion. The PRACH occasion is associated with the selected SSB and/or the selected RSRP level.

[0201] FIG. **7** is a flow diagram illustrating one implementation of a method **700** for determining an SSB and a preamble index for a UE **101**.

[0202] In the implementation of the present disclosure, the UE **101** may receive **701** system information which is broadcasted by the BS **102**. The system information may include PRACH configuration information. The PRACH configuration information may contain one or more RRC parameters.

[0203] The RRC parameter "rsrp-ThresholdSSB" may be used for the UE to select an SSB and select corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "rsrp-ThresholdSSB". The RRC parameter "rsrp-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "rsrp-ThresholdSSB" may be used in the 4-step random access type. The RRC parameter "rsrp-ThresholdSSB" may be also considered as a parameter indicating an RSRP threshold to determine whether the UE **101** is in CE mode or not.

[0204] The RRC parameter "msgA-RSRP-ThresholdSSB" may be used for the UE to select an SSB and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "msgA-RSRP-ThresholdSSB". The RRC parameter "msgA-RSRP-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "msgA-RSRP-ThresholdSSB" may be used in the 2-step random access type. The RRC parameter "msgA-RSRP-ThresholdSSB" may be also considered as a parameter indicating an RSRP threshold to determine whether the UE **101** is in CE mode or not.

[0205] The RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may be referred to as a first RSRP threshold, i.e. the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may indicate the first RSRP threshold. Additionally or alternatively, the BS **102** may transmit, to the UE **101**, another RRC parameter (e.g. "rsrp-ThresholdCE") included in the PRACH configuration information. The another RRC parameter (e.g. "rsrp-ThresholdCE") can be used to indicate the first RSRP threshold. In other words, the BS **102** and/or the UE **101**

may use the another RRC parameter (e.g. "rsrp-ThresholdCE") to determine whether the UE **101** is in CE mode or not, and may not use the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" to determine whether the UE **101** is in CE mode or not. The RSRP threshold indicated by the RRC parameter "rsrp-ThresholdCE" may be smaller than the RSRP threshold indicated by the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB". The BS **102** may configure the UE **101** a RRC parameter, which can be included in the SIB1 or the PRACH configuration information, to indicate whether to use the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" as the first RSRP threshold or to use another RRC parameter (e.g. "rsrp-ThresholdCE") as the first RSRP threshold. In other words, The BS **102** may configure the UE **101** a RRC parameter, which can be included in the SIB1 or the PRACH configuration information, to indicate the use of the RRC parameter "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" to determine whether the UE **101** is in CE mode or not. Alternatively, or additionally, the BS **102** may configure the UE **101** a RRC parameter, which can be included in the SIB1 or the PRACH configuration information, to indicate the use of another RRC parameter (e.g. "rsrp-ThresholdCE") to determine whether the UE **102** is in CE mode or not.

[0206] The PRACH configuration information may further include one or more preambles with consecutive indexes associated with each SSB from one or more SSBs. The one or more preambles associated with an SSB may include a set of one or more preambles associated with a non-CE mode for the UE **101**. A list of the sets of the one or more preambles associated with the non-CE mode and associated with the one or more SSBs respectively may be referred to as a first list of the sets of the one or more preambles. The one or more preambles with consecutive indexes associated with each SSB may also include a set of one or more preambles associated with a CE mode for the UE **101**. A list of the sets of the one or more preambles associated with the CE mode and associated with the one or more SSBs respectively may be referred to as a second list of the sets of the one or more preambles. Alternatively, or additionally, the first list of the sets of the one of more preambles and the second list of the sets of the one or more preambles can be configured, by the BS **102**, through independent RRC parameters for the UE **101**. That is, each SSB of the one or more SSBs may correspond to one set of one or more preambles in the first list of the sets and one set of one or more preambles in the second list of the sets. The one or more preambles with consecutive indexes associated with each SSB may be used for contention-based random access and/or contention-free random access.

[0207] Additionally, or alternatively, the one or more preambles with consecutive indexes associated with each SSB may include a preamble index range associated with a CE mode for the UE **101**. The preamble index ranges associated with the non-CE mode for the one or more SSBs respectively may be referred to as a first list of preamble index ranges. The one or more preambles with consecutive indexes associated with each SSB may also include another preamble index range associated with a CE mode for the UE **101**. The preamble index ranges associated with the CE mode for one or more SSBs respectively may be referred to as a second list of preamble index ranges. Alternatively, or additionally, the first list of preamble index ranges and the second list of preamble lists can be configured, by the BS **102**, through independent RRC parameters for the UE **101**. The preamble index range associated with each SSB may be used for contention-based random access and/or contention-free random access.

[0208] In other words, the PRACH configuration information may include a first list of sets of one or more preambles (or a first list of preamble index ranges) and a second list of sets of one or more preambles (or a second list of preamble index ranges). The first list is associated with a non-CE mode while the second list is associated with a CE mode. Each set of the one or more preambles in the first list (or each preamble index range in the first list) is associated with an SSB from one or more SSBs. Each set of the one or more preambles in the second list (or each preamble index range in the second list) is associated with an SSB from one or more SSBs. That is, each SSB from one or more SSBs corresponds to one set of one or more preambles (or a preamble index range) in the first list and one set of one or more preambles (or a preamble index range) in the second list.

[0209] The first list of the sets of the one or more preambles (or the first list of the preamble index ranges) and the second list of the sets of the one or more preambles (or the second list of the preamble index ranges) may be explicitly indicated by one or more RRC parameters included in the PRACH configuration information.

[0210] Additionally, or alternatively, the first list of the sets of the one or more preambles (or the first list of the preamble index ranges) and the second list of the sets of the one or more preambles (or the second list of the preamble index ranges) may be implicitly indicated by one or more RRC parameters included in the PRACH configuration information. For example, the first index of each set of the one or more preambles in the first list may be configured equal to the first index of the one or more preambles associated with each SSB. The indexes of the one or more preambles associated with each SSB may be implicitly determined by RRC parameters which indicate the number of SSBs per RACH occasion and the number of preambles per SSB. The last index of each set of the one or more preambles in the first list may be determined by subtracting one from the first index of the set of the one or more preambles in the second list minus one, where the set of the one or more preambles in the first list and the set of the one or more preambles in the second list are associated with a same SSB. Alternatively, or additionally, the last index of each set of the one or more preambles in the first list may be determined by adding up the first index of the set of the one or more preambles in the first list and the number of preambles configured in the set of the one or more preambles in the first list and subtracting one. The number of preambles configured in the set of the one or more preambles in the first list may be indicated by the RRC parameters included in the PRACH configuration information. Moreover, the first index of each set of the one or more preambles in the second list may be indicated by one or more RRC parameters included in the PRACH configuration information. Additionally, or alternatively, the first index of each set of the one or more preambles in the second list may be determined by adding up the last index of the set of one or more preambles in the first list and one, where the set of the one or more preambles in the first list and the set of the one or more preambles in the second list are associated with a same SSB. The last index

of each set of the one or more preambles in the second list may be configured equal to the last index of the one or more preambles associated with each SSB.

[0211] In an example, there are 64 preambles (with consecutive index {0, 1, 2, . . . , 63}) in total and 4 SSBs (including SSB0, SSB1, SSB2 and SSB3) configured by the BS **102** in the serving cell. In this case, SSB0 may be associated with 16 preambles with consecutive indexes {0, 1, 2, . . . , 15}, SSB1 may be associated with 16 preambles with consecutive indexes {16, 17, 18, . . . , 31}, SSB2 may be associated with 16 preambles with consecutive indexes {32, 33, 34, . . . , 47}, SSB3 may be associated with 16 preambles with consecutive indexes {48, 49, 50, . . . , 63}. Furthermore, {0, 1, 2, . . . , 7}, {16, 17, 18, . . . , 23}, {32, 33, 34, . . . , 39} and {48, 49, 50, . . . , 55}, associated with SSB0, SSB1, SSB2 and SSB3, respectively, may be referred to as the first list of sets of preambles (or the first list of preamble index ranges), which are associated the non-CE mode. Meanwhile, {8, 9, 10, . . . , 15}, {24, 25, 26, . . . , 31}, {40, 41, 42, . . . , 47} and {56, 57, 58, 63}, associated with SSB0, SSB1, SSB2 and SSB3, respectively, may be referred to as the second list of sets of preambles (or the second list of preamble index ranges), which are associated the CE mode.

[0212] The CE mode described above may also be regarded as an enhanced coverage level, an RSRP level, a repetition level (or a repetition number), a CE level, or a CE sub-mode in this implementation and other various implementations of the present disclosure. The non-CE mode described above may also be regarded as an enhanced coverage level 0, an RSRP level 0, a repetition level 0 (or a repetition number 0), a CE level 0, or a CE sub-mode 0 in this implementation and other various implementations of the present disclosure.

[0213] The CE mode may be associated with one, more, or all of a number of PUSCH repetitions, a number of PUCCH repetitions, a number of PDCCH repetitions, a number of PDSCH repetitions, a number of PRACH repetitions and etc. The CE mode may be associated with a number of PUSCH transmissions of a transmission block (TB) within a bundle of a dynamic grant or configured grant. The PUSCH repetitions may be PUSCH repetitions for Msg3. The PUCCH repetitions may be the PUCCH repetitions for Msg4. For example, the non-CE mode may indicate a single transmission of PUSCH and/or PUCCH without repetition. For another example, the CE-mode may indicate transmissions of PUSCH and/or PUCCH with R repetitions. The repetition number R can be a predefined number or can be indicated by the broadcasted system information (e.g., MIB, SIB1, or other SIBs), RRC message, MAC control element, DCI format and so on.

[0214] The UE **101** may decide **702** whether the first RSRP threshold is used for the selection of the non-CE mode or the CE mode, based on an RRC parameter included in the PRACH configuration information provided by the BS **102**. One information element (IE) containing 1 bit in PRACH configuration information or in SIB1 may be used as the RRC parameter to indicate, for the UE **101**, whether the first RSRP threshold is used for the selection of the non-CE mode or the CE mode. In other words, the UE **101** which is capable of the CE mode may decide to work in the non-CE mode if at least one of the SS-RSRP values from the one or more SSBs above (above or equal) the first SSB threshold is available. Alternatively, or additionally, the UE **101** which is capable of the CE mode may only work in CE mode, regardless of the SS-RSRP values from the one or more SSBs and the first RSRP threshold.

[0215] In an example, the UE **101** which is capable of a CE mode may determine whether to select the non-CE mode or the CE mode at least based on the SS-RSRPs of the one or more SSBs. The expression that UE selects the non-CE mode or the CE mode may also imply that the UE considers itself to be in the non-CE mode or in the CE mode. If at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may consider **702** to be in non-CE mode; else, the UE **101** may consider **702** to be in CE mode. If the UE **101** considers itself to be in non-CE mode, the UE **101** may select **703** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold, and the UE **101** may also select **704** a preamble from the set of the one or more preambles (or from the preamble index range) in the first list associated with the selected SSB. The UE **101** may transmit **704** the selected preamble through Msg1 **301** to the BS **102** during the 4-step random access procedure, or alternatively transmit it through Msg A to the BS **102** during the 2-step random access procedure. If the UE **101** considers itself to be in CE mode, the UE **101** may select **703** any SSB, and the UE **101** may also select **704** a preamble from the set of the one or more preambles (or from the preamble index range) in the second list associated with the selected SSB.

[0216] In another example, the UE **101** which is capable of a CE mode may always determine to work only in the CE mode regardless of the SS-RSRPs of the one or more SSBs. That is, even if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may still consider **702** to be in CE mode. The UE **102** may always perform repetition transmission for PRACH transmission, PUSCH transmission, PUCCH transmission. For SSB selection, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **703** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold; else, the UE **101** may select **703** any SSB. Then, UE **101** may select **704** a preamble from the set of the one or more preambles (or from the preamble index range) in the second list associated with the selected SSB regardless of whether the selected SSB with SS-RSRP above the first RSRP threshold. The UE **101** may transmit **704** the selected preamble through Msg1 **301** to the BS **102** during the 4-step random access procedure, or alternatively transmit it through Msg A to the BS **102** during the 2-step random access procedure.

[0217] In another example, the BS **102** may configure the UE **101** which is capable of a CE mode whether (behavior I) to select the non-CE mode or the CE mode based on the SS-RSRPs of the one or more SSBs or (behavior II) to always select the CE mode regardless of the SS-RSRPs of the one or more SSBs via a RRC parameter. That is, the RRC parameter is associated with the CE mode indication. The RRC parameter is used to indicate the UE capable of CE mode to perform behavior I or behavior II. The RRC parameter may be included in the PRACH configuration or in the broadcasted system information, e.g. the SIB **1**. If the RRC parameter is set to 'behavior I', the UE **102** may determine whether to select the non-CE mode or the CE mode at least based on the SS-RSRPs of the one or more

SSBs. If the RRC parameter is set to 'behavior II', the UE **102** may determine to always select the CE mode regardless of the SS-RSRPs of the one or more SSBs. Additionally or alternatively, if the RRC parameter is absent (or if the RRC parameter is disabled), the UE **102** may determine to perform behavior I. That is, if the RRC parameter is present (or if the RRC parameter is enabled), the UE **102** may determine to perform behavior II. Additionally or alternatively, if the RRC parameter is absent (or if the RRC parameter is disabled), the UE **102** may determine to perform behavior II. That is, if the RRC parameter is present (or if the RRC parameter is enabled), the UE **102** may determine to perform behavior I.

[0218] In another example, the BS **102** may configure the UE **101** which is capable of a CE mode a RRC parameter that is used to indicate whether to apply (use) the first RSRP threshold or not. The RRC parameter with for example 1 bit may be included in the PRACH configuration or in the broadcasted system information, e.g. the SIB1. If the RRC parameter is set to a specific value (e.g. '0'), the UE **101** may determine not to use the first RSRP threshold. On the other hand, if the RRC parameter is set to another specific value (e.g. '1'), the UE **101** may determine to use the first RSRP threshold. 'The UE determines to use the first RSRP threshold' may also imply that 'the UE may perform behavior I as above-mentioned, i.e. the UE may select the non-CE mode or the CE mode based on the SS-RSRPs of the one or more SSBs and the first RSRP threshold'. Meanwhile, 'The UE determines not to use the first RSRP threshold' may also imply that 'the UE may perform behavior II as above-mentioned, i.e. the UE may determine to always select the CE mode regardless of whether the SS-RSRPs of the one or more SSBs above the first RSRP threshold'.

[0219] FIG. **8** is a flow diagram illustrating one implementation of a method **800** for determining an SSB and a preamble index for a UE **101**.

[0220] In the implementation of the present disclosure, the UE **101** may receive **801** system information which is broadcasted by the BS **102**. The system information may include PRACH configuration information. The PRACH configuration information may contain one or more RRC parameters.

[0221] The RRC parameter "rsrp-ThresholdSSB" may be used for the UE to select an SSB from a set of SSBs and select corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "rsrp-ThresholdSSB". The RRC parameter "rsrp-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "rsrp-ThresholdSSB" may be used in the 4-step random access type.

[0222] The RRC parameter "msgA-RSRP-ThresholdSSB" may be used for the UE to select an SSB and corresponding PRACH resources for path-loss estimation and (re)transmission based on the SSB that satisfies a threshold indicated by the RRC parameter "msgA-RSRP-ThresholdSSB". The RRC parameter "msgA-RSRP-ThresholdSSB" may be included in the PRACH configuration information. The RRC parameter "msgA-RSRP-ThresholdSSB" may be used in the 2-step random access type.

[0223] The RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may be referred to as a first RSRP threshold, i.e. the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" may indicate the first RSRP threshold. Additionally or alternatively, the BS **102** may transmit, to the UE **101**, another RRC parameter (e.g. "rsrp-ThresholdCE") included in the PRACH configuration information. The another RRC parameter (e.g. "rsrp-ThresholdCE") can be used to indicate the first RSRP threshold. In other words, the BS **102** and/or UE **101** may use the another RRC parameter (e.g. "rsrp-ThresholdCE") to determine whether the UE **101** is in CE mode or not, and may not use the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB" to determine whether the UE **101** is in CE mode or not. The RSRP threshold indicated by the RRC parameter "rsrp-ThresholdCE" may be smaller than the RSRP threshold indicated by the RRC parameters "rsrp-ThresholdSSB" or "msgA-RSRP-ThresholdSSB".

[0224] The PRACH configuration information may further include one or more preambles with consecutive indexes associated with each SSB from the one or more SSBs. In one case, the one or more preambles with consecutive indexes associated with an SSB may be referred to as a set of one or more preambles with consecutive indexes associated with an SSB. A list of the sets of the one or more preambles associated with the one or more SSBs respectively may be referred to as a first list of sets of one or more preambles. In this case, the BS **102** may not configure preambles indicating a CE mode for UEs **101** in the serving cell. That is, the BS **102** may not allow a UE to operate in a CE mode in the serving cell, even though the UE may support a CE mode. Alternatively, or additionally, in another case, the one or more preambles with consecutive indexes associated with each SSB may include a set of one or more preambles associated with a non-CE mode for the UE **101**. A list of the sets of the one or more preambles associated with the non-CE mode and associated with the one or more SSBs respectively may be referred to as a first list of sets of one or more preambles. Moreover, the one or more preambles with consecutive indexes associated with each SSB may further include a set of one or more preambles associated with a CE mode for the UE **101**. A list of the sets of the one or more preambles associated with the CE mode and associated with the one or more SSBs respectively may be referred to as a second list of sets of one or more preambles. Alternatively, or additionally, the first list of the sets of the one or more preambles and the second list of the sets of the one or more preambles may be configured by the BS **102** through independent RRC parameters for the UE **101**. The one or more preambles with consecutive indexes associated with each SSB may be used for contention-based random access and/or contention-free random access.

[0225] In other words, in one case, a list of the one or more preambles with consecutive indexes associated with the one or more SSBs respectively may be referred to as a first list of preamble index ranges. In this case, the BS **102** may not configure preambles indicating a CE mode for UEs **101** in the serving cell. That is, the BS **102** may not allow a UE to operate in a CE mode in the serving cell, even though the UE may support a CE mode. Alternatively, or additionally, in another case, the one or more preambles with consecutive indexes associated with an SSB may include a preamble index range, which is associated with a non-CE mode for the UE **101**. A list of the preamble index ranges associated with the one or more SSBs respectively indicating the non-CE mode of the UE **101** may be referred to as a first list of preamble index ranges. Moreover, the one or more preambles with consecutive indexes associated with an SSB

may also include a preamble index range, which is associated with a CE mode for the UE **101**. A list of the preamble index ranges associated with the one or more SSBs respectively indicating the CE mode of the UE **101** may be referred to as a second list of preamble index ranges. Alternatively, or additionally, in another case, a first list of preamble index ranges and a second list of preamble index ranges may be configured by the BS **102** through independent RRC parameters for the UE **101**.

[0226] The first list of the sets of the one or more preambles (or the first list of the preamble index ranges) and the second list of the sets of the one or more preambles (or the second list of the preamble index ranges) may be explicitly indicated by one or more RRC parameters included in the PRACH configuration information.

[0227] Additionally, or alternatively, the first list of the sets of the one or more preambles (or the first list of the preamble index ranges) and the second list of the sets of the one or more preambles (or the second list of the preamble index ranges) may be implicitly indicated by one or more RRC parameters included in the PRACH configuration information. For example, the first index of each set of the one or more preambles in the first list may be configured equal to the first index of the one or more preambles associated with each SSB. The indexes of the one or more preambles associated with each SSB may be implicitly determined by RRC parameters which indicate the number of SSBs per RACH occasion and the number of preambles per SSB. The last index of each set of the one or more preambles in the first list may be determined by subtracting one from the first index of the set of the one or more preambles in the second list minus one, where the set of the one or more preambles in the first list and the set of the one or more preambles in the second list are associated with a same SSB. Alternatively, or additionally, the last index of each set of the one or more preambles in the first list may be determined by adding up the first index of the set of the one or more preambles in the first list and the number of preambles configured in the set of the one or more preambles in the first list and subtracting one. The number of preambles configured in the set of the one or more preambles in the first list may be indicated by the RRC parameters included in the PRACH configuration information. Moreover, the first index of each set of the one or more preambles in the second list may be indicated by one or more RRC parameters included in the PRACH configuration information. Additionally, or alternatively, the first index of each set of the one or more preambles in the second list may be determined by adding up the last index of the set of one or more preambles in the first list and one, where the set of the one or more preambles in the first list and the set of the one or more preambles in the second list are associated with a same SSB. The last index of each set of the one or more preambles in the second list may be configured equal to the last index of the one or more preambles associated with each SSB.

[0228] In an example, there are 64 preambles (with consecutive index {0, 1, 2, . . . , 63}) in total and 4 SSBs (including SSB0, SSB1, SSB2 and SSB3) configured by the BS **102** in the serving cell. In this case, SSB0 may be associated with 16 preambles with consecutive indexes {0, 1, 2, . . . , 15}, SSB1 may be associated with 16 preambles with consecutive indexes {16, 17, 18, . . . , 31}, SSB2 may be associated with 16 preambles with consecutive indexes {32, 33, 34, . . . , 47}, SSB3 may be associated with 16 preambles with consecutive indexes {48, 49, 50, . . . , 63}. In this serving cell, the BS **102** does not configure CE mode for UEs **101**. Therefore, {0, 1, 2, . . . , 15}, {16, 17, 18, . . . , 31}, {32, 33, 34, . . . , 47} and {48, 49, 50, . . . , 63}, associated with SSB0, SSB1, SSB2 and SSB3, respectively, may be referred to as a first list of sets of preambles (or a first list of preamble index ranges), which are associated the non-CE mode.

[0229] In another example, there are 64 preambles (with consecutive index {0, 1, 2, . . . , 63}) in total and 4 SSBs (including SSB0, SSB1, SSB2 and SSB3) configured by the BS **102** in the serving cell. In this case, SSB0 may be associated with 16 preambles with consecutive indexes {0, 1, 2, . . . , 15}, SSB1 may be associated with 16 preambles with consecutive indexes {16, 17, 18, . . . , 31}, SSB2 may be associated with 16 preambles with consecutive indexes {32, 33, 34, . . . , 47}, SSB3 may be associated with 16 preambles with consecutive indexes {48, 49, 50, . . . , 63}. In this serving cell, the BS **102** may configure both non-CE mode and CE mode for UEs **101**. Therefore, {0, 1, 2, . . . , 7}, {16, 17, 18, . . . , 23}, {32, 33, 34, . . . , 39} and {48, 49, 50, . . . , 55}, associated with SSB0, SSB1, SSB2 and SSB3, respectively, may be configured as a first list of sets of preambles (or the first list of preamble index ranges), which are associated the non-CE mode. Meanwhile, {8, 9, 10, . . . , 15}, {24, 25, 26, . . . , 31}, {40, 41, 42, . . . , 47} and {56, 57, 58, . . . , 63}, associated with SSB0, SSB1, SSB2 and SSB3, respectively, may be configured as a second list of sets of preambles (or the second list of preamble index ranges), which are associated the CE mode.

[0230] The CE mode described above may also indicate an enhanced coverage level, a RSRP level, a repetition level (a repetition number), a CE level, or a CE sub-mode in this implementation and other various implementations of the present disclosure. The non-CE mode described above may also indicate an enhanced coverage level 0, a repetition level 0 (a repetition level 0), a RSRP level 0, a CE level 0, or a CE sub-mode 0 in this implementation and other various implementations of the present disclosure.

[0231] The CE mode may be associated with one, more, or all of a number of PUSCH repetitions, a number of PUCCH repetitions, a number of PDCCH repetitions, a number of PDSCH repetitions, a number of PRACH repetitions and etc. The CE mode may be associated with a number of PUSCH transmissions of a transmission block (TB) within a bundle of a dynamic grant or configured grant. The PUSCH repetitions may be PUSCH repetitions for Msg3. The PUCCH repetitions may be the PUCCH repetitions for Msg4. For example, the non-CE mode may indicate a single transmission of PUSCH and/or PUCCH without repetition. For another example, the CE-mode may indicate transmissions of PUSCH and/or PUCCH with R repetitions. The repetition number R can be a predefined number or can be indicated by the broadcasted system information (e.g., MIB, SIB1, or other SIBs), RRC message, MAC control element, DCI format and so on.

[0232] In an example, the UE **101** is capable of a CE mode. The received **801** PRACH configuration information by the UE **101** from the BS **102** includes a first list of sets of one or more preambles (or a first list of preamble index ranges) and a first RSRP threshold. The received **801** PRACH configuration information by the UE **101** also includes **803** a second list of sets of one or more preambles (or a second list of preamble index ranges). In this example,

if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **802** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold and select **804** a preamble from the set of the one or more preambles (or the preamble index range) associated with the selected SSB among the sets of the one or more preambles (or the preamble index ranges) in the second list; else, the UE **101** may select **802** any SSB and select **804** a preamble from the set of the one or more preambles (or the preamble index range) associated with the selected SSB among the sets of the one or more preambles (or the preamble index ranges) in the second list. The UE **101** may transmit **805** the selected preamble through Msg1 **301** to the BS **102** during the 4-step random access procedure, or alternatively transmit it through Msg A to the BS **102** during the 2-step random access procedure. The UE **101** may also perform **805** Msg3 transmissions with repetitions to the BS **102**.

[0233] In another example, the UE **101** is capable of a CE mode. The received **801** PRACH configuration information by the UE **101** from the BS **102** includes a first list of sets of one or more preambles (a first list of preamble index ranges) and a first RSRP threshold. The received **801** PRACH configuration information by the UE **101** does not include **803** a second list of sets of preamble index ranges. That is, the BS **102** does not provide either explicit or implicit RRC parameters included in PRACH configuration information for the UE **101** to indicate a second list of sets of one or more preambles (or a second list of preamble index ranges). In this example, if at least one of the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold is available, the UE **101** may select **802** an SSB from the one or more SSBs with SS-RSRP above (above or equal to) the first RSRP threshold and select a preamble from the sets of the one or more preambles (or the preamble index range) associated with the selected SSB among the sets of the one or more preambles (or preamble index ranges) in the first list; else, the UE **101** may select **802** any SSB and select **803** a preamble from the set of the one or more preambles (or the preamble index range) associated with the selected SSB among the sets of the one or more preambles (or the preamble index ranges) in the first list. The UE **101** may transmit **804** the selected preamble as the Msg1 **301** to the BS **102** during the 4-step random access procedure, or alternatively transmit it as the Msg A to the BS **102** during the 2-step random access procedure.

[0234] FIG. **9** illustrates various components that may be utilized by a UE **902**. The UE **902** described in FIG. **9** may be implemented in accordance with the UE **101** described in FIG. **1**. The UE **902** includes a processor **981** that controls operation of the UE **902**. The processor **981** may also be referred to as a central processing unit (CPU). Memory **987**, which may include read-only memory (ROM), random access memory (RAM), a combination of the two or any type of device that may store information, provides instructions **983***a* and data **985***a* to the processor **981**. A portion of the memory **987** may also include non-volatile random access memory (NVRAM). Instructions **983***b* and data **985***b* may also reside in the processor **981**. Instructions **983***b* and/or data **985***b* loaded into the processor **981** may also include instructions **983***a* and/or data **985***a* from memory **987** that were loaded for execution or processing by the processor **981**. The instructions **983***b* may be executed by the processor **981** to implement one or more of the methods **200** described above.

[0235] The UE **902** may also include one or more transmitters **958** and one or more receivers **920** to allow transmission and reception of data. The transmitter(s) **958** and receiver(s) **920** may be combined into one or more transceivers **918**. One or more antennas **922***a*—n are attached to the housing and electrically coupled to the transceiver **918**.

[0236] The various components of the UE **902** are coupled together by a bus system **989**, which may include a power bus, a control signal bus and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in FIG. **9** as the bus system **989**. The UE **902** may also include a digital signal processor (DSP) **991** for use in processing signals. The UE **902** may also include a communications interface **993** that provides user access to the functions of the UE **902**. The UE **902** illustrated in FIG. **9** is a functional block diagram rather than a listing of specific components.

[0237] FIG. **10** illustrates various components that may be utilized by a base station **1060**. The base station **1060** described in FIG. **10** may be implemented in accordance with the base station **102** described in FIG. **1**. The base station **1060** includes a processor **1081** that controls operation of the base station **1060**. The processor **1081** may also be referred to as a central processing unit (CPU). Memory **1087**, which may include read-only memory (ROM), random access memory (RAM), a combination of the two or any type of device that may store information, provides instructions **1083***a* and data **1085***a* to the processor **1081**. A portion of the memory **1087** may also include non-volatile random access memory (NVRAM). Instructions **1083***b* and data **1085***b* may also reside in the processor **1081**. Instructions **1083***b* and/or data **1085***b* loaded into the processor **1081** may also include instructions **1083***a* and/or data **1085***a* from memory **1087** that were loaded for execution or processing by the processor **1081**. The instructions **1083***b* may be executed by the processor **1081** to implement one or more of the methods **300** described above.

[0238] The base station **1060** may also include a housing that contains one or more transmitters **1017** and one or more receivers **1078** to allow transmission and reception of data. The transmitter(s) **1017** and receiver(s) **1078** may be combined into one or more transceivers **1076**. One or more antennas **1080***a*—n are attached to the housing and electrically coupled to the transceiver **1076**.

[0239] The various components of the base station **1060** are coupled together by a bus system **1089**, which may include a power bus, a control signal bus and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in FIG. **10** as the bus system **1089**. The base station **1060** may also include a digital signal processor (DSP) **791** for use in processing signals. The base station **1060** may also include a communications interface **1093** that provides user access to the functions of the base station **1060**. The base station **1060** illustrated in FIG. **10** is a functional block diagram rather than a listing of specific components.

[0240] The term "computer-readable medium" refers to any available medium that can be accessed by a computer or a processor. The term "computer-readable medium," as used herein, may denote a computer- and/or processor-readable medium that is non-transitory and tangible. By way of

example, and not limitation, a computer-readable or processor-readable medium may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer or processor. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers.

[0241] It should be noted that one or more of the methods described herein may be implemented in and/or performed using hardware. For example, one or more of the methods described herein may be implemented in and/or realized using circuitry, a chipset, an application-specific integrated circuit (ASIC), a large-scale integrated circuit (LSI) or integrated circuit, etc.

[0242] Each of the methods disclosed herein comprises one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another and/or combined into a single step without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0243] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods and apparatus described herein without departing from the scope of the claims.

1-5. (canceled)

6. A user equipment (UE), comprising:

reception circuitry configured to receive, from a base station, system information including physical random access channel (PRACH) configuration information, for a serving cell, wherein

the PRACH configuration information includes a first reference signal received power (RSRP) threshold, one or more second RSRP thresholds, and a list of preamble index ranges, where each of the preamble index ranges is associated with an synchronization signal and physical broadcasting channel block (SSB) from one or more SSBs, where each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, and

control circuitry configured to, if at least one of the one or more SSBs with synchronization signal (SS)-RSRP above the first RSRP threshold is available, select an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP Level 0; else,

if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP Level 2, and select any SSB; else, select RSRP Level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and

select a preamble from a sub-range associated to the selected RSRP level and the selected SSB.

7. Abase station (BS), comprising:

transmitting circuitry configured to transmit, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein

the PRACH configuration information includes a first RSRP threshold, one or more second RSRP thresholds and a list of preamble index ranges, wherein

each of the preamble index ranges is associated with an SSB from one or more SSBs, wherein

each of the preamble index ranges comprises one or more preamble index sub-ranges, wherein

each of the preamble index sub-ranges is associated with an RSRP level, wherein

the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP Level 0; else,

if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP Level 2, and select any SSB; else,

select RSRP Level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and

select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and

reception circuitry configured to receive, from the UE, the preamble.

8. A method performed by a base station (BS), comprising:

transmitting, to a user equipment (UE), system information including PRACH configuration information, for a serving cell, wherein

the PRACH configuration information includes a first RSRP threshold, and one or more second RSRP thresholds, and a list of preamble index ranges, wherein each of the preamble index ranges is associated with an SSB from one or more SSBs, wherein each of the preamble index ranges comprises one or more preamble index sub-ranges, where each of the preamble index sub-ranges is associated with an RSRP level, wherein

the first RSRP threshold and the one or more second RSRP thresholds are used by the UE to select, if at least one of the one or more SSBs with SS-RSRP above the first RSRP threshold is available, an SSB from one or more SSBs with SS-RSRP above the first RSRP threshold, and select RSRP Level 0; else,

if no SSB with SS-RSRP above the second RSRP threshold A is available, select RSRP Level 2, and select any SSB; else,

select RSRP Level 1, and select any SSB with SS-RSRP above the second RSRP threshold A; and

select a preamble from a sub-range associated to the selected RSRP level and the selected SSB; and

receiving, from the UE, the preamble.

* * * * *