(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 October 2016 (13.10.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/164100 A1

(51) International Patent Classification:
H04W 74/08 (2009.01) *H04W 52/04* (2009.01)
H04L 1/00 (2006.01)

(21) International Application Number:
PCT/US2016/016429

(22) International Filing Date:
3 February 2016 (03.02.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/145,335 9 April 2015 (09.04.2015) US
14/861,828 22 September 2015 (22.09.2015) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: RANDOM ACCESS PROCEDURE FOR ENHANCED COVERAGE SUPPORT

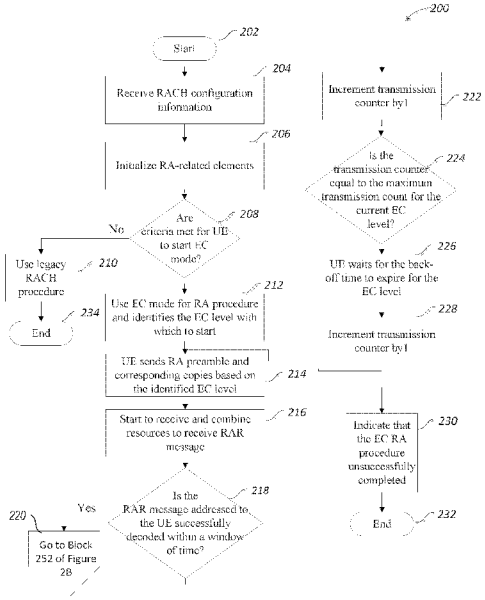

Figure 2A

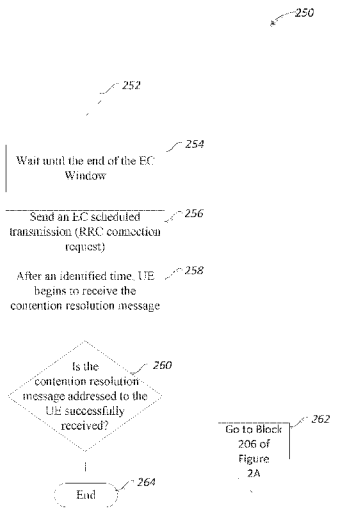

Figure 2B

(57) **Abstract**: Embodiments described herein relate generally to a communication between a user equipment (UE) and an evolved Node B (eNB) that are both running in Enhanced Coverage (EC) mode. The UE and eNB may communicate in a contention-based random access procedure having an EC level that may be used to determine the number of times an RA preamble may be sent, and one or more RA response opportunity windows that may be used to receive one or more RA responses. Other embodiments may be described and/or claimed.

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RANDOM ACCESS PROCEDURE FOR ENHANCED COVERAGE SUPPORT

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Patent Application No. 14/861,828 entitled "RANDOM ACCESS PROCEDURE FOR ENHANCED COVERAGE SUPPORT," filed September 22, 2015, which claims priority to U.S. Provisional Patent Application No. 62/145,335 entitled "Random Access Procedure for Enhanced Coverage Support" filed April 9, 2015. The entire disclosures of which are hereby incorporated by reference in their entireties for all purposes, except for those sections, if any, that are inconsistent with this specification.

FIELD

Embodiments of the present disclosure relate generally to the field of wireless communications, and more particularly, to computer devices operable to implement a contention-based random access procedure.

BACKGROUND

The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure. Unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in the present disclosure and are not admitted to be prior art by their inclusion in this section.

Machine-type communication (MTC) technology may enable ubiquitous computing environments as progress moves towards the concept of the "Internet of Things" (IoT). Potential MTC-based applications include smart metering, healthcare monitoring, remote security surveillance, intelligent transportation systems, individual item inventory control, and so forth. These services and applications may stimulate the design and development of a new type of MTC device that may be seamlessly integrated into current and future generation mobile broadband networks.

Existing mobile broadband networks are designed to optimize performance mainly for human-type communications. Therefore, existing networks may not be adapted or optimized for MTC-related requirements. MTC-specific designs may be explored, for example, by the Third Generation Partnership Project (3GPP). Future 3GPP specifications may support different network design, which may improve MTC.

For example, in 3GPP release 12 a new physical layer UE category, referred to as Category 0, was introduced into the E-UTRA specifications. This UE category has lower capabilities, for example in terms of peak data rate capability and in terms of transmission and reception performance due to support of only a single antenna, than the previous lowest Category 1. One of the aims for introducing Category 0 is to enable lower cost user equipment (UE) for MTC applications.

In 3GPP release 13 a new physical layer UE category (Category X) is being introduced having even lower capability and lower cost, compared to Category 0 added in release 12. In addition, an Enhanced Coverage (EC) feature is being introduced to increase the link budget by up to 15 decibels (dB). The EC feature will enable the E-UTRAN to communicate with UEs that are located in challenging locations where currently coverage cannot be provided or is difficult to provide to UEs, for example deep inside a building, in a basement, inside a pallet of goods and the like. Category X and EC are targeted to UEs primarily used for MTC applications. Category X and EC may be independently implemented and a UE may support either one or both.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the disclosure are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment of the disclosure are not necessarily to the same embodiment, and they may mean at least one. It should also be noted that references to an "example" are references to non-limiting examples, unless otherwise stated.

Figure 1 illustrates a communication message flow between an evolved Node B (eNB) and a user equipment (UE) using EC mode, in accordance with various embodiments.

Figure 2A illustrates a process for a contention-based random access procedure performed by a UE using EC functionality, in accordance with various embodiments.

Figure 2B illustrates a process for contention-based random access procedure performed by a UE using EC functionality, in accordance with various embodiments.

Figures 3A, 3B, and 3C are diagrams illustrating frame structures that may be used for implementing random access response (RAR) opportunities within an EC RAR window that may be used by a UE and an eNB, in accordance with various embodiments.

Figure 4 is a diagram illustrating frame structures for implementing a different modification period for the system information (SI) addressed to a UE in EC mode, in accordance with various embodiments.

Figure 5 is a block diagram illustrating a computing device adapted to operate in a wireless communication network in EC mode, in accordance with various embodiments.

Figure 6 illustrates electronic device circuitry that may be eNB circuitry, UE circuitry, or some other type of circuitry in accordance with various embodiments.

Figure 7 illustrates, for one embodiment, an example system comprising radio frequency (RF) circuitry, baseband circuitry, application circuitry, memory/storage, display, camera, sensor, and input/output (I/O) interface, coupled with each other at least as shown.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

Various operations may be described as multiple discrete actions or operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations may not be performed in the order of presentation. Operations described may be performed in a different order than the described embodiment. Various additional operations may be performed and/or described operations may be omitted in additional embodiments.

For the purposes of the present disclosure, the phrases "A or B" and "A and/or B" means (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C).

The description may use the phrases "in an embodiment," or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms "comprising," "including," "having," and the like, as used with respect to embodiments of the present disclosure, are synonymous.

As used herein, the terms "module" and/or "logic" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality.

As used herein, the term "circuitry" may refer to, be part of, or include an ASIC, an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules.

In embodiments, the disclosure herein may refer to processes, apparatus, and/or techniques for enhancing machine-to-machine communication related to the random access procedure process between an evolved NodeB (eNB) and a user equipment (UE) running in EC mode. These embodiments may include associating multiple levels with an EC mode, and for each level identifying a number of repetitions of messages sent between the UE and the eNB, as well as different power levels that may be used by the UE to attempt communication with an eNB depending upon the EC mode level. In addition, embodiments may include adding additional random access response (RAR) opportunity windows to receive and decode multiple RAR's that may be sent in response to multiple random access preambles. Also, embodiments may include support for a different modification period for the SI messages addressed to release-13 LC UEs and release-13 EC UEs.

In embodiments, UEs using this solution may operate in reduced bandwidth regions, such as 1.4MHz in release-13, or may operate in more narrowband regions, such as 200kHz. The eNB may also operate at higher system bandwidth.

Figure 1 illustrates a communication message flow between a UE and an eNB using EC mode, in accordance with various embodiments. Diagram 100 may include a UE 102 and wireless communication with an access node such as eNB 104. The UE 102 and the eNB 104 may be in communication to establish a radio resource control (RRC) connection using a contention-based RA procedure in EC mode.

An EC random access (RA) preamble assignment 106 may be sent from the eNB 104 to the UE 102. In embodiments, the RA preamble assignment 106 may include random access configuration information related to release 13 LC (low cost) UEs and release 13 EC mode UEs and may be broadcasted through system information (SI), or may be pre-defined in the UE 102. Random access configuration information, in embodiments, may include an EC level to be used by the UE 102, a value indicating the number of additional repetitions of each EC mode message allowed for that EC level, and/or one or more power levels to be used for repeated communication attempts.

An EC RA preamble 108 may be sent from the UE 102 to the eNB 104. An EC RAR message 110 may be sent by the eNB 104 in response to the EC RA preamble 108, within an EC RAR window which, in embodiments, may be received in a plurality of contiguous subframes. The contents of the EC RA preamble 108 may determine the random access radio network temporary identifier (RA-RNTI) that the UE 102 may look for in EC RA response (EC RAR) message 110 subframes received from the eNB 104.

In embodiments, the eNB 104 may have flexibility regarding the location within the EC RAR window the EC RAR message 110 is transmitted. In embodiments, the UE 102 may search for a RA-RNTI on a physical downlink control channel (PDCCH). In embodiments, the PDCCH received by UE in EC mode may be different from legacy PDCCHs. For example, the legacy PDCCH may be sent within the whole system bandwidth in the first OFDMA symbols of a subframe. However, for EC mode, the PDCCH may be sent in reduced bandwidth region within the legacy PDCCH.

The EC RAR message 110 may include a random access preamble identifier (RAPID) and a temporary cell radio network temporary identifier (T-CRNTI).

An EC scheduled transmission 112 may be sent by the UE 102 to the eNB 104. In embodiments, if the EC RAR message 110 is received in sub-frame n, the UE 102 may send a scheduled data item via physical uplink shared channel (PUSCH) in subframe n+k, $k \geq 6$. The UE 102 may further apply Hybrid Automatic Repeat Request (HARQ) with maxHARQ-Msg3Tx. The UE 102 may also start a timer such as timer T300 for RRC connection request and monitor for T-CRNTI on PDCCH. Finally, the UE 102 may start mac-ContentionResolutionTimer. In embodiments, the mac-ContentionResolutionTimer may be restarted at each HARQ retransmission.

An EC contention resolution message 114 may be sent by the eNB 104 to the UE 102. In embodiments, the T-CRNTI is used in PDCCH and HARQ may be applied for the

associated PDSCH by eNB 104. In embodiments, the UE 102 may send HARQ feedback only on PUCCH when it detects its own UE 102 identity as provided in the EC scheduled transmission 112. In embodiments, the EC contention resolution message 114 may be received by UE 102 while mac-ContentionResolutionTimer is running. If EC contention resolution message 114 is received successfully, the UE 102 Contention Resolution Identity MAC CE may contain the UL common control channel (CCCH) service data unit (SDU) of the EC contention resolution message 114.

In embodiments, advantages of the communications in EC mode described above may include a greater likelihood of an RRC connection establishment between a UE and eNB, particularly when the UE is implemented as part of IoT. Advantages may also include providing a greater likelihood of an RRC connection establishment while using less power, for example by ramping up power used by the UE to the point where the RA procedure is able to establish an RRC connection, where the UE does not have to continuously operate a maximum power. In addition, through supporting repeated attempts for transmissions between the UE and the eNB during the RA procedure, the likelihood of an RRC connection establishment is greatly increased.

Figure 2A illustrates a process for a contention-based random access procedure performed by a UE using EC functionality, in accordance with various embodiments. The process 200 describes various processes described above in more detail. The process 200 may be performed by a UE, for example UE 102, used in EC mode operation in accordance with various embodiments. In some embodiments, the UE may include one or more non-transitory computer-readable media having instructions, stored thereon, that when executed cause the UE to perform the process 200.

The process may start at block 202.

At block 204, the UE 102 may receive random access procedure (RACH) configuration information from an eNB 104. In embodiments, the configuration information may be received by the UE 102 from the EC RA preamble assignment message 106, for example when the UE 102 is in idle mode and capable of EC mode. The configuration information may be broadcasted through SI by the eNB 104. In other embodiments, the configuration information may have been previously stored in the UE 102.

At block 206, the UE 102 may initialize RA related elements. In embodiments, the UE may initialize related elements similar to legacy RA mechanisms. In embodiments,

new RA related parameters for EC mode UEs may be initialized. The RA related parameters may be, for example EC level, initial power level, or number of times to repeat a message.

At block 208, the UE 102 may make a determination related to whether criteria are met for the UE to start EC mode, or if a legacy RA procedure may be started. In embodiments, the UE 102 may decide which RA procedure mode may be used by information defined in specification, stored on the UE, and/or indicated to the UE through broadcast or dedicated messages. In examples, new rules, conditions, or criteria may be defined. For example, a rule may be defined that a UE having one or more unsuccessful completions under a legacy RA procedure may attempt to use EC RA procedure.

In other non-limiting examples, threshold values may be used to trigger or determine when a UE should use an EC RA procedure. These threshold values could be defined based on some UE specific parameter, such as measured reference signal received power (RSRP), measured reference signal received quality (RSRQ), preamble transmission counter value or physical random access channel (PRACH) preamble transmission power.

In other non-limiting examples, the determination may be based on the predefined category/capability specific information that is stored at the UE 102. For example, UE Category X may be required to always use EC RA procedures, or alternatively UE Category X may be allowed to use EC RA procedure based on other criteria in addition to its category.

If the criteria are not met to start EC mode, then at block 210 the UE 102 may use the legacy RA procedure. The process 200 may then end at block 234.

Otherwise, if the criteria are met to start EC mode, then at block 212 the UE 102 may use EC mode for the RA procedure and identify the starting EC level. In embodiments, the UE 102 may identify the EC level to use based on a stored value within the UE 102, or by receiving and/or decoding EC level information sent by the eNB 104 in the EC RA preamble assignment 106. The EC level may be important for a variety of reasons. For example, the RA related configuration may need to be updated based on the EC level. The maximum UL transmit power may be chosen directly with any EC level, or RA preambles and/or configurations may be based on the identified EC level. The EC level may also be associated with a specific number of message repetitions that are

available to the UE 102 while attempting to communicate with the eNB. As a result, the RA procedure may use, for example, a number of repeated messages, with each subsequent repeat using an increased power level, or power ramp-up, when attempting to establish an RRC connection. Other aspects related to the RA message resource allocation information within the EC RA preamble assignment 106 may include details of frequency hopping, the group of sequences that may be used for the preamble transmission if the UE is in EC mode, and/or if different EC levels are identified by their preamble sequences.

At block 214, the UE 102 may send an RA preamble and corresponding copies of the RA preamble based on the identified EC level. In embodiments, the RA preamble may be repeatedly sent for a number of times based on the identified EC level. In embodiments, the RA preamble group and/or subgroup, RA preamble time resource (PRACH subframes), frequency resources, and the like may depend on the identified EC level, as well as the subframes where the UE 102 sends the multiple copies of the EC RA preamble to allow the network to combine the multiple EC RA preamble copies. In embodiments, there may be a maximum of n preamble copies sent, n depending on the identified EC level. In embodiments, the UE 102 may determine the RA-RNTI based on the identified EC level, RA preamble, and RA preamble time and frequency resource.

At block 216, the UE 102 may begin to receive and/or to combine resources to receive an EC RAR message 110. In embodiments, the resource location of the EC RAR message 110 may be known by the UE after determining release 13 RA-RNTI, through a release 13 enhanced physical downlink control channel (ePDCCH) addressed to a group of UEs that attempt to access with same EC level or EC RA preamble 108, or through a release 13 ePDCCH addressed to specific UE or based on pre-configured/pre-defined information that is pre-defined and/or broadcasted in an SI message. In addition, the EC RAR message 110 could be a release 13 RAR different for that EC level or could be UE specific or a new kind of EC RAR message 110 that may carry the random access response. This process might be done only once, or repeated several times if a release 13 EC RAR-window concept is also defined and/or extended, as described below.

At block 218, the UE 102 may determine whether the EC RAR message 110 addressed to the UE was successfully decoded within a window of time. In embodiments, the window of time may be the EC window value. In embodiments, the window of time may vary based on the EC level, for example it may be proportional to the EC level

identified or may be based on the maximum number of preamble repetitions allowed for the EC level.

If the EC RAR message 110 was successfully decoded within a window of time, then at block 220 the process goes to block 252 of Figure 2B.

Otherwise, if the EC RAR message 110 was not successfully decoded within a window of time, then at block 222 the transmission counter may be incremented by one. In embodiments, the EC RAR message 110 may not have been successfully decoded because it may not have been sent by the eNB, or may have been sent but may not have contained the RAPID that the UE included in the EC RA preamble 108.

At block 224, the UE 102 may determine if the transmission counter is equal to the maximum transmission count for the current EC level. If the transmission counter is equal to the maximum transmission count for the current EC level, then at block 230 the UE 102 may determine that the EC RA procedure has unsuccessfully completed. In embodiments, this may occur if the maximum number of attempts is reached for the highest EC level. In embodiments, the UE may inform the RRC upper layers about the RA failure, and the upper layers may initiate the EC RA procedure again at a later time. Based on the previous RA failure, the RA procedure may be initiated by changing the EC level, for example incrementing the EC level, to a level more suitable for when the UE is deeper within the enhanced coverage region of the cell such as deep within a building. At block 232, the process 200 may end.

Otherwise, if the transmission counter is not equal to the maximum transmission count for the current EC level, then at block 226 the UE 102 may wait for the back-off time to expire for the EC level. In embodiments, the UE may try to send the EC RA preamble 108 again. For example, this may be done after applying preamble power ramping if specified or configured for EC. In embodiments, a transmission counter may be used to place a limit on the maximum number of PRACH preamble transmission trials for the current EC level. In embodiments, a transmission counter may determine when the UE may switch to another EC level, for example to a higher EC level which may allow for more message repetitions or a higher power level.

At block 228, the UE 102 may increment the transmission counter by 1, and the process 200 may proceed to block 212.

Figure 2B illustrates a process 250 for contention-based random access procedure performed by a UE using EC functionality, in accordance with various embodiments. The

process 250 may be performed by a UE (e.g., UE 102) for EC mode operation in accordance with various embodiments. In some embodiments, the UE may include one or more non-transitory computer-readable media having instructions, stored thereon, that when executed cause the UE to perform the process 250.

At block 252, the process 250 may continue from block 220 of Figure 2A.

At block 254, the UE 102 may wait until the end of the EC window. In embodiments, the UE may wait until the end of the EC window before it starts transmitting the EC Scheduled Transmission message 112. In embodiments, for any particular EC level identified, as described for example in block 212, that EC level may have an associated number of repetitions identifying the number of times the EC RAR message 110 has been sent. If the UE is able to decode the EC RAR message 110 earlier than the number of times the EC RAR message 110 has been sent, the UE may wait for the amount of time it may take the last EC RAR message 110 to be received. In embodiments, the UL allocation of the EC scheduled transmission 112 may be scheduled only after the last repetition of the EC RAR message 110 is sent by the eNB.

At block 256, the UE 102 may send a scheduled transmission, for example an RRC connection request, to the eNB.

At block 258 the UE 102 may, after an identified time, begin to receive the contention resolution message.

At block 260, the UE 102 may determine if the contention resolution message addressed to the UE has been successfully received. A process similar to the EC RA procedure, as described above, may be applied or extended if the RA procedure fails in contention resolution phase 114. In embodiments, this may occur if the EC scheduled transmission 112 was not correctly received at the eNB or if the EC scheduled transmission 112 from the given UE collided with another EC scheduled transmission 112 and only the other UE's EC scheduled transmission 112 was detected. For the latter case, the given UE may receive the EC contention resolution message 114 from the eNB but may determine that it was not addressed to that specific UE.

In other embodiments, a concept similar to legacy mac-ContentionResolutionTimer may be applied if EC contention resolution 114 is not received while using EC mode. In these embodiments, the value of this timer may scale or may be updated based on how long the EC repetitions of the scheduled transmission 112 are expected to take. This may occur when the EC scheduled

transmission 112 was not correctly received by the eNB or the eNB received and responded but the EC contention resolution 114 was not received successfully at the UE.

If the UE 102 determines that the contention resolution message has been successfully received, then at block 264 the process 250 may end.

If the UE 102 determines that the contention resolution message has not been successfully received, then the process may proceed to block 262 which then may return the process to block 208 of Figure 2A.

In embodiments, when the EC contention resolution 114 fails, the UE may apply an analogous procedure to resend the RA preamble with incrementing or re-initializing the preamble transmission counter. For the option of re-initialization of the preamble transmission counter, the UE may restart the RA process again as in the case of legacy operation.

In embodiments, if the network conditions may have changed since the previous RA trial, the process may allow the UE to switch to legacy procedure instead of EC procedure, or vice versa. Additionally, the updated network conditions may tell the UE to start from different EC level.

For the embodiments described herein, for simplicity, the use of the contention-based RA procedure for EC mode by a UE in RRC_IDLE may be shown, for example initiating an RRC connection. However, the contention-based RA procedure for EC mode may also be used by a UE in RRC_CONNECTED. In addition, for simplicity, legacy names may be used for the new release 13 EC RA parameters and embodied procedures. However, this should not be restricted to these names, as some of the names may refer to same parameters as used in the legacy RA procedure or may also refer to completely new and different parameters that get defined to fulfil the same functionality explained herein.

For example, in embodiments the UE may select the RA resources differently depending on whether the UE uses the legacy RA procedure or the EC RA procedure. In addition, for the EC RA procedure, different values of the legacy RA parameters or even different or new parameters may be defined for EC mode or for each EC level. For example, back-off time, which may be a parameter involved in the RA procedure, may have one or more different values per EC level or different parameters might be defined for each EC level. In another example, the PREAMBLE_TRANS_MAX value may be updated or a new parameter may be defined to trigger when the legacy RA procedure may pass to the EC RA procedure. Alternatively, power ramping for preamble transmission

may not be considered when EC mode is used in RA procedure, as the UE may use maximum transmit power in challenging locations with poor coverage. In embodiments, the new release 13 criteria or conditions may be defined in the specification or may be broadcasted for the UE to know which parameters or values should be used for EC RA procedure or for a specific EC RA level.

Figures 3A, 3B, and 3C are diagrams illustrating example frame structures for implementing RAR opportunities within an EC RAR window that may be used by a UE when receiving an EC RAR, in accordance with various embodiments.

In Figure 3A, diagram 300 shows one implementation of an EC RAR window 304 within a sequence of frames 302. In embodiments, the EC RAR window 304 may start k subframes after the EC RA preamble transmission 108 is supposed to finish. In embodiments, k may be defined to a value of 3, for example, to accommodate devices operating in accordance with legacy long term evolution (LTE) RA procedures, or it may be a greater value, for example, in order to account for increased processing requirements for the eNB to support a reduced bandwidth UEs and EC mode.

In embodiments, the EC RAR window 304 may contain one or more EC RAR opportunities 306. The number of EC RAR opportunities 306a, 306b, 306c within the EC RAR window 304 may be defined in the specification or may be broadcasted as part of the EC RA Preamble assignment 106. In embodiments, the first EC RAR 306a may start at the same sub-frame as the EC RAR window 304. The length of the EC RAR opportunity 306a may vary. For example, the length may depend on the number of repetitions required for the EC level, or on how many of the subframes in the EC RAR opportunity 306a carry an actual EC RAR message 110. In embodiments, this may be due to the EC RAR message 110 being repeated multiple times due to repeated transmissions permitted by the EC level. Diagram 300 shows an example where all of the subframes in the EC RAR opportunities 306a, 306b, 306c carry an EC RAR message 110.

In embodiments, the first transmission of the EC RA preamble 106 for a specific EC level may occur within multiple RA preamble sub frames 302a. In embodiments, a specific EC RA preamble 302a1 may be sent in specific time and frequencies, (i.e. resources) for the eNB to know that the UE is using a certain EC level. In embodiments, the EC RA preamble may also identify whether this UE is release 13 LC. In embodiments, subsequent transmissions of the EC RA preamble 302a2 may use the EC

RACH process for a specific EC level. For example, the subsequent transmissions of the EC RA preamble 302a2 may be in different subframes (not shown).

In embodiments, after one or more transmissions of the EC RA preamble 302a, the UE may wait k subframes before starting the EC RAR window 304.

In embodiments, the RAR opportunities 306 may have the same number of frames as the EC RAR window. In some embodiments, within the EC RAR window 304, there may be a first EC RAR opportunity 306a. UE may combine the EC RAR related resources of each sub-frame within the first EC RAR opportunity 306a so that the EC RAR message 110 may be decoded. In embodiments, the UE may then look for a RA-RNTI and, if the RA-RNTI is found, the UE may then look for the RAR message.

In embodiments, the second EC RAR opportunity 306b of the EC RAR window 306 may be identified. In embodiments, this may be in response to subsequent transmissions of the EC RAR message 110, for example a response to one of the EC RA preamble 108 repetitions, where the number of repetitions may be identified based on EC level.

In embodiments, UE 102 using a certain EC level may require x 310 and y 308 EC total repetitions for the uplink and downlink directions respectively, where x 310 or y 308 may have the same or different values for uplink and downlink. In these embodiments, the EC repetitions are consecutive.

In embodiments, after the EC RAR message 110 has been successfully decoded, for example using data received from the second EC RAR opportunity 306b, the UE may wait z 312 subframes before sending an EC scheduled transmission 112 in the UL in accordance with the allocated grant from the decoded EC RAR message 110. In this example, the other EC RAR opportunity 306c may be ignored because the UE has already successfully decoded the RAR message from the eNB.

In embodiments, EC RAR window 304 may be formed in a number of ways. For example, the EC RAR window 304 may be formed by EC RAR opportunities 306a, 306b, 306c of one specific EC level. In embodiments, UEs that may be checking that EC RAR window would have the same EC level requirement. As a result, the network might have a different EC RAR window 304 region for each EC level, which may have different locations in time, frequency and/or number of EC required repetitions.

In embodiments, EC RAR opportunities 306a, 306b, 306c may differ based on different EC levels. In these embodiments, the network may indicate or the 3GPP

LTE specification may define which EC level may correspond to each EC RAR opportunity (not shown). In embodiments, all opportunities of the same EC level may be located consecutively or they may be alternated.

In Figure 3B diagram 325 shows an example of an EC RAR window where not all subframes in the EC RAR opportunities 306a, 306b, 306c carry an EC RAR message 110. For example, UE 102 may be using an EC level that may require x 316 and y 314 EC total repetitions for each downlink and uplink direction respectively, where x 316 and y 314 may have the same or different values. In this example, EC repetitions are not in consecutive subframes.

In Figure 3C, diagram 350 shows embodiments where the length of the EC RAR opportunities 306a, 306b, 306c may also vary if, in addition to the EC RAR message 110, an RA control indicator (EC RA-RNTI) is received. For example, in the second EC RAR opportunity window 318, the RA control identifier 318a is prepended to the RAR message 318b. In this example 350, the EC repetitions are consecutive. In embodiments the RA control identifier 318a area may be used for other RAR messaging.

The additional message added to the RAR opportunity window may be due to repetitions of the Physical Downlink Control Channel (PDCCH) for MTC that may be based on release 13 enhanced physical downlink control channel (ePDCCH). The downlink control information (DCI) carried by this PDCCH, with its cyclic redundancy check CRC scrambled with the EC RA-RNTI, may schedule the transmission of the RAR message using cross-sub-frame scheduling.

In embodiments (not shown), some EC RA parameters, such as EC RA preamble, EC RAR window, and EC RAR opportunity, may be defined differently depending on the EC level, for example 5 decibels (dB) EC vs 10dB EC. Examples may include different starting times, different allocation of frequency resources, or number of EC repetitions required.

Additionally, in embodiments, the number of EC repetitions for each RA message sent between the UE and eNB in EC mode may be the same or may differ for each message. In embodiments, the number of repetitions may differ, based on the number of repetitions of one or more of the previous messages sent between the UE and eNB in EC mode. For example, the number of repetitions for the EC RAR message 110 may be a function of the number of repetitions for EC RA preamble 108, with an adjustment based on the difference between the downlink and uplink timing. In another example,

the number of repetitions for the EC scheduled transmission 112 may be indicated in the EC RAR message 110 or may be otherwise specified.

Figure 4 is a diagram illustrating frame structures for implementing a different modification period for the SI addressed to a UE in EC mode, in accordance with various embodiments.

Diagram 400 shows, in embodiments, an rSIB1 which may be used for release 13 low complexity and delay tolerant UEs, such as release 13 LC UE and release 13 UEs capable of using EC mode. For this rSIB1 that contains cell specific configuration information may be changed same as for legacy SIBs at instances other than that of the N + k * M frame 404. In embodiments, implementing an rSIB1 may have the advantage of lessening the impact and restrictions on legacy network behavior.

In embodiments, a first rSIB, rSIB1 406, may have the same modification period as legacy SIBs and the rSIB1 406 also may be updated at the N+M frame 408. In embodiments, other rSIBs 410 which do not contain cell specific configuration information may be changed less frequently, for example less often with longer modification periods. In embodiments, rSIB1 406 and other SIBs 412 may have the same modification period and may be updated at the end of the N + k * M frame 404.

Figure 5 illustrates a simplified block diagram of UE 102 of Fig. 1 in accordance with various embodiments of the disclosure. As shown in Figure 5, UE 102 includes a processor 510, radio frequency (RF) circuitry 540 and a memory 520. The processor 510 may include one or more single-core or multi-core processors, and may include any combination of general-purpose processors and dedicated processors (e.g. graphics processors, application processors, baseband processors, etc.). In accordance with various embodiments, the processor 510 (and in particular, a baseband chipset of the processor 510) may include configuration logic. The configuration logic may be operable to identify an initial EC level that is to be used during a contention-based RA procedure, the EC level having at least an associated power level, window of time, and number of send attempts. The configuration logic may be operable to send a first message to a radio access network (RAN) based on the identified EC level. The configuration logic may be operable to determine whether a second message from the RAN in response to the first message is received within the window of time. The configuration logic may be operable to, if the second message is received from the eNB within the window of time, decode the received second message. The configuration logic may be operable to, if the second message is not

received from the eNB within the window of time, re-send the first message to the RAN and track a number of times the first message has been sent using a transmission counter having a numerical value; and output an indication that the EC RA procedure did not complete successfully based on determination of a whether the second message is received within a window of time and a comparison of the transmission counter to a transmission threshold value.

The RF circuitry 540 may be coupled to the processor 510, for example via a bus 530, and may be used to transmit or receive data.

The memory 520 may include one or more non-transitory, computer-readable media having instructions stored thereon, and the instructions when executed by the processor 510 may cause UE 102 to perform the operations described above in connection with the processor 510. However, this is only illustrative rather than limiting; those of ordinary skill in the art will appreciate alternative implementations in software, hardware, firmware, or any combination thereof.

Figure 6 illustrates electronic device circuitry 602 that may be eNB circuitry, UE circuitry, or some other type of circuitry in accordance with various embodiments. In embodiments, the electronic device circuitry 602 may be, or may be incorporated into or otherwise a part of, an eNB, a UE, or some other type of electronic device. In embodiments, the electronic device circuitry 602 may include radio transmit circuitry and receive circuitry coupled to control circuitry 606. In embodiments, the transmit 604 and/or receive circuitry 608 may be elements or modules of transceiver circuitry, as shown. The electronic device circuitry 602 may be coupled with one or more plurality of antenna elements of one or more antennas 610. The electronic device circuitry and/or the components of the electronic device circuitry may be configured to perform operations similar to those described elsewhere in this disclosure.

In embodiments where the electronic device circuitry 602 is a UE or is part of or otherwise incorporated into a UE, the UE may be capable of operation in accordance with EC mode. The control circuitry 606 may be to identify the EC mode. The control circuitry 606 may be further to operate in accordance with the EC mode. The transmit 604 and/or receive circuitry 608 may be to send and/or receive one or more signals or transmissions in accordance with the EC mode.

In embodiments where the electronic device circuitry 602 is an eNB or is part of or otherwise incorporated into an eNB the electronic device may be capable of operation of

different modification periods for transmission and update of SI. The control circuitry 606 may be to identify a modification period from a plurality of modification periods. The transmit circuitry 604 may be to transmit a transmission and/or update of SI in accordance with the identified modification period.

As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the electronic device circuitry 602 may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules.

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 7 illustrates, for one embodiment, an example system 702 comprising RF circuitry 704, baseband circuitry 706, application circuitry 708, memory/storage 710, display 712, camera 714, sensor 716, and input/output (I/O) interface 718, coupled with each other at least as shown.

The application circuitry 708 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with memory/storage and configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems running on the system.

The baseband circuitry 706 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include a baseband processor. The baseband circuitry 706 may handle various radio control functions that enables communication with one or more radio networks via the RF circuitry. The radio control functions may include, but are not limited to, signal modulation, encoding, decoding, radio frequency shifting, etc. In some embodiments, the baseband circuitry 706 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 706 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local

area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

In various embodiments, baseband circuitry 706 may include circuitry to operate with signals that are not strictly considered as being in a baseband frequency. For example, in some embodiments, baseband circuitry 706 may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

RF circuitry 704 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 704 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network.

In various embodiments, RF circuitry 704 may include circuitry to operate with signals that are not strictly considered as being in a radio frequency. For example, in some embodiments, RF circuitry 704 may include circuitry to operate with signals having an intermediate frequency, which is between a baseband frequency and a radio frequency.

In various embodiments, transmit circuitry 604, control circuitry 606, and/or receive circuitry 608 discussed or described herein may be embodied in whole or in part in one or more of the RF circuitry, the baseband circuitry, and/or the application circuitry. As used herein, the term "circuitry" may refer to, be part of, or include an ASIC, an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the electronic device circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules.

In some embodiments, some or all of the constituent components of the baseband circuitry, the application circuitry, and/or the memory/storage may be implemented together on a system on a chip (SOC).

Memory/storage 710 may be used to load and store data and/or instructions, for example, for system. Memory/storage 710 for one embodiment may include any combination of suitable volatile memory (e.g., dynamic random access memory (DRAM)) and/or non-volatile memory (e.g., Flash memory).

In various embodiments, the I/O interface 718 may include one or more user interfaces designed to enable user interaction with the system and/or peripheral component interfaces designed to enable peripheral component interaction with the system. User interfaces may include, but are not limited to a physical keyboard or keypad, a touchpad, a speaker, a microphone, etc. Peripheral component interfaces may include, but are not limited to, a non-volatile memory port, a universal serial bus (USB) port, an audio jack, and a power supply interface.

In various embodiments sensor 716 may include one or more sensing devices to determine environmental conditions and/or location information related to the system. In some embodiments, the sensors 716 may include, but are not limited to, a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may also be part of, or interact with, the baseband circuitry 706a and/or RF circuitry 704 to communicate with components of a positioning network, e.g., a global positioning system (GPS) satellite.

In various embodiments, the display 712 may include a liquid crystal display, a touch screen display, and the like.

In various embodiments, the system 702 may be a mobile computing device such as, but not limited to, a laptop computing device, a tablet computing device, a netbook, an ultrabook, a smartphone, etc. In various embodiments, system may have more or less components, and/or different architectures.

In various embodiments, the system 702 may be a mobile computing device such as, but not limited to, a laptop computing device, a tablet computing device, a netbook, an ultrabook, a smartphone, etc. In various embodiments, system may have more or less components, and/or different architectures. For example, in some embodiments the RF circuitry 704 and/or the baseband circuitry 706 may be embodied in communication circuitry (not shown). The communication circuitry may include circuitry such as, but not limited to, one or more single-core or multi-core processors and logic circuits to provide signal processing techniques, for example, encoding, modulation, filtering, converting, amplifying, etc., suitable to the appropriate communication interface over which communications will take place. The communication circuitry may communicate over wireline, optical, or wireless communication mediums. In embodiments in which the system is configured for wireless communication, the communication circuitry may include the RF circuitry and/or baseband circuitry to provide for

communication compatible with one or more radio technologies. For example, in some embodiments, the communication circuitry may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN).

Embodiments of the technology herein may be described as related to the 3GPP long term evolution (LTE) or LTE-advanced (LTE-A) standards. For example, terms or entities such as eNB, mobility management entity (MME), UE, etc. may be used that may be viewed as LTE-related terms or entities. However, in other embodiments the technology may be used in or related to other wireless technologies such as the Institute of Electrical and Electronic Engineers (IEEE) 802.16 wireless technology (WiMax), IEEE 802.11 wireless technology (WiFi), various other wireless technologies such as global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), GSM EDGE radio access network (GERAN), universal mobile telecommunications system (UMTS), UMTS terrestrial radio access network (UTRAN), or other 2G, 3G, 4G, 5G, etc. technologies either already developed or to be developed. In those embodiments, where LTE-related terms such as eNB, MME, UE, etc. are used, one or more entities or components may be used that may be considered to be equivalent or approximately equivalent to one or more of the LTE-based terms or entities.

Some non-limiting examples may include the following:

Example 1 may include a user equipment (UE) capable of operation in accordance with enhanced coverage (EC) mode, the UE comprising: control circuitry to: identify the EC mode; and operate in accordance with the EC mode; and transmit and/or receive circuitry coupled with the control circuitry, the transmit and/or receive circuitry to send and/or receive one or more signals or transmissions in accordance with the EC mode.

Example 2 may include the subject matter of Example 1 or some other example herein, wherein the control circuitry, transmit circuitry, and/or receive circuitry are further to transmit, receive, and/or combine multiple repetitions of a message to enhance its coverage.

Example 3 may include the subject matter of Example 1 or some other example herein, wherein the UE is to operate on normal system bandwidth (BW) as well as reduced BW within the whole system BW.

Example 4 may include the subject matter of Example 1 or some other example herein, wherein the UE is to operate with delay tolerant machine type communications (MTC).

Example 5 may include the subject matter of Example 1 or some other example herein, wherein the UE may trigger the usage of one or more different EC levels based on a desired coverage enhancement.

Example 6 may include the subject matter of Example 1 or some other example herein, wherein the UE may use EC mode for a random access (RA) procedure.

Example 7 may include the subject matter of Example 6 or some other example herein, wherein the UE may use EC mode for contention-based RA procedure.

Example 8 may include the subject matter of Example 6 or some other example herein, wherein the trigger events to use EC mode for RA procedure may be related to or based on a desired EC level.

Example 9 may include the subject matter of Example 6 or some other example herein, wherein the trigger to use EC mode for RA procedure may be based on or related to a failure of a normal (legacy) RA procedure.

Example 10 may include the subject matter of Example 6 or some other example herein, wherein the trigger to use EC mode for RA procedure may be related to or based on reaching a certain threshold, criteria or condition such as, maximum number of preamble transmissions, maximum preamble transmission power or thresholds for measured reference signal power/quality (RSRP/RSRQ).

Example 11 may include the subject matter of Example 6 or some other example herein, wherein the UE may use different RA configuration information depending on the EC level.

Example 12 may include the subject matter of Example 6 or some other example herein, wherein the control circuitry may trigger the usage of EC mode due to failure of the reception of RA message 2 (RAR).

Example 13 may include the subject matter of Example 6 or some other example herein, wherein the UE may trigger the usage of EC mode due to failure of the reception of RA message 4 (such as, RRC Connection Setup).

Example 14 may include the subject matter of Example 6 or some other example herein, wherein the UE may use enhanced coverage random access response (EC RAR)

window to monitor the RA message 2 (RAR) sent in response to RA message 1 (RA preamble).

Example 15 may include the subject matter of Example 14 or some other example herein, wherein EC RAR opportunities may be defined within the EC RAR window.

Example 16 may include the subject matter of Example 14 or some other example herein, wherein the repetitions of the RA message 2 may be scheduled with a known pattern i.e. predefined or preconfigured within the EC RAR opportunities.

Example 17 may include the subject matter of Example 14 or some other example herein, wherein repetitions of the RA message 2 may not be included in all subframes within the EC RAR opportunities.

Example 18 may include the subject matter of Example 14 or some other example herein, wherein within the EC RAR opportunities control information carrying the EC RA control identifier (i.e. EC RA radio network temporary identifier (RNTI)) as well as the EC RA message 2 (RAR) is transmitted.

Example 19 may include the subject matter of Example 18 or some other example herein, wherein the UE may not need to receive EC RA message 2 if no control information is received that includes the EC RA RNTI that is addressed to the UE.

Example 20 may include an evolved NodeB (eNB) capable of operation of different modification periods for transmission and update of system information (SI), the eNB comprising: control circuitry to identify a modification period from a plurality of modification periods; and transmit circuitry to transmit a transmission and/or update of SI in accordance with the identified modification period.

Example 21 may include the subject matter of Example 20 or some other example herein, wherein the eNB may be capable to operate a cell in normal mode and in EC mode.

Example 22 may include the subject matter of Example 20 or some other example herein, wherein the eNB may define different modification periods for transmission and update of system information specific to normal mode and EC mode.

Example 23 may include the subject matter of Example 20 or some other example herein, wherein the eNB may define the modification periods for SI parameters specific to the cell configuration with same value as normal (legacy) UEs.

Example 24 may include a method comprising determining by the UE of Examples 1-19, or of some other example herein, to choose between the legacy RA proc. and EC RA proc. based on certain thresholds, criteria, configurations and/or requirements.

Example 25 may include the subject matter of Example 24 or some other example herein, wherein the thresholds, criteria, configurations and/requirements are either preconfigured in the UE or signaled to the UE by the network using unicast and/or broadcast messages.

Example 26 may include the subject matter of Example 24, or of some other example herein, comprising repetition of RA message 1 (preamble) to support UEs requiring EC.

Example 27 may include the subject matter of Example 26 or some other example herein, further comprising of corresponding repetitions of the subsequent RA responses and messages to support the UEs requiring EC.

Example 28 may include a method for the eNB in Examples 20-23 or some other example herein, notifying the UEs of Examples 1-19 of the certain thresholds, criteria, configurations and/or requirements for the EC UEs using dedicated, unicast or broadcast messaging.

Example 29 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 24-28, or any other example, method or process described herein.

Example 30 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 24-28, or any other example, method or process described herein.

Example 31 may include an apparatus comprising control circuitry, transmit circuitry, and/or receive circuitry to perform one or more elements of a method described in or related to any of examples 24-28, or any other example, method or process described herein.

Example 32 may include a method of communicating in a wireless network as shown and described herein.

Example 33 may include a system for providing wireless communication as shown and described herein.

Example 34 may include a device for providing wireless communication as shown and described herein.

Example 35 is an apparatus to be employed in a user equipment, UE, the apparatus comprising: one or more processors; a memory coupled to the one or more processors having instructions thereon that when executed cause the processors to: identify an initial enhanced coverage, EC, level that is to be used in a radio cell during a contention-based random access, RA, procedure, the EC level having at least an associated power level, window of time, and number of send attempts; send a first message to a radio access network, RAN, based on the identified EC level; determine whether a second message from the RAN in response to the first message is received within the window of time; if the second message is received from the eNB within the window of time, decode the received second message; and if the second message is not received from the eNB within the window of time: re-send the first message to the RAN.

Example 36 may include the subject matter of Example 35 or some other example herein, wherein the RAN includes at least one enhanced NodeB, eNB.

Example 37 may include the subject matter of Example 35 or some other example herein, wherein re-send the first message to the RAN further comprises: track a number of times the first message has been sent using a transmission counter having a numerical value; and output an indication that the RA EC procedure did not complete successfully based on determination of a whether the second message is received within a window of time and a comparison of the transmission counter to a transmission threshold value.

Example 38 may include the subject matter of Example 35 or some other example herein, wherein the first message is a random access, RA, preamble and the second message is a random access response, RAR.

Example 39 may include the subject matter of Example 35 or some other example herein, wherein an initial EC level is configured in the UE or is received in a system information block, SIB.

Example 40 may include the subject matter of Example 39 or some other example herein, wherein the SIB is received in a higher bandwidth or in a reduced bandwidth.

Example 41 may include the subject matter of Example 35 or some other example herein, wherein the power level at which the first message is sent is based on one or more of: the value of the transmission counter, or the value of the EC level.

Example 42 may include the subject matter of Example 35 or some other example herein, wherein re-send the first message further includes power ramping.

Example 43 may include the subject matter of Example 42 or some other example herein, wherein the power ramping includes increasing the power to a maximum power level associated with the EC level.

Example 44 may include the subject matter of Example 35 or some other example herein, wherein the window of time is dependent at least on a number of EC RAR opportunities defined within an EC RAR window and/or the number of send attempts for the EC level.

Example 45 may include the subject matter of Example 35 or some other example herein, wherein re-send the first message to the RAN further comprises: include a delay time before re-sending the first message, the delay being one of a function of at least the EC level.

Example 46 may include the subject matter of any one of Examples 35-45 or some other example herein, wherein the UE may be capable to operate in a normal coverage mode and in EC mode.

Example 47 is an apparatus to be employed in an evolved NodeB, eNB, the apparatus comprising: one or more processors; a memory coupled to the one or more processors having instructions thereon that when executed cause the processors to: determine enhanced coverage, EC, levels to be used in a radio cell during a contention-based random access, RA, procedure, send, in a system information block, SIB, to a user equipment, UE, located in the radio cell, an indication of the determined EC levels; receive an RA preamble from a UE, responsive to the RA preamble, transmit a random access response, RAR, message.

Example 48 may include the subject matter of Example 47 or some other example herein, wherein send in a SIB an indication of the determined EC levels further includes send in a reduced bandwidth of 1.4 megahertz or 200 kilohertz.

Example 49 may include the subject matter of Example 47 or some other example herein, wherein the eNB may be to operate a radio cell in normal coverage mode and in EC mode.

Example 50 is an apparatus to be employed in a user equipment, UE, the apparatus comprising: logic circuitry to identify an enhanced coverage, EC level; transmit circuitry to send to a radio access network, RAN, a random access, RA, preamble based on the identified EC level; logic circuitry to identify an EC random access response, RAR, window region having a plurality of subframes.

Example 51 may include the subject matter of Example 50 or some other example herein, further comprising: logic circuitry to identify an EC random access response, RAR, window region having a plurality of subframes, the EC RAR window region including one or more EC RAR opportunities, each being a contiguous group of subframes, the first EC RAR opportunity beginning at the same sub-frame as the beginning of the RAR window region and beginning K subframes after the RA preamble was sent.

Example 52 may include the subject matter of Example 51 or some other example herein, further comprising receive circuitry to: receive, from the RAN, a candidate RAR in the first EC RAR opportunity; until a candidate RAR is able to be decoded, receive, from the RAN, a candidate RAR from an EC RAR opportunity; and if a candidate RAR is able to be decoded, send, to the RAN, an RRC connection request.

Example 53 may include the subject matter of Example 50 or some other example herein, wherein the EC RAR window region is dependent on a value: defined in the specification, broadcast as a part of the SI message, associated with the EC level, or associated with the number of the subframes in EC RAR opportunities that contain an RAR message.

Example 54 is an evolved NodeB, eNB, comprising: control circuitry to identify a system information, SI, modification period associated with a radio cell configuration from a plurality of SI modification periods when in reduced bandwidth mode; and transmit circuitry coupled with the control circuitry, the transmit circuitry to transmit an SI message in accordance with the identified modification period.

Example 55 may include the subject matter of Example 54 or some other example herein, wherein the control circuitry and transmit circuitry are to operate in normal coverage mode and/or in EC mode.

Example 56 may include the subject matter of Example 54 or some other example herein, wherein the control circuitry further defines the modification periods for SI parameters associated with the radio cell configuration with a same value as a normal coverage user equipment, UE.

Example 57 is one or more non-transitory computer-readable media comprising instructions that cause a user equipment, UE, in response to execution of the instructions by the computing device, to: identify an initial enhanced coverage, EC, level that is to be used in a radio cell during a contention-based random access, RA, procedure, the EC level having at least an associated power level, window of time, and number of send attempts;

send a first message to a radio access network, RAN, based on the identified EC level; determine whether a second message from the RAN in response to the first message is received within the window of time; if the second message is received from the eNB within the window of time, decode the received second message; and if the second message is not received from the eNB within the window of time, re-send the first message to the RAN.

Example 58 may include the subject matter of Example 57 or some other example herein, wherein the RAN includes at least one enhanced NodeB, eNB.

Example 59 may include the subject matter or Example 57 or some other example herein, wherein re-send the first message to the RAN further comprises: track a number of times the first message has been sent using a transmission counter having a numerical value; and output an indication that the RA EC procedure did not complete successfully based on determination of whether the second message is received within a window of time and a comparison of the transmission counter to a transmission threshold value.

Example 60 may include the subject matter of Example 57 or some other example herein, wherein the first message is a random access, RA, preamble and the second message is a random access response, RAR.

Example 61 may include the subject matter of Example 57 or some other example herein, wherein an initial EC level is configured in the UE or is received in a system information block, SIB.

Example 62 may include the subject matter of Example 61 or some other example herein, wherein the SIB is received in a higher bandwidth or in a reduced bandwidth.

Example 63 may include the subject matter of Example 57 or some other example herein, wherein the power level at which the first message is sent is based on one or more of: the value of the transmission counter, or the value of the EC level.

Example 64 may include the subject matter of Example 57 or some other example herein, wherein re-send the first message further includes power ramping.

Example 65 may include the subject matter of Example 64 or some other example herein, wherein the power ramping includes increasing the power to a maximum power level associated with the EC level.

Example 66 may include the subject matter of Example 57 or some other example herein, wherein the window of time is dependent at least on a number of EC RAR

opportunities defined within an EC RAR window and/or the number of send attempts for the EC level.

Example 67 may include the subject matter of Example 57 or some other example herein, wherein re-send the first message to the RAN further comprises: include a delay time before re-sending the first message, the delay being one of a function of at least the EC level.

Example 68 may include the subject matter of any one of Examples 57-67 or some other example herein, wherein the UE may be capable to operate in a normal coverage mode and in EC mode.

Example 69 is one or more non-transitory computer-readable media comprising instructions that cause an enhanced enodeB, eNB, in response to execution of the instructions by the computing device, to: determine enhanced coverage, EC, levels to be used in a radio cell during a contention-based random access, RA, procedure, send, in a system information block, SIB, to a user equipment, UE, located in the radio cell, an indication of the determined EC levels; receive an RA preamble from a UE, responsive to the RA preamble, transmit a random access response, RAR.

Example 70 may include the subject matter of Example 69 or some other example herein, wherein send in a SIB an indication of the determined EC levels further includes send in a higher bandwidth or in a reduced bandwidth.

Example 71 may include the subject matter of Example 69 or some other example herein, wherein the eNB may be to operate a radio cell in normal coverage mode and in EC mode.

Some portions of the preceding detailed description have been presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the ways used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the arts. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the above discussion, it is appreciated that throughout the description, discussions utilizing

terms such as those set forth in the claims below refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission, or display devices.

Embodiments of the disclosure also relate to an apparatus for performing the operations herein. Such a computer program is stored in a non-transitory computer-readable medium. A machine-readable medium includes any mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a machine-readable (e.g., computer-readable) medium includes a machine- (e.g., a computer-) readable storage medium (e.g., read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices).

The processes or methods depicted in the preceding figures can be performed by processing logic that comprises hardware (e.g., circuitry, dedicated logic, etc.), software (e.g., embodied on a non-transitory computer-readable medium), or a combination of both. Although the processes or methods are described above in terms of some sequential operations, it should be appreciated that some of the operations described can be performed in a different order. Moreover, some operations can be performed in parallel rather than sequentially.

Embodiments of the present disclosure are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages can be used to implement the teachings of embodiments of the disclosure as described herein. In the foregoing Specification, embodiments of the disclosure have been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications can be made thereto without departing from the broader spirit and scope of the disclosure as set forth in the following claims. The Specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

CLAIMS

What is claimed is:

1. An apparatus to be employed in a user equipment, UE, the apparatus comprising:

one or more processors;

a memory coupled to the one or more processors having instructions thereon that when executed cause the processors to:

identify an initial enhanced coverage, EC, level that is to be used in a radio cell during a contention-based random access, RA, procedure, the EC level having at least an associated power level, window of time, and number of send attempts;

send a first message to a radio access network, RAN, based on the identified EC level;

determine whether a second message from the RAN in response to the first message is received within the window of time;

if the second message is received from the eNB within the window of time, decode the received second message; and

if the second message is not received from the eNB within the window of time:

re-send the first message to the RAN.

2. The apparatus of claim 1, wherein the RAN includes at least one enhanced NodeB, eNB.

3. The apparatus of claim 1, wherein re-send the first message to the RAN further comprises:

track a number of times the first message has been sent using a transmission counter having a numerical value; and

output an indication that the RA EC procedure did not complete successfully based on determination of a whether the second message is received within a window of time and a comparison of the transmission counter to a transmission threshold value.

4. The apparatus of claim 1, wherein the first message is a random access, RA, preamble and the second message is a random access response, RAR.

5. The apparatus of claim 1, wherein an initial EC level is configured in the UE or is received in a system information block, SIB.

6. The apparatus of claim 5, wherein the SIB is received in a higher bandwidth or in a reduced bandwidth.

7. The apparatus of claim 1, wherein the power level at which the first message is sent is based on one or more of: the value of the transmission counter, or the value of the EC level.

8. The apparatus of claim 1, wherein re-send the first message further includes power ramping.

9. The apparatus of claim 8, wherein the power ramping includes increasing the power to a maximum power level associated with the EC level.

10. The apparatus of claim 1, wherein the window of time is dependent at least on a number of EC RAR opportunities defined within an EC RAR window and/or the number of send attempts for the EC level.

11. The apparatus of claim 1, wherein re-send the first message to the RAN further comprises: include a delay time before re-sending the first message, the delay being one of a function of at least the EC level.

12. The apparatus of any one of claims 1-11, wherein the UE may be capable to operate in a normal coverage mode and in EC mode.

13. An apparatus to be employed in an evolved NodeB, eNB, the apparatus comprising:

one or more processors;

a memory coupled to the one or more processors having instructions thereon that when executed cause the processors to:

determine enhanced coverage, EC, levels to be used in a radio cell during a contention-based random access, RA, procedure,

send, in a system information block, SIB, to a user equipment, UE, located in the radio cell, an indication of the determined EC levels;

receive an RA preamble from a UE,

responsive to the RA preamble, transmit a random access response, RAR, message.

14. The eNB of claim 13, wherein send in a SIB an indication of the determined EC levels further includes send in a reduced bandwidth of 1.4 megahertz or 200 kilohertz.

15. The eNB of claim 13, wherein the eNB may be to operate a radio cell in normal coverage mode and in EC mode.

16. An apparatus to be employed in a user equipment, UE, the apparatus comprising:

logic circuitry to identify an enhanced coverage, EC level;

transmit circuitry to send to a radio access network, RAN, a random access, RA, preamble based on the identified EC level;

logic circuitry to identify an EC random access response, RAR, window region having a plurality of subframes.

17. The apparatus of claim 16, further comprising:

logic circuitry to identify an EC random access response, RAR, window region having a plurality of subframes, the EC RAR window region including one or more EC RAR opportunities, each being a contiguous group of subframes, the first EC RAR opportunity beginning at the same sub-frame as the beginning of the RAR window region and beginning K subframes after the RA preamble was sent.

18. The apparatus of claim 17, further comprising receive circuitry to:

receive, from the RAN, a candidate RAR in the first EC RAR opportunity;

until a candidate RAR is able to be decoded, receive, from the RAN, a candidate RAR from an EC RAR opportunity; and

if a candidate RAR is able to be decoded, send, to the RAN, an RRC connection request.

19. The apparatus of claim 16, wherein the EC RAR window region is dependent on a value:

defined in the specification,

broadcast as a part of the SI message,

associated with the EC level, or

associated with the number of the subframes in EC RAR opportunities that contain an RAR message.

20. An evolved NodeB, eNB, comprising:

control circuitry to identify a system information, SI, modification period associated with a radio cell configuration from a plurality of SI modification periods when in reduced bandwidth mode; and

transmit circuitry coupled with the control circuitry, the transmit circuitry to transmit an SI message in accordance with the identified modification period.

21. The apparatus of claim 20, wherein the control circuitry and transmit circuitry are to operate in normal coverage mode and/or in EC mode.

22. One or more non-transitory computer-readable media comprising instructions that cause a user equipment, UE, in response to execution of the instructions by the computing device, to:

identify an initial enhanced coverage, EC, level that is to be used in a radio cell during a contention-based random access, RA, procedure, the EC level having at least an associated power level, window of time, and number of send attempts;

send a first message to a radio access network, RAN, based on the identified EC level;

determine whether a second message from the RAN in response to the first message is received within the window of time;

if the second message is received from the eNB within the window of time, decode the received second message; and

if the second message is not received from the eNB within the window of time, re-send the first message to the RAN.

23. The one or more non-transitory computer-readable media of claim 22, wherein the RAN includes at least one enhanced NodeB, eNB.

24. One or more non-transitory computer-readable media comprising instructions that cause an enhanced enodeB, eNB, in response to execution of the instructions by the computing device, to:

determine enhanced coverage, EC, levels to be used in a radio cell during a contention-based random access, RA, procedure,

send, in a system information block, SIB, to a user equipment, UE, located in the radio cell, an indication of the determined EC levels;

receive an RA preamble from a UE,

responsive to the RA preamble, transmit a random access response, RAR.

25. The one or more non-transitory computer-readable media of claim 24, wherein the eNB may be to operate a radio cell in normal coverage mode and in EC mode.

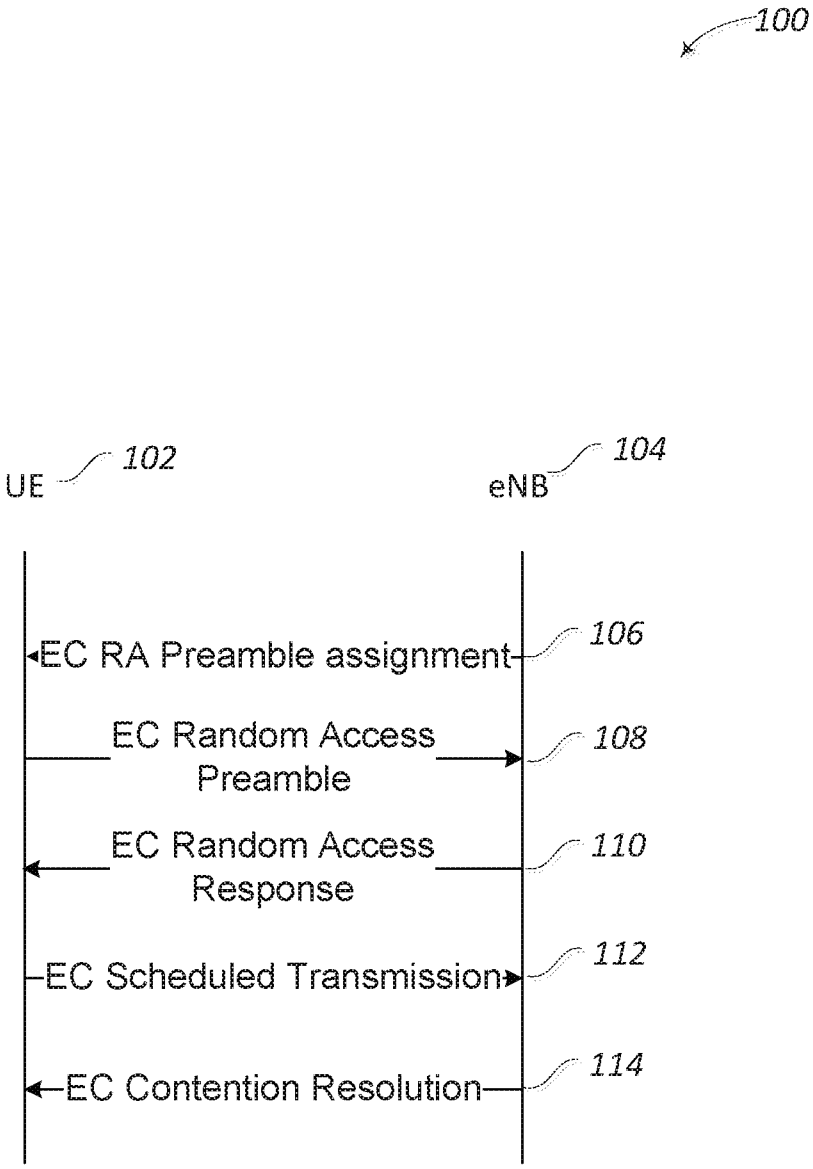
100
UE
102
eNB
104
EC RA Preamble assignment
106
EC Random Access Preamble
108
EC Random Access Response
110
EC Scheduled Transmission
112
EC Contention Resolution
114

Figure 1

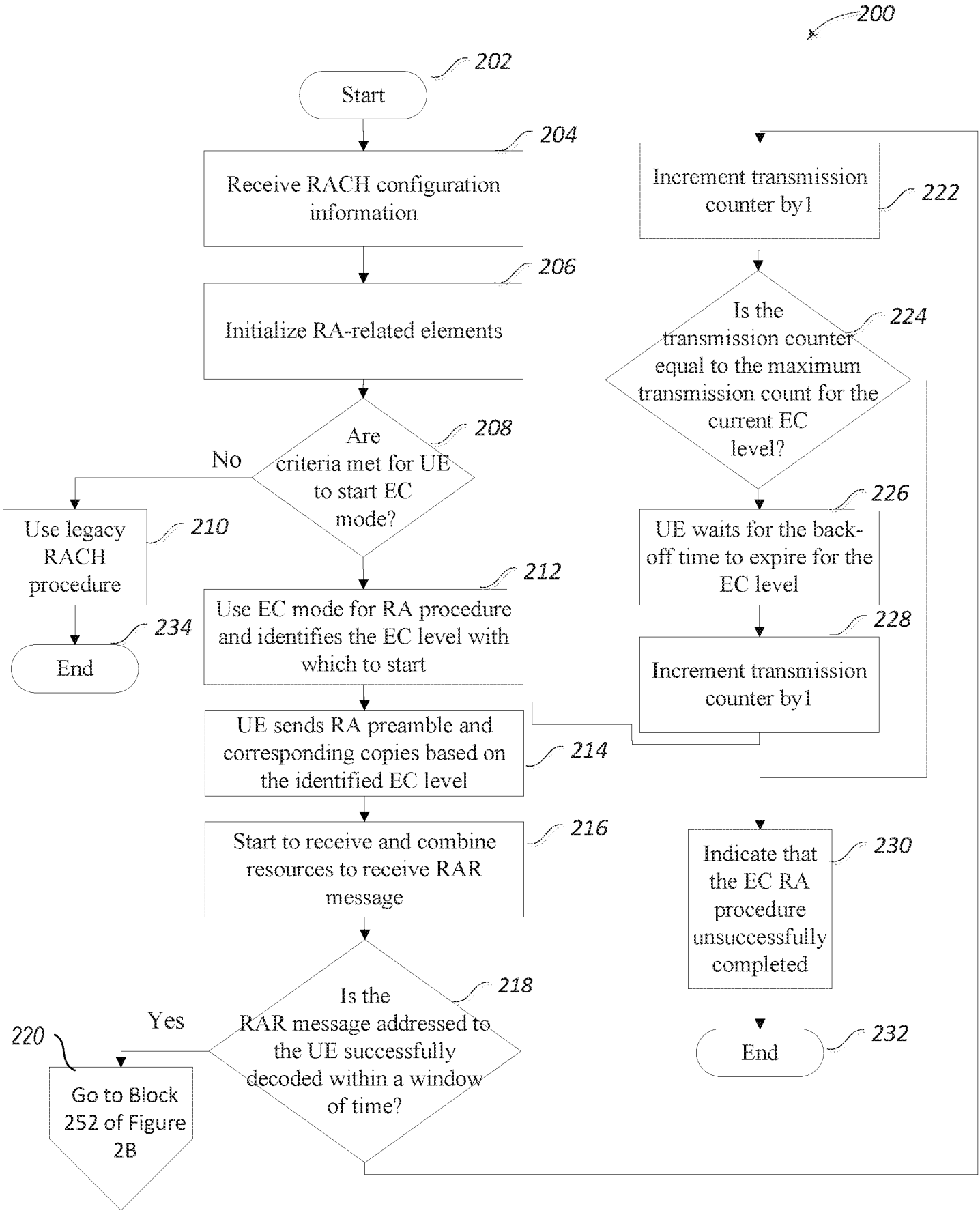
200
202
Start
204
Receive RACH configuration information
206
Initialize RA-related elements
208
Are criteria met for UE to start EC mode?
No
210
Use legacy RACH procedure
234
End
212
Use EC mode for RA procedure and identifies the EC level with which to start
214
UE sends RA preamble and corresponding copies based on the identified EC level
216
Start to receive and combine resources to receive RAR message
218
Is the RAR message addressed to the UE successfully decoded within a window of time?
Yes
220
Go to Block 252 of Figure 2B
222
Increment transmission counter by1
224
Is the transmission counter equal to the maximum transmission count for the current EC level?
226
UE waits for the back-off time to expire for the EC level
228
Increment transmission counter by1
230
Indicate that the EC RA procedure unsuccessfully completed
232
End

Figure 2A

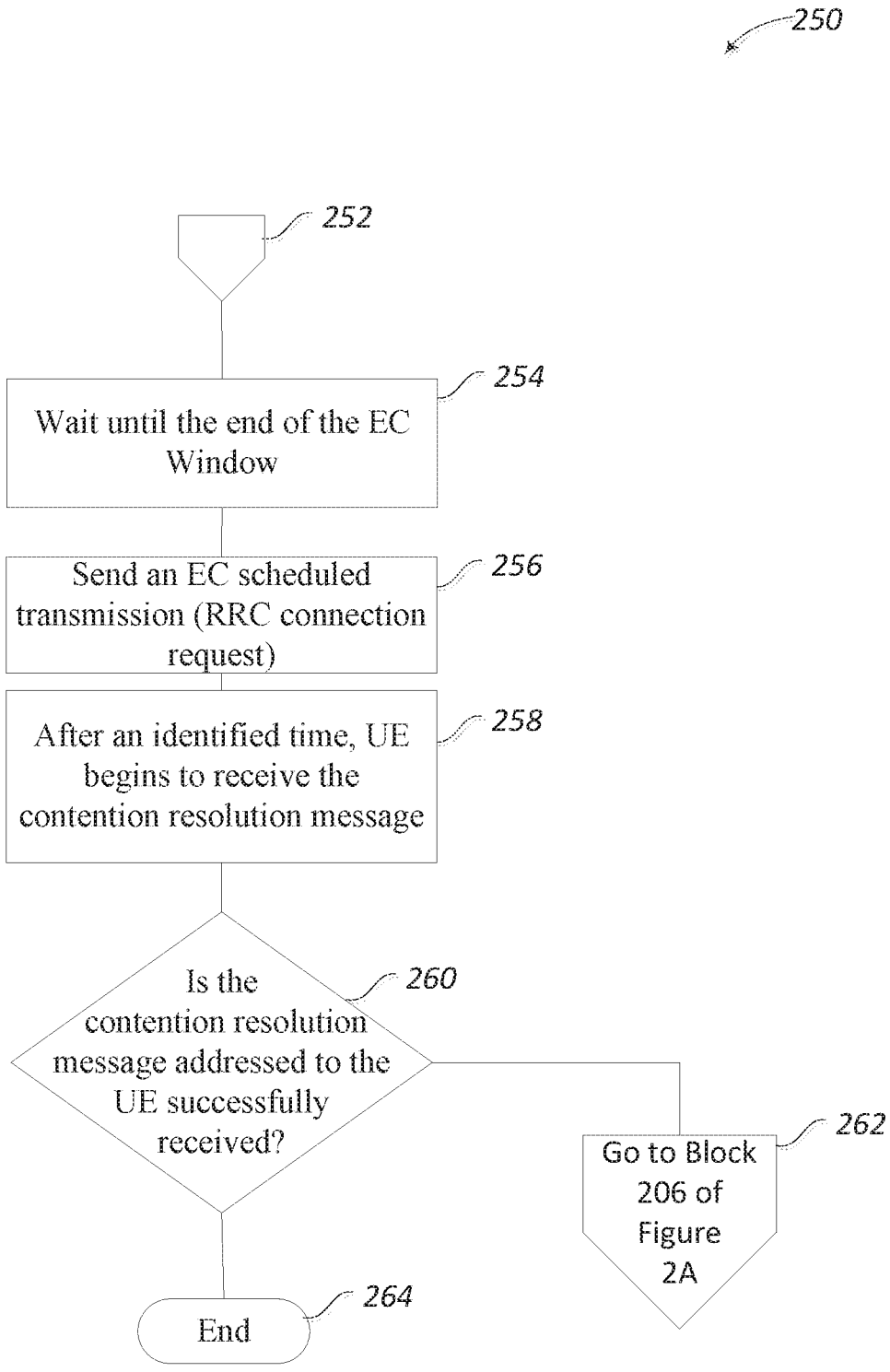
250
252
Wait until the end of the EC Window
254
Send an EC scheduled transmission (RRC connection request)
256
After an identified time, UE begins to receive the contention resolution message
258
Is the contention resolution message addressed to the UE successfully received?
260
Go to Block 206 of Figure 2A
262
End
264

Figure 2B

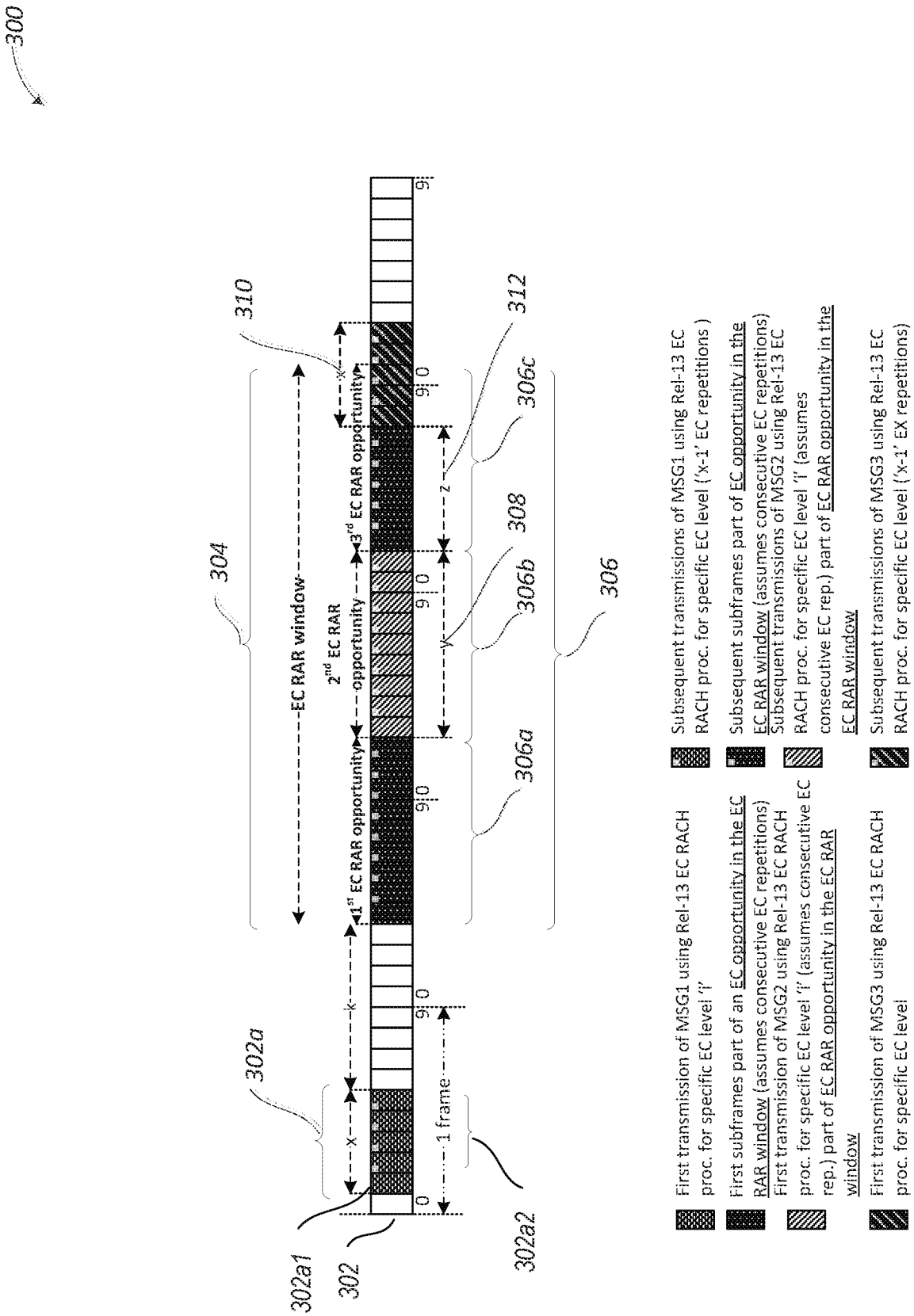
300
310
304
312
306c
308
306b
306
306a
302a
302a1
302
302a2
EC RAR window
2nd EC RAR
opportunity
1st EC RAR opportunity
2nd EC RAR opportunity
3rd EC RAR opportunity
1 frame
x
y
z
0
9
First transmission of MSG1 using Rel-13 EC RACH proc. for specific EC level 'i'
First subframes part of an EC opportunity in the EC RAR window (assumes consecutive EC repetitions) First transmission of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' (assumes consecutive EC rep.) part of EC RAR opportunity in the EC RAR window
First transmission of MSG3 using Rel-13 EC RACH proc. for specific EC level
Subsequent transmissions of MSG1 using Rel-13 EC RACH proc. for specific EC level ('x-1' EC repetitions)
Subsequent subframes part of EC opportunity in the EC RAR window (assumes consecutive EC repetitions) Subsequent transmissions of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' (assumes consecutive EC rep.) part of EC RAR opportunity in the EC RAR window
Subsequent transmissions of MSG3 using Rel-13 EC RACH proc. for specific EC level ('x-1' EX repetitions)

Figure 3A

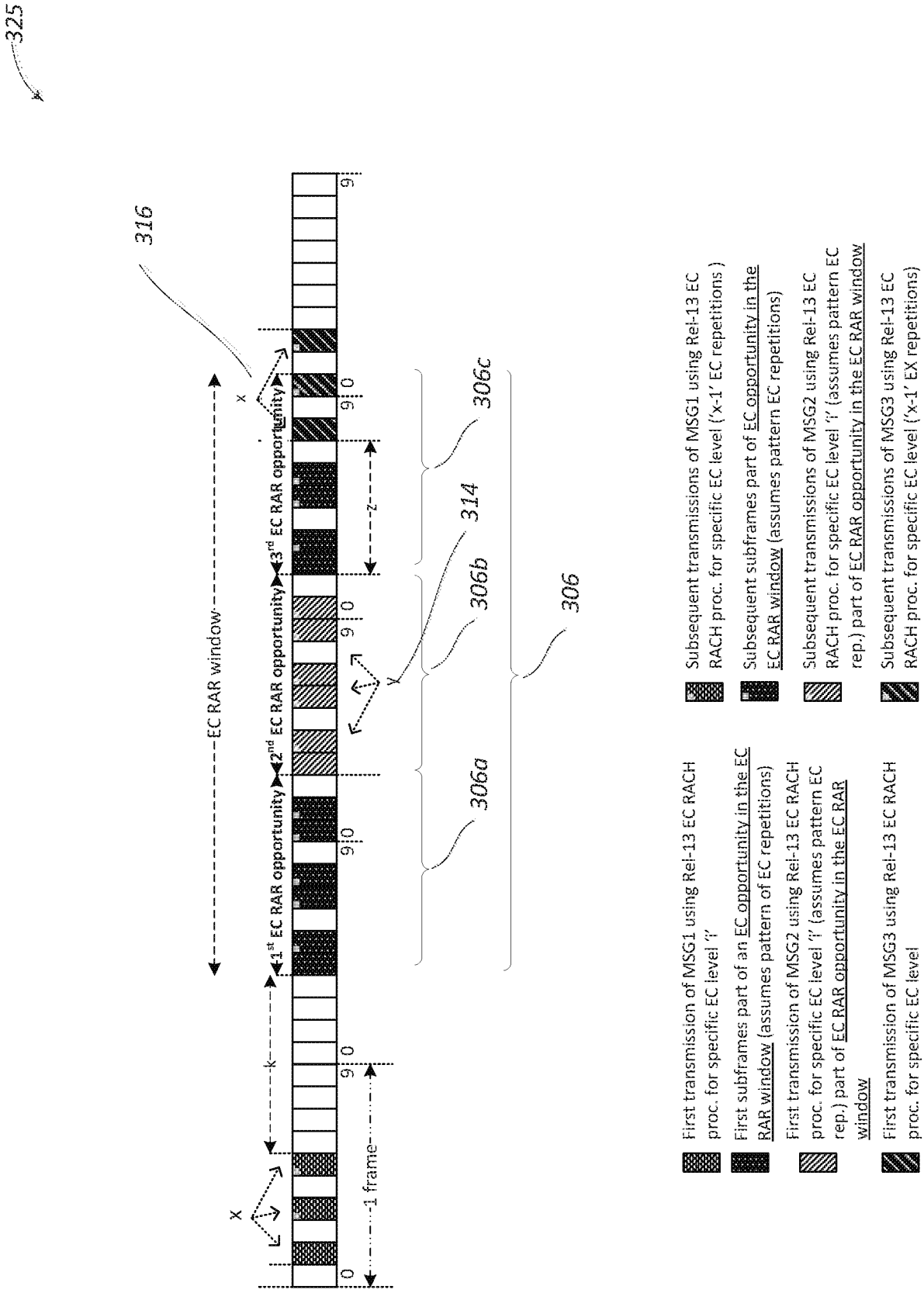
325
316
EC RAR window
1st EC RAR opportunity
2nd EC RAR opportunity
3rd EC RAR opportunity
1 frame
x
y
z
k
306a
306b
306c
314
306
First transmission of MSG1 using Rel-13 EC RACH proc. for specific EC level 'i'
First subframes part of an EC opportunity in the EC RAR window (assumes pattern of EC repetitions)
First transmission of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' (assumes pattern EC rep.) part of EC RAR opportunity in the EC RAR window
First transmission of MSG3 using Rel-13 EC RACH proc. for specific EC level
Subsequent transmissions of MSG1 using Rel-13 EC RACH proc. for specific EC level ('x-1' EC repetitions)
Subsequent subframes part of EC opportunity in the EC RAR window (assumes pattern EC repetitions)
Subsequent transmissions of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' (assumes pattern EC rep.) part of EC RAR opportunity in the EC RAR window
Subsequent transmissions of MSG3 using Rel-13 EC RACH proc. for specific EC level ('x-1' EX repetitions)

Figure 3B

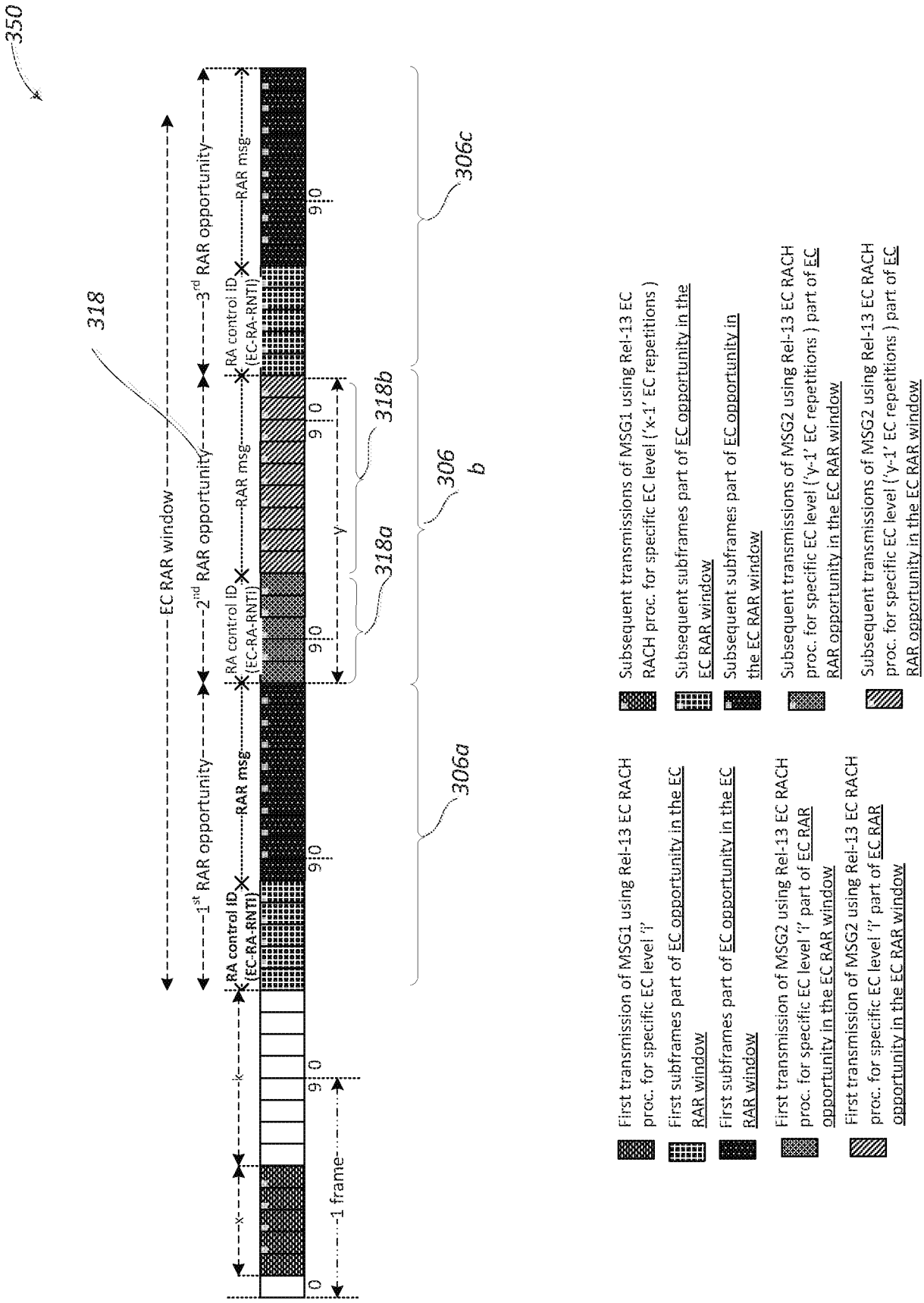
350
318
EC RAR window
1st RAR opportunity
2nd RAR opportunity
3rd RAR opportunity
RA control ID (EC-RA-RNTI)
RAR msg
RA control ID (EC-RA-RNTI)
RAR msg
RA control ID (EC-RA-RNTI)
RAR msg
x
y
1 frame
0
9
10
306a
306
b
306c
318a
318b
First transmission of MSG1 using Rel-13 EC RACH proc. for specific EC level 'i'
First subframes part of EC opportunity in the EC RAR window
First subframes part of EC opportunity in the EC RAR window
First transmission of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' part of EC RAR opportunity in the EC RAR window
First transmission of MSG2 using Rel-13 EC RACH proc. for specific EC level 'i' part of EC RAR opportunity in the EC RAR window
Subsequent transmissions of MSG1 using Rel-13 EC RACH proc. for specific EC level ('x-1' EC repetitions)
Subsequent subframes part of EC opportunity in the EC RAR window
Subsequent subframes part of EC opportunity in the EC RAR window
Subsequent transmissions of MSG2 using Rel-13 EC RACH proc. for specific EC level ('y-1' EC repetitions) part of EC RAR opportunity in the EC RAR window
Subsequent transmissions of MSG2 using Rel-13 EC RACH proc. for specific EC level ('y-1' EC repetitions) part of EC RAR opportunity in the EC RAR window

Figure 3C

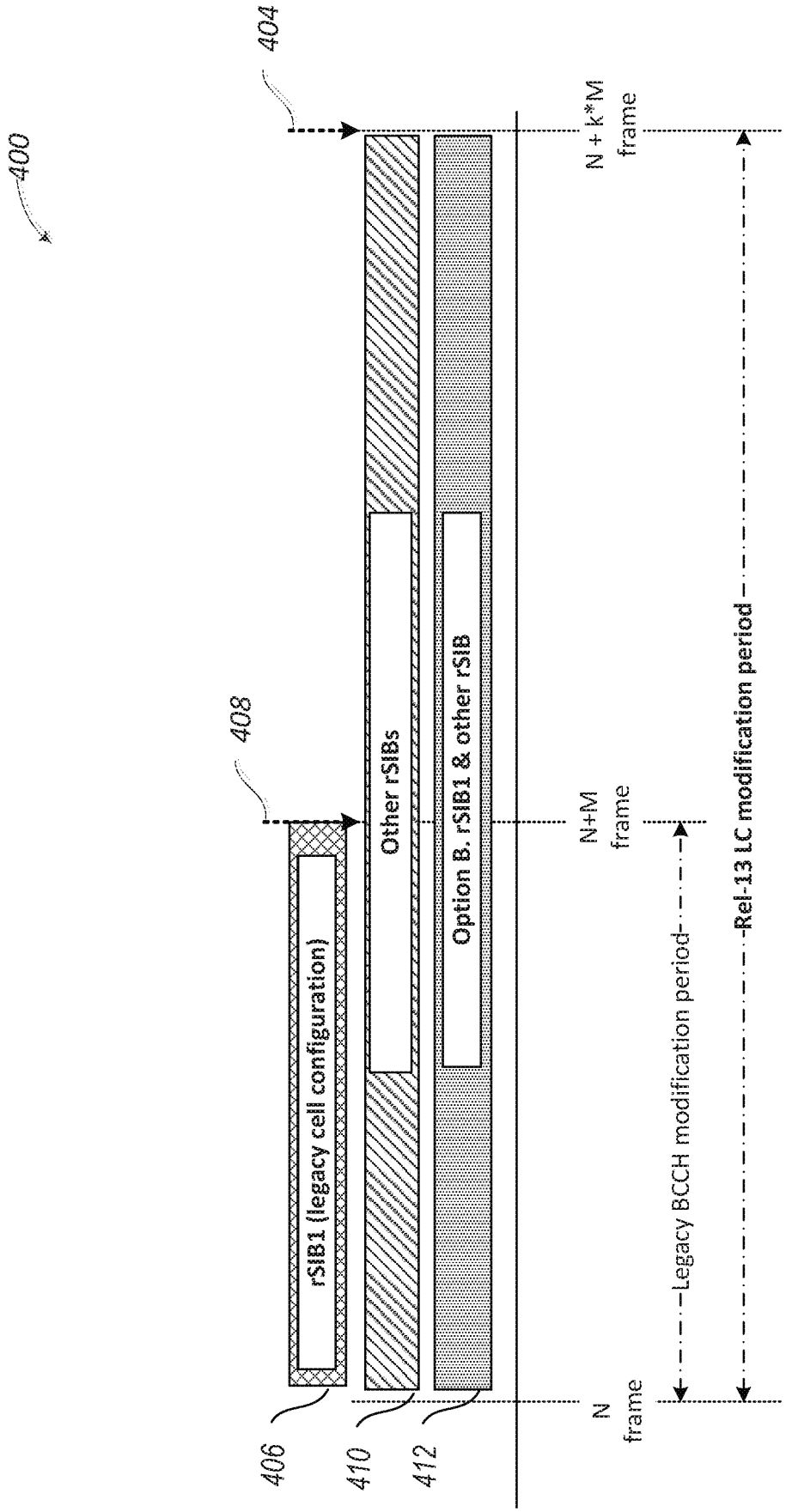
400
404
408
406
410
412
rSIB1 (legacy cell configuration)
Other rSIBs
Option B. rSIB1 & other rSIB
N frame
N+M frame
N + k*M frame
Legacy BCCH modification period
Rel-13 LC modification period

Figure 4

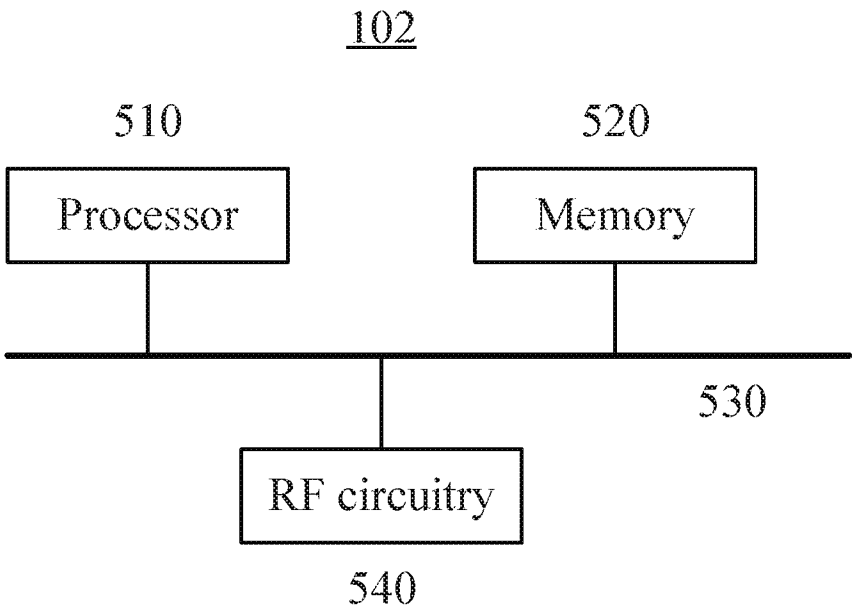

Figure 5

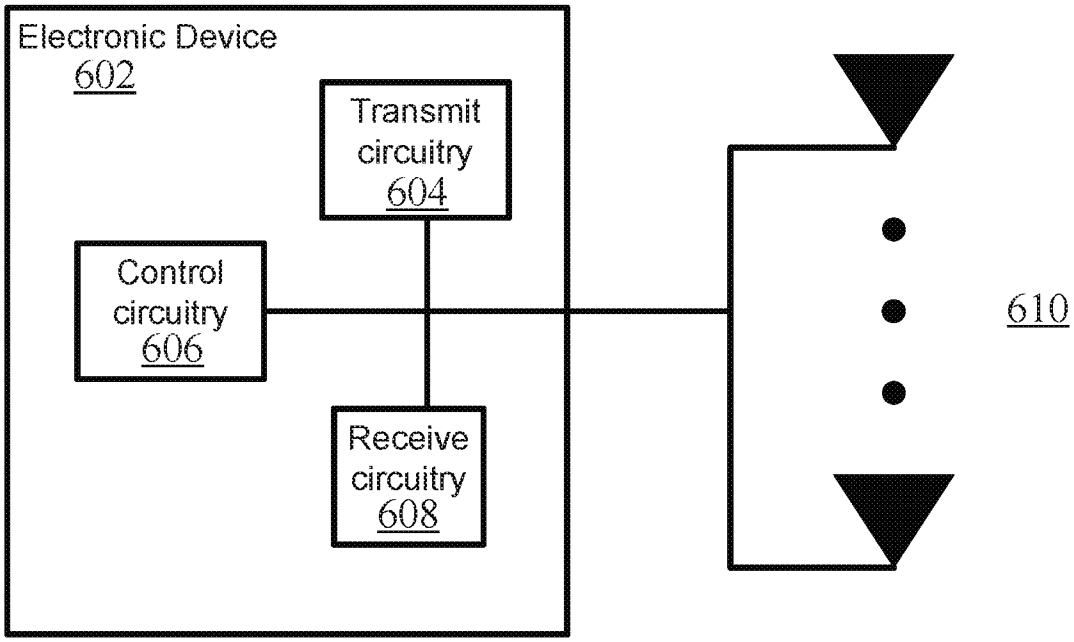
Electronic Device
602
Transmit circuitry
604
Control circuitry
606
Receive circuitry
608
610

Figure 6

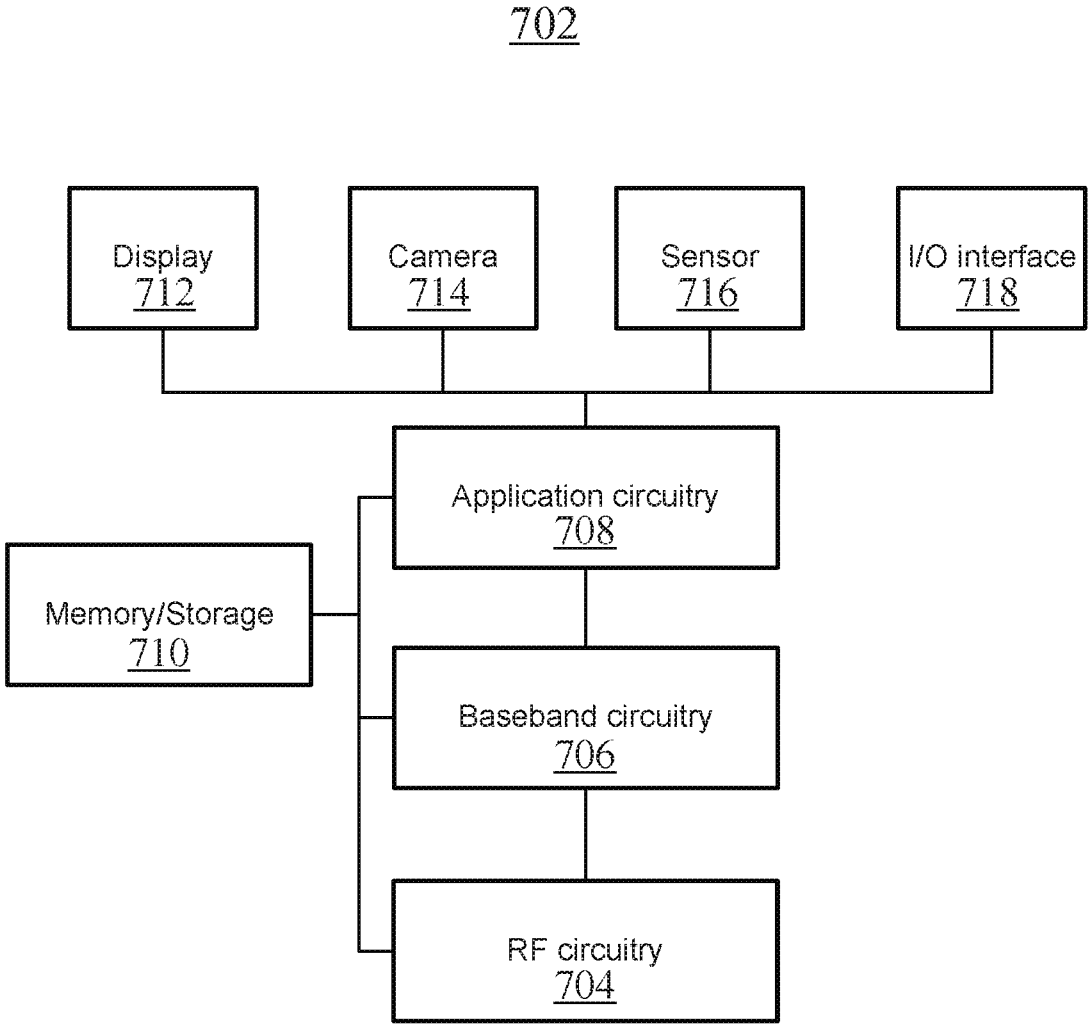
702
Display
712
Camera
714
Sensor
716
I/O interface
718
Application circuitry
708
Memory/Storage
710
Baseband circuitry
706
RF circuitry
704

Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/016429

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08 H04L1/00 H04W52/04
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04L

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2015/021318 A2 (INTERDIGITAL PATENT HOLDINGS [US]) 12 February 2015 (2015-02-12) paragraph [0023] paragraph [0081] paragraph [0085] paragraph [0197] paragraph [0209] paragraph [0213] paragraph [0313] paragraph [0323] paragraph [0335] paragraph [0345] - paragraph [0349] paragraph [0353] paragraph [0238] ----- -/--	1-9, 11-16, 22-25 10,17-19

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 April 2016	28/06/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Orfanos, Georgios

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/016429

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	INTERDIGITAL: "PRACH coverage enhancement for MTC UE", 3GPP DRAFT; R1-150688_LC-MTC PRACH, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Athens, Greece; 20150209 - 20150213 8 February 2015 (2015-02-08), XP050933886, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-02-08]	1,16,22
A	paragraph [0002]	2-15, 17-19, 23-25

X	NSN ET AL: "PRACH Coverage Enhancement", 3GPP DRAFT; R1_140549, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Prague, Czech Republic; 20140210 - 20140214 9 February 2014 (2014-02-09), XP050735568, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN/RAN1/Docs/ [retrieved on 2014-02-09]	13,24
A	paragraph [0001] - paragraph [0002]; table 1	1-12, 14-19, 22,23,25

Y	LG ELECTRONICS: "RACH procedure for coverage enhancement of MTC UEs", 3GPP DRAFT; R1-134393 MTC_RACH FOR CE (FINAL), 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Guangzhou, China; 20131007 - 20131011 28 September 2013 (2013-09-28), XP050717518, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_74b/Docs/ [retrieved on 2013-09-28]	10,17-19
A	paragraph [0002]	1-9, 11-16, 22-25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/016429

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-19, 22-25

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-19, 22-25

   Random access in enhanced coverage mode.

   ---

2. claims: 20, 21

   Periodic modification of the system information in reduced bandwidth mode.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/016429

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015021318 A2	12-02-2015	EP 3031283 A2	15-06-2016
		WO 2015021318 A2	12-02-2015

(19)中华人民共和国国家知识产权局

(12)发明专利申请

(10)申请公布号 CN 107431986 A
(43)申请公布日 2017.12.01

(21)申请号 201680013635.2

(22)申请日 2016.02.03

(30)优先权数据
62/145,335 2015.04.09 US
14/861,828 2015.09.22 US

(85)PCT国际申请进入国家阶段日
2017.09.04

(86)PCT国际申请的申请数据
PCT/US2016/016429 2016.02.03

(87)PCT国际申请的公布数据
WO2016/164100 EN 2016.10.13

(71)申请人 英特尔IP公司
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理查德·伯比奇 许允亨
乌莫什·普也拉

(74)专利代理机构 北京东方亿思知识产权代理有限责任公司 11258
代理人 孙洋

(51)Int.Cl.
H04W 52/48(2009.01)
H04W 74/00(2009.01)
H04W 74/08(2009.01)
H04L 1/18(2006.01)

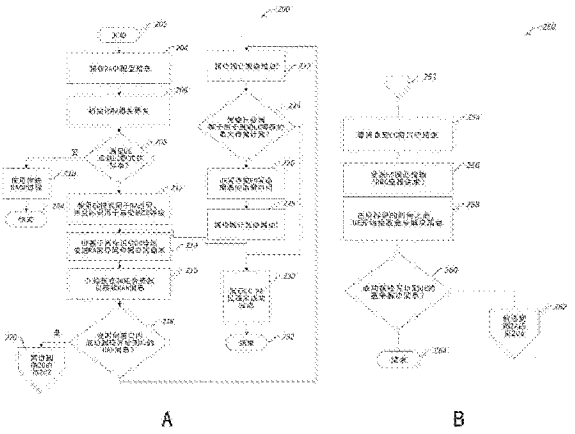
权利要求书3页 说明书17页 附图9页

(54)发明名称

用于增强型覆盖支持的随机接入过程

(57)摘要

本文描述的实施例总体涉及均在增强型覆盖(EC)模式下运行的用户设备(UE)和演进节点B(eNB)之间的通信。UE和eNB可以在具有可用于确定RA前导码可被发送的次数的EC等级、以及可用于接收一个或多个RA响应的一个或多个RA响应机会窗口的基于竞争的随机访问过程中进行通信。可以描述和/或要求保护其他实施例。



A B

CN 107431986 A

1.一种在用户设备(UE)中采用的装置,所述装置包括:

一个或多个处理器;

耦合到所述一个或多个处理器的存储器,其上具有指令,所述指令当被执行时,使得所述处理器:

标识在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的初始增强型覆盖(EC)等级,所述EC等级至少具有相关联的功率等级、时间窗口、以及发送尝试的数目;

基于所标识的EC等级向无线电接入网(RAN)发送第一消息;

确定来自所述RAN的响应于所述第一消息的第二消息是否在所述时间窗口内被接收;

若所述第二消息是在所述时间窗口内被从所述eNB接收,则解码接收到的第二消息;以及

若所述第二消息不是在所述时间窗口内被从所述eNB接收:

则向所述RAN重新所述发送所述第一消息。

2.如权利要求1所述的装置,其中,所述RAN包括至少一个增强型节点B(eNB)。

3.如权利要求1所述的装置,其中,向所述RAN重新发送所述第一消息还包括:

使用具有数值的传输计数器来跟踪所述第一消息已被发送的次数;以及

基于所述第二消息是否在时间窗口内被接收的确定以及所述传输计数器和传输阈值的比较来输出RA EC过程未成功完成的指示。

4.如权利要求1所述的装置,其中,所述第一消息是随机接入(RA)前导码,并且所述第二消息是随机接入响应(RAR)。

5.如权利要求1所述的装置,其中,初始EC等级在所述UE中被配置或在系统信息块(SIB)中被接收。

6.如权利要求5所述的装置,其中,所述SIB在较高带宽或在减少的带宽中被接收。

7.如权利要求1所述的装置,其中,发送所述第一消息的功率等级基于下列项中的一项或多项:所述传输计数器的值、或所述EC等级的值。

8.如权利要求1所述的装置,其中,重新发送所述第一消息还包括功率提升。

9.如权利要求8所述的装置,其中,所述功率提升包括将所述功率增加到与所述EC等级相关联的最大功率等级。

10.如权利要求1所述的装置,其中,所述时间窗口至少取决于在EC RAR窗口内定义的EC RAR机会的数目和/或用于所述EC等级的发送尝试的数目。

11.如权利要求1所述的装置,其中,向所述RAN重新发送所述第一消息还包括:在重新发送所述第一消息之前包括延迟时间,所述延迟是至少所述EC等级的一个函数。

12.如权利要求1-11中的任一项所述的装置,其中,所述UE能够在常规覆盖模式和EC模式下操作。

13.一种在演进节点B(eNB)中采用的装置,所述装置包括:

一个或多个处理器;

耦合到所述一个或多个处理器的存储器,其上具有指令,所述指令当被执行时,使得所述处理器:

确定在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的增强型覆盖(EC)等级;

在系统信息块(SIB)中向位于所述无线电小区中的用户设备(UE)发送对所确定的EC等级的指示；

接收来自UE的RA前导码；以及

响应于所述RA前导码，发送随机接入响应(RAR)消息。

14.如权利要求13所述的eNB，其中，在SIB中发送对所述所确定的EC等级的指示还包括在1.4兆赫或200千赫的减少的带宽中进行发送。

15.如权利要求13所述的eNB，其中，所述eNB可以在常规覆盖模式和EC模式下操作无线电小区。

16.一种在用户设备(UE)中采用的装置，所述装置包括：

逻辑电路，所述逻辑电路标识增强型覆盖(EC)等级；

发送电路，所述发送电路基于所标识的EC等级向无线电接入网(RAN)发送随机接入(RA)前导码；

逻辑电路，所述逻辑电路标识具有多个子帧的EC随机接入响应(RAR)窗口区域。

17.如权利要求16所述的装置，还包括：

逻辑电路，所述逻辑电路标识具有多个子帧的EC随机接入响应(RAR)窗口区域，所述EC RAR窗口区域包括一个或多个EC RAR机会，每个EC RAR机会是连续的子帧组，第一EC RAR机会在与所述RAR窗口区域的开始相同的子帧处开始，并且在发送所述RA前导码之后开始K个子帧。

18.如权利要求17所述的装置，还包括接收电路，所述接收电路：

从所述RAN接收所述第一EC RAR机会中的候选RAR；

直到候选RAR能够被解码为止，从所述RAN接收来自EC RAR机会的候选RAR；以及

若候选RAR能够被解码，则向所述RAN发送RRC连接请求。

19.如权利要求16所述的装置，其中，所述EC RAR窗口区域取决于下列值：

在本说明书中定义的值；

作为所述SI消息的部分被广播的值；

与所述EC等级相关联的值；或

与包含RAR消息的EC RAR机会中的所述子帧的数目相关联的值。

20.一种演进节点B(eNB)，包括：

控制电路，所述控制电路在处于减少带宽模式时从多个系统信息(SI)修改时段中标识与无线电小区配置相关联的SI修改时段；以及

与所述控制电路相耦合的发送电路，所述发送电路根据所标识的修改时段来发送SI消息。

21.如权利要求20所述的装置，其中，所述控制电路和发送电路在常规覆盖模式和/或EC模式下操作。

22.一个或多个非暂态计算机可读介质，包括指令，响应于所述指令由计算设备执行，使得用户设备(UE)：

标识在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的初始增强型覆盖(EC)等级，所述EC等级至少具有相关联的功率等级、时间窗口、以及发送尝试的数目；

基于所标识的EC等级向无线电接入网(RAN)发送第一消息；

确定来自所述RAN的响应于所述第一消息的第二消息是否在所述时间窗口内被接收；

若所述第二消息是在所述时间窗口内被从所述eNB接收，则解码接收到的第二消息；以及

若所述第二消息不是在所述时间窗口内被从所述eNB接收，则向所述RAN重新所述发送第一消息。

23.如权利要求22所述的一个或多个非暂态计算机可读介质，其中，所述RAN包括至少一个增强型节点B(eNB)。

24.一个或多个非暂态计算机可读介质，包括指令，响应于所述指令由计算设备执行，使得增强型节点B(eNB)：

确定在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的增强型覆盖(EC)等级；

在系统信息块(SIB)中向位于所述无线电小区中的用户设备(UE)发送对所确定的EC等级的指示；

接收来自UE的RA前导码，

响应于所述RA前导码，发送随机接入响应(RAR)消息。

25.如权利要求24所述的一个或多个非暂态计算机可读介质，其中，所述eNB可以在常规覆盖模式和EC模式下操作无线电小区。

用于增强型覆盖支持的随机接入过程

[0001] 相关申请的交叉引用

[0002] 本申请要求于2015年9月22日递交的、名称为“RANDOM ACCESS PROCEDURE FOR ENHANCED COVERAGE SUPPORT(用于增强型覆盖支持的随机接入过程)”的美国专利申请No.14/861,828的优先权,该美国专利申请要求于2015年4月9日递交的、名称为“Random Access Procedure for Enhanced Coverage Support(用于增强型覆盖支持的随机接入过程)”的美国临时专利申请No.62/145,335的优先权。除了与本说明书不一致的那些部分(若存在的话)外,上述美国申请的全部公开内容为所有目的而通过引用整体结合于此。

技术领域

[0003] 本公开的实施例总体涉及移动通信的领域,并且更具体地,涉及可操作来实现基于竞争的随机接入过程的计算机设备。

背景技术

[0004] 这里提供的背景技术描述是为了总体呈现本公开的上下文的目的。当前署名的发明人的工作(到该背景技术部分中所描述的程度)以及说明书中在递交时可能不能以其他方式被视为现有技术的方面,既不明确地也不隐含地被承认为抵触本公开的现有技术。除非本文中另有指示,否则这部分所描述的方法对于本公开的权利要求而言不是现有技术,并且不因被包括在这部分中而被承认是现有技术。

[0005] 随着向“物联网”(IoT)的概念的发展,机器类型通信(MTC)技术可能使无所不在的计算环境成为可能。潜在的基于MTC的应用包括:智能计量、医疗保健监测、远程安全监控、智能交通系统、个别物品库存控制等。这些服务和应用可以刺激可被无缝地集成到当前和未来世代移动宽带网络中的新型MTC设备的设计和开发。

[0006] 现有移动宽带网络被设计为优化主要用于人类通信的性能。因此,现有网络可能不会针对MTC相关的要求进行适配或优化。例如,可以通过第三代合作伙伴计划(3GPP)来开发特定于MTC的设计。未来的3GPP规范可能支持不同的网络设计,这可能会改善MTC。

[0007] 例如,在3GPP版本12中,在E-UTRA规范中引入被称为类别0的新物理层UE类别。例如,在峰值数据速率能力方面和在发送和接收性能方面,相比于此前的最低类别1,该UE类别由于仅支持单个天线而具有更低的能力。引入类别0的目的之一是为了支持用于MTC应用的较低成本用户设备(UE)。

[0008] 在3GPP版本13中,与在版本12中添加的类别0相比,具有甚至更低能力和更低成本的新物理层UE类别(类别X)被引入。此外,引入增强型覆盖(EC)特征以增加高达15分贝(dB)的链路预算。EC特征将使得E-UTRAN能够与位于当前无法或难以向UE提供覆盖的具有挑战性的位置(例如,在建筑深处、在地下室内、在货物托盘中等)的UE进行通信。类别X和EC针对主要用于MTC应用的UE。可以独立地实现类别X和EC,并且UE可支持任一个或二者。

附图说明

[0009] 在附图的图示中通过示例的方式而非限制的方式示出了本发明的实施例，其中，相似的参考标号指示类似的元件。应注意的是，对本公开的“一”或“一个”实施例的引用不一定都指同一实施例，并且它们可表示至少一个实施例。还应注意的是，引用“示例”是引用非限制性示例，除非另有说明。

[0010] 图1示出了根据各个实施例的使用EC模式的演进节点B(eNB)和用户设备(UE)之间的通信消息流。

[0011] 图2A示出了根据各个实施例的由UE使用EC功能来执行的基于竞争的随机接入过程的过程。

[0012] 图2B示出了根据各个实施例的由UE使用EC功能来执行的基于争用的随机接入过程的过程。

[0013] 图3A、3B、以及3C是示出根据各个实施例的可用于实现可以由UE和eNB使用的EC随机接入响应(RAR)窗口内的RAR机会的帧结构的图示。

[0014] 图4是示出根据各个实施例的用于在EC模式下实现用于寻址到UE的系统信息(SI)的不同修改时段的帧结构的图示。

[0015] 图5是示出根据各个实施例的适于在EC模式下在无线通信网络中操作的计算设备的框图。

[0016] 图6示出了根据各个实施例的可以是eNB电路、UE电路、或一些其他类型的电路的电子设备电路。

[0017] 图7示出了针对一个实施例的示例系统，包括至少如图所示彼此耦合的射频(RF)电路、基带电路、应用电路、存储器/存储装置、显示器、相机、传感器、以及输入/输出(I/O)接口。

具体实施方式

[0018] 在以下具体实施方式中，参考形成本文的部分的附图，其中，相似的标号通篇表示相似的部分，并且这些附图通过示例的方式示出了可被实施的实施例。将理解的是，在不脱离本公开的范围的情况下可以利用其他实施例，并且可以做出结构变化或逻辑变化。因此，以下具体实施方式不应被理解为是限制意义的，并且实施例的范围由所附权利要求及其等同物来限定。

[0019] 各种操作可以以最有助于理解所要求保护的主题的方式被描述为依次的多个离散动作或操作。然而，描述的顺序不应当被解释为暗示这些操作必须依赖于顺序。具体地，这些操作可以不按呈现的顺序来执行。所描述的操作可以按照与所描述的实施例不同的顺序来执行。在附加的实施例中可以执行各种附加的操作和/或可以省略所描述的操作。

[0020] 出于本公开的目的，短语“A或B”和“A和/或B”意为(A)、(B)、或(A和B)。出于本公开的目的，短语“A、B和/或C”意为(A)、(B)、(C)、(A和B)、(A和C)、(B和C)、或(A、B和C)。

[0021] 本说明书可以使用短语“在一个实施例中”或“在实施例中”，它们可各自指代相同或不同实施例中的一个或多个实施例。另外，关于本公开的实施例所使用的术语“包括”、“包含”、“具有”等是同义词。

[0022] 如本文所使用的，术语“模块”和/或“逻辑”可以指代下列项、可以是下列项的部分、或可包括下列项：执行一个或多个软件或固件程序的专用集成电路(ASIC)、电子电路、

(共享的、专用的、或者群组的)处理器、和/或(共享的、专用的、或者群组的)存储器、组合逻辑电路、和/或提供所描述的功能的其他合适的硬件组件。

[0023] 如本文使用的,术语"电路"可以指代下列项、可以是下列项的部分、或可包括下列项:执行一个或多个软件或固件程序的专用集成电路(ASIC)、电子电路、(共享的、专用的、或者群组的)处理器和/或(共享的、专用的、或者群组的)存储器、组合逻辑电路、和/或提供所描述的功能的其他适当的硬件组件。在一些实施例中,电路可以在一个或多个软件或固件模块中实现,或与电路相关联的功能可以由一个或多个软件或固件模块来实现。

[0024] 在实施例中,本文的公开内容可涉及用于增强与演进节点B(eNB)和在EC模式下运行的用户设备(UE)之间的随机接入过程相关的机器到机器通信的过程、装置、和/或技术。这些实施例可包括将多个等级与EC模式相关联,并且针对每个等级,标识在UE和eNB之间发送的消息的重复次数,以及可以由UE用于根据EC模式等级来尝试与eNB进行通信的不同的功率等级。此外,实施例可包括添加另外的随机接入响应(RAR)机会窗口,以接收和解码可响应于多个随机接入前导码被发送的多个RAR。此外,实施例可包括支持用于寻址到版本13LC UE和版本13EC UE的SI消息的不同修改时段。

[0025] 在实施例中,使用该解决方案的UE可以在减少的带宽区域(例如,版本13中的1.4MHz)中操作,或可以在更窄的窄带区域(例如,200kHz)中操作。eNB还可在较高系统带宽处操作。

[0026] 图1示出了根据各个实施例的使用EC模式的UE和eNB之间的通信消息流。图示100可包括UE 102以及与诸如eNB 104之类的接入点的无线通信。UE 102和eNB 104可以通信以在EC模式下使用基于竞争的RA过程来建立无线电资源控制(RRC)连接。

[0027] EC随机接入(RA)前导码分配106可以从eNB 104被发送到UE 102。在实施例中,RA前导码分配106可包括与版本13LC(低成本)UE和版本13EC模式UE相关的随机接入配置信息,并且可以通过系统信息(SI)进行广播,或可以在UE 102中进行预定义。在实施例中,随机接入配置信息可包括要由UE 102使用的EC等级、指示针对该EC等级所允许的每个EC模式消息的附加重复次数的值、和/或要用于重复的通信尝试的一个或多个功率等级。

[0028] EC RA前导码108可以从UE 102被发送到eNB 104。EC RAR消息110可以由eNB 104响应于EC RA前导码108而在EC RAR窗口内发送,在实施例中,可以在多个连续子帧中接收EC RAR窗口。EC RA前导码108的内容可以确定UE 102可以在从eNB 104接收到的EC RA响应(EC RAR)消息110子帧中寻找的随机接入无线电网络临时标识符(RA-RNTI)。

[0029] 在实施例中,eNB 104可关于在EC RAR窗口内发送EC RAR消息110的位置具有灵活性。在实施例中,UE 102可以在物理下行链路控制信道(PDCCH)上搜索RA-RNTI。在实施例中,由UE在EC模式下接收到的PDCCH可与传统PDCCH不同。例如,可以在子帧的第一OFDMA符号中的整个系统带宽内发送传统PDCCH。然而,对于EC模式,可以在传统PDCCH内的减少带宽区域中发送PDCCH。

[0030] EC RAR消息110可包括随机接入前导码标识符(RAPID)和临时小区无线电网络临时标识符(T-CRNTI)。

[0031] EC调度传输112可以由UE 102发送到eNB 104。在实施例中,若在子帧n中接收到EC RAR消息110,则UE 102可以在子帧n+k(k≥6)中经由物理上行链路共享信道(PUSCH)发送调度的数据项。UE 102还可应用具有maxHARQ-Msg3Tx的混合自动重传请求(HARQ)。UE 102还

可以启动用于RRC连接请求的诸如定时器T300之类的定时器以及在PDCCH上监测T-CRNTI。最后，UE 102可以启动mac-ContentionResolutionTimer。在实施例中，可以在每次HARQ重新传输时重新启动mac-ContentionResolutionTimer。

[0032] EC竞争解决消息114可以由eNB 104发送到UE 102。在实施例中，在PDCCH中使用T-CRNTI，并且HARQ可以由eNB 104应用于相关联的PDSCH。在实施例中，当UE 102监测到如在EC调度传输112中所提供的其自己的UE 102标识时，UE 102可以仅在PUCCH上发送HARQ反馈。在实施例中，EC竞争解决消息114可以由UE 102在mac-ContentionResolutionTimer正在运行时接收。若成功接收EC竞争解决消息114，则UE 102竞争解决标识MAC CE可以包含EC竞争解决消息114的UL公共控制信道(CCCH)服务数据单元(SDU)。

[0033] 在实施例中，上述EC模式下的通信的优势可包括UE和eNB之间的RRC连接建立的较大可能性，特别是当UE被实现为IoT的部分时。优势还可包括提供RRC连接建立的较大可能性但使用较少功率，例如，通过将UE使用的功率提升到RA过程能够建立RRC连接的点，其中，UE不必持续运行最大功率。此外，通过在RA过程期间支持UE与eNB之间的传输的重复尝试，大大增加了RRC连接建立的可能性。

[0034] 图2A示出了根据各个实施例的由UE使用EC功能来执行的基于竞争的随机接入过程的过程。过程200更详细地描述了上述各种处理。过程200可以由根据各个实施例的在EC模式操作中使用的UE(例如，UE 102)来执行。在一些实施例中，UE可包括在其上存储有指令的一个或多个非暂态计算机可读介质，指令当被执行时，使得UE执行过程200。

[0035] 过程可以在框202处开始。

[0036] 在框204处，UE 102可以接收来自eNB 104的随机接入过程(RACH)配置信息。在实施例中，例如，当UE 102处于空闲模式并且支持EC模式时，可以由UE 102从EC RA前导码分配消息106接收配置信息。配置信息可以由eNB 104通过SI来广播。在其他实施例中，配置信息可能此前已被存储在UE 102中。

[0037] 在框206处，UE 102可以初始化RA相关要素。在实施例中，UE可以初始化类似于传统RA机制的相关要素。在实施例中，可以初始化用于EC模式UE的新RA相关参数。RA相关参数可以是例如，EC等级、初始功率等级、或重传消息的次数。

[0038] 在框208处，UE 102可以关于是否满足UE启动EC模式的标准、或是否可以启动传统RA过程做出确定。在实施例中，UE 102可以通过本说明书中定义的、存储在UE上的、和/或通过广播或专用消息指示给UE的信息来确定使用哪个RA过程模式。在示例中，可以定义新的规则、条件、或标准。例如，可以定义这样的规则：在传统RA过程下具有一个或多个不成功完成的UE可以尝试使用EC RA过程。

[0039] 在其他非限制性示例中，可以使用阈值来触发或确定UE何时应使用EC RA过程。可以基于一些UE特定参数来定义这些阈值，例如，测量的参考信号接收功率(RSRP)、测量的参考信号接收质量(RSRQ)、前导码传输计数器值、或物理随机接入信道(PRACH)前导码传输功率。

[0040] 在其他非限制性示例中，该确定可以基于存储在UE 102处的预定类别/能力特定信息。例如，可能要求UE类别X始终使用EC RA过程，或替代地，可以允许UE类别X基于除了其类别之外的其他标准来使用EC RA过程。

[0041] 若不满足启动EC模式的标准，则然后在框210处，UE 102可以使用传统RA过程。过

程220然后可以在框234处结束。

[0042] 否则，若满足启动EC模式的标准，则然后在框212处，UE 102可以使用EC模式用于RA过程，并且标识起始EC等级。在实施例中，UE 102可以基于存储在UE 102中的值、或通过接收和/或解码EC RA前导码分配106中的由eNB 104发送的EC等级信息来标识EC等级。EC等级可能由于各种原因而是重要的。例如，可能需要基于EC等级来更新RA相关配置。可以利用任意EC等级来直接选择最大UL发送功率，或RA前导码和/或配置可以基于所标识的EC级别。EC等级还可以与UE 102在尝试与eNB进行通信时可用的消息重复的特定数目相关联。因此，RA过程可以使用例如多个重传消息，在尝试建立RRC连接时，每个后续重传使用增加的功率等级或功率提升。与EC RA前导码分配106内的RA消息资源分配信息相关的其他方面可包括若UE处于EC模式和/或若不同的EC等级由它们的前导码序列标识时可用于前导码传输的序列组、跳频的细节。

[0043] 在框214处，UE 102可以基于所标识的EC等级来发送RA前导码和RA前导码的相应副本。在实施例中，RA前导码可以基于所标识的EC等级被多次重复发送。在实施例中，RA前导码组和/或子组、RA前导码时间资源(PRACH子帧)、频率资源等可取决于所标识的EC等级，以及UE 102发送EC RA前导码的多个副本以允许网络组合多个EC RA前导码副本的子帧。在实施例中，可能存在最多n个被发送的前导码，n取决于所标识的EC等级。在实施例中，UE 102可以基于所标识的EC等级、RA前导码、以及RA前导码时间和频率资源来确定RA-RNTI。

[0044] 在框216处，UE 102可以开始接收和/或组合资源以接收EC RAR消息110。在实施例中，通过寻址到尝试利用同一EC等级或EC RA前导码108进行接入的UE组的版本13增强型物理下行链路控制信道(ePDCCH)、或通过寻址到特定UE的版本13ePDCCH或基于在SI消息中预先定义和/或广播的预配置/预定义信息，EC RAR消息110的资源位置可以在确定版本13RA-RNTI之后被UE知道。此外，EC RAR消息110可以是对于该EC等级不同的版本13RAR，或可以是可运载随机接入响应的UE特定或新型EC RAR消息110。该过程可以仅完成一次、或重复多次(若还定义和/或扩展了版本13EC RAR窗口概念)，如下文所述。

[0045] 在框218处，UE 102可以确定是否在时间窗口内成功解码寻址到UE的EC RAR消息110。在实施例中，时间窗口可以是EC窗口值。在实施例中，时间窗口可以基于EC等级而变化，例如，它可以与所标识的EC等级成比例，或可以基于针对EC等级所允许的前导码最大重复次数。

[0046] 若在时间窗口内成功解码EC RAR消息110，则在框220处，过程前进到图2B的框252。

[0047] 否则，若未在时间窗口内成功解码EC RAR消息110，则在框222处，传输计数器可增加一。在实施例中，EC RAR消息110可能因为它未被eNB发送、或已被发送但不包含UE包括在EC RA前导码108中的RAPID而未被成功解码。

[0048] 在框224处，UE 102可以确定传输计数器是否等于针对当前EC等级的最大传输计数。若传输计数器等于针对当前EC等级的最大传输计数，则在框230处，UE 102可以确定EC RA过程未成功完成。在实施例中，若针对最高EC等级达到最大尝试次数，则这种情况可能发生。在实施例中，UE可以将RA失败通知给RRC较上层，并且较上层稍后可以再次发起EC RA过程。基于此前的RA失败，可以通过将EC等级改变(例如，增加EC等级)为更适用于当UE在小区的增强型覆盖区域更深处(例如，在建筑的深处)时的等级来发起RA过程。在框232处，过程

200可以结束。

[0049] 否则，若传输计数器不等于针对当前EC等级的最大传输计数，则在框226处，UE 102可以等待使该EC等级期满的退避时间。在实施例中，UE可以尝试再次发送EC RA前导码108。例如，可以在应用了前导码功率提升(如果针对EC指定或配置了的话)之后这样做。在实施例中，传输计数器可用于限制针对当前EC等级的PRACH前导码传输试验的最大次数。在实施例中，传输计数器可以确定UE何时可以切换到另一EC等级(例如，较高EC等级)，这可允许更多消息重复或更高功率等级。

[0050] 在框228处，UE 102可以将传输计数器增加1，并且过程200可前进到框212。

[0051] 图2B示出了根据各个实施例的由UE使用EC功能来执行的基于竞争的随机接入过程的过程250。过程250可以由根据各个实施例的用于EC模式操作的UE(例如，UE 102)来执行。在一些实施例中，UE可包括在其上存储有指令的一个或多个非暂态计算机可读介质，指令当被执行时，使得UE执行过程250。

[0052] 在框252处，过程250可以从图2A的框220继续。

[0053] 在框254处，UE 102可以等待，直到EC窗口的结束。在实施例中，UE可以在开始发送EC调度传输消息112之前等待，直到EC窗口的结束。在实施例中，对于所标识的任意特定EC等级，如针对框212中的示例所描述的，该EC等级可具有对EC RAR消息110已被发送的次数进行标识的相关联的重复次数。若UE能够比EC RAR消息110已被发送的次数更早的解码EC RAR消息110，则UE可以等待接收最后一个EC RAR消息110可能所需的时间。在实施例中，可以仅在eNB所发送的EC RAR消息110的最后一次重复之后，调度EC调度传输112的UL分配。

[0054] 在框256处，UE 102可以向eNB发送调度传输，例如，RRC连接请求。

[0055] 在框258处，UE 102可以在所标识的时间之后开始接收竞争解决消息。

[0056] 在框260处，UE 102可以确定是否已成功接收寻址到UE的竞争解决消息。若RA过程在竞争解决阶段114中失败，则可以应用或扩展类似于如上所述的EC RA过程的过程。在实施例中，如果未在eNB处正确接收EC调度传输112，或如果来自给定UE的EC调度传输112与另一EC调度传输112冲突并且仅检测到另一UE的EC调度传输112，则这可能发生。对于后一种情况，给定UE可以从eNB接收EC竞争解决消息114，但可以确定它未被寻址到该特定UE。

[0057] 在其他实施例中，若在使用EC模式时未接收到EC竞争解决114，则可以应用类似于传统mac-ContentionResolutionTimer的概念。在这些实施例中，可以基于调度传输112的EC重复期望占用的时间长短来缩放或更新该定时器的值。当eNB未正确接收EC调度传输112或eNB接收并响应但未在UE处成功接收EC竞争解决114时，这可能发生。

[0058] 若UE 102确定竞争解决消息已被成功接收，则然后在框264处，过程250可以结束。

[0059] 若UE 102确定竞争解决消息未被成功接收，则然后过程可前进到框262，然后可以将过程返回到图2A的框208。

[0060] 在实施例中，当EC竞争解决114失败时，UE可以应用类似的过程以利用增加或重新初始化前导码传输计数器来重新发送RA前导码。对于前导码传输计数器的重新初始化的选项，UE可以如传统操作情况那样再次重新启动RA过程。

[0061] 在实施例中，若网络条件由于此前的RA试验而已发生变化，则过程可以允许UE切换到传统过程而非EC过程，反之亦然。此外，经更新的网络条件可以告知UE从不同的EC等级启动。

[0062] 对于本文描述的实施例，为简单起见，可以示出由处于RRC_IDLE的UE来使用用于EC模式的基于竞争的RA过程，例如，发起RRC连接。然而，用于EC模式的基于竞争的RA过程还可以由处于RRC_CONNECTED的UE使用。此外，为简单起见，传统名称可用于新版本13EC RA参数以及所体现的过程。然而，这不应该被限制于这些名称，因为一些名称可以指代与传统RA过程中所使用的相同的参数，或还可以指代为了实现本文解释的相同功能而定义的完全新的和不同的参数。

[0063] 例如，在实施例中，UE可以根据UE是使用传统RA过程还是EC RA过程来不同地选择RA资源。此外，对于EC RA过程，可以针对EC模式或针对每个EC等级来定义不同的传统RA参数值，或甚至不同的或新的参数。例如，RA过程可能涉及的参数退避时间对于每个EC等级可具有一个或多个不同的值，或针对每个EC等级可以定义不同的参数。在另一示例中，可以更新PREAMBLE_TRANS_MAX值或可以定义新的参数，以在传统RA过程可能转到EC RA过程时进行触发。替代地，当在RA过程中使用EC模式时，可不考虑用于前导码传输的功率提升，因为UE可以在具有较差覆盖的挑战性位置中使用最大发送功率。在实施例中，新的版本13标准或条件可以在本说明书中进行定义或可被广播给UE，以知道哪些参数或值应被用于EC RA过程或特定EC RA等级。

[0064] 图3A、3B以及3C是示出根据各个实施例的用于实现UE在接收EC RAR时可以使用的EC RAR窗口内的RAR机会的示例帧结构的图示。

[0065] 在图3A中，图300示出了帧序列302内的EC RAR窗口304的一种实现方式。在实施例中，EC RAR窗口304在EC RA前导码传输108完成之后可以开始k个子帧。在实施例中，k可被定义为3的值例如以适应根据传统长期演进(LTE)RA过程进行操作的设备，或其可以是更大的值，例如以便用于针对eNB的增加的处理要求以支持带宽减少的UE和EC模式。

[0066] 在实施例中，EC RAR窗口304可包含一个或多个EC RAR机会306。EC RAR窗口304内的EC RAR机会306a、306b、306c的数目可以在本说明书中进行定义，或可以作为EC RA前导码分配106的部分进行广播。在实施例中，第一EC RAR 306a可以在与EC RAR窗口304相同的子帧处开始。EC RAR机会306a的长度可以变化。例如，该长度可以取决于EC等级所需的重复次数，或取决于EC RAR机会306a中有多少个子帧运载实际的EC RAR消息110。在实施例中，这可能是由于EC RAR消息110由于EC等级所允许的重复传输而被多次重复。图示300示出了EC RAR机会306a、306b、306c中的所有子帧都运载EC RAR消息110的示例。

[0067] 在实施例中，用于特定EC等级的EC RA前导码106的第一传输可以在多个RA前导码子帧302a内发生。在实施例中，可以在特定时间和频率(即资源)中发送特定EC RA前导码302a1，以使得eNB知道UE正在使用某个EC等级。在实施例中，EC RA前导码还可以标识该UE是否是版本13LC。在实施例中，EC RA前导码302a2的后续传输可以使用用于特定EC等级的EC RACH过程。例如，EC RA前导码302a2的后续传输可以在不同的子帧(未示出)中。

[0068] 在实施例中，在EC RA前导码302a的一次或多次传输之后，UE可以在启动EC RAR窗口304之前等待k个子帧。

[0069] 在实施例中，RAR机会306可以具有与EC RAR窗口相同数目的帧。在一些实施例中，在EC RAR窗口304内，可存在第一EC RAR机会306a。UE可以组合第一EC RAR机会306a内的每个子帧的EC RAR相关资源，以使得可以解码EC RAR消息110。在实施例中，UE然后可以寻找RA-RNTI，并且若发现RA-RNTI，则UE然后可以寻找RAR消息。

[0070] 在实施例中，可以标识EC RAR窗口306的第二EC RAR机会306b。在实施例中，这可以响应于EC RAR消息110的后续传输，例如，对EC RA前导码108重复中的一个的响应，其中，可以基于EC等级来标识重复次数。

[0071] 在实施例中，使用某个EC等级的UE 102可能针对上行链路和下行链路方向分别要求x 310和y 308的EC总重复，其中，x 310或y 308可具有用于上行链路和下行链路的相同或不同的值。在这些实施例中，EC重复是连续的。

[0072] 在实施例中，在已成功解码EC RAR消息110之后，例如，使用从第二EC RAR机会306b接收到的数据，UE可以根据来自经解码的EC RAR消息110的所分配的授权，来在在UL中发送EC调度传输112之前等待z312个子帧。在该示例中，可以忽略另一EC RAR机会306c，因为UE已经成功解码了来自eNB的RAR消息。

[0073] 在实施例中，可以以多种方式形成EC RAR窗口304。例如，可以由一个特定EC等级的EC RAR机会306a、306b、306c形成EC RAR窗口304。在实施例中，UE可以检查EC RAR窗口将具有相同的EC等级要求。因此，对于每个EC等级，网络可能具有不同的EC RAR窗口304区域，其可能具有时间、频率、和/或EC所需重复次数的不同位置。

[0074] 在实施例中，EC RAR机会306a、306b、306c可以基于不同的EC等级而不同。在这些实施例中，网络可以指示或3GPP LTE规范可以定义哪个EC等级可对应于每个EC RAR机会(未示出)。在实施例中，同一EC等级的所有机会可被连续地定位，或它们可被交替。

[0075] 在图3B中，图示325示出了其中并非EC RAR机会306a、306b、306c中的所有子帧都运载EC RAR消息110的EC RAR窗口的示例。例如，UE 102可能正在使用针对每个下行链路和上行链路方向可能分别要求x316和y 314EC的总重复的EC等级，其中，x 316和y 314可具有相同或不同的值。在该示例中，EC重复不在连续的子帧中。

[0076] 在图3C中，图示350示出了这样的实施例，其中，若除了EC RAR消息110之外还接收到RA控制指示符(EC RA-RNTI)，则EC RAR机会306a、306b、306c的长度也可变化。例如，在第二EC RAR机会窗口318中，RA控制标识符318a被插入到RAR消息318b前面。在该示例350中，EC重复是连续的。在实施例中，RA控制标识符318a区域可用于其他RAR消息传递。

[0077] 被添加到RAR机会窗口的另外的消息可能是由于用于MTC的物理下行链路控制信道(PDCCH)的重复，该重复可基于版本13增强型物理下行链路控制信道(ePDCCH)。该PDCCH所运载的下行链路控制信息(DCI)及其利用EC RA-RNTI进行加扰的循环冗余校验CRC，可以使用跨子帧调度来调度RAR消息的传输。

[0078] 在实施例(未示出)中，可以根据EC等级(例如，5分贝(dB)EC对10dB EC)来不同地定义一些EC RA参数(例如，EC RA前导码，)、EC RAR窗口、以及EC RAR机会。示例可包括不同起始时间、频率资源的不同分配、或所需的EC重复次数。

[0079] 此外，在实施例中，在EC模式下在UE和eNB之间发送的每个RA消息的EC重复次数对于每个消息可以是相同的或可以不同。在实施例中，重复次数可以基于在EC模式下在UE和eNB之间发送的一个或多个此前的消息的重复次数而不同。例如，EC RAR消息110的重复次数可以是ECRA前导码108的重复次数的函数，其具有基于下行链路和上行链路定时时序的差异的调整。在另一个示例中，可以在EC RAR消息110中指示或可以以其他方式来指定EC调度传输112的重复次数。

[0080] 图4是示出根据各个实施例的用于在EC模式下实现用于寻址到UE的SI的不同修改

时段的帧结构的图示。

[0081] 在实施例中，图示400示出了可用于版本13低复杂度和延迟容限UE(例如，版本13LC UE和能够使用EC模式的版本13UE)的rSIB1。对于包含小区特定配置信息的该rSIB1，可以在除了N+k*M帧404的情况之外的情况下与传统SIB相同地来改变。在实施例中，实现rSIB1可具有减轻对传统网络行为的影响和限制的优势。

[0082] 在实施例中，第一rSIB(rSIB1 406)可具有与传动SIB相同的修改时段，并且还可以在N+M帧408处更新rSIB1 406。在实施例中，可以较不频繁地改变不包含小区特定配置信息的其他rSIB 410，例如，利用较长的修改时段来较不频繁改变。在实施例中，rSIB1 406和其他SIB 412可具有相同的修改时段，并且可以在N+k*M帧404的结尾处进行更新。

[0083] 图5示出了根据本公开的各个实施例的图1的UE 102的简化框图。如图5所示，UE 102包括处理器510、射频(RF)电路540、以及存储器520。处理器510可包括一个或多个单核或多核处理器，并且可包括通用处理器和专用处理器(例如，图形处理器、应用处理器、基带处理器等)的任意组合。根据各个实施例，处理器510(并且特别地，处理器510的基带芯片组)可包括配置逻辑。配置逻辑可操作来标识将在基于竞争的RA过程期间使用的初始EC等级，EC等级至少具有相关联功率等级、时间窗口、以及发送尝试的次数。配置逻辑可操作来基于所标识的EC等级向无线电接入网络(RAN)发送第一消息。配置逻辑可操作来确定来自RAN的响应于第一消息的第二消息是否在时间窗口内被接收。若第二消息在时间窗口内从eNB被接收，则配置逻辑可操作来解码接收到的第二消息。若第二消息未时间窗口内从eNB被接收，则配置逻辑可操作来向RAN重新发送第一消息，并且使用具有数值的传输计数器来跟踪第一消息已被发送的次数；以及基于第二消息是否在时间窗口内被接收的确定以及传输计数器和传输阈值的比较来输出EC RA过程未成功完成的指示。

[0084] RF电路540可以例如经由总线530耦合到处理器510，并且可用于发送或接收数据。

[0085] 存储器520可包括其上存储有指令的一个或多个非暂态计算机可读介质，并且指令当由处理器510执行时，可以使得UE 102执行上面结合处理器510所描述的操作。然而，这仅是说明性的而非限制的，本领域普通技术人员将理解软件、硬件、固件、或其任意组合中的替代实现方式。

[0086] 图6示出了根据各个实施例的可以是eNB电路、UE电路、或一些其他类型的电路的电子设备电路602。在实施例中，电子设备电路602可以是eNB、UE、或一些其他类型的电子设备、或可被合并在eNB、UE、或一些其他类型的电子设备中、或可以以其他方式是eNB、UE、或一些其他类型的电子设备的部分。在实施例中，电子设备电路602可包括耦合到控制电路606的无线电发送电路和接收电路。在实施例中，发送电路604和/或接收电路608可以是收发器电路的元件或模块，如图所示。电子设备电路602可以与一个或多个天线610的一个或多个天线元件相耦合。电子设备电路和/或电子设备电路的组件可被配置为执行与本公开在别处所描述的那些相类似的操作。

[0087] 在电子设备电路602是UE、或是UE的部分、或以其他方式被合并在UE中的实施例中，UE可能够根据EC模式来操作。控制电路606可标识EC模式。控制电路606还可根据EC模式来操作。发送电路604和/或接收电路608可以根据EC模式来发送和/或接收一个或多个信号或传输。

[0088] 在电子设备电路602是eNB、或是eNB的部分、或以其他方式被合并在eNB中的实施

例中，电子设备可能够操作用于SI的传输和更新的不同修改时段。控制电路606可以从多个修改时段中标识修改时段。发送电路604可以根据所标识的修改时段来发送SI的传输和/或更新。

[0089] 如本文使用的，术语“电路”可以指代下列项、可以是下列项的部分、或可包括下列项：专用集成电路(ASIC)、电子电路、执行一个或多个软件或固件程序的(共享的、专用的、或者群组的)处理器和/或(共享的、专用的、或者群组的)存储器、组合逻辑电路、和/或提供所描述的功能的其他适当的硬件组件。在一些实施例中，电子设备电路602可以在一个或多个软件或固件模块中实现，或与电路相关联的功能可以由一个或多个软件或固件模块来实现。

[0090] 本文描述的实施例可被实现在使用任意适当配置的硬件和/或软件的系统中。图7示出了针对一个实施例的示例系统702，包括至少如图所示彼此耦合的RF电路704、基带电路706、应用电路708、存储器/存储装置710、显示器712、相机714、传感器716、以及输入/输出(I/O)接口718。

[0091] 应用电路708可包括电路，例如但不限于，一个或多个单核或多核处理器。(一个或多个)处理器可包括通用处理器和专用处理器(例如，图形处理器、应用处理器等)的任意组合。处理器可以与存储器/存储装置相耦合，并且可被配置为执行存储在存储器/存储装置中的指令以支持在系统上运行的各种应用和/或操作系统。

[0092] 基带电路706可包括电路，例如但不限于，一个或多个单核或多核处理器。(一个或多个)处理器可包括基带处理器。基带电路706可以处理使得能够经由RF电路来与一个或多个无线电网络进行通信的各种无线电控制功能。无线电控制功能可包括但不限于：信号调制、编码、解码、无线电频移等。在一些实施例中，基带电路706可以提供与一个或多个无线电技术相兼容的通信。例如，在一些实施例中，基带电路706可以支持与演进通用陆地无线电接入网络(EUTRAN)和/或其他无线城域网(WMAN)、无线局域网(WLAN)、无线个域网(WPAN)进行通信。其中基带电路被配置为支持多于一个的无线协议的无线电通信的实施例可被称为多模基带电路。

[0093] 在各个实施例中，基带电路706可包括使用不被严格地视为处于基带频率中的信号进行操作的电路。例如，在一些实施例中，基带电路706可包括利用具有中频(在基带频率和射频之间)的信号进行操作的电路。

[0094] RF电路704可以使得能够通过非固态介质来使用经调制的电磁辐射与无线网络进行通信。在各个实施例中，RF电路704可包括交换机、滤波器、放大器等以促进与无线网络进行通信。

[0095] 在各个实施例中，RF电路704可包括使用不被严格地视为处于射频中的信号进行操作的电路。例如，在一些实施例中，RF电路704可包括利用具有中频(在基带频率和射频之间)的信号进行操作的电路。

[0096] 在各个实施例中，本文讨论或描述的发送电路604、控制电路606、和/或接收电路608可被整体或部分地体现在RF电路、基带电路、和/或应用电路中的一项或多项中。如本文使用的，术语“电路”可以指代下列项、可以是下列项的部分、或可包括下列项：ASIC、电子电路、执行一个或多个软件或固件程序的(共享的、专用的、或者群组的)处理器和/或(共享的、专用的、或者群组的)存储器、组合逻辑电路、和/或提供所描述的功能的其他适当的硬

件组件。在一些实施例中，电子设备电路可以在一个或多个软件或固件模块中实现，或与电路相关联的功能可以由一个或多个软件或固件模块来实现。

[0097] 在一些实施例中，可以在片上系统(SOC)上一起实现基带电路、应用电路、和/或存储器/存储装置的一些或全部组成组件。

[0098] 存储器/存储装置710可用于加载和存储例如用于系统的数据和/或指令。针对一个实施例的存储器/存储装置710可包括适当的易失性存储器(例如，动态随机存取存储器(DRAM))和/或非易失性存储器(例如，闪速存储器)的任意组合。

[0099] 在各个实施例中，I/O接口718可包括被设计为使得用户能够与系统进行交互的一个或多个用户接口和/或被设计为使得外围组件能够与系统进行交互的外围组件接口。用户接口可包括但不限于：物理键盘或小键盘、触摸板、扬声器、麦克风等。外围组件接口可包括但不限于：非易失性存储器端口、通用串行总线(USB)端口、音频插孔、以及电源接口。

[0100] 在各个实施例中，传感器716可包括一个或多个传感设备以确定与系统有关的环境条件和/或位置信息。在一些实施例中，传感器716可包括但不限于：陀螺传感器、加速度计、接近度传感器、环境光传感器、以及定位单元。定位单元还可以是基带电路706a和/或RF电路704的部分或可以与基带电路706a和/或RF电路704进行交互，以与定位网络的组件(例如，全球定位系统(GPS)卫星)进行通信。

[0101] 在各个实施例中，显示器712可包括液晶显示器、触摸屏显示器等。

[0102] 在各个实施例中，系统702可以是移动计算设备，例如但不限于：膝上型计算设备、平板计算设备、上网本计算机、超级本计算机，智能电话等。在各个实施例中，系统可以具有更多或更少的组件、和/或不同的架构。

[0103] 在各个实施例中，系统702可以是移动计算设备，例如但不限于：膝上型计算设备、平板计算设备、上网本计算机、超级本计算机，智能电话等。在各个实施例中，系统可以具有更多或更少的组件、和/或不同的架构。例如，在一些实施例中，RF电路704和/或基带电路706可被体现在通信电路(未示出)中。通信电路可包括诸如但不限于一个或多个单核或多核处理器之类的电路，以及提供适于通信在其上将发生的适当通信接口的信号处理技术(例如，编码、调制、滤波、转换、放大等)的逻辑电路。通信电路可以通过有线、光、或无线通信介质进行通信。在其中系统被配置为用于无线通信的实施例中，通信电路可包括RF电路和/或基带电路，以提供与一个或多个无线电技术兼容的通信。例如，在一些实施例中，通信电路可以支持与演进通用陆地无线电接入网络(EUTRAN)和/或其他无线城域网(WMAN)、无线局域网(WLAN)、无线个域网(WPAN)进行通信。

[0104] 本文的技术的实施例可被描述为与3GPP长期演进(LTE)或LTE高级(LTE-A)标准相关。例如，诸如eNB、移动性管理实体(MME)、UE等之类的术语或实体可被视为LTE相关术语或实体。然而，在其他实施例中，技术可用于其他无线技术或可以与其他无线技术相关，例如，电气和电子工程师协会(IEEE)802.16无线技术(WiMax)、IEEE 802.11无线技术(WiFi)、各种其他无线技术，例如，全球移动通信系统(GSM)、增强型数据速率GSM演进(EDGE)、GSM EDGE无线电接入网(GERAN)、通用移动电信系统(UMTS)、UMTS陆地无线电接入网(UTRAN)、或已被开发或将要开发的其他2G、3G、4G、5G等技术。在使用诸如eNB、MME、UE等之类的LTE相关术语的那些实施例中，一个或多个实体或组件可被认为等同于或大致等同于一个或多个基于LTE的术语或实体。

[0105] 一些非限制性示例可包括下列示例：

[0106] 示例1可包括一种能够根据增强型覆盖(EC)模式进行操作的用户设备(UE)，UE包括：控制电路，用于标识EC模式并且根据EC模式进行操作；以及与控制电路相耦合的发送和/或接收电路，该发送和/或接收电路根据EC模式来发送和/或接收一个或多个信号或传输。

[0107] 示例2可包括示例1或本文的一些其他示例的主题，其中，控制电路、发送电路、和/或接收电路还发送、接收、和/或组合消息的多个重复以增强其覆盖。

[0108] 示例3可包括示例1或本文的一些其他示例的主题，其中，UE在常规系统带宽(BW)以及整个系统BW内的减少的BW上操作。

[0109] 示例4可包括示例1或本文的一些其他示例的主题，其中，UE利用延迟容限来操作机器类型通信(MTC)。

[0110] 示例5可包括示例1或本文的一些其他示例的主题，其中，UE可以基于期望的覆盖增强来触发一个或多个不同EC等级的使用。

[0111] 示例6可包括示例1或本文的一些其他示例的主题，其中，UE可以使用EC模式用于随机访问(RA)过程。

[0112] 示例7可包括示例6或本文的一些其他示例的主题，其中，UE可以使用EC模式用于基于竞争的RA过程。

[0113] 示例8可包括示例6或本文的一些其他示例的主题，其中，将EC模式用于RA过程的触发事件可以与期望EC等级相关或可以基于期望EC等级。

[0114] 示例9可包括示例6或本文的一些其他示例的主题，其中，将EC模式用于RA过程的触发可以基于常规(传统)RA过程的失败或可以与常规(传统)RA过程的失败相关。

[0115] 示例10可包括示例6或本文的一些其他示例的主题，其中，将EC模式用于RA过程的触发可以与达到某个阈值、标准、或条件相关或可以基于达到某个阈值、标准、或条件，例如，最大次数的前导码传输、最大前导码传输功率、或用于测量的参考信号功率/质量(RSRP/RSRQ)的阈值。

[0116] 示例11可包括示例6或本文的一些其他示例的主题，其中，UE可以根据EC等级使用不同的RA配置信息。

[0117] 示例12可包括示例6或本文的一些其他示例的主题，其中，控制电路可由于RA消息2(RAR)的接收的失败而触发EC模式的使用。

[0118] 示例13可包括示例6或本文的一些其他示例的主题，其中，UE可由于RA消息4(例如，RRC连接设置)的接收的失败而触发EC模式的使用。

[0119] 示例14可包括示例6或本文的一些其他示例的主题，其中，UE可以使用增强型覆盖随机接入响应(EC RAR)窗口来监测响应于RA消息1(RA前导码)发送的RA消息2(RAR)。

[0120] 示例15可包括示例14或本文的一些其他示例的主题，其中，ECRAR机会可以在EC RAR窗口内进行定义。

[0121] 示例16可包括示例14或本文的一些其他示例的主题，其中，RA消息2的重复可以利用已知模式进行调度，即在EC RAR机会内进行预定义或预配置。

[0122] 示例17可包括示例14或本文的一些其他示例的主题，其中，RA消息2的重复可不被包括在EC RAR机会内的所有子帧中。

[0123] 示例18可包括示例14或本文的一些其他示例的主题，其中，在EC RAR机会内，运载EC RA控制标识符(即EC RA无线电网络临时标识符(RNTI))的信息以及EC RA消息2(RAR)被发送。

[0124] 示例19可包括实施例18或本文的一些其他示例的主题，其中，若未接收到包括寻址到UE的EC RA RNTI的控制信息，则UE可不需要接收EC RA消息2。

[0125] 示例20可包括一种能够操作用于系统信息(SI)的传输和更新的不同修改时段的演进节点B(eNB)，该eNB包括：控制电路，用于从多个修改时段中标识修改时段；以及发送电路，用于根据所标识的修改时段来发送SI的传输和/或更新。

[0126] 示例21可包括示例20或本文的一些其他示例的主题，其中，eNB可能够在常规模式和EC模式下操作小区。

[0127] 示例22可包括示例20或本文的一些其他示例的主题，其中，eNB可以针对特定于常规模式和EC模式的系统信息的传输和更新来定义不同的修改时段。

[0128] 示例23可包括示例20或本文的一些其他示例的主题，其中，eNB可以针对特定于具有与常规(传统)UE相同的值的小区配置的IS参数来定义修改时段。

[0129] 示例24可包括一种方法，包括由示例1-19或本文的一些其他示例中的UE确定，基于某些阈值、标准、配置、和/或要求来在传统RA过程和EC RA过程之间进行选择。

[0130] 示例25可包括示例24或本文的一些其他示例的主题，其中，阈值、标准、配置、和/或要求在UE中被预配置，或由网络使用单播和/或广播信号发送到UE。

[0131] 示例26可包括示例24或本文的一些其他示例的主题，包括RA消息1(前导码)的重复以支持要求EC的UE。

[0132] 示例27可包括示例26或本文的一些其他示例的主题，还包括后续RA响应和消息的相应重复以支持要求EC的UE。

[0133] 示例28可包括一种用于示例20-23或本文的一些其他示例中的eNB的方法，使用专用、单播、或广播信令来通知示例1-19的UE用于EC UE的某些阈值、标准、配置、和/或要求。

[0134] 示例29可包括一种装置，包括用于执行在示例24-28中的任意示例中描述的或与示例24-28中的任意示例相关的方法、或本文描述的任意其他示例、方法、过程中的一个或多个元素的装置。

[0135] 示例30可包括具有指令的一个或多个非暂态计算机可读介质，当指令由电子设备的一个或多个处理器执行指令时，使得电子设备执行在示例24-28中的任意示例中描述的或与示例24-28中的任意示例相关的方法、或本文描述的任意其他示例、方法、过程中的一个或多个元素。

[0136] 示例31可包括一种装置，包括用于执行在示例24-28中的任意示例中描述的或与示例24-28中的任意示例相关的方法、或本文描述的任意其他示例、方法、过程中的一个或多个元素的控制电路、发送电路、和/或接收电路。

[0137] 示例32可包括如本文示出和描述的在无线网络中进行通信的方法。

[0138] 示例33可包括如本文示出和描述的用于提供无线通信的系统。

[0139] 示例34可包括如本文示出和描述的用于提供无线通信的设备。

[0140] 示例35是一种将在用户设备(UE)中采用的装置，该装置包括：一个或多个处理器；耦合到该一个或多个处理器的存储器，其上具有指令，指令当被执行时，使得处理器：标识

在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的初始增强型覆盖(EC)等级，EC等级至少具有相关联的功率等级、时间窗口、以及发送尝试的数目；基于所标识的EC等级向无线电接入网(RAN)发送第一消息；确定来自RAN的响应于第一消息的第二消息是否在时间窗口内被接收；若第二消息在时间窗口内被从eNB接收，则解码接收到的第二消息；以及若第二消息不是在时间窗口内被从eNB接收，则向RAN重新发送第一消息。

[0141] 示例36可包括示例35或本文的一些其他示例的主题，其中，RAN包括至少一个增强型节点B(eNB)。

[0142] 示例37可包括示例35或本文的一些其他示例的主题，其中，向RAN重新发送第一消息还包括：使用具有数值的传输计数器来跟踪第一消息已被发送的次数；以及基于第二消息是否在时间窗口内被接收的确定以及传输计数器和传输阈值的比较来输出RA EC过程未成功完成的指示。

[0143] 示例38可包括示例35或本文的一些其他示例的主题，其中，第一消息是随机接入(RA)前导码，并且第二消息是随机接入响应(RAR)。

[0144] 示例39可包括示例35或本文的一些其他示例的主题，其中，初始EC等级在UE中被配置或在系统信息块(SIB)中被接收。

[0145] 示例40可包括示例39或本文的一些其他示例的主题，其中，SIB在较高带宽或在减少的带宽中被接收。

[0146] 示例41可包括示例35或本文的一些其他示例的主题，其中，发送第一消息的功率等级基于下列项中的一项或多项：传输计数器的值、或EC等级的值。

[0147] 示例42可包括示例35或本文的一些其他示例的主题，其中，重新发送第一消息还包括功率提升。

[0148] 示例43可包括示例42或本文的一些其他示例的主题，其中，功率提升包括将功率增加到与EC等级相关联的最大功率等级。

[0149] 示例44可包括示例35或本文的一些其他示例的主题，其中，时间窗口至少取决于在EC RAR窗口内定义的EC RAR机会的数目和/或用于EC等级的发送尝试的数目。

[0150] 示例45可包括示例35或本文的一些其他示例的主题，其中，向RAN重新发送第一消息还包括：在重新发送第一消息之前包括延迟时间，该延迟是至少EC等级的一个函数。

[0151] 示例46可包括示例35-45中的任一项或本文的一些其它示例的主题，其中，UE可以能够在常规覆盖模式和EC模式下操作。

[0152] 示例47是一种将在演进节点B(eNB)中采用的装置，该装置包括：一个或多个处理器；耦合到该一个或多个处理器的存储器，其上具有指令，指令当被执行时，使得处理器：确定在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的增强型覆盖(EC)等级，在系统信息块(SIB)中向位于无线电小区中的用户设备(UE)发送对所确定的EC等级的指示；接收来自UE的RA前导码，响应于该RA前导码，发送随机接入响应(RAR)消息。

[0153] 示例48可包括示例47或本文的一些其他示例的主题，其中，在SIB中发送对所确定的EC等级的指示还包括在1.4兆赫或200千赫的减少的带宽中进行发送。

[0154] 示例49可包括示例47或本文的一些其他示例的主题，其中，eNB可以在常规覆盖模式和EC模式下操作无线电小区。

[0155] 示例50是一种将在用户设备(UE)中采用的装置，该装置包括：逻辑电路，标识增强

型覆盖(EC)等级;发送电路,基于所标识的EC等级向无线电接入网(RAN)发送随机接入(RA)前导码;逻辑电路,标识具有多个子帧的EC随机接入响应(RAR)窗口区域。

[0156] 示例51可包括示例50或本文的一些其他示例的主题,还包括:逻辑电路,标识具有多个子帧的EC随机接入响应(RAR)窗口区域,该EC RAR窗口区域包括一个或多个EC RAR机会,每个EC RAR机会是连续的子帧组,第一EC RAR机会在与RAR窗口区域的开始相同的子帧处开始,并且在发送RA前导码之后开始K个子帧。

[0157] 示例52可包括示例51或本文的一些其他示例的主题,还包括接收电路:从RAN接收第一EC RAR机会中的候选RAR;直到候选RAR能够被解码为止,从RAN接收来自EC RAR机会的候选RAR;并且若候选RAR能够被解码,则向RAN发送RRC连接请求。

[0158] 示例53可包括示例50或本文的一些其他示例的主题,其中,EC RAR窗口区域取决于下列值:本说明书中定义的值、作为SI消息的部分被广播的值、与EC等级相关联的值、或与包含RAR消息的EC RAR机会中的子帧的数目相关联的值。

[0159] 示例54是一种演进节点B(eNB),包括:控制电路,该控制电路当处于减少带宽模式时,从多个系统信息(SI)修改时段中标识与无线电小区配置相关联的SI修改时段;以及与该控制电路相耦合的发送电路,该发送电路根据所标识的修改时段来发送SI消息。

[0160] 示例55可包括示例54或本文的一些其他示例的主题,其中,控制电路和发送电路在常规覆盖模式和/或EC模式下操作。

[0161] 示例56可包括示例54或本文的一些其他示例的主题,其中,控制电路还定义用于与具有与常规覆盖用户设备(UE)相同的值的无线电小区配置相关联的SI参数的修改时段。

[0162] 示例57是包括指令的一个或多个非暂态计算机可读介质,响应于指令由计算设备执行,使得用户设备(UE):标识在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的初始增强型覆盖(EC)等级,EC等级至少具有相关联的功率等级、时间窗口、以及发送尝试的数目;基于所标识的EC等级向无线电接入网(RAN)发送第一消息;确定来自RAN的响应于第一消息的第二消息是否在时间窗口内被接收;若第二消息在时间窗口内被从eNB接收,则解码接收到的第二消息;以及若第二消息不是在时间窗口内被从eNB接收,则向RAN重新发送第一消息。

[0163] 示例58可包括示例57或本文的一些其他示例的主题,其中,RAN包括至少一个增强型节点B(eNB)。

[0164] 示例59可包括示例57或本文的一些其他示例的主题,其中,向RAN重新发送第一消息还包括:使用具有数值的传输计数器来跟踪第一消息已被发送的次数;以及基于第二消息是否在时间窗口内被接收的确定以及传输计数器和传输阈值的比较来输出EC RA过程未成功完成的指示。

[0165] 示例60可包括示例57或本文的一些其他示例的主题,其中,第一消息是随机接入(RA)前导码,并且第二消息是随机接入响应(RAR)。

[0166] 示例61可包括示例57或本文的一些其他示例的主题,其中,初始EC等级在UE中被配置或在系统信息块(SIB)中被接收。

[0167] 示例62可包括示例61或本文的一些其他示例的主题,其中,SIB在较高带宽或在减少的带宽中被接收。

[0168] 示例63可包括示例57或本文的一些其他示例的主题,其中,发送第一消息的功率

等级基于下列项中的一项或多项:传输计数器的值、或EC等级的值。

[0169] 示例64可包括示例57或本文的一些其他示例的主题,其中,重新发送第一消息还包括功率提升。

[0170] 示例65可包括示例64或本文的一些其他示例的主题,其中,功率提升包括将功率增加到与EC等级相关联的最大功率等级。

[0171] 示例66可包括示例57或本文的一些其他示例的主题,其中,时间窗口至少取决于在EC RAR窗口内定义的多个EC RAR机会和/或用于EC等级的发送尝试的数目。

[0172] 示例67可包括示例57或本文的一些其他示例的主题,其中,向RAN重新发送第一消息还包括:在重新发送第一消息之前包括延迟时间,该延迟是至少EC等级的一个函数。

[0173] 示例68可包括示例57-67中的任一项或本文的一些其它示例的主题,其中,UE可以能够在常规覆盖模式和EC模式下操作。

[0174] 示例69是包括指令的一个或多个非暂态计算机可读介质,响应于指令由计算设备执行,使得增强型节点B(eNB):确定在基于竞争的随机访问(RA)过程期间将在无线电小区中使用的增强型覆盖(EC)等级,在系统信息块(SIB)中向位于无线电小区中的用户设备(UE)发送对所确定的EC等级的指示;接收来自UE的RA前导码,响应于该RA前导码,发送随机接入响应(RAR)。

[0175] 示例70可包括示例69或本文的一些其他示例的主题,其中,在SIB中发送对所确定的EC等级的指示还包括在较高带宽或减少的带宽中进行发送。

[0176] 示例71可包括示例69或本文的一些其他示例的主题,其中,eNB可以在常规覆盖模式和EC模式下操作无线电小区。

[0177] 已经根据对计算机存储器内的数据位的操作的算法和符号表示呈现了前述具体实施例方式的一些部分。这些算法描述和表示是数据处理领域的技术人员所使用的最为有效地将其工作的实质传递给本领域其他技术人员的方式。在这里并且一般情况下,算法被看作是产生想要的结果的自相一致的操作序列。这些操作是需要对物理量进行物理处理的操作。

[0178] 然而,应记住的是,所有这些及类似的术语都将与适当的物理量相关联,并且仅是应用于这些量的方便标签。如从上面的讨论可见的,除非另有具体说明,否则应当认识到,整个说明书中,使用诸如在所附权利要求中所给出的那些术语所进行的讨论指代计算机系统或类似的电子计算设备的动作和处理,该计算机系统或类似的电子计算设备将在该计算机系统的寄存器和存储器内被表示为物理(电子)量的数据操纵或转换为在该计算机系统存储器或寄存器或其他这样的信息存储、传输或显示设备内被类似地表示为物理量的其他数据。

[0179] 本公开的实施例还涉及用于执行本文的操作的装置。这样的计算机程序被存储在非暂态计算机可读介质中。机器可读介质包括用于以机器(例如,计算机)可读的形式存储信息的任意机制。例如,机器可读(例如,计算机可读)介质包括机器(例如,计算机)可读存储介质(例如,只读存储器(ROM)、随机存取存储器(RAM)、磁盘存储介质、光存储介质、闪速存储器设备)。

[0180] 上述附图中所描绘的处理或方法可以由处理逻辑来执行,该处理逻辑包括硬件(例如,电路、专用逻辑等)、软件(例如,体现在非暂态计算机可读介质上的软件)、或二者的

组合。尽管上面根据一些顺序操作描述了这些处理和方法，但是应理解的是，所描述的操作中的一些操作可以以不同的顺序被执行。此外，一些操作可以并行地而非顺序地被执行。

[0181] 本公开的实施例未参考任何具体的编程语言进行描述。将理解的是，各种编程语言可被用于实现如本文描述的本公开的实施例的教导。在上述说明书中，已参考本公开的实施例的具体示例性实施例对这些实施例进行了描述。显然，在不脱离所附权利要求中所阐述的本公开的广义精神和范围的情况下，可对其做出各种修改。因此，说明书及附图将被视为说明性的而非限制性的。

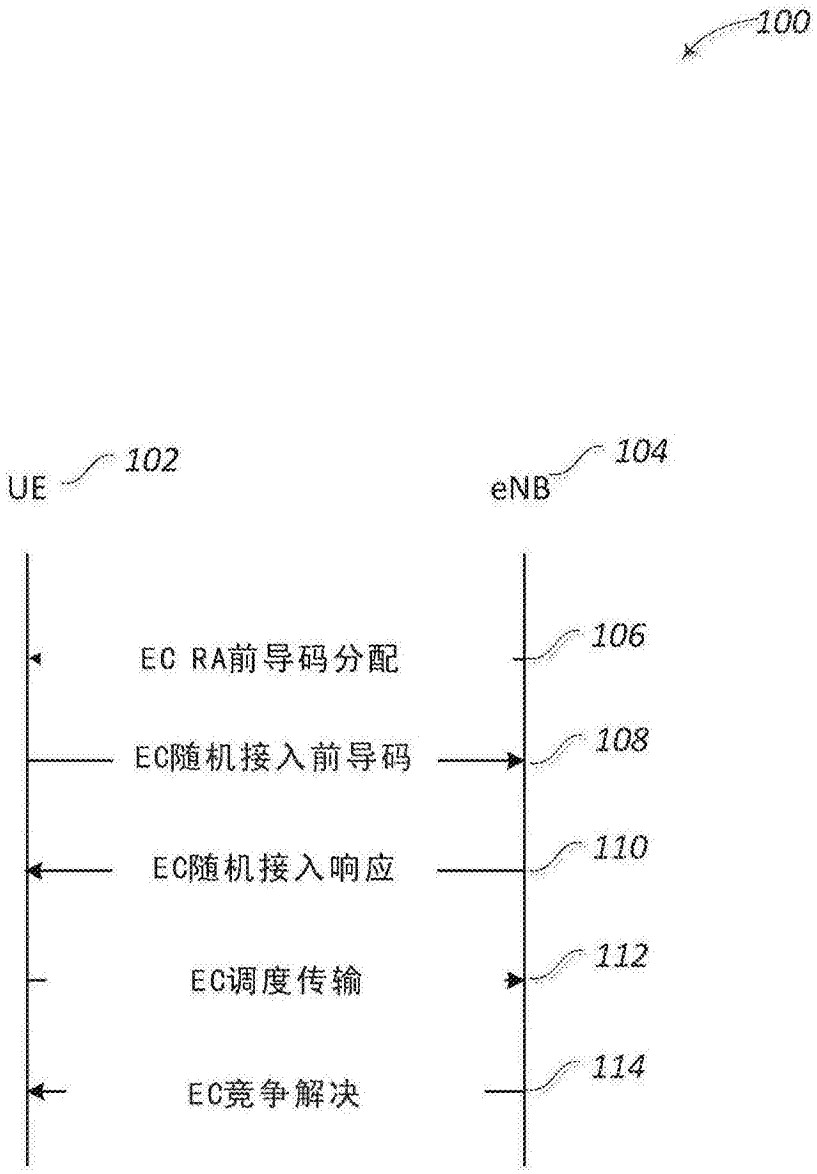

100
UE
102
eNB
104
EC RA前导码分配
106
EC随机接入前导码
108
EC随机接入响应
110
EC调度传输
112
EC竞争解决
114

图1

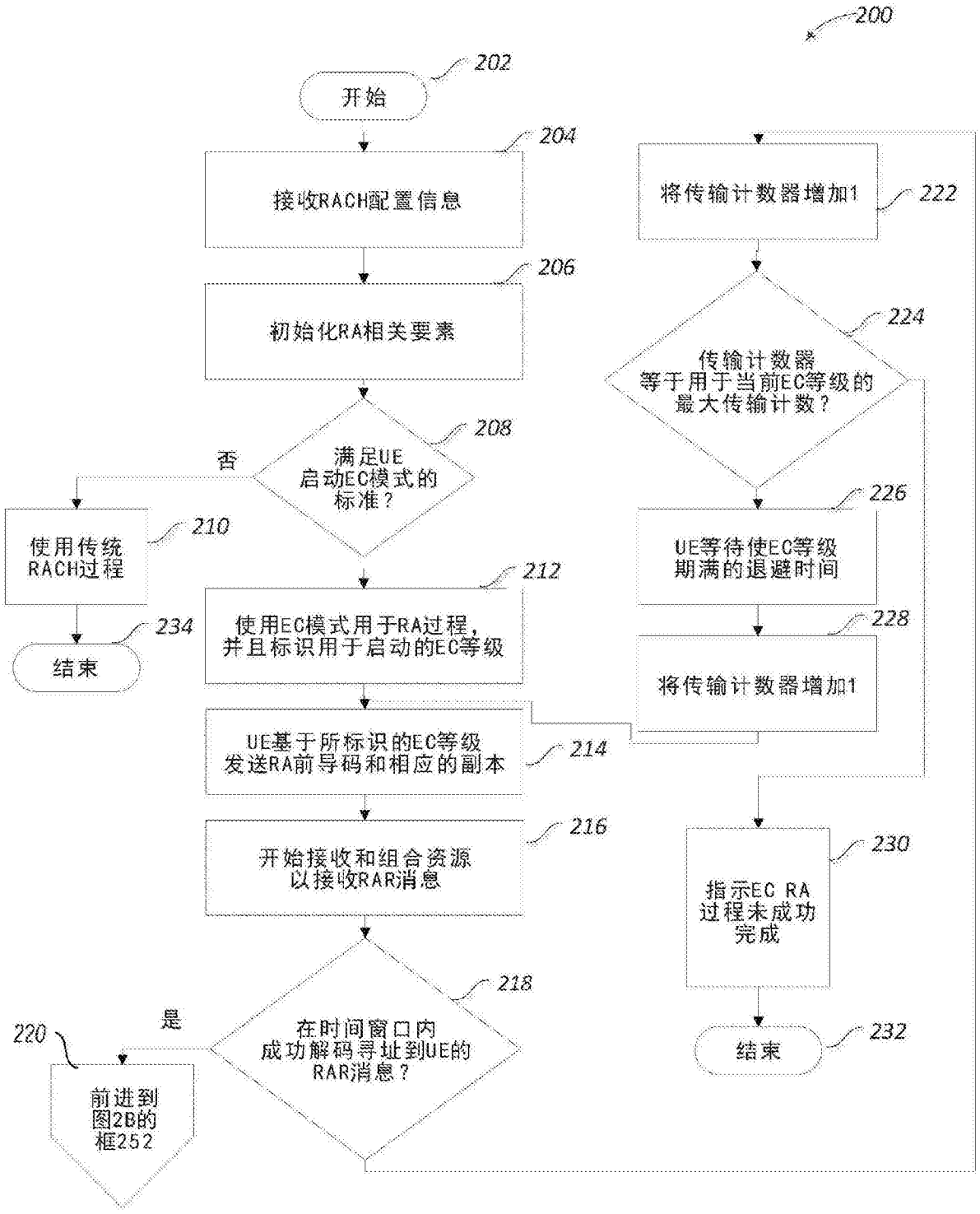

200
202
开始
204
接收RACH配置信息
206
初始化RA相关要素
208
满足UE
启动EC模式的
标准？
否
210
使用传统
RACH过程
234
结束
212
使用EC模式用于RA过程，
并且标识用于启动的EC等级
214
UE基于所标识的EC等级
发送RA前导码和相应的副本
216
开始接收和组合资源
以接收RAR消息
218
在时间窗口内
成功解码寻址到UE的
RAR消息？
是
220
前进到
图2B的
框252
222
将传输计数器增加1
224
传输计数器
等于用于当前EC等级的
最大传输计数？
226
UE等待使EC等级
期满的退避时间
228
将传输计数器增加1
230
指示EC RA
过程未成功
完成
232
结束

图2A

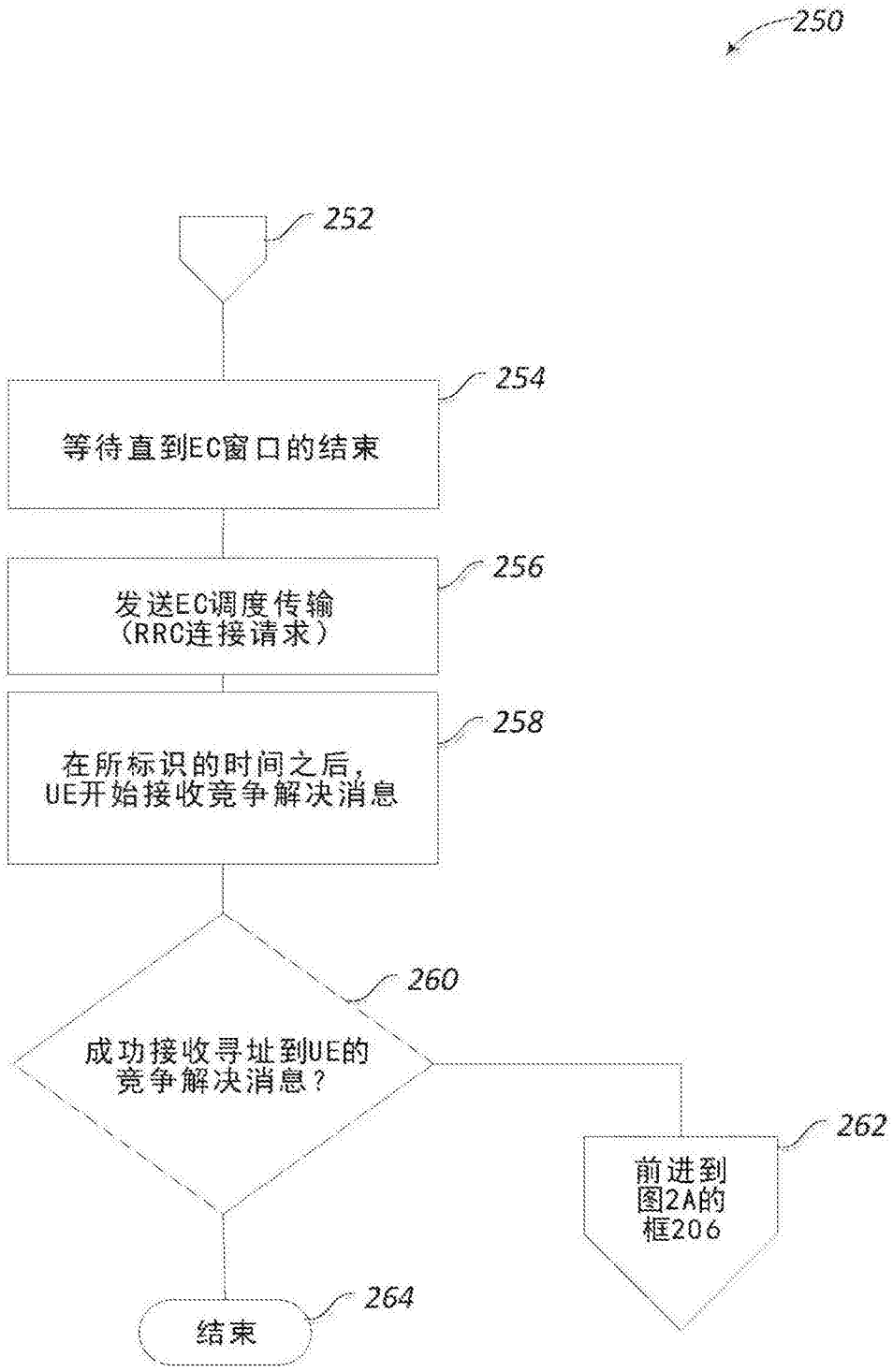

250
252
254
等待直到EC窗口的结束
256
发送EC调度传输
(RRC连接请求)
258
在所标识的时间之后,
UE开始接收竞争解决消息
260
成功接收寻址到UE的
竞争解决消息?
262
前进到
图2A的
框206
264
结束

图2B

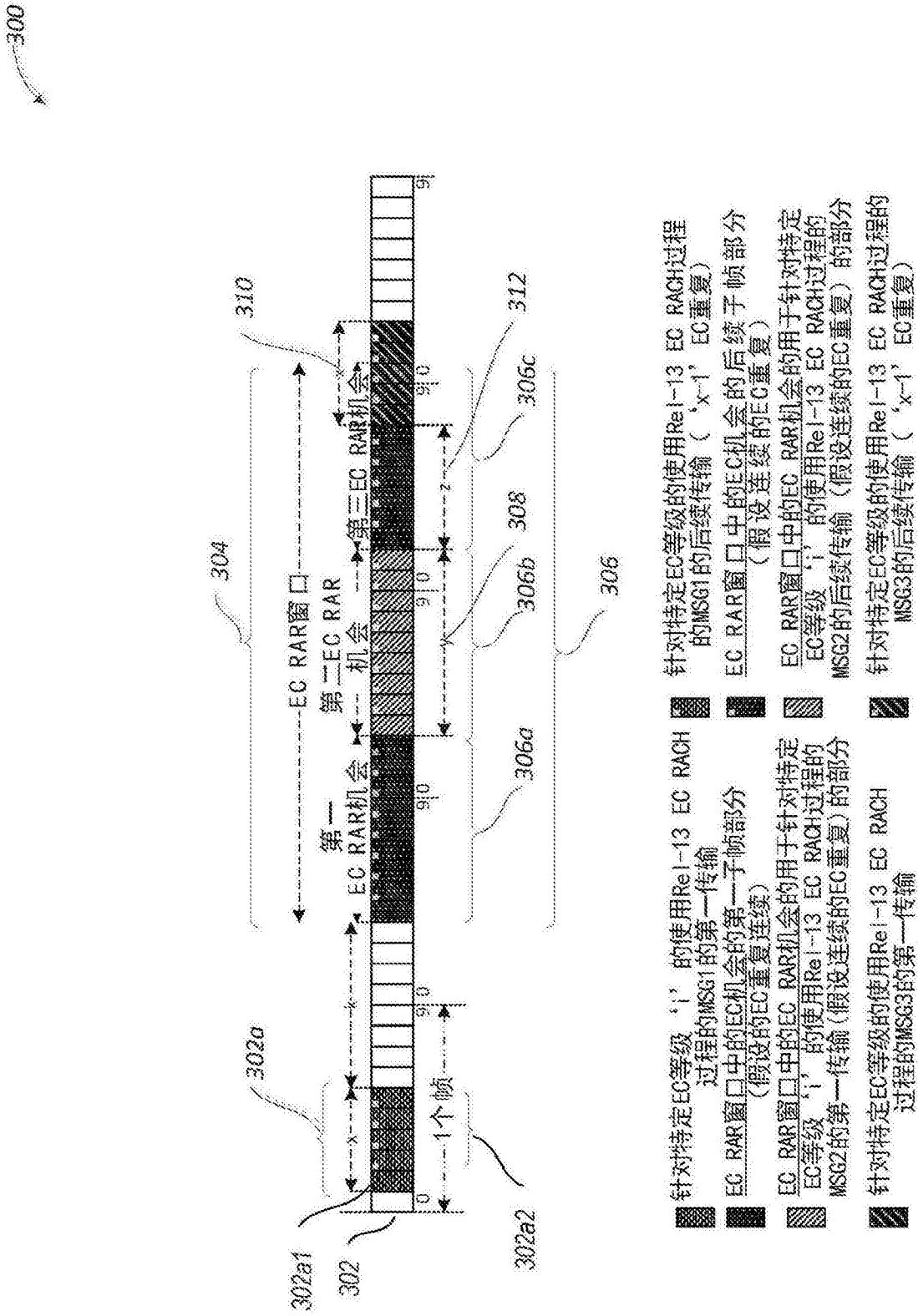

300
302a
302a1
302
302a2
1个帧
第一EC RAR机会
第二EC RAR机会
第三EC RAR机会
EC RAR窗口
304
306
306a
306b
306c
308
310
312
针对特定EC等级‘i’的使用Rel-13 EC RACH过程的MSG1的第一传输
EC RAR窗口中的EC机会的第一子帧部分（假设的EC重复连续）
EC RAR窗口中的EC RAR机会的用于针对特定EC等级‘i’的使用Rel-13 EC RACH过程的MSG2的第一传输（假设连续的EC重复）的部分
针对特定EC等级的使用Rel-13 EC RACH过程的MSG3的第一传输
针对特定EC等级的使用Rel-13 EC RACH过程的MSG1的后续传输（‘x-1’ EC重复）
EC RAR窗口中的EC机会的后续子帧部分（假设连续的EC重复）
EC RAR窗口中的EC RAR机会的用于针对特定EC等级‘i’的使用Rel-13 EC RACH过程的MSG2的后续传输（假设连续的EC重复）的部分
针对特定EC等级的使用Rel-13 EC RACH过程的MSG3的后续传输（‘x-1’ EC重复）

图3A

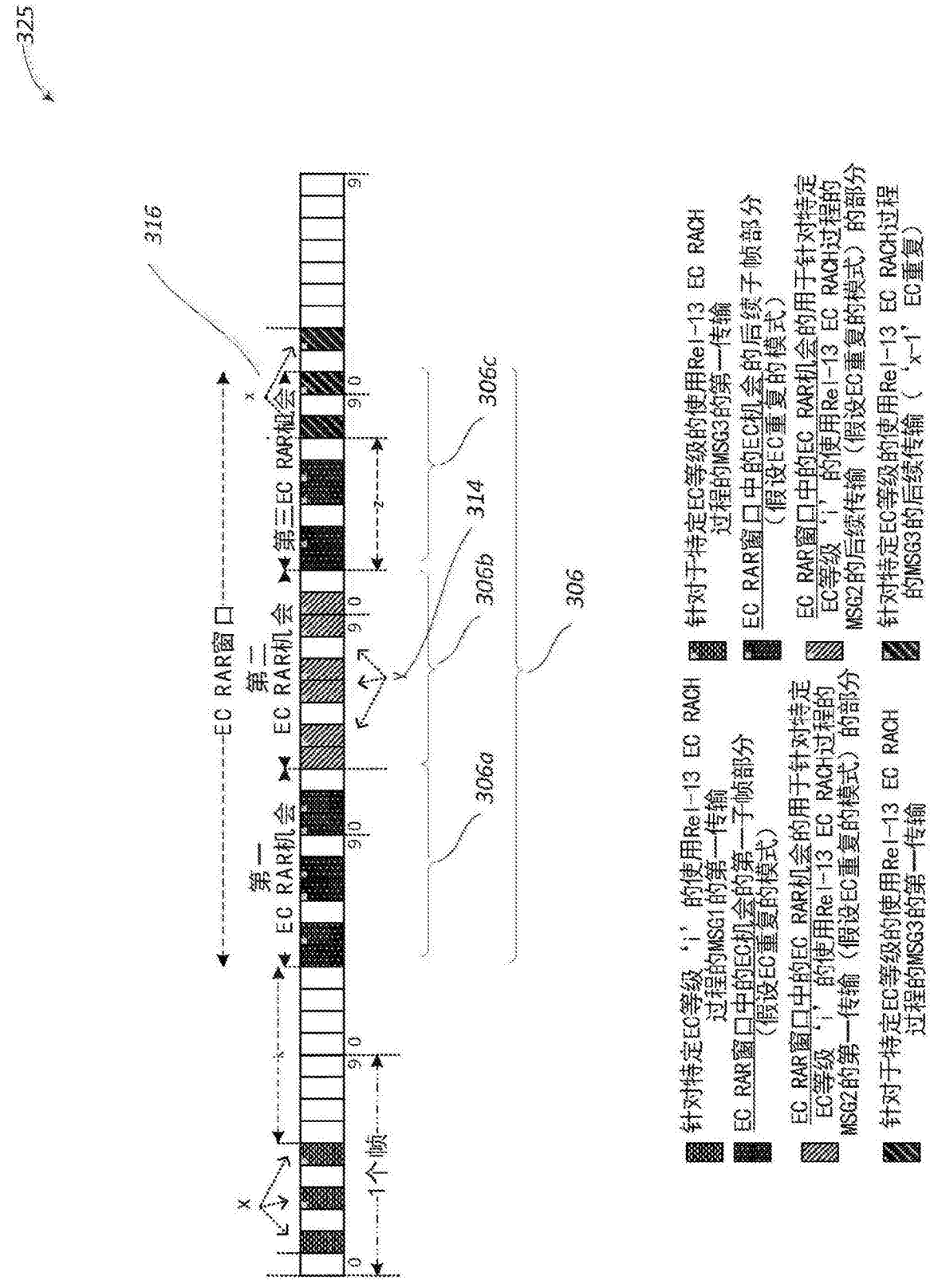

325
316
EC RAR窗口
第一 EC RAR机会
第二 EC RAR机会
第三EC RAR机会
1个帧
306a
306b
306c
314
306
针对特定EC等级‘1’的使用Rel-13 EC RACH过程的MSG1的第一传输
EC RAR窗口中的EC机会的第一子帧部分（假设EC重复的模式）
EC RAR窗口中的EC RAR机会的用于针对特定EC等级‘1’的使用Rel-13 EC RACH过程的MSG2的第一传输（假设EC重复的模式）的部分
针对特定EC等级的使用Rel-13 EC RACH过程的MSG3的第一传输
针对特定EC等级的使用Rel-13 EC RACH过程的MSG3的后续传输
EC RAR窗口中的EC机会的后续子帧部分（假设EC重复的模式）
EC RAR窗口中的EC RAR机会的用于针对特定EC等级‘1’的使用Rel-13 EC RACH过程的MSG2的后续传输（假设EC重复的模式）的部分
针对特定EC等级的使用Rel-13 EC RACH过程的MSG3的后续传输（‘x-1’ EC重复）

图3B

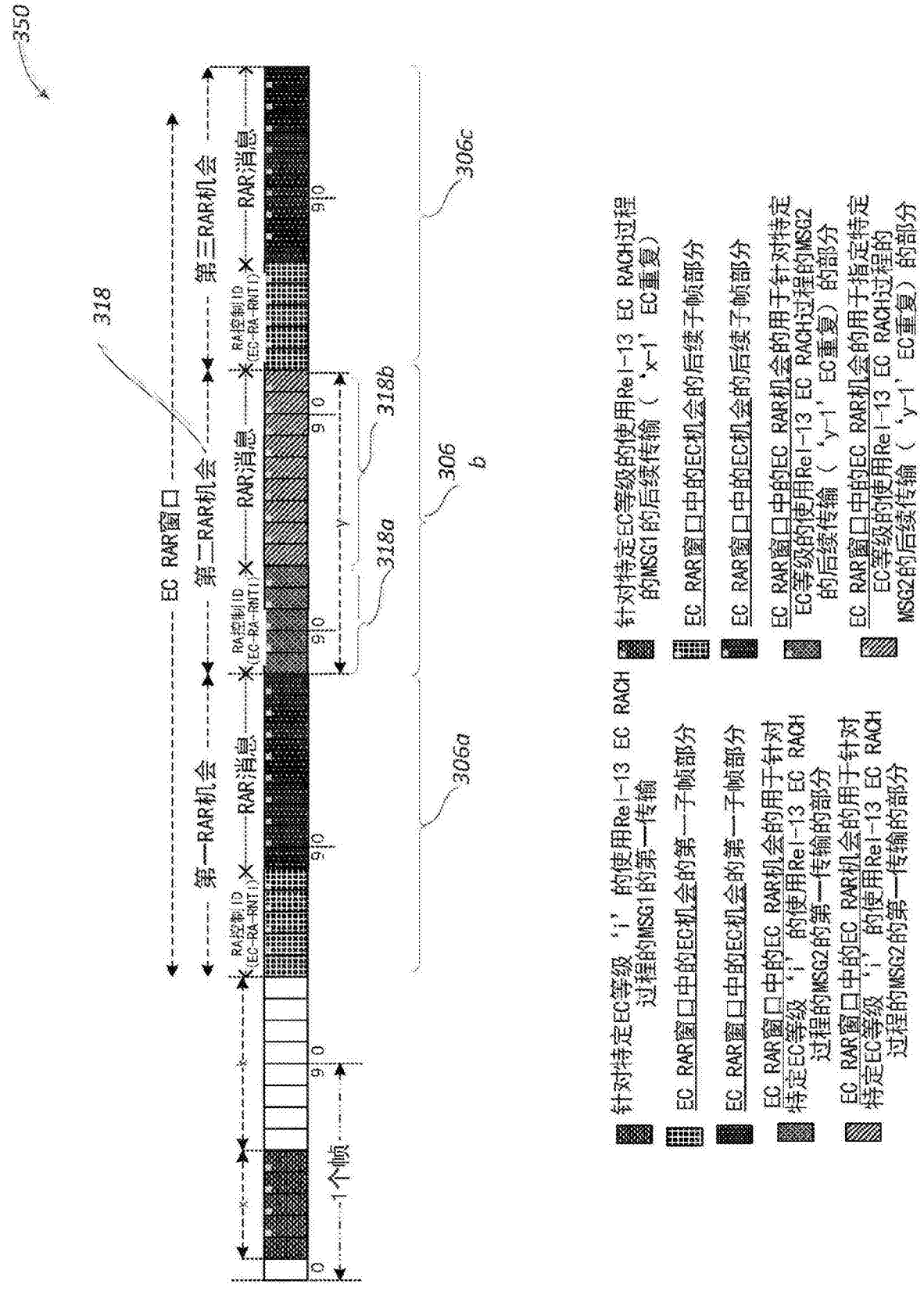

350
EC RAR窗口
第一RAR机会
第二RAR机会
第三RAR机会
318
RA控制ID (EC-RA-RNTI)
RAR消息
0
1个帧
306a
306b
306c
306
b
针对特定EC等级的使用Rel-13 EC RACH过程的MSG1的后续传输（'x-1' EC重复）
EC RAR窗口中的EC机会的后续子帧部分
EC RAR窗口中的EC机会的后续子帧部分
EC RAR窗口中的EC RAR机会的用于针对特定EC等级的使用Rel-13 EC RACH过程的MSG2的后续传输（'y-1' EC重复）的部分
EC RAR窗口中的EC RAR机会的用于指定特定EC等级的使用Rel-13 EC RACH过程的MSG2的后续传输（'y-1' EC重复）的部分
针对特定EC等级'1'的使用Rel-13 EC RACH过程的MSG1的第一传输
EC RAR窗口中的EC机会的第一子帧部分
EC RAR窗口中的EC机会的第一子帧部分
EC RAR窗口中的EC RAR机会的用于针对特定EC等级'1'的使用Rel-13 EC RACH过程的MSG2的第一传输的部分
EC RAR窗口中的EC RAR机会的用于针对特定EC等级'1'的使用Rel-13 EC RACH过程的MSG2的第一传输的部分

图3C

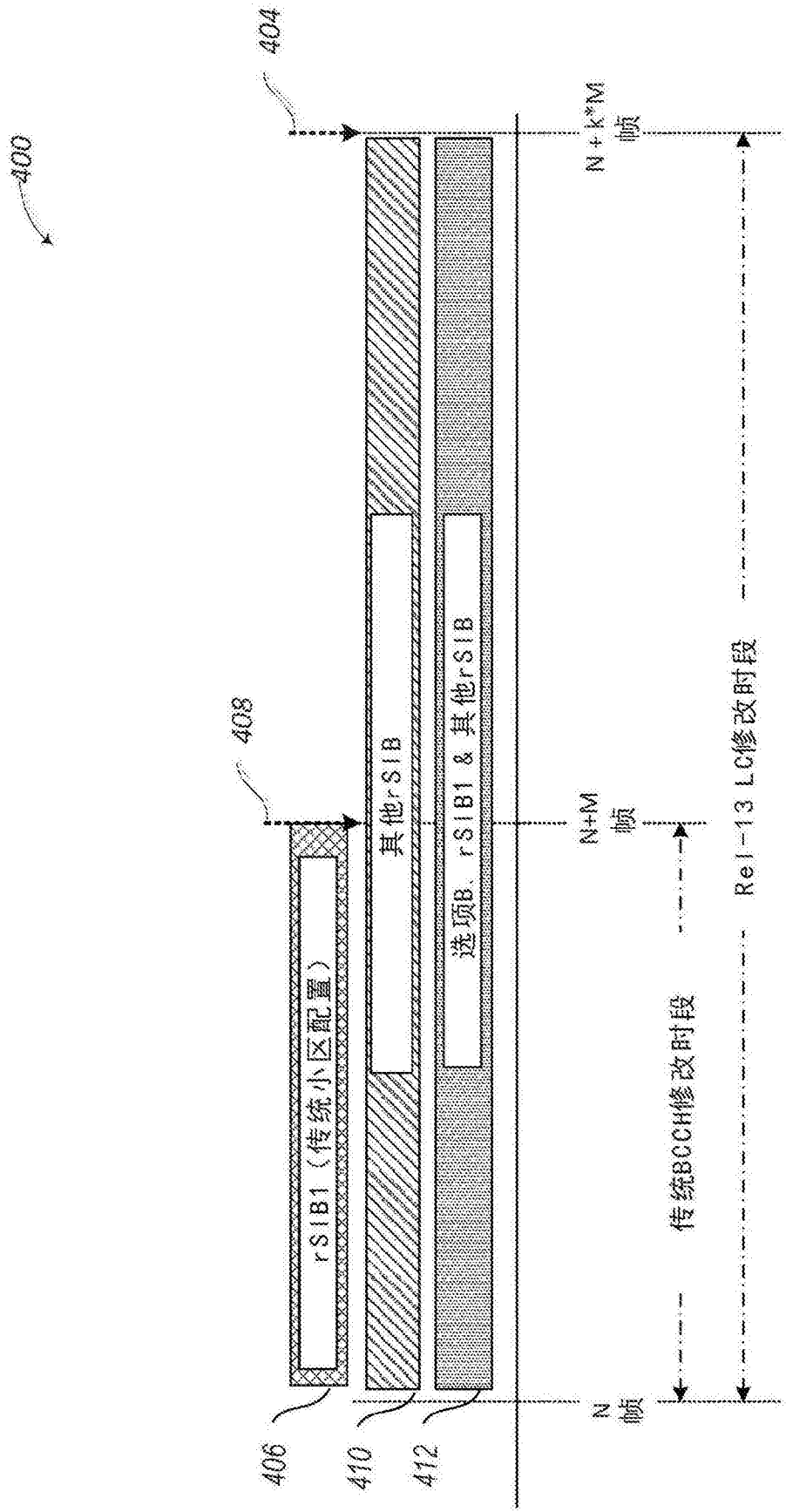

400
404
N + k*M 帧
408
其他rSIB
选项B、rSIB1 & 其他rSIB
rSIB1（传统小区配置）
N+M 帧
N 帧
传统BCCH修改时段
Rel-13 LC修改时段
406
410
412

图4

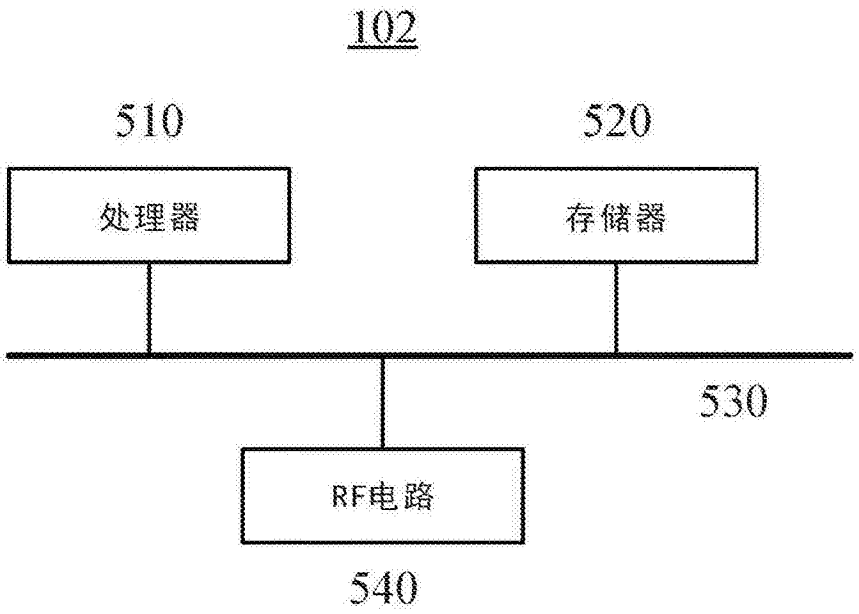

102
510
520
处理器
存储器
530
RF电路
540

图5

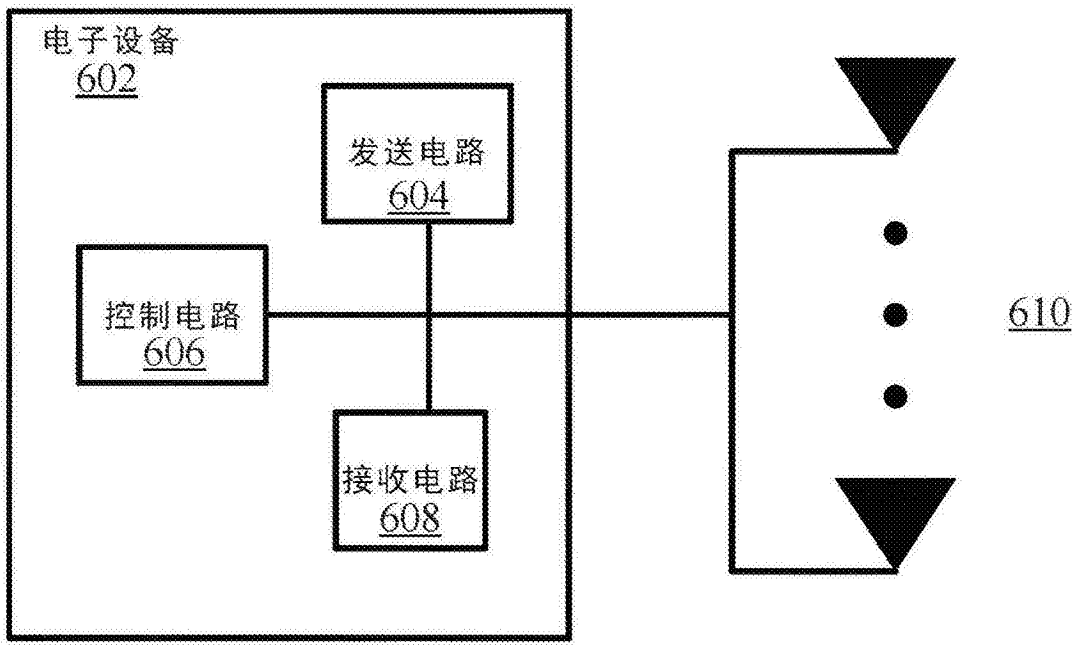

电子设备
602
发送电路
604
控制电路
606
接收电路
608
610

图6

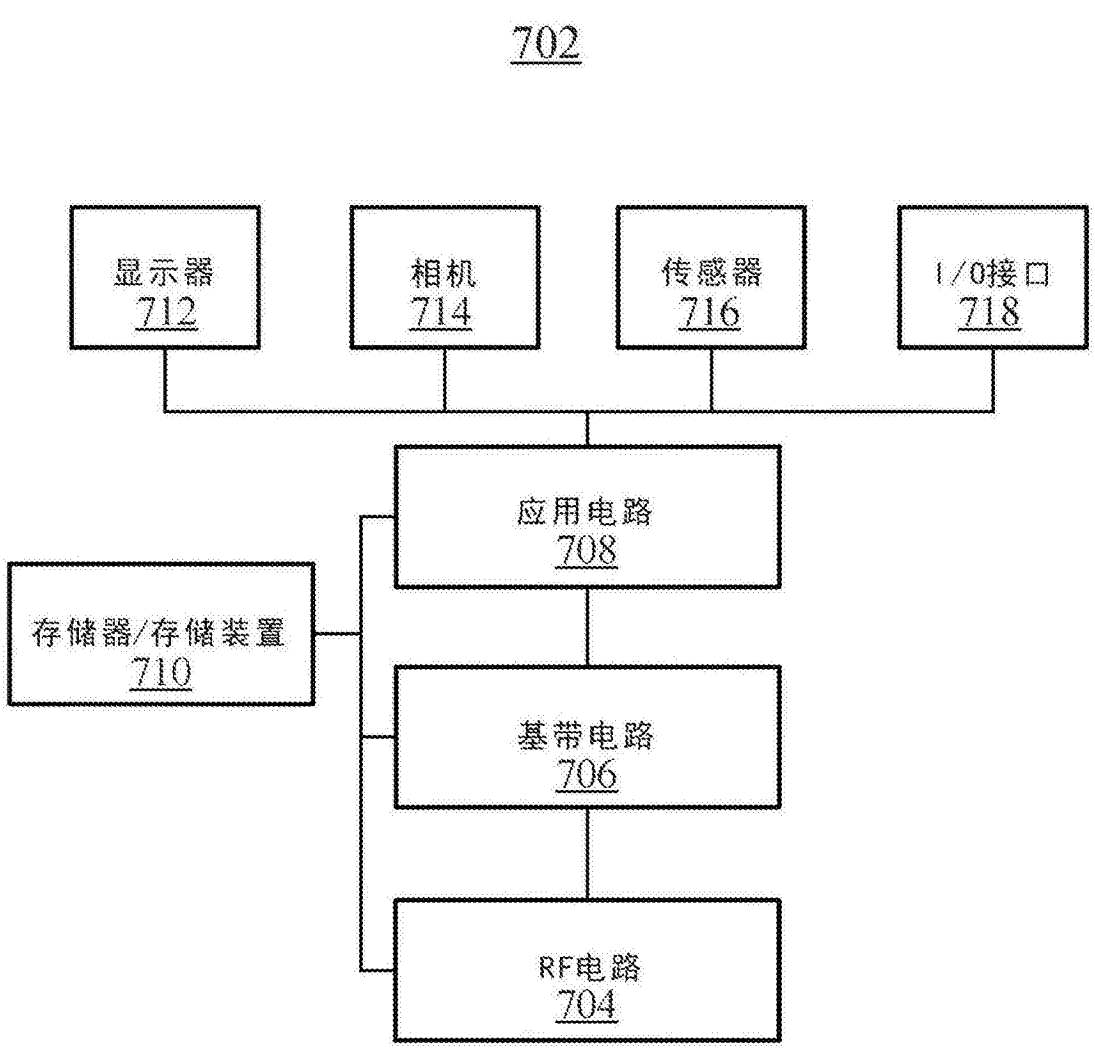

702
显示器
712
相机
714
传感器
716
I/O接口
718
应用电路
708
存储器/存储装置
710
基带电路
706
RF电路
704

图7