US 20250267723A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0267723 A1**

LIU et al. (43) **Pub. Date: Aug. 21, 2025**

(54) **SYSTEMS, METHODS, AND NON-TRANSITORY PROCESSOR-READABLE MEDIA FOR TRANSMISSION DURING RANDOM ACCESS PROCEDURE**

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(21) Appl. No.: **19/203,974**

(22) Filed: **May 9, 2025**

Related U.S. Application Data

(63) Continuation of application No. PCT/CN2023/076560, filed on Feb. 16, 2023.

Publication Classification

(51) **Int. Cl.**

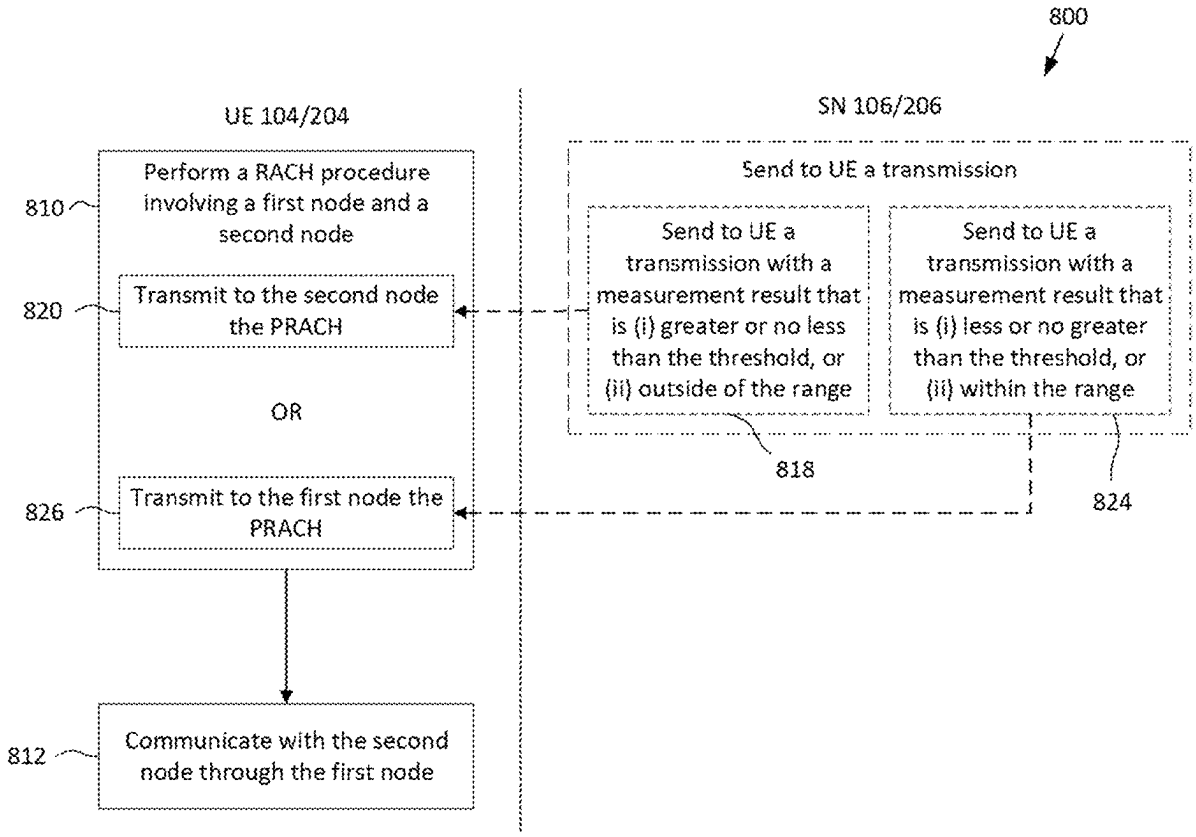
H04W 74/0833	(2024.01)
H04B 7/06	(2006.01)
H04W 24/10	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 74/0833*** (2013.01); ***H04B 7/0626*** (2013.01); ***H04W 24/10*** (2013.01)

(57) **ABSTRACT**

Systems, methods, non-transitory processor-readable media, and apparatuses for performing, by a wireless communication device, a Random Access Channel (RACH) procedure involving a first node and a second node, wherein the wireless communication device receives downlink data from the second node, and communicating by the wireless communication device with the second node through the first node.



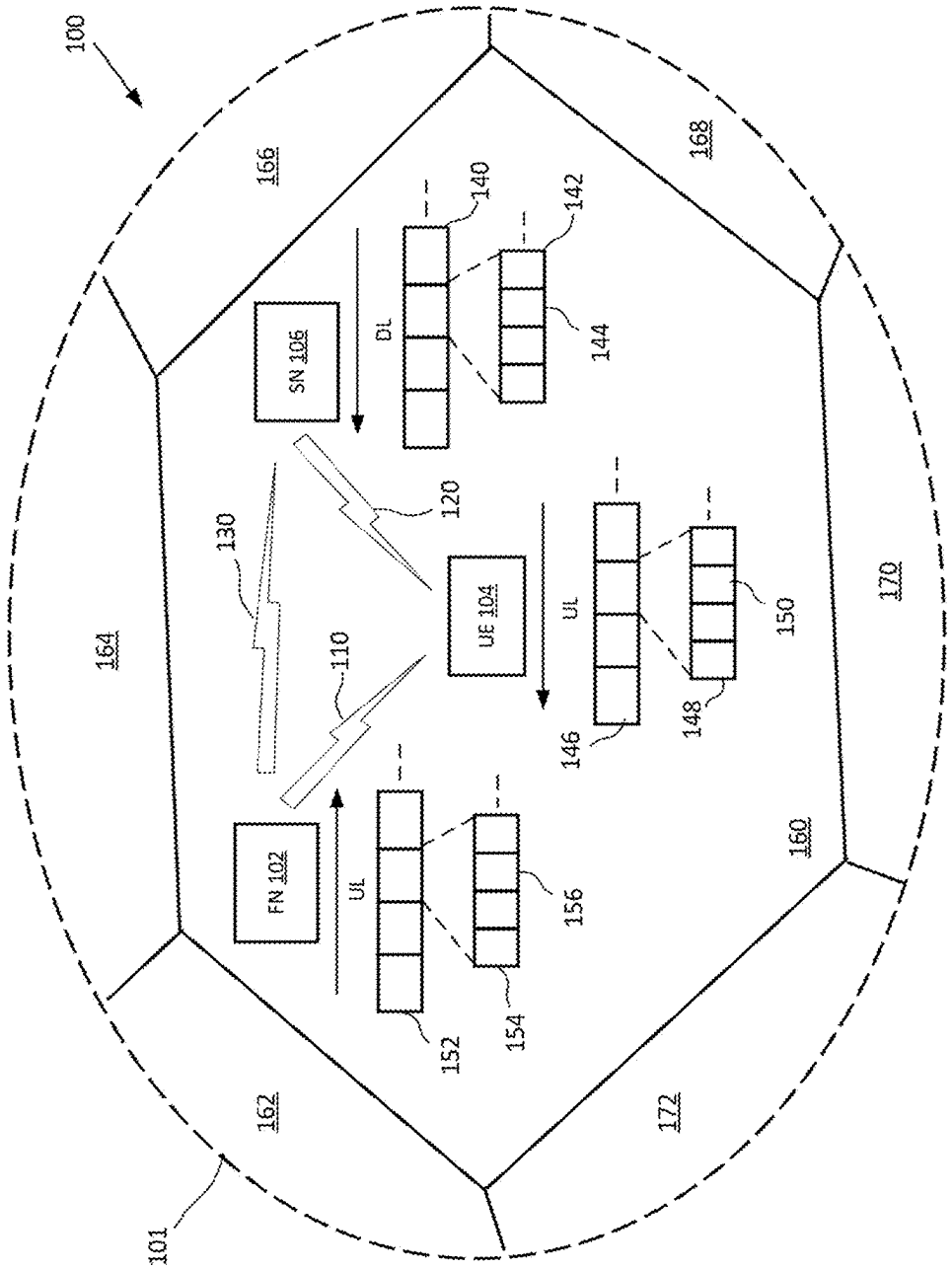

100
166
168
164
170
160
162
172
101
SN 106
FN 102
UE 104
DL
UL
UL
UL
120
130
110
140
142
144
146
148
150
152
154
156

FIG. 1

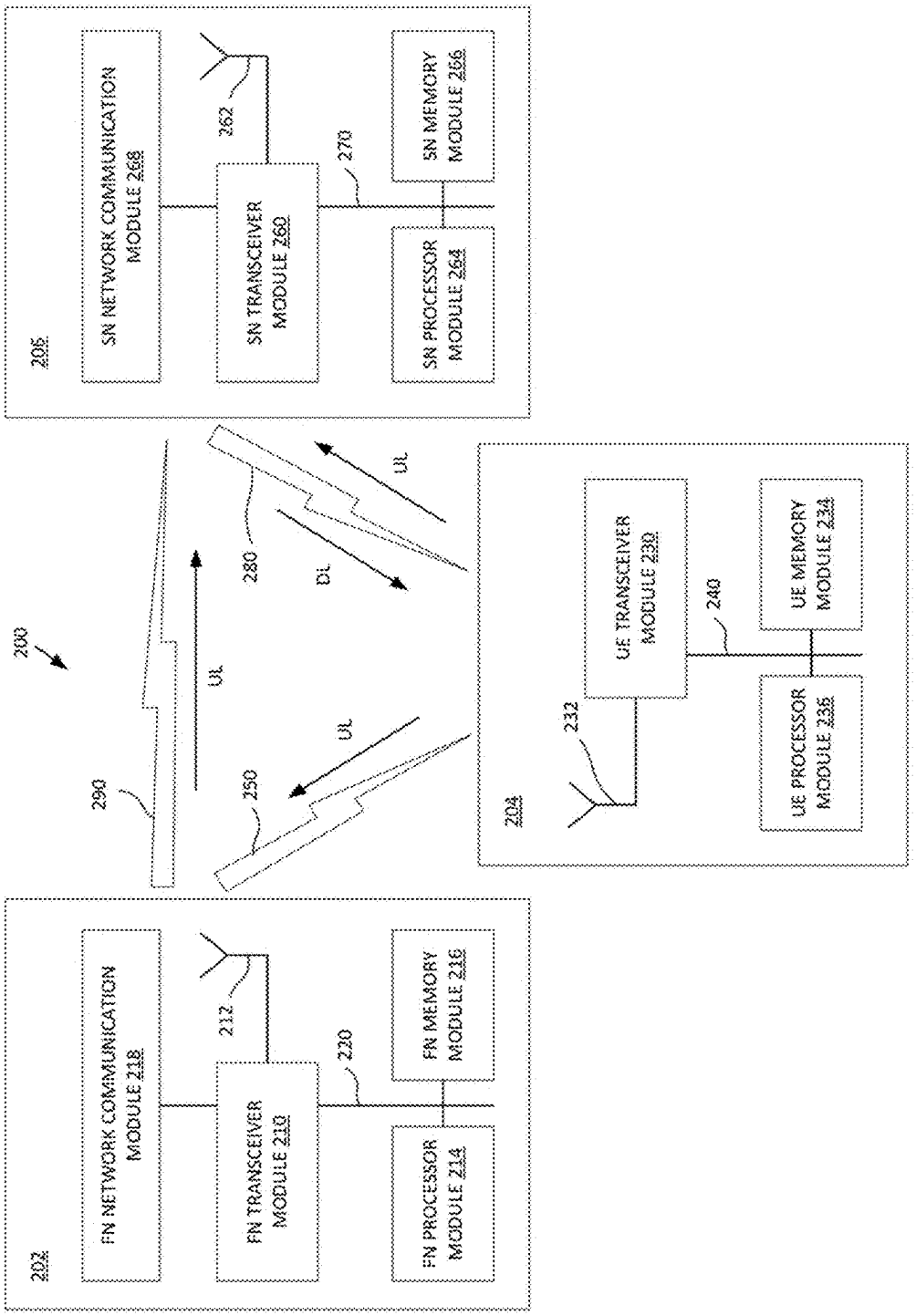

200
202
FN NETWORK COMMUNICATION MODULE 218
FN TRANSCEIVER MODULE 210
FN PROCESSOR MODULE 214
FN MEMORY MODULE 216
212
220
204
UE TRANSCEIVER MODULE 230
UE PROCESSOR MODULE 236
UE MEMORY MODULE 234
232
240
206
SN NETWORK COMMUNICATION MODULE 268
SN TRANSCEIVER MODULE 260
SN PROCESSOR MODULE 264
SN MEMORY MODULE 266
262
270
290
250
280
UL
UL
DL
UL

FIG. 2

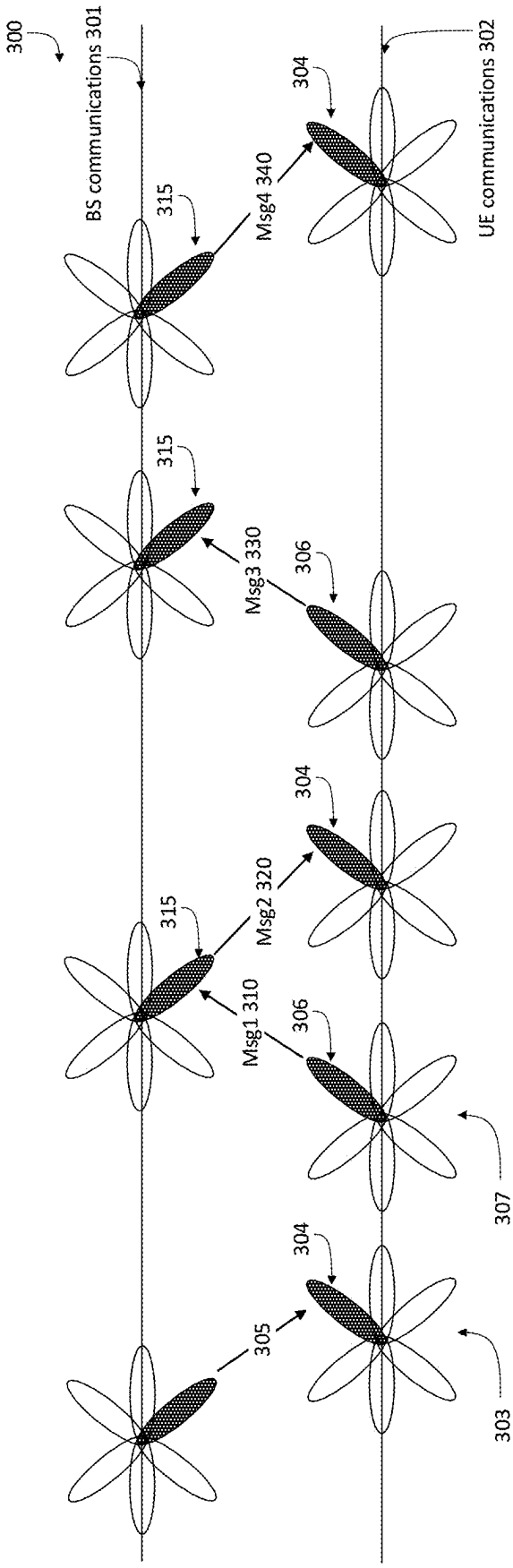

300
BS communications 301
UE communications 302
315
304
Msg4 340
315
306
Msg3 330
304
315
Msg2 320
306
Msg1 310
307
304
305
303

FIG. 3

PRACH Configuration Index	Preamble format	$n_f \bmod x = y$		Subframe number	Starting symbol	Number of PRACH slots within a subframe	$N_t^{RA,slot}$, number of time-domain PRACH occasions within a PRACH slot	N_{dur}^{RA}, PRACH duration
		x	y					
0	0	16	1	1	0	-	-	0
1	0	16	1	4	0	-	-	0
2	0	16	1	7	0	-	-	0
3	0	16	1	9	0	-	-	0
4	0	8	1	1	0	-	-	0
5	0	8	1	4	0	-	-	0
6	0	8	1	7	0	-	-	0
7	0	8	1	9	0	-	-	0
8	0	4	1	1	0	-	-	0
9	0	4	1	4	0	-	-	0
...								

FIG. 4

Preamble SCS	N_{gap}
1.25 kHz or 5 kHz	0
15 kHz or 30 kHz or 60 kHz or 120 kHz	2
480 kHz	8
960 kHz	16

FIG. 5

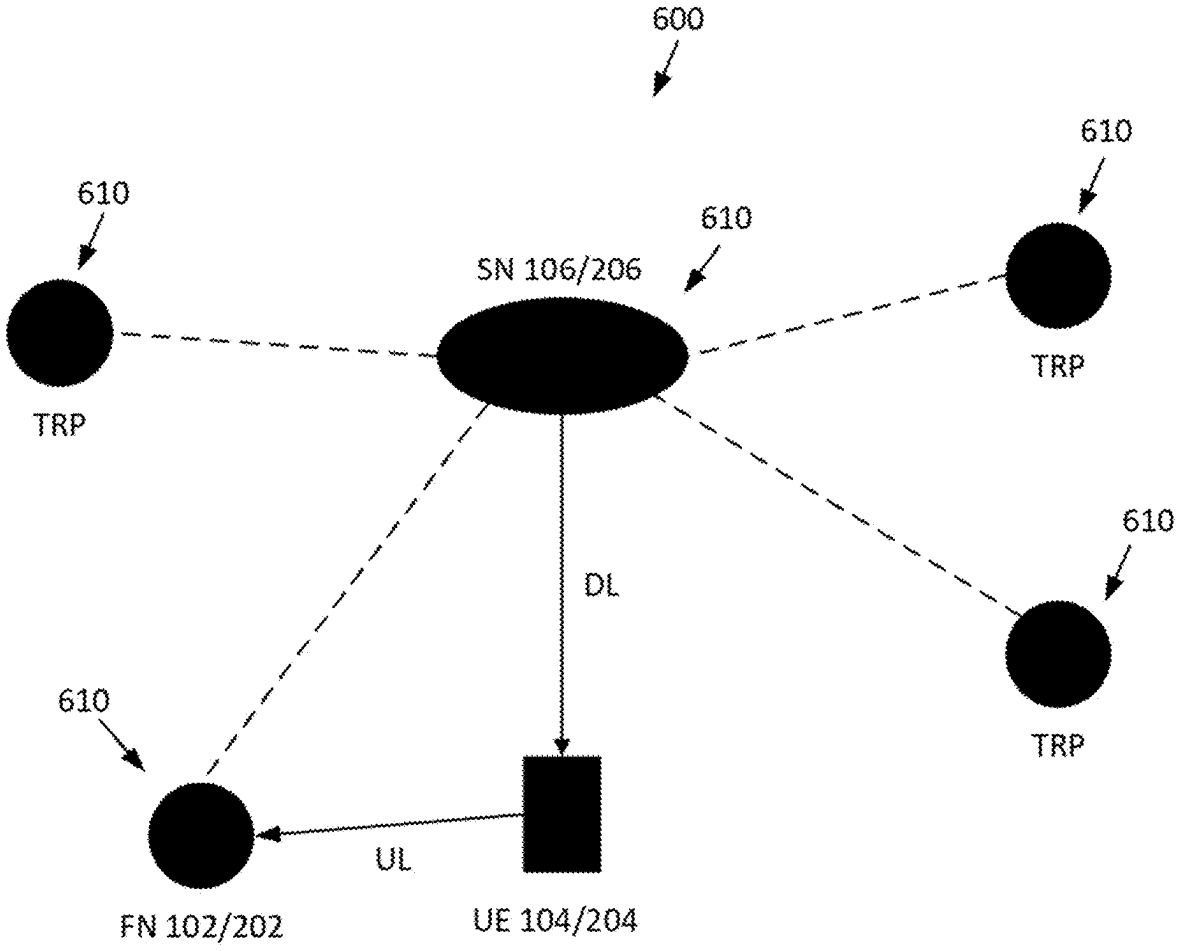


FIG. 6

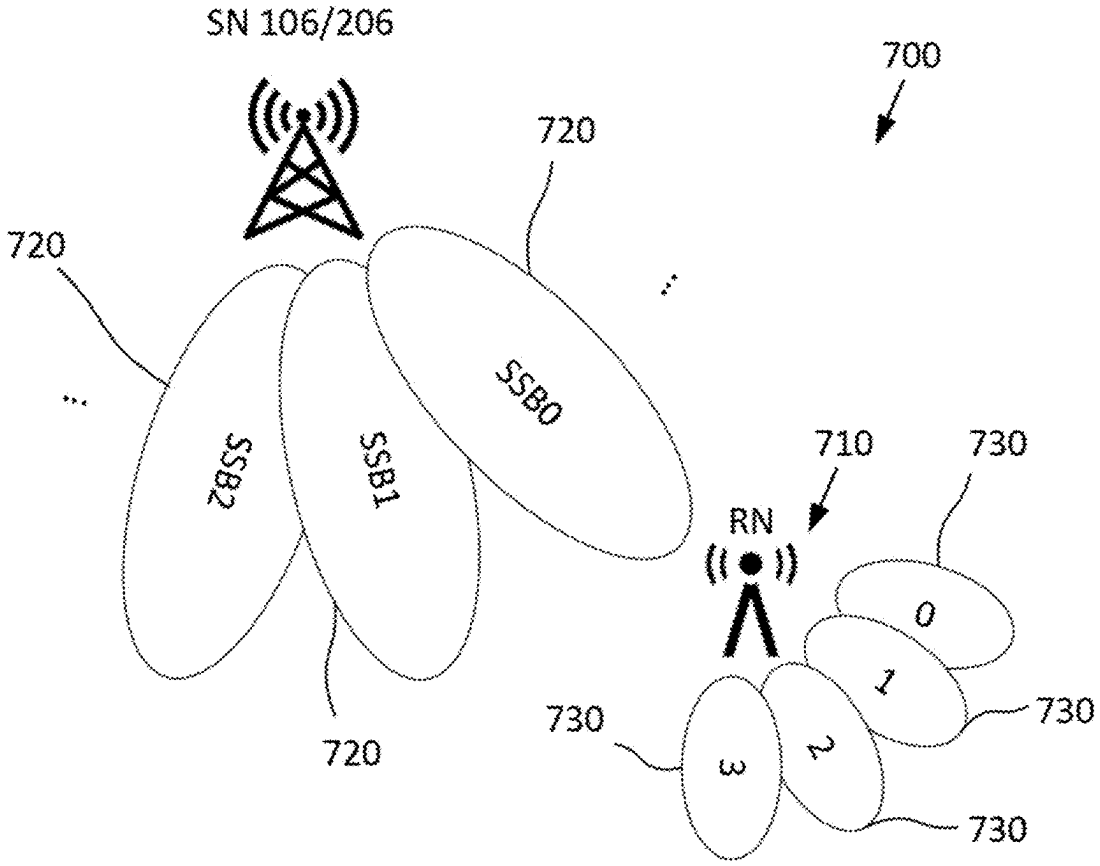

SN 106/206
700
720
720
SSB0
SSB1
SSB2
720
710
730
RN
0
1
730
730
2
3
730

FIG. 7

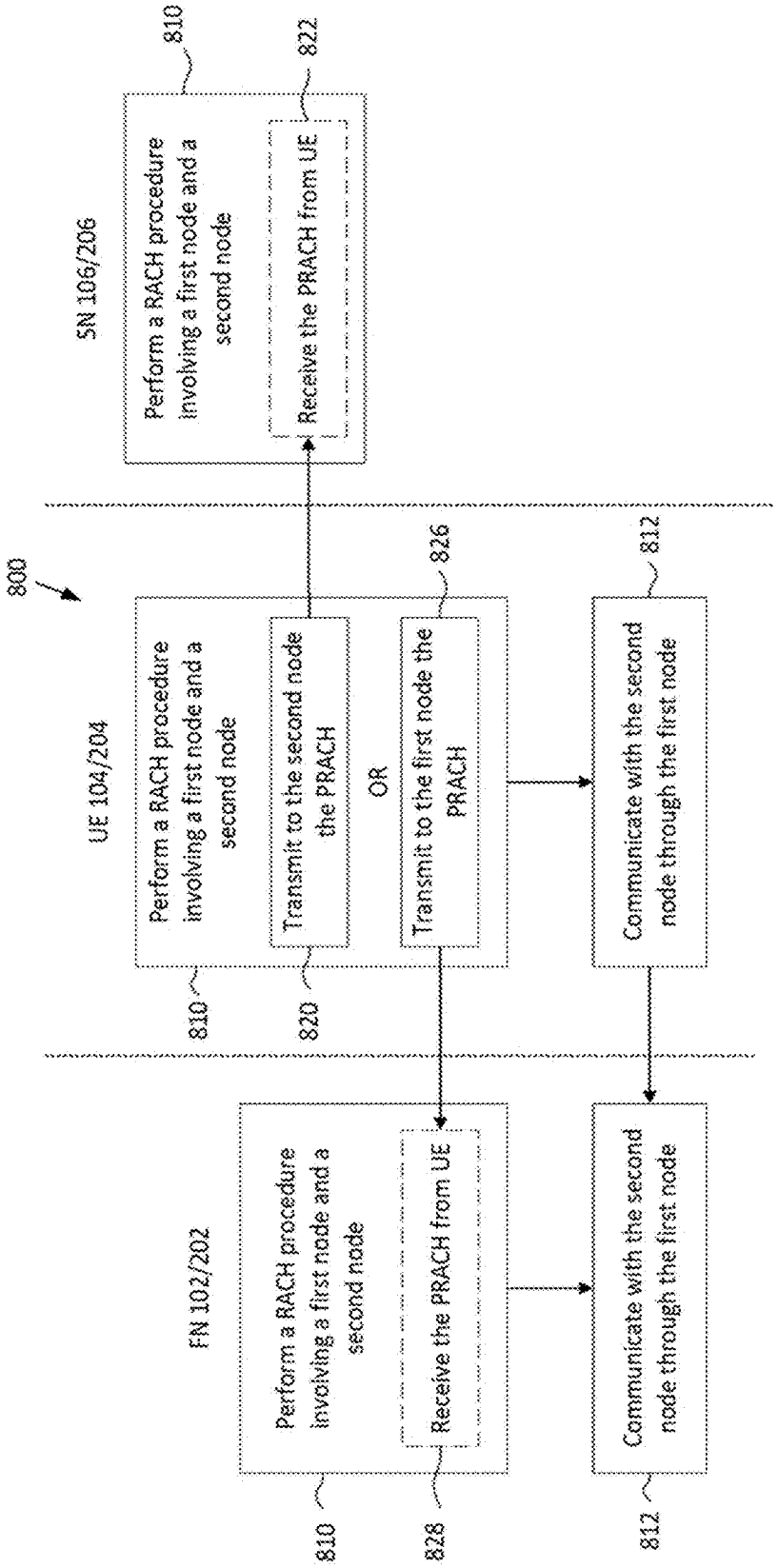

800
UE 104/204
Perform a RACH procedure involving a first node and a second node
810
Transmit to the second node the PRACH
820
OR
Transmit to the first node the PRACH
826
Communicate with the second node through the first node
812
FN 102/202
Perform a RACH procedure involving a first node and a second node
810
Receive the PRACH from UE
828
Communicate with the second node through the first node
812
SN 106/206
Perform a RACH procedure involving a first node and a second node
810
Receive the PRACH from UE
822

FIG. 8A

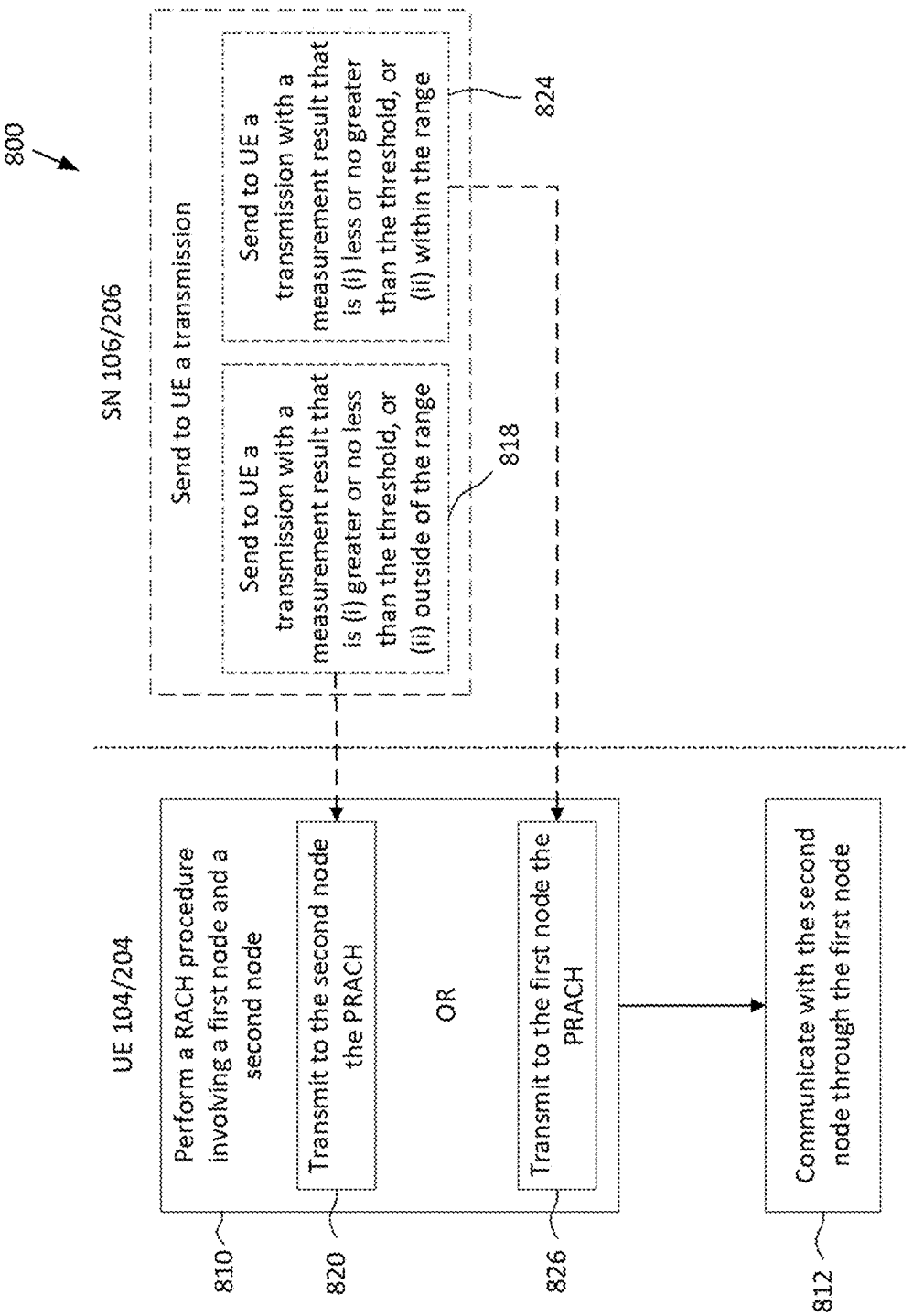

800
SN 106/206
Send to UE a transmission
Send to UE a transmission with a measurement result that is (i) greater or no less than the threshold, or (ii) outside of the range
818
Send to UE a transmission with a measurement result that is (i) less or no greater than the threshold, or (ii) within the range
824
UE 104/204
Perform a RACH procedure involving a first node and a second node
Transmit to the second node the PRACH
OR
Transmit to the first node the PRACH
Communicate with the second node through the first node
810
820
826
812

FIG. 8B

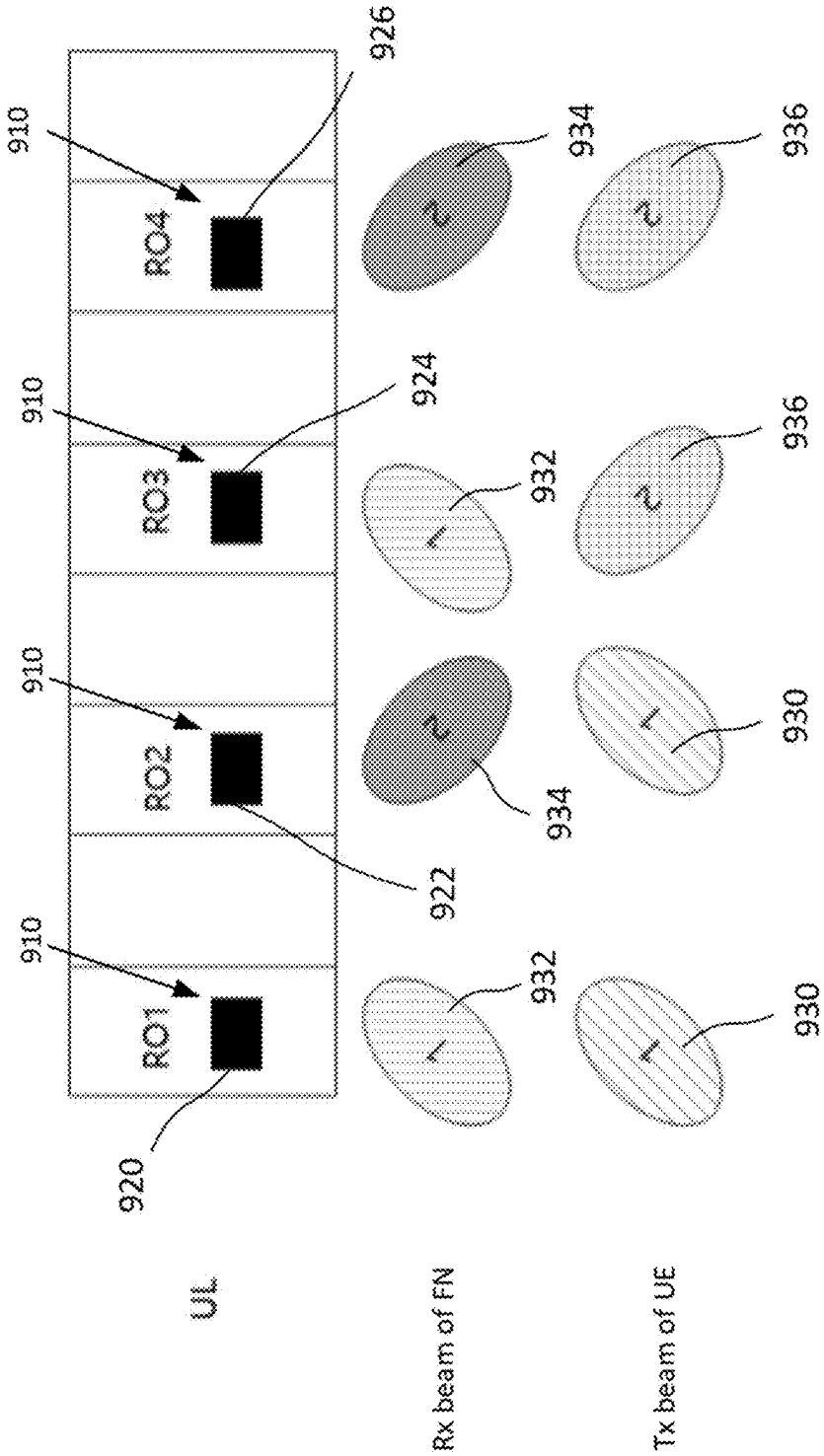

UL
Rx beam of FN
Tx beam of UE
RO1
RO2
RO3
RO4
910
920
922
924
926
930
932
934
936
1
2

FIG. 9

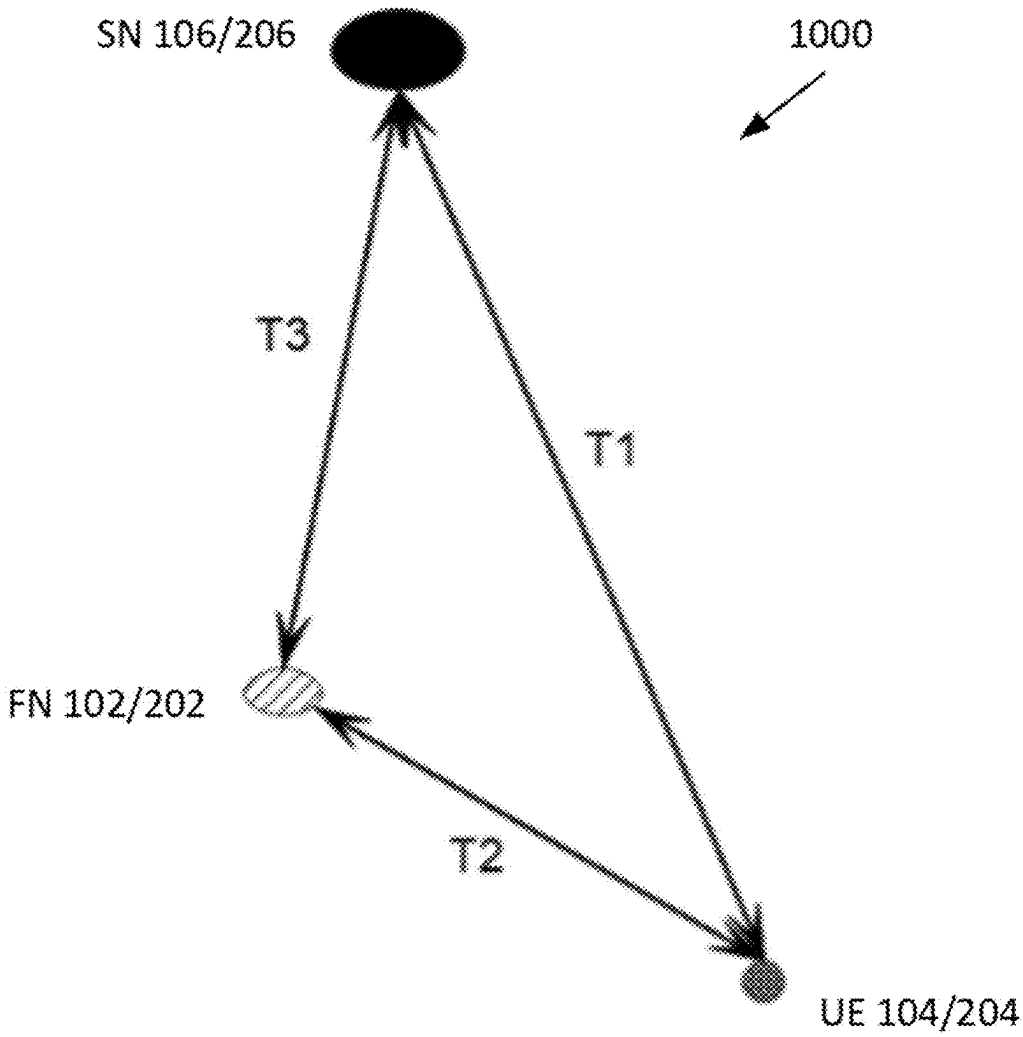


FIG. 10

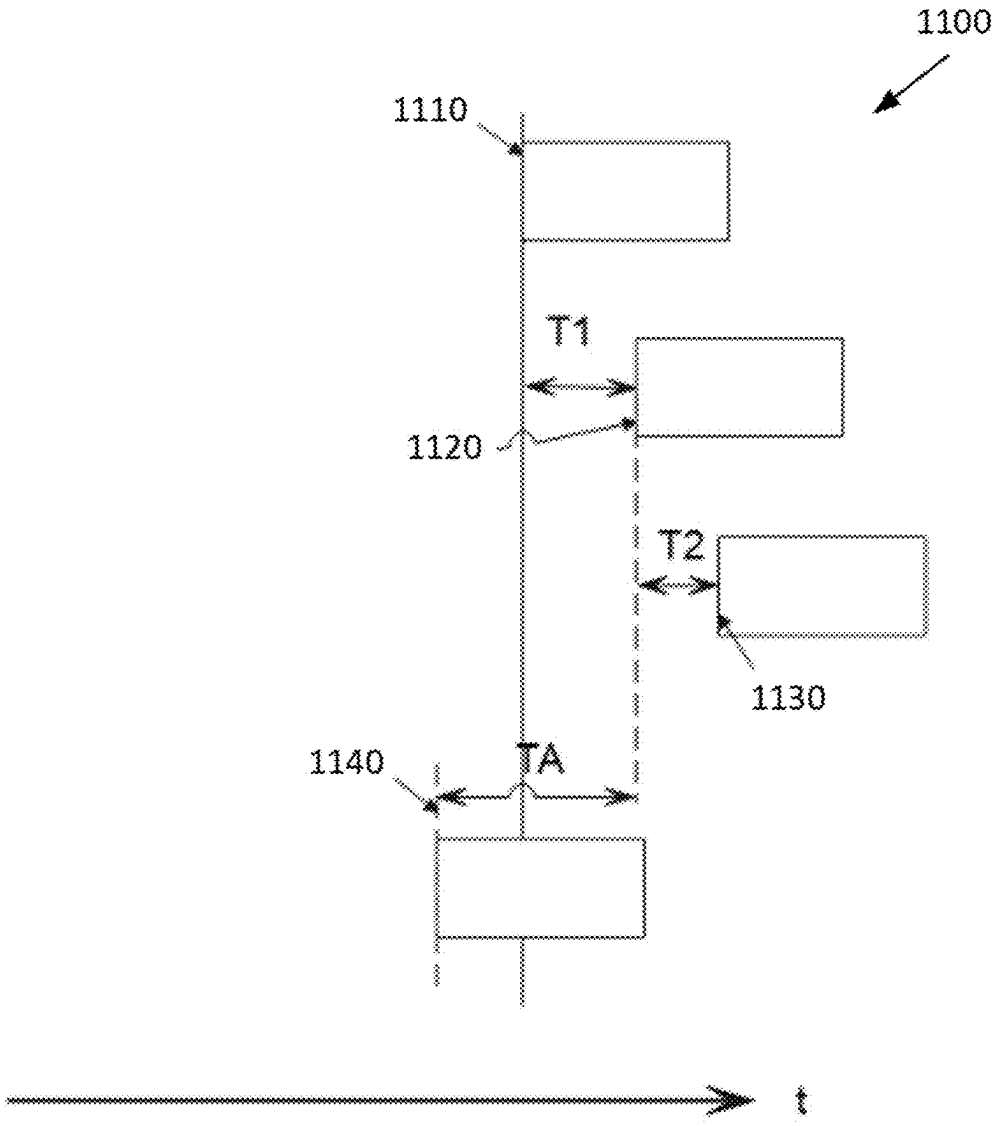


FIG. 11

case	SS-RSRP	P_offset
1	X < Threshold or X ≤ Threshold	P_offset
2	Threshold ≤ X or Threshold < X	0

FIG. 12

case	SS-RSRP	P_offset
1	X < Threshold1 or X ≤ Threshold1	P_offset1
2	Threshold1 ≤ X < Threshold2 or Threshold1 < X ≤ Threshold2	P_offset2
3	X ≥ Threshold2 or X > Threshold2	0

FIG. 13

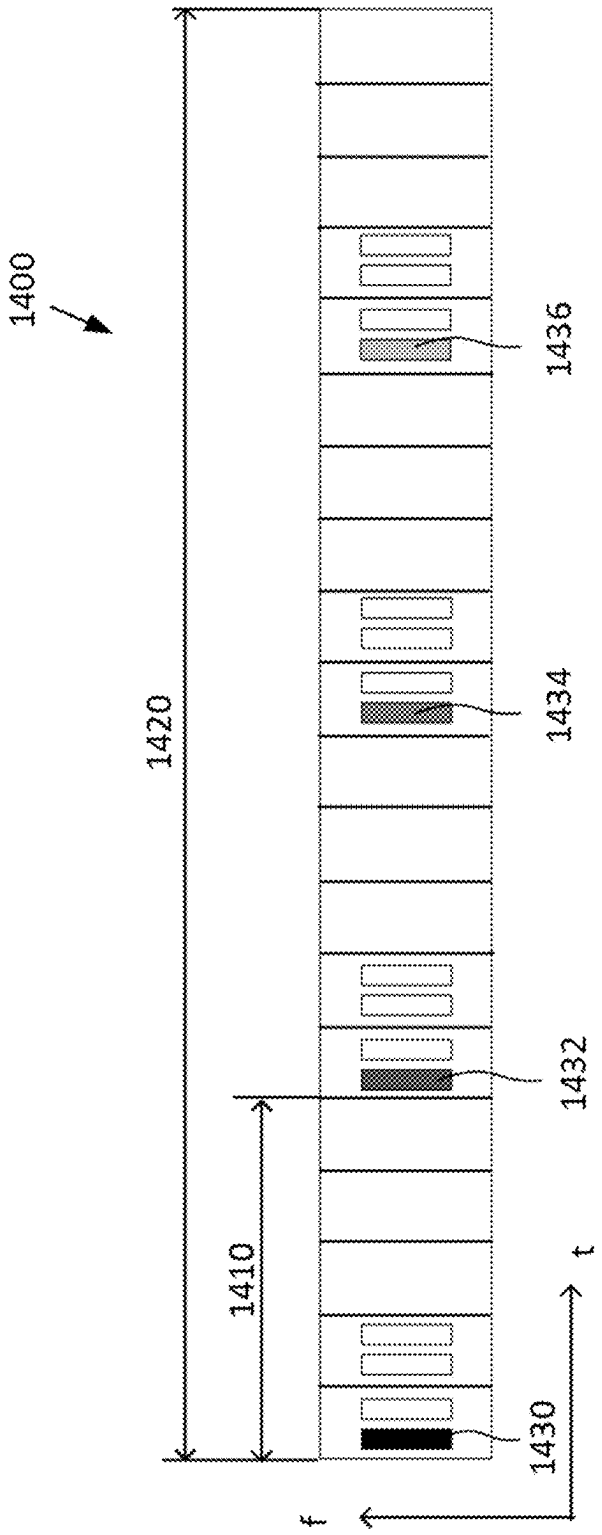


FIG. 14

Refined-SSB index	System frame number(SFN)	Half frame(first/second)
0	SFN mod P = 0	First
1	SFN mod P = 0	Second
2	SFN mod P = 1	First
3	SFN mod P = 1	Second

FIG. 15

Refined-SSB index	System frame number(SFN)
0	SFN mod P1 = 0
1	SFN mod P1 = P2
2	SFN mod P1 = 2*P2
3	SFN mod P1 = 3*P2
...	...
N	SFN mod P1 = N*P2

FIG. 16

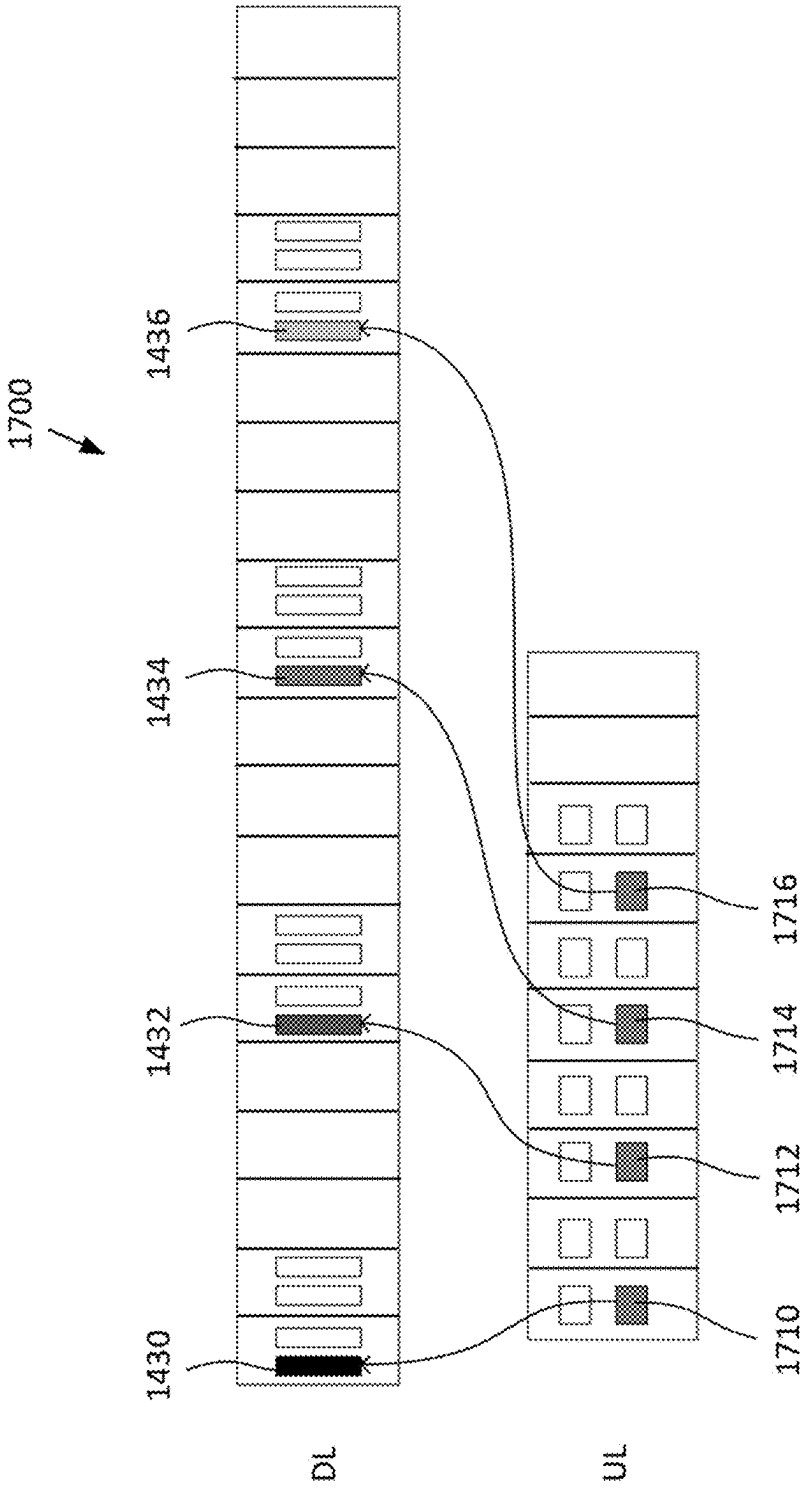


FIG. 17

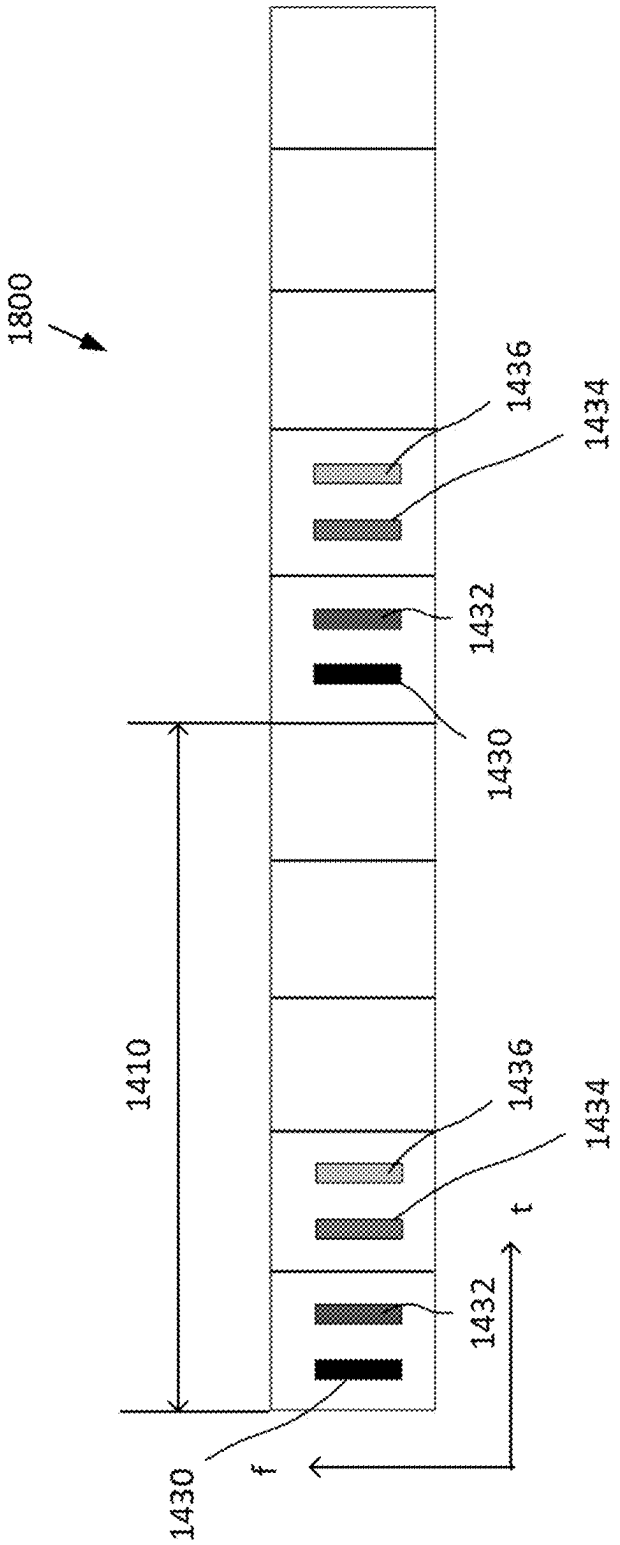


FIG. 18

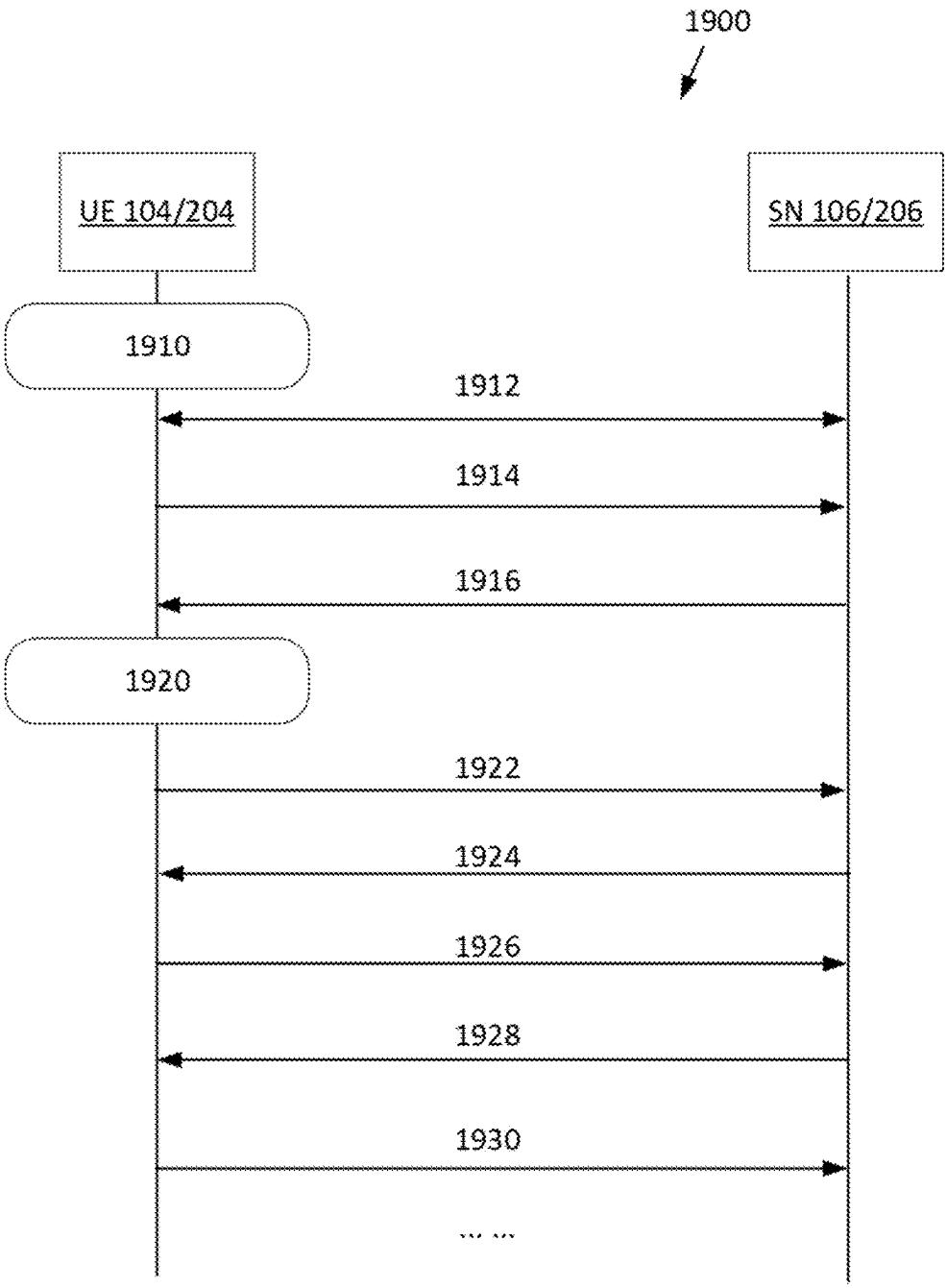

1900
UE 104/204
SN 106/206
1910
1912
1914
1916
1920
1922
1924
1926
1928
1930
... ...

FIG. 19

SYSTEMS, METHODS, AND NON-TRANSITORY PROCESSOR-READABLE MEDIA FOR TRANSMISSION DURING RANDOM ACCESS PROCEDURE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 120 as a continuation of International Patent Application No. PCT/CN 2023/076560, filed on Feb. 16, 2023, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The disclosure relates generally to wireless communications and, more particularly, to systems, methods, and non-transitory processor-readable media for information transmission during random access procedure.

BACKGROUND

[0003] Network deployment forms continue to change and evolve on the basis of traditional network deployment. One cell may include a plurality of Transmit-Receive Points (TRPs) in the same or different geographical locations. Some TRPs may support both downlink (DL) transmission and uplink (UL) reception. Some TR Ps may support only part of transmission types, for example, only UL reception (e.g., UL only TRP, UL TRP, UL only cell, etc.). In this network deployment mode, UL only TRP can be used to expand the uplink coverage and the uplink capacity. Another network deployment includes a forwarding-based network, where special relay nodes (e.g., Relay, Integrated Access Backhaul (IA B), Network Controlled Repeater (RN), etc.) are deployed to amplify and forward the received signals between a base station (BS) and user equipment (UE), thereby expanding the UL and DL coverage area of the BS. However, these network deployments face issues relating to performing Physical Random Access Channel (PRACH) transmission when the UL and DL transmit and receive nodes are different, such as transmission resource configuration, transmission timing, transmission power determining, how the relay node forwards the initial access-related signal channel (e.g., Synchronization Signal/Physical Broadcasting Channel (SS/PBCH) Block (SSB), PRACH, etc.).

SUMMARY

[0004] In some arrangements, systems, methods, apparatuses, and non-transitory computer-readable media for performing, by a wireless communication device (e.g., UE, etc.), a Random Access Channel (RACH) procedure involving a first node (e.g., UL TRP, etc.) and a second node (e.g., BS, etc.), wherein the wireless communication device receives downlink data from the second node, and communicating by the wireless communication device with the second node through the first node.

[0005] The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various example arrangements of the present solution are described in detail below with reference to the following figures or drawings. The drawings are provided for purposes of illustration only and merely depict example arrangements of the present solution to facilitate the reader's understanding of the present solution. Therefore, the drawings should not be considered limiting of the breadth, scope, or applicability of the present solution. It should be noted that for clarity and ease of illustration, these drawings are not necessarily drawn to scale.

[0007] FIG. **1** is a diagram illustrating an example cellular communication network, in accordance with some arrangements.

[0008] FIG. **2** illustrates block diagrams of an example UL device, an example UE device, and an example BS device, in accordance with some arrangements.

[0009] FIG. **3** illustrates an example scheme implemented for supporting the initial access.

[0010] FIG. **4** is a table illustrating an example mapping relationship between PRACH Configuration Index, preamble formats, system frame number (SFN), subframe number, starting symbol, number of PRACH slots within a subframe, number of time-domain PRACH occasions within a PRACH slot, and PRACH duration, according to various arrangements.

[0011] FIG. **5** is a table illustrating an example mapping relationship between preamble subcarrier spacing (SCS) and N_{gap} symbols, according to various arrangements.

[0012] FIG. **6** is a diagram illustrating an example wireless communication system including UL only TRP, in accordance with some arrangements.

[0013] FIG. **7** is a diagram illustrating an example network deployment including forwarding-based network, in accordance with some arrangements.

[0014] FIGS. **8**A and **8**B are flowchart diagrams illustrating example methods for performing a RACH procedure involving multiple nodes, according to various arrangements.

[0015] FIG. **9** is a diagram illustrating an example combination of transmitting (Tx) and receiving (Rx) to identify the best or acceptable Tx/Rx beam pair, in accordance with some arrangements.

[0016] FIG. **10** is a diagram illustrating an example cellular communication network including transmission delays (T1, T2, T3), in accordance with some arrangements.

[0017] FIG. **11** is a diagram illustrating an example timeline of reception and transmission timings, in accordance with some arrangements.

[0018] FIG. **12** is a table illustrating an example mapping relationship between Synchronization Signal Reference Signal Received Power (SS-RSRP) measurement result and a power offset (P_offset), according to various arrangements.

[0019] FIG. **13** is a table illustrating another example mapping relationship between SS-RSRP and P_offset, according to various arrangements.

[0020] FIG. **14** is a diagram illustrating an example SSB transmission, according to various arrangements.

[0021] FIG. **15** is a table illustrating an example mapping relationship between a refined-SSB index, a SFN, and a half frame, according to various arrangements.

[0022] FIG. **16** is a table illustrating another example mapping relationship between the refined-SSB index and the SFN, according to various arrangements.

[0023] FIG. **17** is a diagram illustrating an example mapping relationship between the refined-SSBs and the ROs, according to various arrangements.

[0024] FIG. **18** is a diagram illustrating an example transmission of the refined-SSBs, according to various arrangements.

[0025] FIG. **19** is a diagram illustrating an example method for Radio Resource Control (RRC) setup, according to various arrangements.

DETAILED DESCRIPTION

[0026] Various example arrangements of the present solution are described below with reference to the accompanying figures to enable a person of ordinary skill in the art to make and use the present solution. As would be apparent to those of ordinary skill in the art, after reading the present disclosure, various changes or modifications to the examples described herein can be made without departing from the scope of the present solution. Thus, the present solution is not limited to the example arrangements and applications described and illustrated herein. Additionally, the specific order or hierarchy of steps in the methods disclosed herein are merely example approaches. Based upon design preferences, the specific order or hierarchy of steps of the disclosed methods or processes can be re-arranged while remaining within the scope of the present solution. Thus, those of ordinary skill in the art will understand that the methods and techniques disclosed herein present various steps or acts in a sample order, and the present solution is not limited to the specific order or hierarchy presented unless expressly stated otherwise.

[0027] The UL only TRP and the forwarding-based network deployments have issues with regards to initial access procedure due to having different UL and DL transmitting and receiving nodes. The arrangements disclosed herein relate to improving the initial access procedure of UL only TRP and the forwarding-based network deployments. The arrangements disclosed herein relate to information transmission during random access procedure.

[0028] FIG. **1** illustrates an example wireless communication system **100**, in accordance with an arrangement of the present disclosure. In the following discussion, the wireless communication system **100** may be any wireless network, such as a cellular network or a narrowband network. The system **100** includes an first node (FN) **102** and a UE **104** that can communicate with each other via a first communication link **110** (e.g., a wireless communication channel). In some arrangements, the first node **102** includes an uplink only node (e.g., UL only TRP, etc.). In some arrangements, the first node **102** includes an uplink and downlink TRP (e.g., TRP, UL and DL TRP, etc.). The system **100** further includes a second node (SN) **106** that can communicate with the UE **104** via a second communication link **120** and that can communicate with the first node **102** via a third communication link **130**. In some arrangements, the second node **106** includes a base station. The system **100** further includes a cluster of cells, e.g., at least **160**, **162**, **164**, **166**, **168**, **170**, and **172** overlaying a geographical area **101**. In FIG. **1**, the first node **102**, the UE **104**, and the second node **106** are shown to be located within a respective geographic boundary of cell **160**. Each of the other cells **162**, **164**, **166**, **168**, **170**, and **172** may include at least one BS operating at its allocated bandwidth to provide adequate radio coverage to its intended users. For example, the second node **106** may operate at an allocated channel transmission bandwidth to provide adequate coverage to the UE **104**. In some arrangements, the first node **102** is TRP that support part of transmission types, for example, only UL reception (e.g., UL only TRP, UL TRP, UL only cell, etc.).

[0029] In some embodiments, the second node **106** communicates with the UE **104** via a downlink radio frame **140**, the UE **104** communicates with the first node **102** via a first uplink radio frame **146**, and the first node **102** communicates with the second node **106** via a second uplink radio frame **152**. Each radio frame **140**, **146**, **152** may be further divided into subframes (or slots) **142**, **148**, **154** which may include data symbols **144**, **150**, **156**. In the present disclosure, the first node **102**, the UE **104**, and the second node **106** are described herein as non-limiting examples of communication nodes, generally, which can practice the methods disclosed herein. Such communication nodes may be capable of wireless and/or wired communications, in accordance with various arrangements of the present solution.

[0030] FIG. **2** illustrates a block diagram of an example wireless communication system **200** for transmitting and receiving wireless communication signals, in accordance with some arrangements. The system **200** may include components and elements configured to support known or conventional operating features that need not be described in detail herein. In some arrangements, system **200** can be used to communicate (e.g., transmit and receive) data symbols in a wireless communication environment such as the wireless communication system **100** of FIG. **1**, as described above.

[0031] The system **200** generally includes a first node (FN) **202**, a UE **204**, and a second node (SN) **206**. In some arrangements, the first node **202** includes an uplink only node (e.g., UL only TRP, etc.). In some arrangements, the first node **202** includes an uplink and downlink TRP (e.g., TRP, UL and DL TRP, etc.). The first node **202** includes a FN transceiver module **210**, a FN antenna **212**, a FN processor module **214**, a FN memory module **216**, and a FN network communication module **218**, each module being coupled and interconnected with one another as necessary via a FN data communication bus **220**. The UE **204** includes a UE transceiver module **230**, a UE antenna **232**, a UE memory module **234**, and a UE processor module **236**, each module being coupled and interconnected with one another as necessary via a UE data communication bus **240**. The UE **204** communicates with the first node **202** via a first communication channel **250** (e.g., a first wireless transmission link, a first wireless data transmission link, etc.), which can be any wireless channel or other medium suitable for transmission of data as described herein. In some arrangements, the second node **106** includes a base station. The second node **206** includes a SN transceiver module **260**, a SN antenna **262**, a SN processor module **264**, a SN memory module **266**, and a SN network communication module **268**, each module being coupled and interconnected with one another as necessary via a SN data communication bus **270**. The second node **206** communicates with the UE **204** via a second communication channel **280** (e.g., a second wireless transmission link, a second wireless data transmission link, etc.), which can be any wireless channel or other medium suitable for transmission of data as described herein. The first node **202** communicates with the second node **206** via a third communication channel **290** (e.g., a third wireless transmission link, a third wireless data transmission link, etc.), which

can be any wireless channel or other medium suitable for transmission of data as described herein.

[0032] The system **200** may further include any number of modules other than the modules shown in FIG. **2**. The various illustrative blocks, modules, circuits, and processing logic described in connection with the arrangements disclosed herein may be implemented in hardware, computer-readable software, firmware, or any practical combination thereof. To clearly illustrate this interchangeability and compatibility of hardware, firmware, and software, various illustrative components, blocks, modules, circuits, and steps are described generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware, or software can depend upon the particular application and design constraints imposed on the overall system. Those familiar with the concepts described herein may implement such functionality in a suitable manner for each particular application, but such implementation decisions should not be interpreted as limiting the scope of the present disclosure.

[0033] In accordance with some arrangements, the FN transceiver module **210** may be referred to herein as a first uplink transceiver that includes a Radio Frequency (RF) transmitter and a RF receiver each comprising circuitry that is coupled to the FN antenna **212**. A duplex switch (not shown) may alternatively couple the uplink transmitter or receiver to the uplink antenna in time duplex fashion. Similarly, the UE transceiver module **230** may be referred to herein as a second uplink transceiver that includes a RF transmitter and a RF receiver each comprising circuitry that is coupled to the UE antenna **232**. A duplex switch (not shown) may alternatively couple the uplink transmitter or receiver to the uplink antenna in time duplex fashion. Similarly, in accordance with some arrangements, the SN transceiver module **260** may be referred to herein as a downlink transceiver that includes a RF transmitter and a RF receiver each comprising circuitry that is coupled to the SN antenna **262**. A downlink duplex switch may alternatively couple the downlink transmitter or receiver to the downlink antenna in time duplex fashion.

[0034] In some embodiments, the operations of two transceiver modules **230** and **260** can be coordinated in time such that the second uplink transceiver is coupled to the UE antenna **232** for reception of transmissions over the second wireless transmission link **280** at the same time that the downlink transmitter is coupled to the SN antenna **262**. In some arrangements, there is close time synchronization with a minimal guard time between changes in duplex direction. In some embodiments, the second uplink transceiver is coupled to the UE antenna **232** for reception of transmissions over the second wireless transmission link **280**, and the first uplink transceiver is coupled to the FN antenna **212** for reception of transmissions over the first wireless transmission link **250**, and at the same time the downlink transmitter is coupled to the SN antenna **262** for transmission of transmissions over the second wireless transmission link **280**.

[0035] The UE transceiver module **230** and the SN transceiver module **260** are configured to communicate via the second wireless data communication link **280**, and cooperate with a suitably configured RF antenna arrangement **232**/**262** that can support a particular wireless communication protocol and modulation scheme. The UE transceiver module **230** and the FN transceiver module **210** are configured to communicate via the first wireless data communication link **250**, and cooperate with a suitably configured RF antenna arrangement **232**/**212** that can support a particular wireless communication protocol and modulation scheme. The UE transceiver module **230** and the SN transceiver module **260** are configured to communicate via the third wireless data communication link **290**, and cooperate with a suitably configured RF antenna arrangement **212**/**262** that can support a particular wireless communication protocol and modulation scheme. In some illustrative arrangements, the FN transceiver module **210**, the UE transceiver module **230**, and the SN transceiver module **260** are configured to support industry standards such as the Long Term Evolution (LTE) and emerging 5G standards, and the like. It is understood, however, that the present disclosure is not necessarily limited in application to a particular standard and associated protocols. Rather, the FN transceiver module **210**, the UE transceiver module **230**, and the SN transceiver module **260** may be configured to support alternate, or additional, wireless data communication protocols, including future standards or variations thereof.

[0036] In accordance with various arrangements, the first node **202** may be a UL only TRP, for example. In some arrangements, the UE **204** may be embodied in various types of user devices such as a mobile phone, a smart phone, a personal digital assistant (PDA), tablet, laptop computer, wearable computing device, etc. In some arrangements, the second node **206** may be an gNB, evolved node B (eNB), a serving eNB, a target eNB, a femto station, or a pico station, for example. The processor modules **214**, **236**, and **264** may be implemented, or realized, with a general purpose processor, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array, any suitable programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof, designed to perform the functions described herein. In this manner, a processor may be realized as a microprocessor, a controller, a microcontroller, a state machine, or the like. A processor may also be implemented as a combination of computing devices, e.g., a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a digital signal processor core, or any other such configuration.

[0037] Furthermore, the steps of a method or algorithm described in connection with the arrangements disclosed herein may be embodied directly in hardware, in firmware, in a software module executed by processor modules **214**, **236**, and **264**, respectively, or in any practical combination thereof. The memory modules **216**, **234**, and **266** may be realized as RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. In this regard, memory modules **216**, **234**, and **266** may be coupled to the processor modules **214**, **236**, and **264**, respectively, such that the processors modules **214**, **236**, and **264** can read information from, and write information to, memory modules **216**, **234**, and **266**, respectively. The memory modules **216**, **234**, and **266** may also be integrated into their respective processor modules **214**, **236**, and **264**. In some arrangements, the memory modules **216**, **234**, and **266** may each include a cache memory for storing temporary variables or other intermediate information during execution of instructions to be

executed by processor modules **214**, **236**, and **264**, respectively. The memory modules **216**, **234**, and **266** may also each include non-volatile memory for storing instructions to be executed by the processor modules **214**, **236**, and **264**, respectively.

[0038] The FN network communication module **218** generally represents the hardware, software, firmware, processing logic, and/or other components of the first node **202** that enable bi-directional communication between the FN transceiver module **210** and other network components and communication nodes configured to communication with the first node **202**. For example, the FN network communication module **218** may be configured to support internet or WiMAX traffic. In a typical deployment, without limitation, the FN network communication module **218** provides an 802.3 Ethernet interface such that the FN transceiver module **210** can communicate with a conventional Ethernet based computer network. In this manner, the FN network communication module **218** may include a physical interface for connection to the computer network (e.g., Mobile Switching Center (MSC)). The terms "configured for," "configured to" and conjugations thereof, as used herein with respect to a specified operation or function, refer to a device, component, circuit, structure, machine, signal, etc., that is physically constructed, programmed, formatted and/or arranged to perform the specified operation or function.

[0039] Similarly, the SN network communication module **268** generally represents the hardware, software, firmware, processing logic, and/or other components of the second node **206** that enable bi-directional communication between the SN transceiver module **260** and other network components and communication nodes configured to communication with the second node **206**. For example, the SN network communication module **268** may be configured to support internet or WiMAX traffic. In a typical deployment, without limitation, the SN network communication module **268** provides an 802.3 Ethernet interface such that the SN transceiver module **260** can communicate with a conventional Ethernet based computer network. In this manner, the SN network communication module **268** may include a physical interface for connection to the computer network.

[0040] In some examples, FIG. **3** illustrates an example scheme **300** implemented for supporting the initial access (e.g., PRACH procedure) under frequency ranges FR1 (e.g., sub-6G Hz band) and frequency range FR2 (e.g., beyond 6G Hz band). In FIG. **3**, the base station communications **301** (e.g., beamforming) of a base station (e.g., the second node **106**/**206**) can be shown on the top rail while UE communications **302** (e.g., beamforming) of a UE (e.g., the UE **104**, **204**) can be shown on the bottom rail. The transmission of PRACH for example can be transmitted via Msg1 **310**. The scheme **300** further includes different PRACH formats, PRACH resource configurations, the relationship between the Synchronization Signal/Physical Broadcasting Channel (SS/PBCH) Block (SSB) and PRACH occasion (RO), the mechanism of PRACH retransmission, the mechanism of PRACH power control, and so on.

[0041] The shaded beams in FIG. **3** are beams used to transmit or receive data. As shown in FIG. **3**, the UE transmits a preamble in RO, according to the configuration of PRACH transmission and a selected SSB. In transmitting the preamble in RO, if the transmit-receive (Tx-Rx) correspondence on the UE-side can be guaranteed, a fixed mapping between the UE's receiving (Rx) beam and the UE's transmitting (Tx) beam can be used. A unique Tx beam can be determined according to its reception of the SSB. For example, the UE can attempt to use different Rx beams **303** to receive the SSB from the base station (e.g., at **305**), and determine the best Rx beam **304**. In some arrangements, the best Rx beam **304** (e.g., the best downlink Rx beam) is a beam with the highest Reference Signal Received Power (RSRP) or with a RSRP value that is higher than a predefined threshold. According to the best Rx beam **304**, the best Tx beam **306** (e.g., best uplink Tx beam) is determined based on beam correspondence. The RO used for transmitting the PRACH is determined according to the relationship between the SSB and RO. Based on the relationship, the base station can determine the SSB selected by the UE. The same beam **315** can be used for transmitting subsequent downlink transmissions, including, Msg2 **320** (which can also be referred to as Random Access Response (RAR)) and Msg4 **340** (which can be a Physical Downlink Shared Channel (PDSCH) with UE contention resolution identity). According to a RACH procedure, the RAR (e.g., Msg2 **320**) is communicated after the end of PRACH transmission (e.g., Msg1 **310**). The UE may monitor RAR Physical Downlink Control Channel (PDCCH) within a RAR window. The RAR window starts at the first symbol of the earliest Control Resource Set (CORESET) for which the UE is configured to receive PDCCH for Type1-PDCCH Common Search Space (CSS) set, that is at least a predefined number of time units (e.g., symbols) after the last symbol of the RO corresponding to the PRACH transmission.

[0042] In some arrangements, if the Tx-Rx correspondence on the UE-side cannot be guaranteed, the UE can try different Tx beams for transmitting the PRACH. According to the RACH procedure, the UE may find suitable transmission beam through RACH retransmission/reattempt with variant beams after the failure of the previous RACH transmission, which may be inefficient.

[0043] In some arrangements, a first network deployment mode includes a plurality of Transmit-Receive Points (TRPs), which all may be located in the same or different geographical location. Some TRPs may support both downlink transmission and uplink reception. Other TRPs may support only part of transmission types, for example, only uplink reception (e.g., UL only TRP, UL TRP, UL only cell, etc.). In the first network deployment mode, UL only TRP can be used to expand the uplink coverage and the uplink capacity. In some arrangements, a second network deployment mode includes a forwarding-based network, where special relay nodes (e.g., Relay, Integrated Access Backhaul (IA B), Network Controlled Repeater (RN), etc.) are deployed to amplify and forward the received signals between the BS and the UE, thereby expanding the UL and DL coverage area of the BS.

[0044] The first and second network deployment modes may face issues relating to performing PRACH transmission when the UL and DL transmit and receive nodes are different (e.g., the SSB is transmitted by the BS and the PRACH is received by the UL, etc.), such as transmission resource configuration, transmission timing, transmission power determining, how the relay node forwards the initial access-related signal channel (e.g., PBCH Block SSB, PRACH, etc.).

[0045] FIG. **4** is a table illustrating an example mapping relationship between PRACH Configuration Index, preamble formats, SFN, subframe number, starting symbol,

number of PRACH slots within a subframe, number of time-domain ROs within a PRACH slot, and PRACH duration, according to various arrangements. In some arrangements, the SFN in which the PRACH resource is located can be calculated using the formula nf mod x=y, where x corresponds to a period of PRACH resource (in terms of system frame or milliseconds) and y corresponds to a frame the PRACH resource is located within for each period. In some arrangements, the table illustrated in FIG. **4** is a table of random access configurations. The time domain resource of RACH transmission is configured via Radio Resource Control (RRC) signaling PRACH Configuration Index. The PRACH Configuration Index will map to a line in the table illustrated in FIG. **4** to determine one or more of the preamble formats, the frame number, the subframe number, the starting symbol, the number of PRACH slots within the subframe, the number of time-domain ROs within the PRACH slot, and the PRACH duration. In some arrangements, the table illustrated in FIG. **4** includes 256 rows (e.g., lines). In some arrangements, the value of the PRACH Configuration Index will be between approximately 0 and approximately 255.

[0046] In some arrangements, a frequency domain resource of the PRACH transmission is configured via the RRC signaling, where msg1-FrequencyStart provides a frequency starting RB within the carrier or bandwidth part and msg1-Frequency Division Multiplexing (FDM) provides how many RACH transmission resource are FDM ed. For example, the frequency domain resource of the RACH transmission may be configured via the following RRC signaling:

```
msg1-FDM                ENUMERATED {one, two, four, eight},
msg1-FrequencyStart     INTEGER (0..maxNrofPhysicalResourceBlocks-1),
```

[0047] In some arrangements, the RO can be determined based on the time and frequency domain resource configuration.

[0048] FIG. **5** is a table illustrating an example mapping relationship between preamble subcarrier spacing (SCS) and N_{gap} symbols (e.g., number of PRACH slots within a subframe), according to various arrangements. In some arrangements, the N_{gap} symbols can be determined based on the preamble SCS. For example, based on FIG. **5**, a subframe that includes a duration of 1 millisecond (ms) for a 30 kHz SCS (which includes PRACH slots with durations equal to 0.5 ms) corresponds to an N_{gap} symbol of 2. In some arrangements, the validity of the RO can be verified. For example, if a UE is provided (e.g., tdd-UL-DL-ConfigurationCommon), the RO in the PRACH slot can be verified as valid if (i) the RO is within the UL symbols, or (ii) (a) the RO does not precede a SS/PB CH block in the PRACH slot, (b) the RO starts at least N_{gap} symbols after a last downlink symbol, and (c) the RO starts at least No gap symbols after a last SS/PBCH block symbol. In some arrangements, the preamble formats illustrated in FIG. **4** correspond to N_{gap} symbols, For example, a B **4** preamble format may correspond to an N_{gap} symbol of 0.

[0049] FIG. **6** is a diagram illustrating an example wireless communication system **600** including UL only TRP, in accordance with some arrangements. The wireless communication system **600** includes a plurality of TRPs **610**. In some arrangements, each TRP **610** is located in a different geographical location. In some arrangements, one TRP (e.g., the second node **106**/**206**) of the plurality of TRPs **610** supports both downlink transmission and uplink reception, while the remaining four TRPs **610** (e.g., first node **102**/**202**, UL only TRPs, UL TRPs, etc.) support part of transmission types, for example, uplink reception. During the initial access procedure, the UE **104**/**204** will detect SSB for DL synchronization and system information acquisition transmitted by the second node **106**/**206**. After detection of the SSB, the UE **104**/**204** will initiate the RACH procedure for this SSB. As illustrated in FIG. **6**, the downlink transmission node (e.g., the second node **106**/**206**) may be different from the uplink receiving node (e.g., first node **102**/**202**), resulting in the downlink measurement being inapplicable for usage as a reference for the uplink transmission, such as determining beam information, timing information, power information, and so on.

[0050] FIG. **7** is a diagram illustrating an example wireless communication system **700** including a forwarding-based network, in accordance with some arrangements. The wireless communication system **700** includes one or more relay nodes (RNs) **710** (e.g., Relay, IAB (Integrated Access Backhaul), NCR (Network Controlled Repeater), etc.) that are configured to amplify and forward received signals between the second node **106**/**206** and the UE **104**/**204**, thereby expanding bother the uplink and downlink coverage area of the SB **106**/**206**. The wireless communication system **700** further includes one or more backhaul links **720** between the second node **106**/**206** and the RN **710** and one or more access links **730** between the RN **710** and the UE **104**/**204**. In some arrangements, each of the one or more backhaul links **720** are associated with a particular SSB (e.g., SSB0, SSB1, SSB2, etc.), such that the RN **710** receives the particular SSB of a corresponding backhaul link **720** (e.g., SSB0), and each of the one or more access links **730** is associated with a particular refined SSB (e.g., refined-SSB #0, refined-SSB #1, refined-SSB #2, etc.). The arrangements discloses herein provide a method for forwarding the SSB (e.g., the particular refined SSB) to the UE **104**/**204**, forwarding subsequent uplink transmission from the UE **104**/**204** (e.g., PRACH), and defining action for when forwarding nodes accept initial access of a subordinate UE (e.g., UE **104**/**204**).

[0051] In some arrangements, an uplink coverage area of the UE **104**/**204** may correspond to the first node **102**/**202** or the second node **106**/**206**, such that the uplink transmission of the UE **104**/**204** may be transmitted to the second node **106**/**206** directly or forwarded to the second node **106**/**206** via the first node **102**/**202**. Different uplink receiving nodes can affect a subsequent initial access process of the UE **104**/**204** (different initial access processes are referred to as different RACH modes for UE **104**/**204**). In some arrangements, the UE **104**/**204** can select from at least two RACH modes that includes a first RACH mode and a second RACH mode. The determination of the RACH mode by the UE **104**/**204** can also be considered as determination of the transmission link for PRACH transmission, e.g., the PRACH is transmitted to the first node **102**/**202** (corresponding to the first RACH mode) or the second node **106**/**206**

(corresponding to the second RACH mode). In other words, the determination of the RACH mode by the UE **104/204** is related with how the UE **104/204** determines the receiving node for the uplink transmission.

[0052] In some arrangements, before initiating the random access process or during the random access process, the UE **104/204** determines or selects the RACH mode by utilizing a particular mechanism. In some examples, the mechanism for selecting the RACH mode includes defining a measurement threshold (e.g., RSRP threshold, etc.). For example, the UE **104/204** performs the measurement and compares the measurement result with the measurement threshold. In some arrangements, the transmission includes at least one of a reference signal, data, or the like. In some arrangements, the measurement includes at least one of RSRP, SS-RSRP, Received Signal Strength Indication (RSSI), Signal-to-Noise-plus-Interference Ratio (SINR), (Channel Quality Indicator (CQI), or the like. In some examples, the measurement includes SS-RSRP measurement. In response to determining that the measurement result is lower than or no higher than the measurement threshold, the UE **104/204** selects the first RACH mode (e.g., selecting the first node **102/202** as the uplink receiving node (the uplink receiving node is not the node which transmits the SSB)). In response to determining that the measurement result is no lower than or higher than the measurement threshold, the UE **104/204** selects the second RACH mode (e.g., selecting the second node **106/206** as the uplink receiving node (the uplink receiving node is the node which transmits the SSB)).

[0053] In some examples, the mechanism for selecting the RACH mode includes defining a measurement threshold range (e.g., RSRP value range including two RSRP values (a minimum RSRP value and a maximum RSRP value)). For example, the UE **104/204** performs the measurement and compares the measurement result and the measurement threshold range. In response to determining that the measurement result is within the measurement threshold range, the UE **104/204** selects the first RACH mode (e.g., selecting the first node **102/202** as the uplink receiving node). In response to determining that the measurement result is out of the measurement threshold range, the UE **104/204** selects the second RACH mode (e.g., selecting the second node **106/206** as the uplink receiving node).

[0054] In some examples, the mechanism for selecting the RACH mode includes the UE **104/204** performing random access using a default RA CH mode (e.g., one of the first RACH mode and the second RACH mode), and when the number of times that the RACH fails reaches a certain threshold (e.g., number of failed attempts), the UE **104/204** switches to a non-default RACH mode (e.g., other one of the first RACH mode and the second RACH mode) to continue the random access procedure. For example, selecting the first RACH mode or the second RACH mode includes selecting one of the first RACH mode or the second RACH mode in response to failing the RACH procedure for a number of attempts using another one of the first RACH mode or the second RACH mode, where the number of attempts is equal to or greater than a threshold.

[0055] In some examples, the mechanism for selecting the RACH mode includes the UE **104/204** performing random access using the default RACH mode, and when the preamble transmission power reaches a maximum value but still fails, the UE **104/204** switches to the non-default RACH mode to continue the random access procedure. For example, selecting the first RACH mode or the second RACH mode includes selecting one of the first RACH mode or the second RACH mode in response to a power of a preamble transmission in another one of the first RACH mode or the second RACH mode reaching a predefined value and still failing. In some arrangements, the predefined value includes a maximum transmission power of the preamble transmission configured by the second node. In some arrangements, the power of the preamble transmission increases after each failed attempt.

[0056] The mechanisms for selecting the RACH mode may be SSB specific, such that for different SSBs whether RACH mode selection need to be performed can be independently configured, and parameter value in a RACH mode selection mechanism may be different for different SSBs. In some arrangements, for each SSB, the second node **106/206** may configure whether a plurality of RACH modes exist when the SSB is selected for random access (e.g., whether RACH mode selection needs to be performed for this SSB). In some examples, when there is only one RACH mode for an SSB, the only one RACH mode can be indicated. In some examples, when there is no RACH mode indicated, the default RACH mode is applied. In some arrangements, there are multiple RACH modes for the SSB, and the configuration information further includes the parameter value required for RACH mode selection for the SSB. As described above, different RACH modes are defined and some rules for RACH mode determination or selection are also defined. The UE **104/204** can effectively select a proper RACH mode for the random access procedure.

[0057] FIGS. **8**A and **8**B are flowchart diagrams illustrating an example method **800** for performing a RACH procedure involving multiple nodes, according to various arrangements. The method can be performed by the first node **102/202**, the UE **104/204**, and the second node **106/206**, according to various arrangements.

[0058] As shown in FIG. **8**A, at **810**, the UE **104/204** performs a RACH procedure involving a first node (e.g., the first node **102/202**) and a second node (e.g., the second node **106/206**), where the UE **104/204** receives downlink data from the second node. At **812**, the UE **104/204** communicates with the second node **106/206** through the first node **102/202**. In some arrangements, the UE **104/204** receives the DL transmission from the second node **106/206** and transmits the UL transmission through the first node **102/202**. In some arrangements, the UE **104/204** selects a first RACH mode or a second RACH mode. In some arrangements, the first RACH mode or the second RACH mode is selected for a SSB, each beam, or a Channel State Information-Reference Signal (CSI-RS). In some examples, the UE **104/204** selects at least one of the SSB, the beam, or the CSI-RS and determines the RACH mode based on the selected at least one of the SSB, the beam, or the CSI-RS.

[0059] At **820**, in the second RACH mode, the UE **104/204** transmits a PRACH to the second node **106/206**. At **822**, the second node **106/206** receives the PRACH from the UE **104/204**. At **826**, in the first RACH mode, the UE **104/204** transmits the PRACH to the first node **102/202**. At **828**, the first node **102/202** receives the PRACH from the UE **104/204**.

[0060] In some arrangements, as shown in FIG. **8**B, at **818**, the second node **106/206** sends a transmission to the UE **104/204**. In some examples, the UE **104/204** selects the second RACH mode in response to determining that a

measurement result of the transmission from the second node **106/206** is (i) greater or no less than a threshold, or (ii) outside of a range. In some arrangements, at least one of "greater than" or "less than" does not include equal to. In some arrangements, at least one of "greater than" or "less than" does include equal to (e.g., equal to or greater than, equal to or less than, etc.). In some arrangements, at **824**, the second node **106/206** sends a transmission to the UE **104/204**. In some examples, the UE **104/204** selects the first RACH mode in response to determining that the measurement result of the transmission from the second node **106/206** is (i) less or no greater than the threshold, or (ii) within the range.

[0061] In some arrangements, a wireless communication apparatus includes at least one processor and a memory, where the at least one processor is configured to read code from the memory and implement the method **800**. In some arrangements, a computer program product including a computer-readable program medium code stored thereupon, where the code, when executed by at least one processor, causes the at least one processor to implement the method **800**.

[0062] In some arrangements, the UE **104/204** selects a first transmission link for the RACH procedure or a second transmission link for the PRACH transmission, where the first transmission link is between the wireless communication device and the first node and the second transmission link is between the wireless communication device and the second node.

[0063] In some arrangements, the UE **104/204** determines an DL cell by detecting SSBs. For example, the UE **104/204** selects an SSB whose SS-RSRP is higher than a predefined threshold (an RSRP threshold configured by the second node **106/206**) and a synchronization signal (including a primary synchronization signal (PSS) and a secondary synchronization signal (SSS)) in the SSB carries cell id information. The UE **104/204** uses the beam for receiving the SSBs as the reception beam for subsequent downlink reception in the RACH procedure.

[0064] In some arrangements, the UE **104/204** sends the preamble (e.g., Msg.1) on a group of ROs using different transmission beams. Due to the uplink and downlink of the UE **104/204** being asymmetrical (the downlink transmission is received from the second node (e.g., the second node **106/206**, gN B, etc.) and the uplink is transmitted to the first node (e.g., first node **102/202**, UL only TRP, etc.)), the beam used for the uplink transmission cannot be determined based on the downlink reception. In some examples, the beam used for the uplink transmission is based on performing a training of receiving beam for first node **102/202** and transmission beam of the UE **104/204**. For example, different Rx/Tx beam pairs can be attempted for receiving and transmitting the PRACHs to determine an optimal or acceptable Rx/Tx beam pair for subsequent UL transmission (e.g., Msg.3 PUSCH). In some examples, the UE **104/204** selects a reception/transmission (Rx/Tx) beam pair by attempting a plurality of reception/transmission beam pairs, where the reception/transmission beam pair is used for sending uplink transmission from the UE **104/204** to the first node.

[0065] FIG. **9** is a diagram illustrating an example combination of transmission (Tx) and reception (Rx) to identify the best or acceptable Tx/Rx beam pair, in accordance with some arrangements. As shown in FIG. **9**, a plurality of ROs **910** (e.g., four ROs) are associated with the same SSB. In this example illustrated in FIG. **9**, when the UE **104/204** selects the SSB to initiate a random access process, there are M (e.g., M=2) Tx beams at the UE side, and there are N (e.g., N=2) Rx beams at the UL only TRP side. When the UE **104/204** initiates initial access to the UL only TRP, the UE **104/204** does not know which Tx beam is used to enable the network side to receive data effectively, nor does the first node **102/202** know which Rx beam is used to receive data effectively. In some arrangements, within the at least M*N (i.e., 4) ROs **910**, the preambles are transmitted/received through different combinations of Tx and Rx beams to identify the best or acceptable Tx/Rx beam pair. For example, the UE **104/204** transmits to the network a preamble using a transmission beam of each of the plurality of reception/transmission beam pairs, where each of the plurality of reception/transmission beam pairs comprises one of a plurality of reception beams (e.g., N) and one of a plurality of transmission beams (e.g., M). The transmission beam is one of the plurality of transmission beams. The network receives the preamble using a reception beam of each of the plurality of reception/transmission beam pairs, where the reception beam is one of the plurality of reception beams.

[0066] In some examples, the Tx/Rx switching rule between different R Os can be predefined. For example, the UE **104/204** may utilize the first Tx beam to transmit the preamble for a predefined number of times, switch the Tx beam to a second one to transmit the preamble for the predefined number of times, and so on until all Tx beams are traversed. In some examples, for preamble transmissions of each predefined number, the first node **102/202** can switch its Rx beams. In some arrangements, the predefined number is larger than or equal to the number of Rx beams of the first node **102/202**. In some arrangements, the ROs **910** used in the preamble transmission in one RACH attempt can be defined as an RO group. For example, the preamble is transmitted in a group of ROs using the plurality of reception/transmission beam pairs, where each RO in the group of ROs corresponds to each of the plurality of reception/transmission beam pairs. In some arrangements, the ROs **910** used for transmitting preamble with same transmission beam within one RACH attempt can be defined as an RO group, and MRO groups will be used during one RACH attempt. For example, the preamble is transmitted in a plurality of groups of ROs using the plurality of reception/transmission beam pairs, where each of the plurality of groups of ROs corresponds to a transmission beam of the plurality of transmission beams.

[0067] In some arrangements, the plurality of ROs **910** includes a first RO **920** (e.g., RO1), a second RO **922** (e.g., RO2), a third RO **924** (e.g., RO3), and a fourth RO **926** (e.g., RO4). As shown in FIG. **9**, in the first RO **920**, the UE **104/204** sends data using a Tx beam1 **930** and the first node **102/202** receives the data using a Rx beam1 **932**. In the second RO **922**, the UE **104/204** sends data using the Tx beam1 **930** and the first node **102/202** receives the data using a Rx beam2 **934**. In the third RO **924**, the UE **104/204** sends data using a Tx beam2 **936** and the first node **102/202** receives the data using the Rx beam1 **932**. In the fourth RO **926**, the UE **104/204** sends data using the Tx beam2 **936** and the first node **102/202** receives the data using the Rx beam2 **934**. The first node **102/202** may identify, by receiving the plurality of ROs **910** (e.g., the first RO **920**, the second RO **922**, the third RO **924**, and the fourth RO **926**), which Rx beam has the best receiving quality. For example, the first

node **102/202** may identify the fourth RO **926** has the best receiving quality, which determines that the Tx/Rx beam pair (the Tx beam2 **936** and the Rx beam2 **934**) used in the fourth RO **926** is the best Tx/Rx beam pair. In response to determining that the fourth RO **926** has the best receiving quality, the first node **102/202** (i) determines that the Rx beam2 **934** is the best Rx beam for receiving uplink transmission from the UE **104/204**, and (ii) utilizes the Rx beam2 **934** for receiving the subsequent uplink transmission from the UE **104/204**. In some arrangements, in response to determining that the fourth RO **926** has the best receiving quality, the first node **102/202** also determines that the Tx beam2 **936** is the best Tx beam, but this is unknown to the UE **104/204**. In some examples, the second node **106/206** will indicate to the UE **104/204** that the Tx beam2 **936** is the best Tx beam is subsequent steps such that the optimal Tx beam (e.g., the Tx beam2 **936**) can be used for subsequent uplink transmission (e.g., Msg.3).

[0068] In some arrangements, the first node **102/202** receives the preamble, the second node **106/206** can determine the Tx beam to send RARs according to the association between the RO and the SSB. In some examples, the second node **106/206** will use Tx beam of the SSB to transmit the RAR, where the SSB is associated with the RO that is identified by the first node **102/202** during the process of preamble reception. In some arrangements, the best or suitable Tx beam for uplink transmission can be indicated in the RAR. In some arrangements, some information related with Timing Advance (TA) determination for subsequent uplink transmission is transmitted within the RAR. In some arrangements, some information related with and power control for subsequent uplink transmission (e.g., Msg.3 PUSCH) is transmitted within the RAR. In some arrangements, the UE **104/204** transmits the Msg.3 PUSCH by using the indicated Tx beam.

[0069] In some arrangements, the UE **104/204** is indicated the best or suitable Tx beam for uplink transmission after receiving RAR. In some examples, the uplink transmission after receiving RAR can be Msg.3 PUSCH and other uplink transmissions. For each RO used for transmitting the preamble, the used Tx beam is known for the UE **104/204** who transmits the preamble. In some examples, the indication information can be a RO index within a RO group, and the indication information can be included in the RAR. In some arrangements, the ROs used in the preamble transmission in one RACH attempt can be defined as an RO group. In some arrangements, the R Os used for transmitting preamble with same beam within one RACH attempt can be defined as an RO group, and MRO groups will be used during one RACH attempt. In some examples, the UE **104/204** receives from the second node a RAR that indicates a transmission beam using which the UE **104/204** transmits an uplink transmission, where the RAR indicates the transmission beam using an RO index within an RO group.

[0070] In some arrangements, RAR is carried on a PDSCH which is scheduled by a Downlink Control Information (DCI) format with Cyclic Redundancy Check (CRC) scrambled by a parameter (e.g., Random Access Radio Network Temporary Identifier (RA_RNTI)). The RA_RNTI can be calculated according to the time domain location of the RO group. For example, the time domain position of the last RO or the first RO within a RO group can be used for calculating the RA_RNTI. In some examples, the RAR is carried on a downlink channel (e.g., PDSCH) scheduled by the DCI format having a CRC scrambled by a parameter (e.g., RA_RNTI), where the parameter is determined according to a time-domain location of at least one RO (e.g., a first RO, a last RO, etc.) in the RO group.

[0071] In some arrangements, if there are N ROs (N is a positive integer) in one RO group, $\lceil \log_2 N \rceil$ bits is utilized for indicated RO index within one RO group. In some examples, the $\lceil \log_2 N \rceil$ bits can be included in RAR. In some arrangements, the RO group includes a number Q of ROs, and a number of bits in the RAR used to indicate the RO index within the RO group can be determined using $|\log_2 Q|$, where Q is a positive integer. In some examples, Q may be greater than or equal to N.

[0072] In some other arrangements, if there are N ROs in one RO group, $\log_2 N$ bits is utilized for indicated RO index within one RO group, where N is a positive integer and is equal to a value of 2. In some examples, the $\log_2 N$ bits can be included in RAR. In some arrangements, the RO group includes a number Q of ROs, and a number of bits in the RAR used to indicate the RO index can be determined using $\log_2 Q$, where Q is a positive integer and is equal to a value of 2 (e.g., is a power of 2). In some examples, Q may be greater than or equal to N.

[0073] In some arrangements, in response to receiving the RAR, the UE **104/204** determines the RO group according to the RA_RNTI and the RO index within the RO group according to the indication information in the RAR. In some examples, in response to receiving the RAR, the UE **104/204** further determines that the Tx beam used for transmitting preamble in the RO is the best or suitable Tx beam for uplink transmission (e.g., Msg.3 PUSCH).

[0074] In some arrangements, the UE **104/204** determines the transmission timing for uplink transmission after receiving RAR. In some examples, the UE **104/204** receives from the second node a RAR and determines a transmission time for an uplink transmission transmitted by the UE **104/204** after receiving the RAR. In some arrangements, an uplink transmission TA determining mechanism for the uplink transmission after receiving RAR (e.g., when the downlink transmitting node is the same as the uplink receiving node, for example, both of them are BSs) includes the receiving timing being considered as the transmitting timing for sending the preamble. After receiving the preamble, the second node **106/206** may use the offset between the receiving timing and the BS frame boundary as a component of the TA, and notify it to the UE **104/204** in the RAR. In some arrangements, the TA can be determined as a sum of a transmission time between the second node **106/206** and the UE **104/204** and a transmission time between the UE **104/204** and the first node **102/202**. In some examples, a TA offset (TA_offset) is configured in the System Information Block1 (SIB1) as another component of the TA. The TA_offset may be utilized to reserve enough time for switching from Rx to Tx on the BS side. In some examples, a process time of the first node **102/202** for forwarding the information received from UE **104/204** to the second node **106/206** is another component of the TA.

[0075] In some examples, the UE **104/204** determines a TA for the uplink transmission relative to a downlink receiving timing at which the RAR is received and (i) in response to selecting the first RACH mode, a value of a timing advance offset provided in the SIB is omitted for determining the TA, where the first RACH mode includes the UE **104/204** transmitting the PRACH to the first node, and (ii)

in response to selecting a second RACH mode, the value of the TA_offset provided in the SIB is used for determining the TA, where the second RACH mode includes the UE **104/204** transmitting the PRACH to the second node.

[0076] In some arrangements, in deployment of forwarding the uplink transmission to the second node **106/206** by using the first node **102/202**, because the first node **102/202** does not need a Rx/Tx switching time, when the UE **104/204** determines that current uplink receive node is an first node **102/202**, the TA_offset configured in the SIB1 is not included in the TA. In some examples, other factors, such as, the transmission delay between the first node **102/202** and the second node **106/206**, timing difference between reception timing of the first node **102/202** and the BS frame boundary, and process time of the first node **102/202** for forwarding the information received from UE **104/204** to the second node **106/206**, are considered. In some arrangements, the uplink transmission after receiving RAR can be Msg.3 PUSCH and other uplink transmissions.

[0077] FIG. **10** is a diagram **1000** illustrating an example cellular communication network including transmission delays, in accordance with some arrangements. A first transmission delay T1 is defined as a transmission delay between the second node **106/206** and the UE **104/204**, a second transmission delay T2 is defined as a transmission delay between the first node **102/202** and the UE **104/204**, and a third transmission delay T3 is defined as a transmission delay between the first node **102/202** and the second node **106/206**.

[0078] FIG. **11** is a diagram **1100** illustrating an example timeline of reception and transmission timings, in accordance with some arrangements. At **1110**, a time point represents BS frame boundary or transmission timing of the second node **106/206** or downlink transmission timing of the second node **106/206**. The downlink transmission reaches UE **104/204** after a delay of T1. At **1120**, a time point B represents the downlink transmission reception timing by the UE **104/204**. For the PRACH transmission, the UE **104/204** utilizes the reception timing as the transmission timing to transmit the preamble to the first node **102/202**. At **1130**, a time point C represents the PRACH reception timing by the first node **102/202**. In some examples, the BS frame boundary is known to the first node **102/202**. In some examples, the first node **102/202** may learn of, based on receiving the preamble, a sum of the transmission time between the second node **106/206** and the UE **104/204** (the first transmission delay T1) and the transmission time between the UE **104/204** and the first node **102/202** (the second transmission delay T2), and forward the related information to the second node **106/206**. In some arrangements, the second node **106/206** may configure a TA for the UE **104/204** by using RARs. In some examples, the TA for the UE **104/204** includes an amount of time that needs to be advanced in subsequent uplink transmission relative to the receiving timing. In some examples, the TA for the UE **104/204** enables the uplink transmission to arrive at the network side at a specified time. At **1140**, a time point D represents the transmit uplink transmission by the UE **104/204**.

[0079] In some arrangements, there is an ideal backhaul between the second node **106/206** and the first node **102/202**, and there is no transmission delay between them (e.g., the third transmission delay T3=0). In some examples, the reception timing of the first node **102/202** is aligned with BS frame boundary. In some arrangements, where the RAR includes the TA for the uplink transmission relative to a timing by which the downlink transmission is received, the TA can be determined as a sum of a transmission time between the second node **106/206** and the UE **104/204** (e.g., the first transmission delay T1) and a transmission time between the UE **104/204** and the first node **102/202** (e.g., the second transmission delay T2). For example, the TA value for the UE **104/204** can be calculated by the following formula: TA=T1+T2.

[0080] In some arrangements, an initial transmission delay T0 is related to at least one of the third transmission delay T3 or a timing difference T4 between reception timing of the first node **102/202** and BS frame boundary or a process time of the first node T5. For example, the TA value for the UE **104/204** can be calculated by the following formula: TA=T1+T2+T0. In some arrangements, where the RAR includes the TA for the uplink transmission relative to a time by which the RAR is received, the TA can be determined as a sum of a transmission time between the second node and the UE **104/204** (e.g., the first transmission delay T1), a transmission time between the UE **104/204** and the first node (e.g., the first transmission delay T2), and an offset (e.g., TO) In some arrangements, the offset is at least one of (i) a transmission delay between the second node and the first node (e.g., the third transmission delay T3), (ii) a timing difference between a reception timing of the first node and a frame boundary of the first node (e.g., T4), or (iii) a processing time of the first node (e.g., T5).

[0081] In some examples, there is an ideal backhaul between the second node **106/206** and the first node **102/202** such that there is no transmission delay between the first node **102/202** and the second node **106/206** (e.g., the third transmission delay T3=0). In some examples, the third transmission delay T3 #0. In some examples, the fourth transmission delay T4 can be a positive value, a negative value, or a zero. When T4=0, it indicates that the reception timing of the first node **102/202** is aligned with BS frame boundary. When T4 is a positive value, it indicates that the BS frame boundary is |T4| behind of the reception timing of the first node **102/202**. When T4 is a negative value, it indicates that the BS frame boundary is |T4| ahead of the reception timing of the first node **102/202**.

[0082] In some arrangements, the UE **104/204** determines the transmission power for preamble transmission. In some arrangements, according to transmission power determination mechanism for PRACH transmission, downlink path loss (PL) can be obtained according to measurement of downlink reference signal (e.g., SSB) and it can be used for calculating the PRACH transmission power. In some examples, the PRACH transmission power equals to a sum of a target reception power and the downlink PL. In some arrangements, in deployment of forwarding the uplink transmission to the second node **106/206** by using the first node **102/202**, downlink PL and uplink PL may be different, which prevents usage of the downlink PL for determining uplink transmission power directly.

[0083] In some arrangements, one or more of a path loss adjustment amount or a transmit power adjustment amount (P_offset) can be configured via system information (e.g., SIB1). In some arrangements, the UE **104/204** receives from the second node a power offset (e.g., P_offset) in a SIB. In some examples, the PRACH transmission power can be determined as the sum of the target reception power, the

downlink PL, and the P_offset. In some examples, the P_offset is determined based on the measurement threshold (e.g., RSRP threshold). As described previously, the RSRP threshold is defined for uplink access node determination or selection.

[0084] FIG. **12** is a table illustrating an example mapping relationship between Synchronization Signal Reference Signal Received Power (SS-RSRP) measurement result and the P_offset, according to various arrangements. As shown in FIG. **12**, in some arrangements, if the measurement result is lower than or no greater than the measurement threshold, the first node **102**/**202** is determined or selected as uplink receiving node and the P_offset will be used for calculating the transmission power for the preamble. As shown in FIG. **12**, in some arrangements, if the measurement result is no less than or greater than the measurement threshold, the second node **106**/**206** is determined or selected as uplink receiving node and the P_offset will not be used for calculating the transmission power for the preamble (e.g., P_offset=0).

[0085] In some arrangements, other mechanisms can be used for determining uplink receiving node or RACH mode for the UE **104**/**204**. In some arrangements, if the uplink receiving node is the first node **102**/**202**, the P_offset will be used for calculating the preamble transmission power, and if the uplink receiving node is the second node **106**/**206** which is not the transmission node of the SSB, the P_offset will not be used for calculating the preamble transmission power (e.g., P_offset=0). For example, in response to the UE **104**/**204** sending the preamble to the first node using the transmission power, the UE **104**/**204** determines the transmission power using the power offset (e.g., P_offset), and in response to the UE **104**/**204** sending the preamble to the second node using the transmission power, the UE **104**/**204** determines the transmission power without using the power offset (e.g., P_offset=0).

[0086] FIG. **13** is a table illustrating another example mapping relationship between SS-RSRP and P_offset, according to various arrangements. In some arrangements, more than one P_offset is configured. In some examples, as shown in FIG. **13**, (i) if the measurement result is lower than or no higher than a measurement threshold1, a P_offset1 will be used for calculating the transmission power for the preamble, (ii) if the measurement result is (a) lower than or no higher than a measurement threshold2 and (b) no lower than or higher than the measurement threshold1, a P_offset2 will be used for calculating the transmission power for the preamble, and (iii) if the measurement result is no lower than or higher than the measurement threshold2, the P_offset will not be used for calculating the transmission power for the preamble (e.g., P_offset=0).

[0087] In some arrangements, the UE **104**/**204** determines the transmission power for Msg.3 PUSCH transmission. In some arrangements, according to transmission power determination mechanism for Msg.3 transmission, a first list of delta values (e.g., {−1, . . . , 6}) are defined and an RRC parameter is used for indicating one delta from the list (e.g., Delta1), where the power of Msg.3 transmission is determined as the sum of the transmission power of the preamble and Delta1. In some arrangements, there may be larger power difference between the preamble and the Msg.3. In some arrangements, a second list (e.g., new list, etc.) of delta values with larger granularity can be defined (e.g., {−20, −10, 0, 10, 20, 30}) and an indication may be used for indicating one delta from the new list (e.g., Delta2), where if the UE **104**/**204** determines that the uplink receiving node is the first node **102**/**202**, the delta value from the second list may be used for determining the power of Msg.3 transmission.

[0088] In some arrangements, the UE **104**/**204** receives from the second node the first list of delta values and the second list of delta values and determines a transmission power for transmitting Msg.3 uplink (e.g., PUSCH) transmission according to one of the first list of delta values and the second list of delta values. In some examples, determining the transmission power for transmitting the Msg.3 uplink transmission according to one of the first list of delta values and the second list of delta values is based on which RACH mode (e.g., the first RACH mode and the second RACH mode) the UE **104**/**204** selected.

[0089] In some arrangements, the UE **104**/**204** receives an indication from the second node. In response to selecting the first RACH mode, a delta value from the first list of delta values is determined according to the indication, where the first RACH mode includes the UE **104**/**204** transmitting the PRACH to the first node. In response to selecting the second RACH mode, a delta value from the second list of delta values is determined according to the indication, where the second RACH mode includes the UE **104**/**204** transmitting the PRACH to the second node. The UE **104**/**204** determines the transmission power using the delta value and transmits to the first node the Msg.3 uplink transmission using the transmission power.

[0090] In some arrangements, the Delta2 will be indicated via RAR or SIB1 and will be used for calculating the transmission power of the Msg.3 instead of the Delta1, such that the power of Msg.3 transmission is determined as the sum of the transmission power of the preamble and the Delta2.

[0091] In some arrangements, the Delta2 will be indicated via RAR or SIB1 and will be used for calculating the transmission power of the Msg.3 together with the Delta1, such that the power of Msg.3 transmission is determined as the sum of the transmission power of the preamble, the Delta1, and the Delta2.

[0092] In some arrangements, if a UE **104**/**204** determines that the uplink receiving node is the first node **102**/**202**, a power offset is defined and utilized for determining the power of Msg.3 transmission, such that the transmission power of Msg.3 is determined as the sum of the transmission power of the preamble, the Delta1, and the power offset.

[0093] In some arrangements, as shown in FIG. **7**, the second node **106**/**206** sends three SSBs (e.g., the one or more backhaul links **720**) (e.g., cell-SSBs) to cover the entire cell. To cover a preset range, the RN **710** sends four SSBs (e.g., the one or more access links **730**) (e.g., refined-SSBs), such that the UE **104**/**204** can access the cell via either the second node **106**/**206** or the RN **710**. In some arrangements, accessing the cell via the RN **710** depends on one or more factors.

[0094] In some arrangements, the RN **710** can only forward the cell-SSB received from the second node **106**/**206** (e.g., cell-SSB0), such that more than one refined SSBs (e.g., refined-SSB #0, refined-SSB #1, refined-SSB #2, and refined-SSB #3, etc.) for access link will carry the same SSB index (e.g., SSB index #0). In some examples, the SSB index information is carried by at least one of PBCH Demodulation Reference Signal (DMRS) sequence and PB CH payload. In some examples, only SSB #0 resource can

be used for transmitting refined-SSBs and different refined-SSBs will be transmitted in different periods.

[0095] FIG. **14** is a diagram **1400** illustrating an example SSB transmission, according to various arrangements. The diagram **1400** includes cell specific configured period of SSB transmission **1410** and an actual period of SSB transmission **1420**. In some examples, the cell specific configured period of SSB transmission **1410** is 5 ms such that, for transmitting 4 refined-SSBs (refined-SSB #0 **1430**, refined-SSB #1 **1432**, refined-SSB #2 **1434**, and refined-SSB #3 **1436**) in the resource for SSB index #0, the actual period of SSB transmission (e.g., refined-SSB transmission) **1420** will be extended for four times (e.g., each refined-SSB **1430**, **1432**, **1434**, and **1436** is transmitted in independent period). In some arrangements, because all the refined-SSBs **1430**, **1432**, **1434**, and **1436** carry the same SSB index (e.g., the SSB index #0), both the PBCH DMRS sequence and the PBCH payload used by the refined-SSBs **1430**, **1432**, **1434**, and **1436** can only indicate the SSB index #0. In some arrangements, an additional indication manner distinguishes between the refined-SSBs **1430**, **1432**, **1434**, and **1436**. As shown in FIG. **14**, in an actual transmission period of the refined-SSBs **1420**, different refined-SSBs **1430**, **1432**, **1434**, and **1436** are in different radio frames and half frames. In some arrangements, the refined-SSB index may be indicated by binding the system frame number (SFN) and the half frame.

[0096] FIG. **15** is a table illustrating an example mapping relationship between the refined-SSB index, the SFN, and the half frame, according to various arrangements. In some arrangements, P is an actual transmission period in terms of frames of the refined-SSB. In some examples, P is equal to a value of 2.

[0097] In some arrangements, the transmission period of the cell-SSB is equal to or larger than 10 ms, such that different refined-SSBs will be located within different system frames. In some arrangements, the refined-SSB index may be indicated by the SFN.

[0098] FIG. **16** is a table illustrating another example mapping relationship between the refined-SSB index and the SFN, according to various arrangements. As shown in FIG. **16**, P1 is an actual transmission period of the refined-SSB, P2 is a transmission period of the cell-SSB, and N is the refined-SSB index.

[0099] In some arrangements, the actual transmitted refined-SSBs is indicated to the UE **104**/**204**. In some examples, the actual transmitted cell-SSBs indication received from the second node **106**/**206** can be forwarded by RN **710** directly, such that the UE **104**/**204** will receive that the SSB #0, SSB #1, and SSB #2 are actually transmitted and valid ROs will be associated to the SSB #0, SSB #1, and SSB #2, circularly. In some examples, the actual transmitted SSBs for the access links will be indicated by RN **710**, such that signaling 'ssb-PositionsInBurst' will be updated before forwarding. For example, the actual transmitted SSBs indication received from the second node **106**/**206** is the SSB #0, SSB #1, and SSB #2, but only the SSB #0 is transmitted by itself, so the RN **710** indicates that only the SSB #0 is actually transmitted and all the valid ROs will be associated to the SSB #0.

[0100] In some arrangements, the R Os that are associated with the forwarded SSBs (e.g., SSB0) are used for preamble transmitting while the other ROs may be defined as invalid ROs and can be used for other UL transmission. In some arrangements, additional association between the refined beams and the ROs corresponding to the SSB0 is defined.

[0101] FIG. **17** is a diagram **1700** illustrating an example mapping relationship between the refined-SSBs **1430**, **1432**, **1434**, and **1436** and the ROs **1710**, **1712**, **1714**, and **1716**, according to various arrangements. As shown in FIG. **17**, all the refined-SSBs **1430**, **1432**, **1434**, and **1436** are transmitted on the resource for the SSB index #0 and the refined-SSBs **1430**, **1432**, **1434**, and **1436** are associated with the ROs **1710**, **1712**, **1714**, and **1716** associated with the SSB index #0, circularly.

[0102] In some arrangements, the RN **710** can only forward the cell-SSB received from the second node **106**/**206** (e.g., the cell-SSB0) more than one refined SSBs for access link will carry the same SSB index (e.g., all refined-SSBs **1430**, **1432**, **1434**, and **1436** carrying the SSB index #0). In some examples, the SSB index information is carried by at least one PBCH DMRS sequence and PB CH payload. In some examples, the resource for other SSB index can also be used for refined SSB s transmission.

[0103] FIG. **18** is a diagram **1800** illustrating an example transmission of the refined-SSBs **1430**, **1432**, **1434**, and **1436**, according to various arrangements. In some arrangements, the diagram **1800** includes the cell specific configured period of SSB transmission **1410** being equal to the actual period of refined-SSB transmission **1420**. In some arrangements, the refined-SSBs **1430**, **1432**, **1434**, and **1436** will be transmitted in the resource for different SSB indexes (e.g., SSB index #0, SSB index #1, SSB index #2, SSB index #3, etc.). In some arrangements, additional mechanism is defined for indicating the index of refined-SSBs (e.g., PBCH payload), such that if there are at most L refined-SSBs then $\lceil \log_2 L \rceil$ bits are required for indicating the index of refined-SSB.

[0104] In some arrangements, the RN **710** can generate SSBs that are not received from the second node **106**/**206** (e.g., the SSB1, the SSB2, etc.) and different refined beams can carry different refined-SSB indexes. As shown in FIG. **18**, the SSBs resource can be used for refined beams transmissions with the corresponding SSB index. In some examples, the refined-SSB index can be indicated via at least one of PBCH DMRS sequence and PBCH payload.

[0105] In some arrangements, the actual transmitted refined-SSBs may be indicated to the UE **104**/**204**. In some examples, the actual transmitted SSBs for access link will be indicated by the RN **710**, such that the signaling 'ssb-PositionsInBurst' is updated before forwarding. For example, the actual transmitted SSBs indication received from the second node **106**/**206** is SSB #0, SSB #1, and SSB #2 but the refined-SSB #0, SSB #1, SSB #2, and SSB #3 are transmitted by themselves, so the RN indicates that refined-SSB #0, SSB #1, SSB #2, and SSB #3 are actually transmitted and the valid ROs will be associated to the refined-SSB #0, SSB #1, SSB #2, and SSB #3, circularly.

[0106] In some arrangements, according to PRACH reception, the refined-SSB index selected by the UE **104**/**204** can be identified by the RN **710** and indicated to the second node **106**/**206**. For example, the information (e.g., the refined-SSB index) can be indicated via control-link between the RN **710** and the second node **106**/**206** and the beam of the subsequent DL transmission to the UE **104**/**204** can be indicated to the RN **710** accordingly.

[0107] FIG. **19** is a diagram **1900** illustrating an example method for Radio Resource Control (RRC) setup, according

to various arrangements. At **1910**, the UE **104/204** is RRC idle (e.g., RRC_IDLE). At **1912**, the RACH procedure is executed. In some arrangements, the RACH procedure of **1912** includes, at **1914**, the UE **104/204** transmitting an RRC setup request (e.g., Msg3 'RRCSetupRequest,' etc.) to the second node **106/206**. In some arrangements, the RACH procedure of **1912** includes, at **1916**, the UE **104/204** receiving an RRC setup (e.g., Msg4 'RRC Setup,' etc.) message from the second node **106/206**. At **1920**, the UE **104/204** is RRC connected (e.g., RRC_CONNECTED). At **1922**, the UE **104/204** transmits an RRC setup complete (e.g., Msg5 'RRCSetupComplete,' etc.) message to the second node **106/206**. In some examples, the RRC setup complete message notifies the second node **106/206** that the UE **104/204** has completed the RRC setup. At **1924**, the UE **104/204** receives a capability inquiry (e.g., 'UECapabilityEnquiry,' etc.) from the second node **106/206**. At **1926**, the UE **104/204** transmits the capability information of the UE **104/204** (e.g., 'UECapabilityInformation,' etc.) to the second node **106/206**. At **1928**, the UE **104/204** receives RRC reconfiguration (e.g., 'RRC Reconfiguration,' etc.) from the second node **106/206**. At **1930**, the UE **104/204** transmits an RRC reconfiguration complete (e.g., 'RRCReconfigurationComplete,' etc.) message to the second node **106/206**.

[0108] In some arrangements, as shown in FIG. **19**, after the UE **104/204** performs the RACH procedure (e.g., 4-step RACH procedure, etc.), the network schedules a Msg5 PUSCH transmission to complete the RRC setup. In some arrangements, the network performs the RRC reconfiguration (e.g., at **1928** etc.) according to capability information of the UE **104/204**. In some examples, before the capability information of the UE **104/204** is reported, some functions (which need to be determined based on the capability information of the UE **104/204**) cannot be configured. In some arrangements, before the first RRC configuration (e.g., the RRCReconfiguration message is received by the UE **104/204** at **1928**), DCI formats other than 0_0 cannot be used for UL scheduling, such that the Msg5 PUSCH transmission (which is scheduled by the DCI format 0_0 with CRC scrambled by a parameter (e.g., Cell Radio Network Temporary Identifier (C-RNTI), etc.) cannot be scheduled with repetition.

[0109] In some arrangements, the Msg5 PUSCH transmission is scheduled by DCI formats (e.g., DCI format 0-1 or 0-2) other than DCI format 0-0, such that the repetition transmission can be used for the Msg5 PUSCH, thereby enhancing the coverage of the Msg5 PUSCH transmission. In some arrangements, the UE **104/204** can report the related capability information of the UE **104/204** in advance, for example, through the Msg3, such that the corresponding configurations can be configured by the network according to the reported capability information of the UE **104/204**. In some arrangements, the UE **104/204** can determine the size of information fields of the DCI format other than DCI format 0-0 and further determine the transmission parameter configurations of the scheduled PUSCH in accordance with the indication in the information field. In some arrangements, the reported capability information of the UE **104/204** includes at least one of (i) PUSCH repetition Type A, (ii) PUSCH repetition Type B, (iii) supported Hybrid Automatic Repeat Request Acknowledgement (HARQ-ACK) codebook types (e.g., Dynamic HARQ-ACK codebook and/or Semi-static HARQ-ACK codebook), (iv) PUSCH Multiple Input/Multiple Output (MIMO) transmission capability (e.g., codebook based PUSCH transmission and/or non-codebook based PUSCH transmission), or (v) the maximum number of Orthogonal Frequency-Division Multiplexing (OFDM) symbols for UL front loaded DMRS (1 or 2).

[0110] In some arrangements, the UE **104/204** can report request information for Msg5 PUSCH transmission with repetition, such that the Msg5 PUSCH transmission with repetition can be scheduled by DCI format 0-0 and the repetition factor can be indicated via information in the DCI format or configured in Msg2 or SIB1. In some arrangements, the Msg5 PUSCH transmission with repetition can scheduled by a DCI format other than DCI format 0-0 (e.g., DCI format 0-1 or 0-2) and some default capability information of the UE **104/204** related with the PUSCH transmission can be defined. In some arrangements, the default capability information of the UE **104/204** includes at least one of (i) support PUSCH repetition Type A, (ii) support PUSCH repetition Type B, (iii) support at least one of HARQ-ACK codebook types (e.g., Dynamic HARQ-ACK codebook and/or Semi-static HARQ-ACK codebook), (iv) support at least one of PUSCH MIMO transmission mode (e.g., codebook based PUSCH transmission and/or non-codebook based PUSCH transmission), or (v) the maximum number of OFDM symbols for UL front loaded DMRS (1 or 2).

[0111] In some arrangements, the UE **104/204** reports a PUSCH repetition transmission capability (e.g., PUSCH repetition type A) for PUSCH scheduled by DCI format 0-0 with CRC scrambled by a parameter (e.g., C-RNTI, etc.) by using the PRACH transmission, information in Msg3 (e.g., a RRC or a Media Access Control (MAC) layer signaling), or the RRC signaling (e.g., capability information of the UE **104/204**). In some arrangements, in response to the UE **104/204** requesting the repetition transmission for PUSCH scheduled by DCI format 0-0 with CRC scrambled by the parameter (e.g., C-RNTI, etc.) by using the PRACH transmission, information in Msg3 (a RRC or MAC layer signaling), or the RRC signaling (e.g., capability information of the UE **104/204**), the UE **104/204** receives a repetition factor for a PUSCH transmission by the DCI format scheduling the PUSCH. In some examples, two Most Significant Bits (MSBs) of Modulation and Coding Scheme (MCS) field are used for indicating the repetition factor. For example, one of four RRC configured repetition factors can be indicated by the two MSBs.

[0112] In some arrangements, information fields in the DCI format, such as Time Domain Resource Allocation (TDRA) field, Frequency Domain Resource Allocation (FDRA) field, etc., can be used for indicating the repetition factor. In some arrangements, flexibility of the information fields is affected. For example, in response to the two MSBs of the MCS field being used to indicate the repetition factor, an indication range of thirty-two MCSs of an original 5-bit MCS field is reduced to eight MCSs. In some arrangements, scheduling modes are defined and include a repetition scheduling mode and a non-repetition scheduling mode. In some examples, for a PUSCH transmission scheduled by a DCI format 0-0 within the repetition scheduling mode, at least part bits of the related information field in the DCI format 0-0 will be interpreted as an indication of the repetition factor. In some examples, for a PUSCH transmission scheduled by a DCI format 0-0 within the non-repetition scheduling mode, the related information field in the DCI format 0-0 does not include an indication of the repetition factor. In

some arrangements, conditions are defined to indicate the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode). In some examples, when the repetition scheduling mode is indicated or determined, some bit of the related information field (such as MCS field) in the DCI format 0-0 will be re-interpreted as repetition factor information, thereby improving the flexibility of PUSCHs scheduling.

[0113] In some arrangements, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of a PUSCH scheduled by a DCI format 0-0 (whether at least part bits of an information field in the DCI format 0-0 are re-interpreted as the repetition factor) is determined according to the scheduling mode of another PUSCH scheduled by a non-DCI format 0-0 (e.g., DCI format 0-1 or 0-2). In some arrangements, the non-DCI format 0-0 is the latest non-DCI format before the DCI format 0-0. In some examples, in response to the PUSCH being scheduled by the non-DCI format 0-0 with repetition, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of the PUSCH scheduled by the DCI format 0-0 is also scheduled with repetition (e.g., the repetition scheduling mode), such that the repetition factor is indicated by the at least a part bits of an information field in the DCI format 0-0. In some arrangements, a time interval threshold is defined such that, if a time interval between the DCI format 0-0 and the latest non-DCI format 0-0 exceeds the time interval threshold, a default scheduling mode (e.g., one of the repetition scheduling mode or the non-repetition scheduling mode) is selected. In some examples, if the time interval between the DCI format 0-0 and the latest non-DCI format 0-0 does not exceed the time interval threshold, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of PUSCH scheduled by the DCI format 0-0 will be determined according to the scheduling mode of the PUSCH scheduled by the latest non-DCI format 0-0.

[0114] In some arrangements, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of a PUSCH scheduled by a first DCI format 0-0 will follow that of another PUSCH scheduled by a second DCI format 0-0. In some arrangements, the second DCI format 0-0 is the latest DCI format before the first DCI format 0-0. In some examples, a time interval threshold is defined such that, if a time interval between the first DCI format 0-0 and the second DCI format 0-0 exceeds the time interval threshold, a default scheduling mode (e.g., one of the repetition scheduling mode or the non-repetition scheduling mode) is selected. In some examples, if the time interval between the first DCI format 0-0 and the second DCI format 0-0 does not exceed the time interval threshold, the scheduling mode of the PUSCH scheduled by the first DCI format 0-0 will be determined based on the scheduling mode of another PUSCH scheduled by the second DCI format 0-0.

[0115] In some arrangements, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of a first PUSCH scheduled by a first DCI format 0-0 is determined according to indication information carried in a second PUSCH scheduled by a second DCI format. In some arrangements, the second PUSCH is the latest PUSCH and the second PUSCH carries the indication information before the first PUSCH. In some arrangements, the indication information includes a RRC signaling or a MAC layer signaling (e.g., MAC CE, etc.).

[0116] In some arrangements, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of a PUSCH scheduled by a DCI format 0-0 is determined according to an indication bit in the DCI format 0-0. In some examples, if a first number of bits for a DCI format 1_0 before padding is larger than a second number of bits for a DCI format 0_0 before padding, one bit for indication will be added after the padding bit(s) of the DCI format 0_0. In some arrangements, one value of the indication bit (e.g., 1 or 0) represents that the PUSCH transmission is within the repetition scheduling mode, such that at least part bits of the related information field will be interpreted as repetition factor indication, and another value of the indication bit (e.g., 0 or 1) represents that the PUSCH transmission is within the non-repetition scheduling mode, such that the indication information in the DCI format does not include indication of the repetition factor.

[0117] In some arrangements, the scheduling mode (e.g., the repetition scheduling mode and the non-repetition scheduling mode) of a PUSCH scheduled by a DCI format 0-0 is determined according to a latest downlink measurement result. In some arrangements, the latest downlink measurement result is reported to the second node **106**/**206** before the DCI format 0-0. In some arrangements, a relationship between the measurement result and the scheduling mode is predefined or configured by the second node **106**/**206**. In some examples, according to the reported measurement result, both of the second node **106**/**206** and the UE **104**/**204** can determine the same scheduling mode for the subsequent PUSCH scheduling, such that the UE **104**/**204** can correctly process the information field in the DCI format 0-0.

[0118] While various arrangements of the present disclosure have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. Likewise, the various diagrams may depict an example architectural or configuration, which are provided to enable persons of ordinary skill in the art to understand example features and functions of the present solution. Such persons would understand, however, that the solution is not restricted to the illustrated example architectures or configurations, but can be implemented using a variety of alternative architectures and configurations. Additionally, as would be understood by persons of ordinary skill in the art, one or more features of one arrangement can be combined with one or more features of another arrangement described herein. Thus, the breadth and scope of the present disclosure should not be limited by any of the above-described illustrative arrangements.

[0119] It is also understood that any reference to an element herein using a designation such as "first," "second," and so forth does not generally limit the quantity or order of those elements. Rather, these designations can be used herein as a convenient means of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not mean that only two elements can be employed, or that the first element must precede the second element in some manner.

[0120] Additionally, a person having ordinary skill in the art would understand that information and signals can be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits and symbols, for example, which

may be referenced in the above description can be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0121] A person of ordinary skill in the art would further appreciate that any of the various illustrative logical blocks, modules, processors, means, circuits, methods and functions described in connection with the aspects disclosed herein can be implemented by electronic hardware (e.g., a digital implementation, an analog implementation, or a combination of the two), firmware, various forms of program or design code incorporating instructions (which can be referred to herein, for convenience, as "software" or a "software module), or any combination of these techniques. To clearly illustrate this interchangeability of hardware, firmware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware or software, or a combination of these techniques, depends upon the particular application and design constraints imposed on the overall system. Skilled artisans can implement the described functionality in various ways for each particular application, but such implementation decisions do not cause a departure from the scope of the present disclosure.

[0122] Furthermore, a person of ordinary skill in the art would understand that various illustrative logical blocks, modules, devices, components and circuits described herein can be implemented within or performed by an integrated circuit (IC) that can include a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, or any combination thereof. The logical blocks, modules, and circuits can further include antennas and/or transceivers to communicate with various components within the network or within the device. A general purpose processor can be a microprocessor, but in the alternative, the processor can be any conventional processor, controller, or state machine. A processor can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other suitable configuration to perform the functions described herein.

[0123] If implemented in software, the functions can be stored as one or more instructions or code on a computer-readable medium. Thus, the steps of a method or algorithm disclosed herein can be implemented as software stored on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that can be enabled to transfer a computer program or code from one place to another. A storage media can be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can include 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 store desired program code in the form of instructions or data structures and that can be accessed by a computer.

[0124] In this document, the term "module" as used herein, refers to software, firmware, hardware, and any combination of these elements for performing the associated functions described herein. Additionally, for purpose of discussion, the various modules are described as discrete modules; however, as would be apparent to one of ordinary skill in the art, two or more modules may be combined to form a single module that performs the associated functions according arrangements of the present solution.

[0125] Additionally, memory or other storage, as well as communication components, may be employed in arrangements of the present solution. It will be appreciated that, for clarity purposes, the above description has described arrangements of the present solution with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processing logic elements or domains may be used without detracting from the present solution. For example, functionality illustrated to be performed by separate processing logic elements, or controllers, may be performed by the same processing logic element, or controller. Hence, references to specific functional units are only references to a suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[0126] Various modifications to the implementations described in this disclosure will be readily apparent to those skilled in the art, and the general principles defined herein can be applied to other implementations without departing from the scope of this disclosure. Thus, the disclosure is not intended to be limited to the implementations shown herein, but is to be accorded the widest scope consistent with the novel features and principles disclosed herein, as recited in the claims below.

What is claimed:

1. A wireless communication method, comprising:

performing, by a wireless communication device, a Random Access Channel (RACH) procedure involving a first node and a second node, wherein the wireless communication device receives downlink data from the second node; and

communicating by the wireless communication device with the second node through the first node.

2. The wireless communication method of claim **1**, comprising selecting, by the wireless communication device, a first RACH mode or a second RACH mode, wherein

the first RACH mode comprises transmitting, by the wireless communication device to the first node, a Physical Random Access Channel (PRACH); and

the second RACH mode comprises transmitting, by the wireless communication device, the PRACH to the second node.

3. The wireless communication method of claim **2**, wherein selecting the first RACH mode or the second RACH mode comprises:

selecting the first RACH mode in response to determining by the wireless communication device that a measurement result of a transmission received from the second node is less or no greater than a threshold; or

selecting the second RACH mode in response to determining by the wireless communication device that the measurement result of the transmission received from the second node is greater or no less than the threshold.

4. The wireless communication method of claim **2**, wherein selecting the first RACH mode or the second RACH mode comprises:

selecting the first RACH mode in response to determining by the wireless communication device that a measurement result of a transmission received from the second node is within a range; or

selecting the second RACH mode in response to determining by the wireless communication device that the measurement result of the transmission received from the second node is outside of the range.

5. The wireless communication method of claim **2**, wherein selecting the first RACH mode or the second RACH mode comprises:

selecting one of the first RACH mode or the second RACH mode in response to failing the RACH procedure for a number of attempts using another one of the first RACH mode or the second RACH mode, the number of attempts is equal to or greater than a threshold.

6. The wireless communication method of claim **2**, wherein selecting the first RACH mode or the second RACH mode comprises:

selecting one of the first RACH mode or the second RACH mode in response to power of a preamble transmission in another one of the first RACH mode or the second RACH mode reaching a predefined value, wherein the predefined value comprises a maximum transmission power of the preamble transmission configured by the second node.

7. The wireless communication method of claim **2**, wherein the first RACH mode or the second RACH mode is selected for a Synchronization Signal/PBCH Block (SSB) or a Channel State Information-Reference Signal (CSI-RS).

8. The wireless communication method of claim **1**, comprising selecting, by the wireless communication device, a first transmission link for the RACH procedure or a second transmission link for a Physical Random Access Channel (PRACH) transmission, wherein

the first transmission link is between the wireless communication device and the first node; and

the second transmission link is between the wireless communication device and the second node.

9. The wireless communication method of claim **1**, comprising selecting a reception/transmission beam pair by attempting a plurality of reception/transmission beam pairs, wherein the reception/transmission beam pair is used for sending uplink transmission from the wireless communication device to the first node.

10. The wireless communication method of claim **9**, comprising transmitting, by the wireless communication device to the network, a preamble using a transmission beam of each of the plurality of reception/transmission beam pairs, wherein: each of the plurality of reception/transmission beam pairs comprises one of a plurality of reception beams and one of a plurality of transmission beams, the transmission beam is one of the plurality of transmission beams, and the network receives the preamble using a reception beam of each of the plurality of reception/transmission beam pairs, where the reception beam is one of the plurality of reception beams.

11. The wireless communication method of claim **10**, wherein

the preamble is transmitted in a group of RACH Occasions (ROs) using the plurality of reception/transmission beam pairs, each RO in the group of ROs corresponds to each of the plurality of reception/transmission beam pairs; or

the preamble is transmitted in a plurality of groups of RACH Occasions (ROs) using the plurality of reception/transmission beam pairs, each of the plurality of groups of ROs corresponds to a transmission beam of the plurality of transmission beams.

12. The wireless communication method of claim **1**, comprising receiving, by the wireless communication device from the second node, a Random Access Response (RAR), wherein the RAR indicates a transmission beam with which the wireless communication device transmits an uplink transmission, and the RAR indicates the transmission beam using an RACH Occasion (RO) index within an RO group.

13. The wireless communication method of claim **12**, wherein

the RAR is carried on a downlink channel scheduled by a Downlink Control Information (DCI) format having a Cyclic Redundancy Check (CRC) scrambled by a parameter; and

the parameter is determined according to a time-domain location of at least one RO in the RO group.

14. The wireless communication method of claim **13**, wherein

the RO group comprises a number Q of ROs; and

a number of bits in the RAR used to indicate the RO index within the RO group can be determined using $\lceil \log_2 Q \rceil$, where Q is a positive integer.

15. The wireless communication method of claim **13**, wherein

the RO group comprises a number Q of ROs; and

a number of bits in the RAR used to indicate the RO index can be determined using $\log_2 Q$, where Q is a positive integer and is a power of 2.

16. The wireless communication method of claim **1**, comprising:

receiving, by the wireless communication device from the second node, a Random Access Response (RAR); and

determining, by the wireless communication device, a transmission time for an uplink transmission transmitted by the wireless communication device after receiving the RAR.

17. The wireless communication method of claim **16**, further comprising:

determining, by the wireless communication device, a Timing Advance (TA) for the uplink transmission relative to a downlink receiving timing at which the RAR is received;

in response to selecting a first RACH mode, a value of a timing advance offset provided in System Information Block (SIB) is omitted for determining the TA; and

in response to selecting a second RACH mode, the value of the timing advance offset provided in the SIB is used for determining the TA, wherein the first RACH mode comprises transmitting, by the wireless communication device to the first node, a Physical Random Access Channel (PRACH), and the second RACH mode comprises transmitting, by the wireless communication device, the PRACH to the second node.

18. The wireless communication method of claim **16**, wherein the RAR comprises a Timing Advance (TA) for the uplink transmission relative to a time by which the RAR is received, the TA can be determined as a sum of a transmission time between the second node and the wireless com-

munication device and a transmission time between the wireless communication device and the first node.

19. The wireless communication method of claim **16**, wherein the RAR comprises a Timing Advance (TA) for the uplink transmission relative to a time by which the RAR is received, the TA can be determined as a sum of a transmission time between the second node and the wireless communication device, a transmission time between the wireless communication device and the first node, and an offset, the offset being at least one of:

a transmission delay between the second node and the first node;

a timing difference between a reception timing of the first node and a frame boundary of the first node; or

a processing time of the first node.

20. A wireless communication device, comprising:

at least one processor configured to:

perform a Random Access Channel (RACH) procedure involving a first node and a second node, wherein the wireless communication device receives downlink data from the second node; and

communicate, using a transceiver, with the second node through the first node.

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