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(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; 5775 Morehouse Drive, San Diego, California 92121 (US).

(72) Inventors; and
(71) Applicants (*for US only*): **KRISHNAMOORTHY, Parthasarathy** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121 (US). **MAHAMMAD, Rasul Mastan** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121 (US). **SHAH, Chintan Shirish** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121 (US). **GUO, Jiming** [CN/US]; 5775 Morehouse Drive, San Diego, California 92121 (US). **BANSAL, Pankaj** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121 (US).

(74) Agent: **LEE AND LI - LEAVEN IPR AGENCY LTD.**; Unit 2202, Tower A, Beijing Marriott Center, No. 7, Jian Guo Men South Avenue, Dongcheng District, Beijing 100005 (CN).

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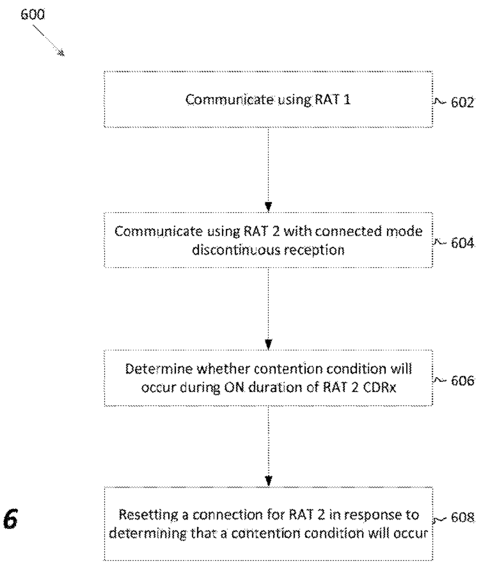

FIG. 6

(57) **Abstract**: Systems, methods, apparatuses, and media are provided for contention management and avoidance. A user equipment may communicate using a first radio access technology. The user equipment may communicate using a second radio access technology, including communicating using a connected mode discontinuous reception (CDRx) of the second radio access technology. The user equipment may determine whether contention will occur between the first radio access technology and the second radio access technology for a shared resource during an ON duration of the CDRx.

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SYSTEMS AND METHODS FOR CONTENTION MANAGEMENT

BACKGROUND

1. Field

[0001] Embodiments described herein generally relate to systems and methods for avoiding contention between radio access technologies in a user equipment.

2. Background

[0002] A user equipment ("UE"), such as a mobile phone device, may be enabled for one or more radio access technologies ("RATs"), such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Universal Mobile Telecommunications Systems (UMTS) (particularly, Long Term Evolution (LTE)), Global System for Mobile Communications (GSM), Wi-Fi, PCS, or other protocols that may be used in a wireless communications network or a data communications network. One or more RATs may be enabled by one, or a plurality of subscriber identity modules ("SIMs"). For example, a UE may be a multi-SIM UE, where each of a plurality of SIMs received or otherwise coupled to the multi-SIM UE may support one or more RATs.

SUMMARY

[0003] Various embodiments relate to systems and methods for avoiding contention between radio access technologies in a user equipment.

[0004] According to some embodiments, a method for managing contention between a first RAT and a second RAT of a UE includes communicating using the first RAT. The method further includes communicating using the second RAT, wherein the communicating using the second RAT comprises communicating using a connected mode discontinuous reception (CDRx). The method further includes determining whether a contention condition will occur between the first RAT and the second RAT for a shared radio-frequency (RF) resource of the UE during an ON duration of the CDRx. The method further includes resetting a connection for the second RAT in response to determining that the contention condition will occur between the first RAT and the second RAT.

[0005] According to some embodiments, the determining whether a contention condition will occur comprises determining whether or not the contention condition will occur during the ON duration prior to the beginning of the ON duration.

[0006] According to some embodiments, the determining whether a contention condition will occur is performed based on a request for the first RAT for the shared RF resource.

[0007] According to some embodiments, the determining whether a contention condition will occur is performed based on a CDRx offset value for the CDRx of the second RAT.

[0008] According to some embodiments, the CDRx offset value is received by the UE from a base station of the second RAT during a radio resource control connection establishment procedure.

[0009] According to some embodiments, the determining whether a contention condition will occur comprises comparing an expected beginning time and an expected ending time for the ON duration based on the CDRx offset value with an expected beginning time and an expected ending time associated with the request for the first RAT for the shared RF resource.

[0010] According to some embodiments, the determining whether a contention condition will occur is performed based on expected future requests for the first RAT for the shared RF resource.

[0011] According to some embodiments, the determining whether a contention condition will occur is performed based on a paging cycle of the first RAT.

[0012] According to some embodiments, the determining whether a contention condition will occur comprises determining a probability of the contention condition for the shared RF resource occurring.

[0013] According to some embodiments, the determining a probability of the contention condition for the shared RF resource comprises determining a probability of the contention condition for the shared RF resource occurring during an upcoming duration of time.

[0014] According to some embodiments, the upcoming duration of time includes two or more ON durations of the CDRx. In such embodiments, the determining the probability of the contention condition for the shared RF resource occurring during the upcoming duration of time comprises determining a probability that the contention condition will occur during one or more of the ON durations included in the upcoming duration.

[0015] According to some embodiments, the determining whether the contention condition will occur comprises determining a proportion of ON durations for which the contention condition for the shared RF resource is expected to occur.

[0016] According to some embodiments, the determining the proportion of ON durations for which the contention condition for the shared RF resource is expected to occur comprises determining a proportion of ON durations for which the contention condition for the shared RF resource is expected to occur during an upcoming duration of time.

[0017] According to some embodiments, the upcoming duration of time includes two or more ON durations of the CDRx. In such embodiments, the determining the proportion of ON durations for which the contention condition for the shared RF resource is expected to occur during the upcoming duration of time comprises determining a proportion of all ON durations included in the upcoming duration of time for which the contention condition for the shared RF resource is expected to occur.

[0018] According to some embodiments, the determining whether a contention condition will occur comprises determining a proportion of ON durations for which the contention condition for the shared RF resource is expected to occur. In such embodiments, the determining whether or not to reset the connection for the second RAT comprises comparing the proportion of ON durations for which the contention condition for the shared RF resource is expected to occur to a contention threshold.

[0019] According to some embodiments, the method further includes resetting the connection for the second RAT if the proportion of ON durations for which the contention condition for the shared RF resource is expected to occur is greater than the contention threshold. In such embodiments, the method further includes not resetting the connection for the second RAT if the proportion of ON durations for which the contention condition for the shared RF resource is expected to occur is less than or equal to the contention threshold.

[0020] According to some embodiments, the resetting the connection for the second RAT comprises the UE declaring a local radio link failure to a base station of the second RAT.

[0021] According to some embodiments, the method further includes receiving a new CDRx offset value from the base station of the second RAT during a radio resource control connection reestablishment procedure.

[0022] According to some embodiments, the new CDRx offset value is different from a CDRx offset value used by the UE during the determining whether a contention condition will occur.

[0023] According to some embodiments, the contention threshold is a predefined value.

[0024] According to some embodiments, the contention threshold is dynamically adjusted by the UE.

[0025] According to some embodiments, the UE performs the determining whether a contention condition will occur without coordination or instruction from a base station of the first RAT or a base station of the second RAT.

[0026] According to some embodiments, the shared resource is a RF resource used by the UE to at least receive communications for both the first RAT and the second RAT.

[0027] According to some embodiments, the UE maintains without resetting the connection for the second RAT, in response to determining that a contention condition will not occur between the first RAT and the second RAT.

[0028] According to some embodiments, a UE apparatus includes a shared radio resource configured to communicate using a first RAT. The shared radio resource is further configured to communicate using a connected mode discontinuous reception (CDRx) for a second RAT. The UE apparatus further includes one or more processors configured to determine whether a contention condition will occur between the first RAT and the second RAT for the shared radio resource during an ON duration of the CDRx. The one or more processors are further configured to determine whether or not to reset a connection for the second RAT based on a result of the determining whether the contention condition will occur.

[0029] According to some embodiments, a UE apparatus includes means for communicating using a first RAT. The UE apparatus further includes means for communicating using a connected mode discontinuous reception (CDRx) for a second RAT. The UE apparatus further includes means for determining whether a contention condition will occur between the first RAT and the second RAT for a shared resource during an ON duration of the CDRx. The UE apparatus further includes means for determining whether or not to reset a connection for the second RAT based on a result of the determining whether the contention condition will occur.

[0030] According to some embodiments, a non-transitory computer-readable medium includes instructions configured to cause one or more computing devices to communicate using a first RAT of a UE. The medium includes instructions configured to cause one or more computing devices to communicate using a connected mode discontinuous reception (CDRx) for a second RAT. The medium includes instructions configured to cause one or more computing devices to determine whether a contention condition will occur between the first RAT and the second RAT for a shared resource during an ON duration of the CDRx. The medium includes instructions configured to cause one or more computing devices to determine whether or not to reset a connection for the second RAT based on a result of the determining whether the contention condition will occur.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary embodiments, and together with the general description given above and the detailed description given below, serve to explain the features of the various embodiments.

[0032] FIG. 1 is a schematic diagram illustrating an example of a system according to various embodiments.

[0033] FIG. 2 is a functional block diagram illustrating an example of a user equipment according to various embodiments.

[0034] FIG. 3 is a schematic diagram illustrating an example of a user equipment according to various embodiments.

[0035] FIG. 4 is a diagram illustrating a communication sequence according to various embodiments.

[0036] FIG. 5A is a diagram illustrating a communication sequence according to various embodiments.

[0037] FIG. 5B is a diagram illustrating a communication sequence according to various embodiments.

[0038] FIG. 6 is a flowchart of a process according to various embodiments.

[0039] FIG. 7 is a flowchart of a process according to various embodiments.

[0040] FIG. 8 is a flowchart of a process according to various embodiments.

[0041] FIG. 9 is a flowchart of a process according to various embodiments.

[0042] FIG. 10 is a component block diagram of a user equipment suitable for use with various embodiments.

DETAILED DESCRIPTION

[0043] Various embodiments will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers may be used throughout the drawings to refer to the same or like parts. Different reference numbers may be used to refer to different, same, or similar parts. References made to particular examples and implementations are for illustrative purposes, and are not intended to limit the scope of the claims.

[0044] Various modern communication devices are described herein. Such a modern communication device may be referred to herein as a user equipment ("UE"). However, such a modern communication device may also be referred to as a mobile station ("MS"), a wireless device, a communications device, a wireless communications device, a mobile device, a mobile phone, a mobile telephone, a cellular device, a cellular telephone, and in other ways. Examples of UE include, but are not limited to, mobile phones, laptop computers, smart phones, and other mobile communication devices of the like that are configured to connect to one or more RATs.

[0045] Some UE may contain one or more subscriber identity modules ("SIMs") that provide users of the UEs with access to one or multiple separate mobile networks, supported by radio access technologies ("RATs"). Examples of RATs may include, but are not limited to, Global Standard for Mobile ("GSM"), Code Division Multiple Access ("CDMA"), CDMA2000, Time Division-Code Division Multiple Access ("TD-CDMA"), Time Division-Synchronous Code Division Multiple Access ("TD-SCDMA"), Wideband-Code Division Multiple Access ("W-CDMA"), Time Division

Multiple Access ("TDMA"), Frequency Division Multiple Access ("FDMA"), Long-Term Evolution ("LTE"), wireless fidelity ("Wi-Fi"), various 3G standards, various 4G standards, and the like.

[0046] Embodiments described herein relate to both single-SIM and multi-SIM UEs. A UE that includes a plurality of SIMs and connects to two or more separate RATs using a same set of RF resources (e.g., radio-frequency ("RF") transceivers) is a multi-SIM-multi-standby ("MSMS") communication device. In one example, the MSMS communication device may be a dual-SIM-dual-standby ("DSDS") communication device, which may include two SIM cards/subscriptions that may both be active on standby, but one is deactivated when the other one is in use. In another example, the MSMS communication device may be a triple-SIM-triple-standby ("TSTS") communication device, which includes three SIM cards/subscriptions that may all be active on standby, where two may be deactivated when the third one is in use. In other examples, the MSMS communication device may be other suitable multi-SIM communication devices, with, for example, four or more SIMs, such that when one is in use, the others may be deactivated.

[0047] Further, a UE that includes a plurality of SIMs and connects to two or more separate mobile networks using two or more separate sets of RF resources is termed a multi-SIM-multi-active ("MSMA") communication device. An example MSMA communication device is a dual-SIM-dual-active ("DSDA") communication device, which includes two SIM cards/subscriptions, each associated with a separate RAT, where both SIMs may remain active at any given time. In another example, the MSMA device may be a triple-SIM-triple-active ("TSTA") communication device, which includes three SIM cards/subscriptions, each associated with a separate RAT, where all three SIMs may remain active at any given time. In other examples, the MSMA communication device may be other suitable multi-SIM communication devices, with, for example, four or more SIMs, such that all SIMs are active at any given time.

[0048] In addition, a plurality of modes is enabled by one SIM, such that each mode may correspond to a separate RAT. Such a SIM is a multi-mode SIM. A UE may include one or more multi-mode SIMs. The UE may be a MSMS communication device (such as, but not limited to, a DSDS or a TSTS communication device), a

MSMA communication device (e.g., a DSDA, TSTA communication device, or the like), or a multi-mode device.

[0049] As used herein, UE refers to one of a cellular telephone, smart phone, personal or mobile multi-media player, personal data assistant, laptop computer, personal computers, tablet computer, smart book, palm-top computer, wireless electronic mail receiver, multimedia Internet-enabled cellular telephone, wireless gaming controller, and similar personal electronic device that include one or more SIMs, a programmable processor, memory, and circuitry for connecting to one or more mobile communication networks (simultaneously or sequentially). Various embodiments may be useful in mobile communication devices, such as smart phones, and such devices are referred to in the descriptions of various embodiments. However, the embodiments may be useful in any electronic device, such as a DSDS, a TSTS, a DSDA, a TSTA communication device (or other suitable multi-SIM, multi-mode devices), that may individually maintain one or more subscriptions that utilize one or a plurality of separate set of RF resources.

[0050] As used herein, the terms “SIM,” “SIM card,” and “subscriber identification module” are used interchangeably to refer to a memory that may be an integrated circuit or embedded into a removable card, and that stores an International Mobile Subscriber Identity (IMSI), related key, and/or other information used to identify and/or authenticate a wireless device on a network and enable a communication service with the network. Because the information stored in a SIM enables the UE to establish a communication link for a particular communication service with a particular network, the term “SIM” may also be used herein as a shorthand reference to the communication service associated with and enabled by the information (e.g., in the form of various parameters) stored in a particular SIM as the SIM and the communication network, as well as the services and subscriptions supported by that network, correlate to one another.

[0051] Embodiments described herein are directed to improved techniques for avoiding contention between radio access technologies in a user equipment. A user equipment may be capable of supporting more than one radio access technology, but the user equipment may nonetheless include some resources (e.g., a transceiver, a demodulator) that are shared between the multiple radio access technologies. In such situations, issues may arise when more than one radio access technology requests usage of the shared resource at the same time. This conflict between the multiple radio access technologies is referred to as contention.

[0052] One situation in which contention may be particularly problematic is when a first radio access technology is communicating using a connected mode discontinuous reception ("CDRx"). With CDRx, the user equipment may be in a "connected" or "active" mode of communication using the first radio access technology. The connected mode is generally known as a mode that allows active communication on the radio access technology. With CDRx, the user equipment may be configured to remain in the connected mode, yet nonetheless alternate between active and inactive states. In the active state, the user equipment may monitor a downlink channel to determine if data is buffered at the base station for the user equipment. The period for which the user equipment is in the active state during CDRx may be referred to as the "ON duration." In the inactive state, the user equipment may "sleep" or otherwise not drive the transceiver circuitry. This may be beneficial in reducing power consumption from the user equipment's battery. The period for which the user equipment is in the inactive state during CDRx may be referred to as the "OFF duration."

[0053] While CDRx introduces various benefits, most notably extended life of the user equipment's battery, the use of CDRx may exacerbate problems caused by contention. In particular, while using CDRx, if the first radio access technology does not have access to the shared resource during the ON duration, then the user equipment may entirely miss the notification from the base station that data is pending for the user equipment. This may cause data to be lost, a call not to be placed, or other problems.

[0054] Situations may occur whereby the first radio access technology is denied such access. For example, the user equipment may give priority to a second radio access technology that is in an idle mode. While the second radio access technology is in the idle mode, the second radio access technology may still periodically request access to the shared resource (e.g., for monitoring a paging channel). The user equipment may give priority to the second radio access technology over the first radio access technology (e.g., because the latter is more tolerant of latency). As such, the user equipment may not be able to effectively communicate using the first radio access technology if the first radio access technology loses access to the shared resource during a CDRx ON duration due to contention with the second radio access technology.

[0055] Some embodiments described herein improve over conventional techniques by determining contention conditions. For example, a user equipment may determine a contention condition by determining that a contention is likely to occur in advance of the contention actually occurring. Based on this determination, the user equipment may be able to take various actions to avoid the contention. For example, the user equipment may reset a connection with the first radio access technology in order to change the timing of the CDRx ON duration. At the same time, the user equipment may determine that contention is likely to occur, but that the contention is likely to occur infrequently enough that the contention can be tolerated without the need to take actions to avoid the contention. With these and other techniques, embodiments described herein may be effective at managing and avoiding contention in ways not possible with conventional techniques.

[0056] Conventional techniques are limited in their effectiveness at least because they do not predetermine contention prior to occurrence of the contention. For example, some conventional techniques monitor the first radio access technology communication and keep a counter for the number of consecutive CDRx ON durations that are not properly performed due to contention with another radio access technology. If the counter reaches a particular number (e.g., three), then corrective action may be taken. However, such an approach may be inefficient and undesirable for numerous reasons. First, the conventional approach allows contention to occur before taking any corrective action. Therefore, with the conventional approach, communication using the first radio access technology is likely to suffer due to contention prior to any attempts to improve the contention issue. Second, the conventional approach may fail to take corrective action where contention is cyclic but not sequential. In particular, the conventional approach tends to assume that any high rate of contention will also occur in numerous sequential CDRx ON durations for the first radio access technology. However, this is not always the case. For instance, contention between the multiple radio access technologies may cause the first radio access technology to lose access to the shared resource during every other CDRx ON duration. This may cause substantial degradation in the first radio access technology communication (i.e., 50% ON duration failure), but nonetheless the counter of sequential CDRx ON duration failures may never reach the threshold needed to cause the user equipment to take corrective action. Therefore, embodiments disclosed herein may improve over conventional techniques by actively avoiding high levels of contention, actively allowing low levels of contention, and properly managing contention regardless of whether the contention is cyclic and/or sequential.

[0057] With reference to FIG. 1, a schematic diagram of a system 100 is shown in accordance with various embodiments. The system 100 may include a UE 110, a first base station 120, and a second base station 130. In some embodiments, each of the first base station 120 and the second base station 130 may represent a separate RAT, such as GSM, CDMA, CDMA2000, TD-CDMA, TD-SCDMA, W-CDMA, TDMA, FDMA, LTE, Wi-Fi, various 3G standards, various 4G standards, and/or the like. In other words, the first base station 120 may represent a first RAT, and the second base station may represent a second RAT, where the first RAT and the second RAT are different RATs. By way of illustrating with a non-limiting example, the first base station 120 may be transmitting W-CDMA while the second base station 130 may be transmitting GSM. In some embodiments, each RAT may be transmitted by the associated base station at different physical locations (i.e., the first base station 120 and the second base station 130 may be at different locations). In other embodiments, each RAT may be transmitted by the associated base station at the same physical location (i.e., the first base station 120 and the second base station 130 may be physically joined, or the base stations are the same base station).

[0058] The first base station 120 and the second base station 130 may each include at least one antenna group or transmission station located in the same or different areas, where the at least one antenna group or transmission station may be associated with signal transmission and reception. The first base station 120 and the second base station 130 may each include one or more processors, modulators, multiplexers, demodulators, demultiplexers, antennas, and the like for performing the functions described herein. In some embodiments, the first base station 120 and the second base station 130 may be utilized for communication with the UE 110 and may be an access point, Node B, evolved Node B (eNode B or eNB), base transceiver station (BTS), or the like.

[0059] A cell 140 may be an area associated with the first base station 120 and the second base station 130, such that the UE 110, when located within the cell 140, may connect to or otherwise access both the first and second RATs, as supported by the first base station 120 and the second base station 130 (e.g., receive signals from and transmit signals to the first base station 120 and the second base station 130), respectively. The cell 140 may be a defined area, or may refer to an undefined area in which the UE 110 may access the RATs supported by the base stations 120, 130.

[0060] In various embodiments, the UE 110 may be configured to access the RATs from the first base station 120 and/or the second base station 130 (e.g., receive/transmit signals of the first and/or the second RAT from/to the first base station 120 and/or the second base station 130). The UE 110 may be configured to access the RATs by virtue of the multi-SIM and/or the multi-mode SIM configuration of the UE 110 as described, such that when a SIM corresponding to a RAT is received, the UE 110 may be allowed to access that RAT, as provided by the associated base station.

[0061] In general, an acquisition process of a RAT refers to the process in which the UE 110 searches and acquires various communication protocols of the RAT in order to acquire and establish communication or traffic with a target base node that is broadcasting the RAT. Some communication protocols include synchronization channels, such as, but not limited to, primary synchronization channel ("P-SCH"), secondary synchronization channel ("S-SCH"), common pilot channel ("CPICH"), and the like. The target base nodes are nodes that transmit, broadcast, or otherwise support the particular RAT being acquired. In some embodiments, the first base station 120 may be a target base node for the first RAT, given that the first RAT may be transmitted by the first base station 120 as described. Thus, when the UE 110 initiates an acquisition process of the first RAT (as supported by the first base station 120), a communication channel is set for future communication and traffic between the UE 110 and the first base station 120. Similarly, the second base station 130 may be a target base node for the second RAT, which is transmitted by the second base station 130 as described. Thus, when the UE 110 initiates an acquisition process of the second RAT, a communication channel is set for future communication and traffic between the UE 110 and the second base station 130. The acquisition process may be initiated when the UE 110 seeks to initially access the RAT or after attaching to an initial RAT to identify a candidate target RAT (that is not the initial RAT) for a handover.

[0062] It should be appreciated by one of ordinary skill in the art that FIG. 1 and its corresponding disclosure are for illustrative purposes, and that the system 100 may include three or more base stations. In some embodiments, three or more base stations may be present, where each of the three or more base stations may represent (i.e., transmits signals for) one or more separate RATs in the manner such as, but not limited to, described herein.

[0063] FIG. 2 is a functional block diagram of a UE 200 suitable for implementing various embodiments. According to various embodiments, the UE 200 may be the same or similar to the UE 110 as described with reference to FIG. 1. With reference to FIGS. 1-2, the UE 200 may include at least one processor 201, memory 202 coupled to the processor 201, a user interface 203, RF resources 204, and one or more SIMs (as denoted SIM A 206 and SIM B 207).

[0064] The processor 201 may include any suitable data processing device, such as a general-purpose processor (e.g., a microprocessor), but in the alternative, the processor 201 may be any suitable electronic processor, controller, microcontroller, or state machine. The processor 201 may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, at least one microprocessor in conjunction with a DSP core, or any other such configuration). The memory 202 may be operatively coupled to the processor 201 and may include any suitable internal or external device for storing software and data for controlling and use by the processor 201 to perform operations and functions described herein, including, but not limited to, random access memory RAM, read only memory ROM, floppy disks, hard disks, dongles or other USB connected memory devices, or the like. The memory 202 may store an operating system ("OS"), as well as user application software and executable instructions. The memory 202 may also store application data, such as an array data structure.

[0065] The user interface 203 may include a display and a user input device. In some embodiments, the display may include any suitable device that provides a human-perceptible visible signal, audible signal, tactile signal, or any combination thereof, including, but not limited to a touchscreen, LCD, LED, CRT, plasma, or other suitable display screen, audio speaker or other audio generating device, combinations thereof, and the like. In various embodiments, the user input device may include any suitable device that receives input from the use, the user input device including, but not limited to one or more manual operator (such as, but not limited to a switch, button, touchscreen, knob, slider or the like), microphone, camera, image sensor, and the like.

[0066] The processor 201 and the memory 202 may be coupled to the RF resources 204. In some embodiments, the RF resources 204 may be one set of RF resources such that only one RAT may be supported by the set of RF resources at any given time. In other embodiments, the RF resources may be a plurality of sets of RF resources, such that each set may support one RAT at a given time, thus enabling the UE 200 to support multiple RATs simultaneously, (e.g., in a MSMA case). The RF resources 204 may include at least one baseband-RF resource chain (with which each SIM in the UE 200, e.g., the SIM A 206 and the SIM B 207, may be associated). The baseband-RF resource chain may include a baseband modem processor 205, which may perform baseband/modem functions for communications on at least one SIM, and may include one or more amplifiers and radios. In some embodiments, baseband-RF resource chains may share the baseband modem processor 205 (i.e., a single device that performs baseband/modem functions for all SIMs on the UE 200). In other embodiments, each baseband-RF resource chain may include physically or logically separate baseband processors 205.

[0067] The RF resources 204 may include transceivers that perform transmit/receive functions for the associated SIM of the UE 200. The RF resources 204 may include separate transmit and receive circuitry, such as a separate transmitter and receiver, or may include a transceiver that combines transmitter and receiver functions. The RF resources 204 may each be coupled to a wireless antenna.

[0068] In some embodiments, the processor 201, the memory 202, and the RF resources 204 may be included in the UE 200 as a system-on-chip. In some embodiments, the one or more SIMs (e.g., SIM A 206 and SIM B 207) and their corresponding interfaces may be external to the system-on-chip. Further, various input and output devices may be coupled to components on the system-on-chip, such as interfaces or controllers.

[0069] The UE 200 is configured to receive one or more SIMs (e.g., SIM A 206 and SIM B 207), an example of which is described herein. A SIM in various embodiments may be a Universal Integrated Circuit Card (UICC) that is configured with SIM and/or

USIM applications, enabling access to various RAT networks as described. The UICC may also provide storage for a phone book and other applications. Alternatively, in a CDMA network, a SIM may be a UICC removable user identity module (R-UIM) or a CDMA subscriber identity module (CSIM) on a card. A SIM card may have a CPU, ROM, RAM, EEPROM and I/O circuits. An Integrated Circuit Card Identity (ICCID) SIM serial number may be printed on the SIM card for identification. However, a SIM may be implemented within a portion of memory of the UE 200, and thus need not be a separate or removable circuit, chip, or card.

[0070] A SIM used in various embodiments may store user account information, an IMSI, a set of SIM application toolkit (SAT) commands, and other network provisioning information, as well as provide storage space for phone book database of the user's contacts. As part of the network provisioning information, a SIM may store home identifiers (e.g., a System Identification Number (SID)/Network Identification Number (NID) pair, a Home PLMN (HPLMN) code, etc.) to indicate the SIM card network operator provider.

[0071] In some embodiments, the UE 200 may include a first SIM interface (not shown) that may receive a first SIM (e.g., SIM A 206), which may be associated with one or more RATs. In addition, the UE 200 may also include a second SIM interface (not shown) that may receive a second SIM (e.g., SIM B 207), which may be associated with one or more RATs that may be different (or the same in some cases) than the one or more RATs associated with SIM A 206. Each SIM may enable a plurality of RATs by being configured as a multi-mode SIM, as described herein. In some embodiments, a first RAT may be a same or different RAT as a second RAT (e.g., a DSDS device may enable two RATs). For example, both of them may be GSM, or one of them may be GSM and the other may be W-CDMA. In addition, two RATs (which may be the same or different) may each be associated with a separate subscription, or both of them may be associated with a same subscription. For example, a DSDS device may enable LTE and GSM, where both of the RATs enabled may be associated with a same subscription, or, in other cases, LTE may be associated with a first subscription and GSM may be associated with a second subscription different from the first subscription.

[0072] In embodiments in which the UE 200 comprises a smart phone, or the like, the UE 200 may have existing hardware and software for telephone and other typical wireless telephone operations, as well as additional hardware and software for providing functions as described herein. Such existing hardware and software includes, for example, one or more input devices (such as, but not limited to keyboards, buttons, touchscreens, cameras, microphones, environmental parameter or condition sensors), display devices (such as, but not limited to electronic display screens, lamps or other light emitting devices, speakers or other audio output devices), telephone and other network communication electronics and software, processing electronics, electronic storage devices and one or more antennae and receiving electronics for receiving various RATs. In such embodiments, some of that existing electronics hardware and software may also be used in the systems and processes for functions as described herein.

[0073] Accordingly, such embodiments can be implemented with minimal additional hardware costs. However, other embodiments relate to systems and process that are implemented with dedicated device hardware (UE 200) specifically configured for performing operations described herein. Hardware and/or software for the functions may be incorporated in the UE 200 during manufacturing, for example, as part of the original equipment manufacturer's ("OEM's") configuration of the UE 200. In further embodiments, such hardware and/or software may be added to the UE 200, after manufacturing of the UE 200, such as by, but not limited to, installing one or more software applications onto the UE 200.

[0074] In some embodiments, the UE 200 may include, among other things, additional SIM(s), SIM interface(s), additional RF resource(s) (i.e., sets of RF resources) associated with the additional SIM(s), and additional antennae for connecting to additional RATs supported by the additional SIMs.

[0075] Embodiments may be implemented in a UE that performs tune-away or other similar procedures to support communication with multiple RATs. In particular, embodiments may be implemented in a UE capable of concurrently communicating with more than one RAT on a single RF chain, (i.e., a single receiver/transmitter module). For example, a UE may be configured to communicate with both the AT&T W-CDMA network and the Verizon CDMA2000 network.

[0076] FIG. 3 is a schematic diagram illustrating an example of a UE 300 according to various embodiments. With reference to FIGS. 1-3, the UE 300 may correspond to the

UE 110, 200. According to some embodiments, the UE 300 may include SIM 1 312, SIM 2 314, system on a chip 320, shared resource 322, transceiver 330, and antenna 340.

[0077] In some embodiments, the SIM 1 312 and the SIM 2 314 may be subscriber identity modules that provide subscriptions for multiple RATs. The SIM 1 312 and the SIM 2 314 may be provided similar to the SIM A 206 and the SIM B 207.

[0078] In some embodiments, the system on a chip 320 may include various components used for the operation of the UE 300, such as a processor, memory, and some RF resources. The system on a chip 320 may be provided as a combination of the processor 201, the memory 202, and portions of the RF resources 204. With respect to RF resources, in some embodiments, the system on a chip 320 may be configured to contain components related to a modem functionality but not components related to transceiver functionality. For example, the system on a chip 320 may contain modulation and demodulation components. The system on a chip 320 may be coupled to the transceiver 330.

[0079] In some embodiments, the system on a chip 320 may contain the shared resource 322. The shared resource 322 may be a hardware or software component that is shared between multiple radio access technologies. For example, the shared resource 322 may be a demodulator component. In order to share the shared resource between the multiple radio access technologies, the UE 300 may determine when to allocate the shared resource 322 to each radio access technology. In some embodiments, the UE 300 (e.g., the processor 201) may make the determination on how to allocate the shared resource 322 without instruction or coordination from any base station or network with which the UE 300 is in communication. Namely, the UE 300 may unilaterally decide how to allocate the shared resource 322 between multiple radio access technologies without the benefit of those radio access technologies coordinating their demand for the shared resource 322. In some embodiments, the UE 300 may determine which radio access technology to allocate the shared resource 322 when contention occurs for the shared resource 322. The UE 300 may determine how to allocate the shared resource 322 based on a priority of the access requested by each radio access technology. The UE 300 may determine how to allocate the shared resource 322 by allocating the shared resource 322 to a voice radio access technology over a data radio access technology. This allocation may be beneficial if the data radio access technology is more tolerant to delay in the communications than is the voice radio access technology. The UE 300 may allocate the shared resource 322 using other techniques in various embodiments.

[0080] In some embodiments, the transceiver 330 may include one or more transmitters and one or more receivers configured to support communication using multiple RATs. The transceiver 330 may support active communication on a first RAT (e.g., RAT 1), while simultaneously supporting simultaneous mode communication for a second RAT (e.g., RAT 2). In some embodiments, the transceiver 330 may support communication on more than two RATs. The transceiver 330 may use the antenna 340 to send and receive electromagnetic signals for the various RATs supported by the UE 300. In some embodiments, the transceiver 330 may be considered a shared resource. In such embodiments, the UE 300 may allocate the transceiver to multiple radio access technologies as described for the shared resource 322, or using other techniques. Other configurations of the transceiver 330 are possible in various embodiments.

[0081] FIG. 4 is a diagram illustrating a communication sequence 400 according to various embodiments. With reference to FIGS. 1-4, the communication sequence 400 may be performed by a UE (e.g., the UEs 110, 200, 300). Time indicator 402 indicates the progression of time in the communication sequence 400.

[0082] In the communication sequence 400, communications are shown for a first radio access technology, RAT 1 404, and a second radio access technology RAT 2 406. The communications progress from time 471 to time 476.

[0083] At the time 471, the RAT 1 404 is in an idle mode – inactive state in block 411, and the RAT 2 406 is in a connected mode – continuously active state in block 431. The idle mode – inactive state of the block 411 may include the RAT 1 404 being in an idle state and not performing continuous active communication. For example, for the idle mode – inactive state of the block 411, the RAT 1 404 may not be using a shared resource (e.g., the shared resource 322, the transceiver 330). The connected mode – continuously active state of the block 431 may include the RAT 2 406 being in a connected state and performing continuous active communication. For example, for the connected mode – continuously active state of the block 431, the RAT 2 406 may be using a shared resource (e.g., the shared resource 322, the transceiver 330). In the connected mode – continuously active state of the block 431, the RAT 2 406 may continuously monitor a downlink channel. For example, in embodiments where the

RAT 2 406 is an LTE RAT, the UE may continuously monitor (e.g., receive and decode all subframes) the physical downlink control channel ("PDCCH").

[0084] At the time 472, a contention condition is determined in block 452. The block 452 may include the UE (e.g., the UE 300) predetermining a contention condition, by determining whether or not RAT 1 404 and RAT 2 406 will need access to the shared resource at the same time in the communication sequence, prior to the time that the actual occurrence of the contention condition would take place in the communication sequence. The block 452 may include the UE determining when the RAT 1 404 and the RAT 2 406 will need access to a shared resource (e.g., the shared resource 322, the transceiver 330). In the block 452, the UE may determine that the RAT 1 404 needs access to the shared resource between the time 473 and time 475. The UE, for example, may determine that the RAT 1 404 needs access to the shared resource based on a request for access to the shared resource received from a module of the RAT 1 404. As another example, the UE may determine that the RAT 1 404 needs access to the shared resource based on a paging cycle for the RAT 1 404.

[0085] In the block 452, the UE may determine that the RAT 2 406 needs access to the shared resource between the time 473 and time 474. The UE, for example, may determine that the RAT 2 406 needs access to the shared resource based on a CDRx offset value for the RAT 2 406. As another example, the UE may determine that the RAT 2 406 needs access to the shared resource based on a CDRx offset value, an inactivity timer value, a CDRx cycle duration value for the RAT 2 406, and/or the like. The UE may determine that the RAT 2 406 needs access to the shared resource based on a request for access to the shared resource received from a module of the RAT 2 406. It should be noted that the examples above for determining when the RAT 1 and/or the RAT 2 needs accesses to the shared resource are merely example. As such, the UE may determine when each of the RAT 1 404 and the RAT 2 406 will need access to the shared resource using any suitable technique in various embodiments.

[0086] The block 452 may include the UE determining that a contention condition will occur for the shared resource between the time 473 and the time 474. The UE may determine that a contention condition will occur for the shared resource between the time 473 and the time 474 based on comparing the beginning time and ending time (i.e., the time 473 and the time 475) for the expected RAT 1 404 usage of the shared resource to the beginning time and ending time (i.e., the time 473 and the time 474) for the expected RAT 2 406 usage of the shared resource. Because these two time intervals overlap between the time 473 and the time 474, the UE may determine contention condition in which contention would occur between the time 473 and the time 474. In the communication sequence 400, the UE may take no further action to avoid the contention condition determined at the block 452. For example, the UE may determine that a contention condition will only occur once for every four CDRx ON durations of the RAT 2 406, which may be lower than an acceptable contention level or threshold. In various other embodiments, the UE may take further action to avoid contention that would result from the contention condition determined at the block 452. For example, the UE may reset a connection between the UE and a base station for the RAT 2 406.

[0087] At the time 473, the RAT 1 404 begins idle mode – active communication in block 412, and the RAT 2 406 begins a CDRx ON duration in block 432. The idle mode – active state of the block 412 may include the RAT 1 404 being in an idle state but nonetheless performing active communication. For example, for the idle mode – active state of the block 412, the RAT 1 404 may be using a shared resource (e.g., the shared resource 322, the transceiver 330). The RAT 1 404 may be using the shared resource in the block 412 in order to monitor a downlink paging channel for the RAT 1 404. The CDRx ON duration of the block 432 may include the RAT 2 406 being in a connected state but also a discontinuous reception state. During the CDRx ON duration of the block 432, the RAT 2 406 may attempt to perform active communication. For example, the RAT 2 406 may attempt to use the shared resource. The RAT 2 406 may attempt to use the shared resource in order to monitor a downlink channel. For example, in embodiments where the RAT 2 406 is an LTE RAT, the UE may monitor (e.g., receive and decode subframes) the physical downlink control channel ("PDCCH") in order to determine whether data for the UE is buffered at the base station for the RAT 2 406.

[0088] Because both the RAT 1 404 and the RAT 2 406 may attempt to use the shared resource beginning at the time 473, contention may occur. This contention condition may be as determined at the block 452. In some embodiments, the UE may give priority to the RAT 1 404 for access to the shared resource. Therefore, the RAT 1 404 may be able to successfully begin the idle mode – active communication of the block 412, but the RAT 2 406 may not be able to successfully begin the CDRx ON duration of the block 432. In some embodiments, the failure of the RAT 2 406 to successfully begin the CDRx ON duration of the block 432 may result in the UE failing to properly monitor a downlink channel for the RAT 2 406. If the base station for the RAT 2 406 transmitted an indication of data buffered for the UE during the CDRx ON duration of the block 432, then the UE may fail to receive this indication. As a result, the UE may fail to receive the buffered data or only receive the buffered data after successful completion of a later CDRx ON duration (e.g., block 434).

[0089] At the time 474, the RAT 1 404 continues idle mode – active communication in the block 412, and the RAT 2 406 transitions from the CDRx ON duration in the block 432 to a CDRx OFF duration in block 433. The transition from the CDRx ON duration in the block 432 to the CDRx OFF duration in the block 433 may include the RAT 2 406 completing the CDRx ON duration of the block 432 and beginning the CDRx OFF duration of the block 433. During the CDRx OFF duration of the block 433, the RAT 2 406 may no longer attempt to perform active communication. For example, the RAT 2 406 may no longer attempt to use the shared resource. For example, in embodiments where the RAT 2 406 is an LTE RAT, the UE may stop attempting to monitor (e.g., receive and decode subframes) the PDCCH. Because the RAT 2 406 may no longer attempt to use the shared resource at the time 474, the contention that began at the time 473 may terminate. This end to the contention may be in accordance with the determination performed at the block 452.

[0090] At the time 475, the RAT 1 404 transitions from idle mode – active communication in the block 412 to an idle mode – inactive state in block 413, and RAT 2 406 transitions from the CDRx OFF duration in the block 433 to the CDRx ON duration in the block 434. The transition from idle mode – active communication in the block 412 to an idle mode – inactive state in block 413 may include the RAT 1 404 completing the active communication of the block 412 (e.g., completing monitoring of paging channel). During the idle mode – inactive state in block 413, the RAT 1 404 may no longer attempt to perform active communication as described with respect to the block 411. As such, the RAT 1 404 may not attempt to use the shared resource during the block 413. The transition from the CDRx OFF duration in the block 433 to the CDRx ON duration in the block 434 may include the RAT 2 406 completing the CDRx OFF duration of the block 433 and beginning the CDRx ON duration of the block 434. During the CDRx ON duration of the block 434, the RAT 2 406 may attempt to perform active communication. For example, the RAT 2 406 may attempt to use the shared resource. For example, in embodiments where the RAT 2 406 is an LTE RAT, the UE may attempt to monitor (e.g., receive and decode subframes) the PDCCH. Because the RAT 1 404 may no longer attempt to use the shared resource at the time 475, contention may not occur as only the RAT 2 406 attempts to use the shared resource. This lack of contention may be in accordance with the determination performed at the block 452.

[0091] Between the time 475 and the time 476, the RAT 1 404 may continue in the idle mode – inactive state in block 413, and the RAT 2 406 may perform numerous CDRx cycles. In particular, the RAT 2 406 may perform CDRx ON durations 434, 436, and 438, and the RAT 2 406 may perform CDRx OFF durations 435, 437, and 439. Each pair of CDRx ON duration 434 with CDRx OFF duration 435, CDRx ON duration 436 with CDRx OFF duration 437, and CDRx ON duration 438 with CDRx OFF duration 439 may be referred to as a CDRx cycle. While the RAT 2 406 is in a CDRx cycle, the RAT 2 406 may be considered to be in the mode 450 that has been referred to as CDRx. During each CDRx ON duration 434, 436, and 438, the RAT 2 406 may attempt to use the shared resource. However, because the RAT 1 404 may not attempt to use the shared resource while in the idle mode – inactive state in block 413, contention may not occur. This lack of contention may be in accordance with the determination performed at the block 452.

[0092] As explained with respect to the communication sequence 400, it may be possible to determine a contention condition in the block 452, before the time that the contention condition actually occurs between the time 473 and the time 474. While the communication sequence 400 further includes the determined contention condition, it may be possible in some embodiments to predetermine (determine before the actual time of the contention condition in the communication sequence 400) the possible contention between the time 473 and the time 474, and then perform one or more actions to prevent the predetermined contention from occurring. Other actions may be taken based on determined contention condition in various embodiments.

[0093] While the communication sequence 400 includes a particular time 472 at which the contention condition is determined, the contention condition determination in the block 452 may be performed at a variety of times. In some embodiments, the UE may determine contention conditions in the block 452 whenever a request for access to the shared resource is received from either the RAT 1 404 or the RAT 2 406. In some embodiments, the UE may determine contention conditions in the block 452 whenever a request for access to the shared resource is received from each of the RAT 1 404 and the RAT 2 406. In some embodiments, the UE may determine contention conditions in the block 452 whenever the RAT 1 404 first enters the idle mode – inactive state. In some embodiments, the UE may determine contention conditions in the block 452 whenever the RAT 2 406 first enters the CDRx mode.

[0094] In some embodiments, the UE may determine contention conditions in the block 452 whenever an inactivity associated with the CDRx mode of the RAT 2 404 reaches a predetermined level. For example, the RAT 2 406 may use an inactivity timer so that the CDRx mode is not used until no activity has been detected for a period of time. This period of inactivity may be tracked by an inactivity timer. The UE may determine contention conditions in the block 452 whenever the inactivity timer reaches a predefined level, e.g., 50% of the original value. In some embodiments, the UE may determine contention conditions in the block 452 based on a predefined cycle (e.g., every five seconds).

[0095] In some embodiments, the UE may determine contention conditions after the RAT 2 406 is already in the CDRx 450. For example, if the UE determines contention conditions in the block 452 based on a predefined cycle (e.g., every ten seconds), then a first performance of the bock 452 may occur prior to the beginning of the CDRx 450, but subsequent performance of the block 452 may occur after the beginning of the CDRx 450. In this same fashion, the performance of the block 452 may occur both before and after contention has occurred. Nonetheless, even if the CDRx 450 has begun and even if contention has occurred, the performance of the block 452 may include determination of expected contention in the future and is not limited to determination of whether contention has already occurred in the past.

[0096] In some embodiments, the UE may be able to determine the timing of upcoming CDRx cycles based on various parameters of the CDRx 450. For example, a base station for the RAT 2 406 may provide the UE with various parameters related to the CDRx 450. The UE may receive the various parameters during a radio resource control connection establishment procedure or a radio resource control connection reestablishment procedure. The UE may receive parameters including: an inactivity timer value, a CDRx cycle duration value, a CDRx ON duration value, a CDRx offset value, and/or the like. As previously discussed, the inactivity timer value may specify a period of time (e.g., one second) to wait prior to beginning CDRx 450. The UE may start the inactivity timer any time no activity is detected for the UE from the base station (e.g., no data for the UE indicated in the PDCCH). If the inactivity timer reaches the specified value (e.g., one second), the RAT 2 406 may enter the CDRx 450. The CDRx cycle duration value may indicate a length of the CDRx cycle (i.e., the length of time for the ON duration and the OFF duration together). In some embodiments, the UE may be configured with multiple CDRx duration values, such as a long cycle value (e.g., two seconds) and a short cycle value (640 milliseconds).

[0097] The CDRx offset value may indicate a period of time (e.g., one second) to wait prior to beginning CDRx 450. For example, the CDRx offset value may indicate a period of time (e.g., 100 milliseconds) to wait after expiration of the inactivity timer prior to entry of the CDRx 450. For example, once the inactivity timer expires, the RAT 2 406 may wait an additional period of time specified by the CDRx offset prior to beginning the CDRx 450. An example may be given from the LTE 136.321 Technical Specification. The LTE 136.321 Technical Specification specifies that the UE should enter CDRx if the following condition is met:

((system_frame_number * 10) + subframe_number) modulo (shortDRX-Cycle)
= (drxStartOffset) modulo (shortDRX-Cycle)

The system_frame_number is an identifier for each frame in the PDCCH (valued 0 to 1023). The subframe_number is an identifier for each subframe in the PDCCH (valued 0 to 9). The shortDRX-Cycle is the duration of the short CDRx cycle. The drxStartOffset is the CDRx offset value. As an example, the UE may receive a drxStartOffset value of 50 and a shortDRX-Cycle value of 640. In this case, the UE would not enter CDRx for the LTE RAT until ((system_frame_number * 10) + subframe_number) modulo 640 is equal to the value of 50. Therefore, the UE would enter the CDRx if the system_frame_number is 5 while the subframe_number is 0; if the system_frame_number is 69 while the subframe_number is 0; if the system_frame_number is 133 while the subframe_number is 0; and so forth. In an LTE RAT, a frame may have a duration of ten milliseconds, while a subframe may have a duration of one millisecond. Therefore, in the example presented above, the RAT 2 406 would be in a condition to begin CDRx (i.e., the condition above is met) every 640 milliseconds (i.e., once every potential CDRx cycle).

[0098] An example of how the UE may be able determine the timing of the CDRx 450 based on the described parameters is now given for embodiments in which the RAT 2 406 is an LTE RAT. For example, the UE may determine at the time 472 that the inactivity timer presently has a value of 500 milliseconds and will expire at a value of one second. Therefore, the UE may determine that the inactivity timer will expire in 500 milliseconds. Further, the UE may determine at the time 472 that the system frame number is 400 and the subframe number is 5. Therefore, the UE may determine that at expiration of the inactivity timer (i.e., in 500 milliseconds), the system frame number will be 450 (500 ms / 10 ms = 50 frames) and the subframe number will be 5. Further, the UE may determine at the time 472 that the CDRx cycle duration is 640 milliseconds, and the CDRx offset value is 50. Therefore, the UE may determine that the next occasion that the RAT 2 406 will begin CDRx 450 is with a system frame number of 453 and a subframe number of 0 (as [453*10+0] mod 640 = 50). Therefore, the UE may determine that the CDRx offset value will cause the RAT 2 406 to wait an additional 25 milliseconds (2 frames, 5 subframes) after the expiration of the inactivity timer prior to beginning the CDRx 450. Based on these determinations, the UE may determine at time 472 that the RAT 2 406 will enter CDRx 450 with the beginning of the CDRx ON duration in the block 432 in 525 milliseconds (500 ms + 25 ms). With this example, then, the time 473 may be 525 milliseconds after the time 472. The UE may determine the beginning of the CDRx 450 using other techniques in various embodiments.

[0099] The preceding example using the embodiments in which the RAT 2 406 is an LTE RAT is now continued to show how the UE may be able to determine the beginning time and end time of various CDRx ON durations and CDRx OFF durations using the determined start time of CDRx 450 as determined in the preceding example. For example, the UE may determine at the time 472 that the CDRx ON duration value is 20 milliseconds. Therefore, the UE may determine at the time 472 that the CDRx ON duration in the block 432 will end 20 milliseconds after beginning. With this example, then, the time 474 may be 545 milliseconds after the time 472 (525 ms + 20 ms). Further, the UE may determine at the time 472 that the CDRx OFF duration will continue for 620 milliseconds (640 ms – 20 ms). With this example, then, the time 475 may be 1.165 seconds after the time 472 (545 ms + 620 ms). Using a similar technique, the UE may determine at the time 472 the beginning time and ending time for each of the CDRx ON durations 434, 436, and 438 and the CDRx OFF durations 435, 437, and 439. The UE may determine the beginning time and ending time of various CDRx ON duration and CDRx OFF durations using other techniques in various embodiments.

[0100] FIG. 5A is a diagram illustrating a communication sequence 500 according to various embodiments. With reference to FIGS. 1-5A, the communication sequence 500 may be performed by a UE (e.g., the UEs 110, 200, 300). Time indicator 502 indicates the progression of time in the communication sequence 500.

[0101] In the communication sequence 500, communications are shown for a first radio access technology, RAT 1 504, and a second radio access technology RAT 2 506. The communications progress from time 571 to time 579.

[0102] At the time 571, the RAT 1 504 is in an idle mode – inactive state in block 511, and the RAT 2 506 is in a connected mode – continuously active state in block 531. The idle mode – inactive state of the block 511 may include the RAT 1 504 being in an idle state and not performing continuous active communication. For example, for the idle mode – inactive state of the block 511, the RAT 1 504 may not be using a shared resource (e.g., the shared resource 322, the transceiver 330). The connected mode – continuously active state of the block 531 may include the RAT 2 506 being in a connected state and performing continuous active communication. For example, for the connected mode – continuously active state of the block 531, the RAT 2 506 may be using a shared resource (e.g., the shared resource 322, the transceiver 330). In the connected mode – continuously active state of the block 531, the RAT 2 506 may continuously monitor a downlink channel. For example, in embodiments where the RAT 2 506 is an LTE RAT, the UE may continuously monitor (e.g., receive and decode all subframes) the PDCCH.

[0103] At the time 572, a contention condition is determined in block 552. The block 552 may include the UE (e.g., the UE 300) predetermining a contention condition, by determining whether or not RAT 1 504 and RAT 2 506 will need access to the shared resource at the same time in the communication sequence 500, prior to the time that the actual occurrence of the contention condition would take place in the communication sequence 500. The block 552 may include the UE determining when the RAT 1 504 and the RAT 2 506 will need access to a shared resource (e.g., the shared resource 322, the transceiver 330). In the block 452, the UE may determine that the RAT 1 504 needs access to the shared resource between the time 573 and time 575 as well as between time 576 and time 578. The UE, for example, may determine that the RAT 1 504 needs access to the shared resource based on a request for access to the shared resource received from a module of the RAT 1 504. As another example, the UE may determine that the RAT 1 504 needs access to the shared resource between the time 573 and the time 575 based on a request for access to the shared resource, while the UE may determine that the RAT 1 504 needs access to the shared resource between the time 576 and the time 578 based on an expectation that a future request for access to the shared resource will be received (e.g., based on a cyclic pattern of prior request including the request for access between the time 573 and the time 575). As another example, the UE may determine that the RAT 1 504 needs access to the shared resource based on a paging cycle for the RAT 1 504.

[0104] In the block 552, the UE may determine that the RAT 2 506 needs access to the shared resource between the time 573 and time 574 as well as between the time 476 and time 577. The UE, for example, may determine that the RAT 2 505 needs access to the shared resource based on a CDRx offset value for the RAT 2 505. As another example, the UE may determine that the RAT 2 505 needs access to the shared resource based on a CDRx offset value, an inactivity timer value, and a CDRx cycle duration value for the RAT 2 505, and/or the like. The UE may determine that the RAT 2 505 needs access to the shared resource based on a request for access to the shared resource received from a module of the RAT 2 506. It should be noted that the examples above for determining when the RAT1 and/or the RAT2 needs accesses to the shared resources are merely examples. As such, the UE may determine when each of the RAT 1 504 and the RAT 2 506 will need access to the shared resource using any suitable technique in various embodiments.

[0105] The block 552 may include the UE determining that a contention condition will occur for the shared resource between the time 573 and the time 574 as well as between the time 576 and the time 577. The UE may determine that contention will occur for the shared resource between these times based on comparing the beginning time and ending time for the expected RAT 1 504 usage of the shared resource to the beginning time and ending time for the expected RAT 2 506 usage of the shared resource. Because these time intervals overlap between the time 573 and the time 574 as well as between the time 576 and the time 577, the UE may determine that a contention condition will occur between the time 573 and the time 574 as well as between the time 576 and the time 577. In the communication sequence 500, the UE may take no further action to avoid the contention condition determined at the block 552. For example, the UE may determine that a contention condition will only occur once for every two CDRx ON durations of the RAT 2 506, which may be lower than an acceptable contention level or threshold. In various other embodiments, the UE may take further action to avoid the contention condition determined at the block 552. For example, the UE may reset a connection between the UE and a base station for the RAT 2 506.

[0106] At the time 573, the RAT 1 504 begins idle mode – active communication in block 512, and the RAT 2 506 begins a CDRx ON duration in block 532. The idle mode – active state of the block 512 may include the RAT 1 504 being in an idle state but nonetheless performing active communication. For example, for the idle mode – active state of the block 512, the RAT 1 504 may be using a shared resource (e.g., the shared resource 322, the transceiver 330). The RAT 1 504 may be using the shared resource in the block 512 in order to monitor a downlink paging channel for the RAT 1 504. The CDRx ON duration of the block 532 may include the RAT 2 506 being in a connected state but also a discontinuous reception state. During the CDRx ON duration of the block 532, the RAT 2 506 may attempt to perform active communication. For example, the RAT 2 506 may attempt to use the shared resource. The RAT 2 506 may attempt to use the shared resource in order to monitor a downlink channel. For example, in embodiments where the RAT 2 506 is an LTE RAT, the UE may monitor (e.g., receive and decode subframes) the PDCCH in order to determine whether data for the UE is buffered at the base station for the RAT 2 506.

[0107] Because both the RAT 1 504 and the RAT 2 506 may attempt to use the shared resource beginning at the time 573, contention may occur. This contention condition may be as determined at the block 552. In some embodiments, the UE may give priority to the RAT 1 504 for access to the shared resource. Therefore, the RAT 1 504 may be able to successfully begin the idle mode – active communication of the block 512, but the RAT 2 506 may not be able to successfully begin the CDRx ON duration of the block 532. In some embodiments, the failure of the RAT 2 506 to successfully begin the CDRx ON duration of the block 532 may result in the UE failing to properly monitor a downlink channel for the RAT 2 506. If the base station for the RAT 2 506 transmitted an indication of data buffered for the UE during the CDRx ON duration of the block 532, then the UE may fail to receive this indication. As a result, the UE may fail to receive the buffered data or only receive the buffered data after successful completion of a later CDRx ON duration (e.g., block 534).

[0108] At the time 574, the RAT 1 504 continues idle mode – active communication in the block 512, and the RAT 2 506 transitions from the CDRx ON duration in the block 532 to a CDRx OFF duration in block 533. The transition from the CDRx ON duration in the block 532 to the CDRx OFF duration in the block 533 may include the RAT 2 506 completing the CDRx ON duration of the block 532 and beginning the CDRx OFF duration of the block 533. During the CDRx OFF duration of the block 533, the RAT 2 506 may no longer attempt to perform active communication. For example, the RAT 2 506 may no longer attempt to use the shared resource. For example, in embodiments where the RAT 2 506 is an LTE RAT, the UE may stop attempting to monitor (e.g., receive and decode subframes) the PDCCH. Because the RAT 2 506 may no longer attempt to use the shared resource at the time 574, the contention that began at the time 573 may terminate. This end to the contention may be in accordance with the determination performed at the block 552.

[0109] At the time 575, the RAT 1 504 transitions from idle mode – active communication in the block 512 to an idle mode – inactive state in block 513, and RAT 2 506 continues the CDRx OFF duration in the block 533. The transition from idle mode – active communication in the block 512 to an idle mode – inactive state in block 513 may include the RAT 1 504 completing the active communication of the block 512 (e.g., completing monitoring of paging channel). During the idle mode – inactive state in block 513, the RAT 1 504 may no longer attempt to perform active communication as described with respect to the block 511. As such, the RAT 1 504 may not attempt to use the shared resource during the block 513. The continuing of the CDRx OFF duration in the block 533 may include the RAT 2 506 continuing to not attempt to use the shared resource. Because neither the RAT 1 504 nor the RAT 2 506 may attempt to use the shared resource at the time 575, contention may not occur. This lack of contention may be in accordance with the determination performed at the block 552.

[0110] Between the time 575 and the time 576, the RAT 1 504 may continue in the idle mode – inactive state in block 513, and the RAT 2 506 may perform an additional CDRx cycle. In particular, the RAT 2 506 may perform CDRx ON duration 534 and CDRx OFF duration 535, forming a CDRx cycle. While the RAT 2 506 is in a CDRx cycle, the RAT 2 506 may be considered to be in the mode 450 that has been referred to as CDRx. During the CDRx ON duration 534, the RAT 2 506 may attempt to use the shared resource. However, because the RAT 1 504 may not attempt to use the shared resource while in the idle mode – inactive state in block 513, contention may not occur. This lack of contention may be in accordance with the determination performed at the block 552.

[0111] At the time 576, the RAT 1 504 begins idle mode – active communication in block 514, and the RAT 2 506 begins a CDRx ON duration in block 536. The idle mode – active state of the block 514 may include the RAT 1 504 being in an idle state but nonetheless performing active communication. For example, for the idle mode – active state of the block 514, the RAT 1 504 may be using a shared resource (e.g., the shared resource 322, the transceiver 330). The RAT 1 504 may be using the shared resource in the block 514 in order to monitor a downlink paging channel for the RAT 1 504. The CDRx ON duration of the block 536 may include the RAT 2 506 being in a connected state but also a discontinuous reception state. During the CDRx ON duration of the block 536, the RAT 2 506 may attempt to perform active communication. For example, the RAT 2 506 may attempt to use the shared resource. The RAT 2 506 may attempt to use the shared resource in order to monitor a downlink channel. For example, in embodiments where the RAT 2 506 is an LTE RAT, the UE may monitor (e.g., receive and decode subframes) the PDCCH in order to determine whether data for the UE is buffered at the base station for the RAT 2 506.

[0112] Because both the RAT 1 504 and the RAT 2 506 may attempt to use the shared resource beginning at the time 576, contention may occur. This contention may occur similarly as discussed with respect to the time 573.

[0113] At the time 577, the RAT 1 504 continues idle mode – active communication in the block 514, and the RAT 2 506 transitions from the CDRx ON duration in the block 536 to a CDRx OFF duration in block 537. The transition from the CDRx ON duration in the block 536 to the CDRx OFF duration in the block 537 may include the

RAT 2 506 completing the CDRx ON duration of the block 536 and beginning the CDRx OFF duration of the block 537. During the CDRx OFF duration of the block 537, the RAT 2 506 may no longer attempt to perform active communication. For example, the RAT 2 506 may no longer attempt to use the shared resource. For example, in embodiments where the RAT 2 506 is an LTE RAT, the UE may stop attempting to monitor (e.g., receive and decode subframes) the PDCCH. Because the RAT 2 506 may no longer attempt to use the shared resource at the time 577, the contention that began at the time 576 may terminate. This end to the contention may be in accordance with the determination performed at the block 552.

[0114] At the time 578, the RAT 1 504 transitions from idle mode – active communication in the block 514 to an idle mode – inactive state in block 515, and RAT 2 506 continues the CDRx OFF duration in the block 537. The transition from idle mode – active communication in the block 514 to an idle mode – inactive state in block 515 may include the RAT 1 504 completing the active communication of the block 514 (e.g., completing monitoring of paging channel). During the idle mode – inactive state in block 515, the RAT 1 504 may no longer attempt to perform active communication as described with respect to the block 511. As such, the RAT 1 504 may not attempt to use the shared resource during the block 515. The continuing of the CDRx OFF duration in the block 537 may include the RAT 2 506 continuing to not attempt to use the shared resource. Because neither the RAT 1 504 nor the RAT 2 506 may attempt to use the shared resource at the time 578, contention may not occur. This lack of contention may be in accordance with the determination performed at the block 552.

[0115] Between the time 578 and the time 579, the RAT 1 504 may continue in the idle mode – inactive state in block 515, and the RAT 2 506 may continue in the CDRx OFF duration in the block 537. Because neither the RAT 1 504 nor the RAT 2 506 may attempt to use the shared resource between the time 578 and the time 579, contention may not occur. This lack of contention may be in accordance with the determination performed at the block 552.

[0116] As explained with respect to the communication sequence 500, it may be possible to determine a contention condition in the block 552 before the time that the contention condition actually occurs between the time 573 and the time 574 and between the time 576 and the time 577. While the communication sequence 500 further includes the determined contention condition, it may be possible in some embodiments to predetermine (determine before the actual time of the contention condition in the communication sequence 500) the possible contention between the time 573 and the time 574 and between the time 576 and the time 577 and then perform one or more actions to prevent the determined contention from occurring. Other actions may be taken based on determined contention conditions in various embodiments.

[0117] While the communication sequence 500 includes a particular time 572 at which a contention condition is determined, the contention condition determination in the block 552 may be performed at a variety of times, such as described with respect to the block 452 of the communication sequence 400.

[0118] In some embodiments, the UE may be able to determine the timing of upcoming CDRx cycles based on various parameters of the CDRx 550, such as described with respect to the block 452 of the communication sequence 400.

[0119] In some embodiments, the UE may be able to determine contention conditions for an upcoming duration of time. In particular, in the block 552, the UE may determine all expected occurrences of contention for a duration of time beginning at the time 572 and proceeding for the duration of time into the future. For example, the UE may be configured to determine all expected occurrences of contention for a fixed, predefined duration of three seconds. If the difference in time between the time 572 and the time 573 is approximately 500 milliseconds, and the difference in time between the time 573 and the time 576 is approximately 2.5 seconds, then the UE at the block 552 may determine all expected occurrence of contention from the time 572 to the time 576. In such a case, the UE may only determine the contention condition between the time 573 and the time 574. In order to perform such an approach for an upcoming duration of time, the UE may begin at the time 572 and determine all expected usage of the shared resource by the RAT 1 504 and the RAT 2 506 through to the end of the upcoming duration of time (e.g., using paging cycle information for the RAT 1 504; using the CDRx cycle determination techniques described with respect to communication sequence 400).

[0120] In some embodiments, the UE may determine a contention condition for an upcoming duration of time, with the upcoming duration of time not beginning at the time of determination. That is, in some embodiments the upcoming duration of time may not necessarily begin at the time 572. For example, the UE may determine that the RAT 2 506 may begin the CDRx 550 beginning at the time 573 (e.g., using the techniques previously described). Then, the UE may determine a contention condition for an upcoming duration of time beginning at the time 573 and extending for the duration of time (e.g., three seconds). Modifying the example from above, if the UE determines a contention condition for an upcoming duration of time of three seconds beginning at the time 573, then the UE may determine both the contention condition between the time 573 and the time 574 as well as the contention condition between the time 576 and the time 577.

[0121] In some embodiments, the UE may determine a contention condition for an upcoming duration of time that is not fixed and predefined. For example, the UE may be configured to determine a contention condition for an upcoming duration of time based on a cycle duration for the RAT 1 504. For instance, the UE may determine a contention condition for an upcoming duration of five times a paging cycle duration for the RAT 1 504 (e.g., 5 * 2.56 seconds = 12.8 seconds). As another example, the UE may be configured to determine a contention condition for an upcoming duration of time based on a cycle duration for the RAT 2 506. For instance, the UE may determine a contention condition for an upcoming duration of five times a CDRx cycle duration for the RAT 2 506 (e.g., 5 * 640 ms = 3.2 seconds). For instance, the UE may determine a contention condition for an upcoming duration of ten times a CDRx cycle duration for the RAT 2 506 (e.g., 10 * 2 seconds = 20 seconds). The UE may determine a contention condition for an upcoming duration of time in other ways in various embodiments.

[0122] Comparison of the communication sequence 400 and the communication sequence 500 demonstrates that the duration of the CDRx cycles can affect the frequency with which contention occurs during a CDRx ON duration of the RAT 2 406/506. In the communications sequences 400 and 500, the RAT 1 404 and the RAT 1 504 transitions between idle mode – inactive state and idle mode – active state may occur with the same duration of time. For example, the duration of time between the time 471 and the time 475 may be the same duration of time between the time 571 and the time 575. For example, this duration of time may be 2.56 seconds (e.g., with a cdma2000 paging channel slot cycle index of 1). In embodiments where the cycle durations of the RAT 1 404 and the RAT 1 504 are the same, the CDRx cycle durations for the RAT 2 506 are longer than the CDRx cycle durations for the RAT 2 406. For example, four CDRx cycles of the RAT 2 406 are completed within one cycle of the RAT 1 404. However, only two CDRx cycles of the RAT 2 506 are completed within one cycle of the RAT 1 504.

[0123] In embodiments where the durations of the CDRx cycles for the RAT 2 406 and RAT 2 506 are different, different levels of contention can be observed. For example, in one cycle of the RAT 1 404, four CDRx cycles of the RAT 2 406 occur. This results in contention affecting one CDRx ON duration for every four CDRx ON durations of the RAT 2 406 (i.e., the block 432 from the blocks 432, 434, 436, 438). In comparison, in one cycle of the RAT 1 504, two CDRx cycles of the RAT 2 506 occur. This results in contention affecting one CDRx ON duration for every two CDRx ON durations of the RAT 2 506 (i.e., the block 532 of the blocks 532, 534). Therefore, in this example, because the CDRx cycle durations for the RAT 2 406 and the RAT 2 506 are different, contention affects 25% of all CDRx ON durations for the RAT 2 406 but affects 50% of all CDRx ON durations for the RAT 2 506.

[0124] In some embodiments, the UE may determine how much contention is expected to occur. While the description of the communication sequence 400 and the communication sequence 500 has generally referred to determination of whether a contention condition would occur, the techniques described may also be used to determine how much contention would occur. In particular, the techniques described with respect to the communication sequence 400 noted that one CDRx ON duration for the RAT 2 406 was expected to suffer from contention. The techniques described with respect to the communication sequence 500 noted that two CDRx ON durations for the RAT 2 506 were expected to suffer from contention. Therefore, the determination of contention conditions of the block 452 and the block 552 may determine how many instances of contention are expected to occur. Similarly, the determination of contention conditions of the block 452 and the block 552 may determine how many separate CDRx ON durations are expected to suffer from contention.

[0125] In some embodiments, the UE may determine contention conditions as an expected proportion, ratio, or percentage. For example, the determination of a contention condition may include determining a proportion, ratio, or percentage of upcoming CDRx ON durations that are expected to suffer from contention. In particular, the techniques described with respect to the communication sequence 400 noted that 25% of CDRx ON durations for the RAT 2 406 were expected to suffer from contention. The techniques described with respect to the communication sequence 500 noted that 50% of CDRx ON durations for the RAT 2 506 were expected to suffer from contention. Therefore, the block 452 may include determining that 2 of 4, 2/4, or 25% of upcoming CDRx ON durations for the RAT 2 406 are expected to suffer from contention. Similarly, the block 552 may include determining that 1 of 2, 1/2, or 50% of upcoming CDRx ON durations for the RAT 2 406 are expected to suffer from contention. Other manners of determination of the expected relative frequency of CDRx ON duration contention may be used in various embodiments.

[0126] In some embodiments, the UE may determine contention conditions as an expected proportion, ratio, or percentage for an upcoming duration of time. In particular, techniques have been described for determining contention conditions as an expected proportion, ratio, or percentage as well as determining contention conditions for an upcoming duration of time. In some embodiments, these techniques may be combined. For example, the UE may determine the proportion of all CDRx ON durations in the next ten seconds for which contention is expected to occur. As another example, the UE may determine the percentage of all CDRx ON durations in time duration of [now + one second] to [now + six seconds] for which contention is expected to occur. As another example, the UE may determine the ratio of the number of CDRx ON durations for which contention is expected to the total number of CDRx ON durations for the next ten CDRx ON durations. Contention conditions may be determined as an expected proportion, ratio, or percentage for an upcoming duration of time in other ways according to various embodiments.

[0127] The communications sequence 400 and the communication sequence 500 and the description thereof demonstrate that contention conditions may occur in a cyclic fashion. In particular, use of the shared resource by the RAT 1 404 and the RAT 1 504 may occur in a cyclic fashion (e.g., according to a paging cycle). In addition, the use of the shared resource by the RAT 2 406 and the RAT 2 506 may occur in a cyclic fashion (i.e., due to the cyclic alternation between CDRx ON durations and CDRx OFF durations). When the cyclic natures of the various radio access technologies (i.e., the RAT 1 404, the RAT 2 406, the RAT 1 504, the RAT 2 506) cause cyclic overlap between the durations of shared resource usage, the contention may thereby become cyclic and thus repetitive. For example, the contention affecting RAT 2 406 may occur repeatedly for every fourth CDRx ON duration (i.e., 25% of all upcoming CDRx ON durations). As another example, the contention affecting RAT 2 506 may occur repeatedly for every second CDRx ON duration (i.e., 50% of all upcoming CDRx ON durations). This repetitive occurrence of contention conditions may be particularly problematic when it causes the RAT 2 406 or the RAT 2 506 to repeatedly fail to properly operate during the CDRx ON durations.

[0128] While cyclic occurrence of contention may be problematic, in some embodiments, contention may be problematic even if the contention is not cyclic. For example, if the RAT 1 404 or the RAT 1 504 does not have cyclic usage of the shared resource but nonetheless has very frequent usage of the shared resource, then the RAT 2 406 or the RAT 2 506 may nonetheless suffer from high levels of contention during CDRx ON durations. As another example, if the UE supports more than two radio access technologies (e.g., a RAT 3, a RAT 4, etc.), then the RAT 2 406 or the RAT 2 506 may nonetheless suffer from high levels of contention during CDRx ON durations. This may occur even if the other radio access technologies (i.e., the RAT 1 404, the RAT 1 504, the RAT 3, the RAT 4, etc.) do not have very frequent usage of the shared resource. If there are more radio access technologies with which to share the shared resource, the chance of contention may increase.

[0129] The description of the communications sequence 400 and the communication sequence 500 has generally referred to "expected" contention. While techniques have been described with respect to the communications sequence 400 and the communication sequence 500 for determining precise values for expected contention, in some embodiments, contention conditions cannot be determined in a perfectly deterministic fashion in advance. In particular, while the techniques described herein may be used to determine a precise value for expected contention, various factors may alter the actual level of contention that occurs after the determination has been made. Some examples for causes of this non-deterministic nature of contention are given below.

[0130] First, the RAT 1 404 or the RAT 1 504 may not use the shared resource for the exact period of time determined in the block 452 or the block 552. For example, while a request from the RAT 1 404 or the RAT 1 504 may specify a requested beginning time for the shared resource usage and a requested duration for the shared resource usage, the RAT 1 404 or the RAT 1 504 may actually use the shared resource for more or less time than specified in the request. This may occur for various reasons, such as the common variability in the time required to demodulate a paging message for the RAT 1 404 or the RAT 1 504.

[0131] As another example, the RAT 1 404 or the RAT 1 504 may change the frequency with which it requests usage of the shared resource. For instance, when the block 452 is performed, a contention condition may be determined based on the then present paging cycle values for the RAT 1 404. If the RAT 1 404 is a CDMA2000 RAT using a slot cycle index value of 1, then the determination at the block 452 may expect the RAT 1 404 to use the shared resource every 2.56 seconds. However, if the RAT 1 404 changes the slot cycle index value to 2 shortly after the performance of the block 452, then the RAT 1 404 may actually only use the shared resource every 5.12 seconds.

[0132] As yet another example, while the block 452 or the block 552 may have been performed based on a paging cycle for the RAT 1 404 or the RAT 1 504, the RAT 1 404 or the RAT 1 504 may request additional use of the shared resource beyond the usage required by the paging cycle. In such a situation, another instance of contention may occur due to the unexpected request, but that contention condition may not have been determined in the block 452 or the block 552. Other causes of non-determinism in contention resulting from the RAT 1 404 or the RAT 1 504 are possible in various embodiments.

[0133] Second, contention may be non-deterministic because the RAT 2 406 or the RAT 2 506 may not begin or maintain the CDRx 450 or the CDRx 550 as determined in the block 452 or the block 552. For example, after performance of the block 452 or the block 552 but prior to the beginning of the CDRx 450 or the CDRx 550, the UE may receive indication of pending data buffered at the base station. In such a case, the UE may receive the data in a downlink and restart an inactivity timer. The restarting of the inactivity timer may delay the actual beginning of the CDRx 450 or the CDRx 550 as compared to the determination made in the block 452 or the block 552.

[0134] Based on the non-deterministic nature of contention, the determination of contention conditions in the block 452 or the block 552 may be considered a determination of expected contention. In particular, techniques described herein that refer to determination of contention conditions, determination of a number of instances of contention, determination of a proportion of contention, or the like may be considered to be determination of expected contention, determination of an expected number of instances of contention, determination of an expected proportion of contention, or the like.

[0135] Furthermore, in some embodiments the techniques described herein may be used to determine a probability of contention. For instance, the techniques described herein involving the determination of contention conditions may be considered to be determination of a probability of contention based on the non-deterministic nature of the contention. In addition, introduction of probabilistic values may be incorporated into the determination of contention conditions at the block 452 or the block 552. For instance, in the block 552, the UE may identify two possible scenarios for the expected upcoming CDRx 550. In particular, the UE may identify the scenario shown in the communication sequence 500 as one possible scenario (i.e., having 50% CDRx ON duration contention). Nonetheless, the UE may identify another possible scenario, such as the RAT 2 506 switching to a shorter CDRx cycle duration (e.g., that of the communication sequence 400 resulting in 25% CDRx ON duration contention). If the UE determines each scenario to be equally likely, then the UE may weight each scenario with a probabilistic value of 0.5 and produce a composite probability of contention of: $50\% * 0.5 + 25\% * 0.5 = 37.5\%$ (or 0.375 expressed as a probabilistic value). Other techniques for the determination of a probability of contention are possible in various embodiments.

[0136] Based on the non-deterministic nature of contention, the determination of contention conditions in the block 452 or the block 552 may be considered a determination of a probability of contention. For instance, the techniques described herein involving the determination of contention conditions may be considered to be determination of a probability of contention based on the non-deterministic nature of the contention. In addition, introduction of probabilistic values may be incorporated into the determination of contention at the block 452 or the block 552. For instance, in the block 552, the UE may identify two possible scenarios for the expected upcoming CDRx 550. In particular, the UE may identify the scenario shown in the communication sequence 500 as one possible scenario (i.e., having 50% CDRx ON duration contention). Nonetheless, the UE may identify another possible scenario, such as the RAT 2 506 switching to a shorter CDRx cycle duration (e.g., that of the communication sequence 400 resulting in 25% CDRx ON duration contention). If the UE determines each scenario to be equally likely, then the UE may weight each scenario with a probabilistic value of 0.5 and produce a composite probability of contention of: 50% * 0.5 + 25% * 0.5 = 37.5% (or 0.375 expressed as a probabilistic value). Other techniques for the determination of a probability of contention are possible in various embodiments. In some embodiments, a probability of contention may be determined for an upcoming duration of time. In such embodiments, the determined probability of contention may be considered a probability that any one CDRx ON duration during the upcoming period of time will suffer contention.

[0137] In some embodiments, the UE may take some action to avoid the contention condition determined in the block 452 or the block 552. As noted with respect to the communication sequence 400 and the communication sequence 500, the UE may determine a contention condition in the block 452 or the block 552 yet nonetheless take no action to avoid the determined contention condition. In some embodiments, though, the UE may instead perform one or more actions to avoid the occurrence of the contention condition that was determined in the block 452 or the block 552.

[0138] In some embodiments, the UE may determine whether or not to avoid the contention condition determined in the block 452 or the block 552 based on the number of contentions, proportion of contentions, probability of contention, or the like that was actually determined in the block 452 or the block 552. For example, if a low level of contention was determined, then the UE may determine to not perform any action to avoid the determined contention condition. In comparison, if a high level of contention was determined, then the UE may determine to perform some action to avoid the determined contention condition. In some embodiments, the UE may compare a proportion of contention determined in the block 452 or the block 552 to a contention threshold in order to determine whether or not to perform an action to avoid the determined contention condition. Thus, for example, a low level of contention may be determined, where proportion of contention determined in the block 452 or the block 552 is below the threshold, while a high level of contention may be determined, where the proportion of contention determined in the block 452 or the block 552 is at or above the threshold. For example, if the contention threshold is a value of 3.5 of 10, and the performance of the block 452 or the block 552 resulted in determination of 2 of 10

CDRx ON durations suffering contention, then the UE may determine to not perform any action to avoid the determined contention. As another example, if the contention threshold is a value of 3.5 of 10, and the performance of the block 452 or the block 552 resulted in determination of 4 of 10 CDRx ON durations suffering contention, then the UE may determine to perform some action to avoid the determined contention.

[0139] In some embodiments, the contention threshold may be defined in a variety of ways. In some embodiments, the contention threshold may be a predefined value (e.g., 0.35). In some embodiments, the contention threshold may be a fixed, predefined value (e.g., 0.35) that is not adjustable by the UE. In some embodiments, the contention threshold may be a predefined value (e.g., 0.35) that is adjustable by the UE. For example, while an initial predefined value may be used (e.g., 0.35), the UE may move the contention threshold up and down based on operation of the CDRx 450 or the CDRx 550. For instance, if a high level of recent contention has caused numerous recent CDRx ON durations to be unsuccessfully performed, the UE may move the contention threshold down (e.g., from 0.35 to 0.15) so as to tolerate less contention in the upcoming CDRx cycles. Other techniques for providing the contention threshold may be used in various embodiments.

[0140] In some embodiments, the UE may reset a connection with the RAT 2 406 or the RAT 2 506 in order to avoid the contention condition determined in the block 452 or the block 552. In particular, if the UE determines to perform at least one action to avoid the contention condition determined in the block 452 or the block 552, the UE may reset a connection between the UE and a base station for the RAT 2 406 or the RAT 2 506 in order to attempt to alter the CDRx cycle of the RAT 2 406 or the RAT 2 506. While it may be preferable for the UE to simply modify the beginning time of the CDRx 450 or the CDRx 550 so that the CDRx ON durations of the CDRx 450 or the CDRx 550 do not frequently overlap with periods of shared resource usage by the RAT 1 404 or the RAT 1 504, this technique may not be possible. In some instances, the beginning time of the CDRx 450 or the CDRx 550 may be determined by one or more parameters (e.g., inactivity timer duration, CDRx offset, CDRx cycle duration) provided to the UE by a base station for RAT 2 406 or the RAT 2 506. As such, the UE may not be able to independently change the beginning time of the CDRx 450 or the CDRx 550. Alternatively, if the CDRx 450 or the CDRx 550 has already begun, the UE may not be able to perform minor shifts (e.g., less than one CDRx cycle duration) in the beginning of the CDRx ON durations in order to avoid the periods of shared resource usage by the RAT 1 404 or the RAT 1 504. As such, the UE may instead reset a connection with the RAT 2 406 or the RAT 2 506. In some embodiments, resetting a connection with the RAT 2 406 or the RAT 2 506 may cause a base station for the RAT 2 406 or the RAT 2 506 to provide new CDRx parameters (e.g., new CDRx offset). Based on the new CDRx parameters (e.g., new CDRx offset), the CDRx ON durations of the CDRx 450 or the CDRx 550 may no longer frequently overlap with the periods of shared resource usage by the RAT 1 404 or the RAT 1 504.

[0141] In some embodiments, the UE may reset a connection with the RAT 2 406 or the RAT 2 506 in order to receive a new CDRx offset value. As just described, resetting a connection with the RAT 2 406 or the RAT 2 506 may cause a base station for the RAT 2 406 or the RAT 2 506 to provide new CDRx parameters (e.g., new CDRx offset). The CDRx offset value may be particularly significant in shifting the occurrence of CDRx ON durations for the CDRx 450 or the CDRx 550.

[0142] Explanation may be made by continuation of the example embodiments of an LTE RAT with application to the communication sequence 500. As previously discussed, the CDRx offset value determines how long after expiration of the inactivity timer the RAT 2 506 will wait prior to entering the CDRx 550. Using the formula from the LTE 136.321 Technical Specification, the CDRx offset determines which subframe (i.e., which millisecond) during a CDRx cycle duration the RAT 2 506 will enter the CDRx 550. Given that the length of the CDRx ON duration may be considerably shorter than the length of the CDRx OFF duration (e.g., 20 ms and 620 ms, respectively), a minor change to the CDRx offset value may completely avoid contention that was frequent with a prior CDRx offset value. As an example, the RAT 1 504 may use a paging cycle of 2.56 seconds, with 100 milliseconds in idle mode – active communication (e.g., receiving and demodulating a paging channel) and 2.46 seconds in idle mode – inactive state. The RAT 2 506 may use a CDRx cycle duration of 1.028 seconds, with 20 milliseconds in CDRx ON duration and 1.018 seconds in CDRx OFF duration. Based on these values, 119 of every 1,028 CDRx offset values will cause at least some contention on 50% of all CDRx ON durations for the RAT 2 506, while 909 of every 1,028 CDRx offset values will cause no contention at all for any CDRx ON duration for the RAT 2 506. Therefore, if the UE determines in the block 552 that it has contention on 50% of all CDRx ON durations for the RAT 2 506, then the UE has an 88.4% chance of removing all contention by resetting the connection with the RAT 2 506 (assuming the base station chooses the CDRx offset value at random). In addition, the UE may be able to rest the connection with the RAT 2 506 more than once. In such a case, the UE has a 98.7% chance of removing all contention by resetting the connection with the RAT 2 506 one or two times (assuming the UE does not reset the connection a second time if the contention is removed after resetting the connection a first time). As such, resetting the connection with the RAT 2 506 may be an effective way to avoid contention between the RAT 1 504 and the RAT 2 506 in some situations.

[0143] FIG. 5B is a diagram illustrating a communication sequence 501 according to various embodiments. With reference to FIGS. 1-5B, the communication sequence 501 may be performed by a UE (e.g., the UEs 110, 200, 300).

[0144] The communication sequence 501 contains similar elements as previously described with respect to the communication sequence 500. In particular, the communication sequence 501 contains the time indicator 502, the RAT 1 504, and the RAT 2 506. The communication sequence 501 contains the blocks 511, 512, 513, 514, and 515 as performed by the RAT 1 504.

[0145] The communication sequence 501 differs from the communication sequence 500 in that the UE resets a connection with a base station of the RAT 2 506 in block 554. The UE may determine contention conditions in the block 552 as described with respect to the communication sequence 500. Based on performing the block 552, the UE may determine that 50% of upcoming CDRx ON durations for the RAT 2 506 are expected to suffer contention (i.e., between the time 573 and the time 574, between the time 576 and the time 577). As a result, the UE may determine to perform an action to avoid the determined contention conditions. As a result, the UE resets the connection with the base station of the RAT 2 506 in block 554. In some embodiments, the UE may perform the block 554 by declaring a local radio link failure.

[0146] At block 541, the UE reestablishes a connection to the RAT 2 506. The block 541 may include the UE performing a radio resource control connection reestablishment procedure. The block 541 may include the UE receiving a new CDRx offset value for the RAT 2 506. In some embodiments, the block 541 may include the UE receiving other CDRx parameters for the RAT 2 506 (e.g., inactivity timer duration, CDRx cycle duration).

[0147] At block 542, the RAT 2 506 operates in a connected mode – continuously active state. The RAT 2 506 may operate in the connected mode – continuously active state in the block 542 based on an inactivity timer being reset as a result of resetting the connection with the RAT 2 506 in the block 554.

[0148] When the RAT 2 506 terminates operation in the connected mode – continuously active state of the block 542, the RAT 2 506 begins the CDRx 550. During the CDRx 550, the RAT 2 506 performs numerous CDRx cycles as described with respect to the communication sequence 500.

[0149] Comparison of the communication sequence 501 with the communication sequence 500 demonstrates the effect of resetting the connection for the RAT 2 506 in the block 554. In particular, in the communication sequence 500, every second CDRx ON duration (i.e., the block 532, the block 536) overlapped with a period of shared resource usage by the RAT 1 504. However, in the communication sequence 501, the resetting of the connection for the RAT 2 506 in the block 554 has caused the timing of the CDRx ON durations (i.e., the block 532, the block 534, the block 536) to be shifted in time. In particular, none of the CDRx ON durations of the CDRx 550 of the communication sequence 501 suffer contention. The shifting in time of the CDRx ON durations of the communication sequence 501 may result from the UE receiving a new CDRx offset value during the connection reestablishment in the block 541.

[0150] FIG. 6 is a flowchart of a process 600 according to various embodiments. With reference to FIGS. 1-6, the process 600 may be performed by a UE (e.g., the UEs 110, 200, 300), such as by the processor 201 of the UE or the like.

[0151] At block 602, communication is performed using a RAT 1. The block 602 may include a UE (e.g., the UE 300) communicating using a first radio access technology.

[0152] At block 604, communication is performed using a connected mode discontinuous reception for a RAT 2. The block 602 may include a UE (e.g., the UE 300) communicating using CDRx for a second radio access technology.

[0153] At block 606, determination is performed as to whether a contention condition will occur during an ON duration of the RAT 2 CDRx. The block 606 may include a UE (e.g., the UE 300) determining whether contention will occur for a shared resource of the UE (e.g., the share resource 322, the transceiver 330). The block 606 may include a UE determining whether or not contention will occur during a CDRx ON duration of the RAT 2 prior to the contention actually occurring. The block 606 may include the UE determining whether or not contention will occur during a CDRx ON duration prior to the beginning of the CDRx ON duration. The block 606 may include the UE determining whether or not a contention will occur without coordination or instruction from a base station for either the RAT 1 or the RAT 2. The block 606 may include the UE determining a proportion of upcoming CDRx ON durations for the RAT 2 for which contention is expected to occur. The block 606 may include the UE determining a probability of contention for upcoming CDRx ON durations for the RAT 2. At block 608, the UE determines whether or not to reset a connection for RAT 2 (or determines whether or not to perform other predefined actions for avoiding contention), based on a result of the UE determining a probability of contention. At block 608, the UE resets a connection for the RAT 2, in response to determining that a contention condition will occur. Alternatively, the UE maintains and does not reset the connection for the RAT 2, in response to determining that a contention condition will not occur.

[0154] FIG. 7 is a flowchart of a process 700 according to various embodiments. With reference to FIGS. 1-7, the process 700 may be performed by a UE (e.g., the UEs 110, 200, 300).

[0155] At block 702, communication is performed using a RAT 1. The block 702 may include a UE (e.g., the UE 300) communicating using a first radio access technology.

[0156] At block 704, communication is performed using a RAT 2. The block 704 may include the UE communicating using a second radio access technology.

[0157] At block 706, a request for use of a shared resource is received for the RAT 1. The block 706 may include a component of the UE (e.g., the processor 201) receiving a request from an internal module for the RAT 1. The block 706 may include receiving a request to use a resource shared with the RAT 2 (e.g., the shared resource 322, the transceiver 330). The block 706 may include the UE receiving a request including a beginning time for the use of the shared resource, a duration for the use of the shared resource, a priority for the use of the shared resource, and/or a reason for the use of the shared resource.

[0158] At block 708, CDRx timing information is received for the RAT 2. The block 708 may include a component of the UE (e.g., the processor 201) receiving CDRx timing information from an internal module for the RAT 2. The block 708 may include the UE receiving CDRx timing information from a base station for the RAT 2. In some embodiments, the CDRx timing information may include an inactivity timer duration, a CDRx offset value, a CDRx cycle duration value, and/or a CDRx ON duration value.

[0159] At block 710, an expected beginning time and ending time for RAT 1 usage of the shared resource is compared to an expected beginning time and ending time for RAT 2 usage of the shared resource. The block 710 may include the UE determining a beginning time and ending time for RAT 1 usage of the shared resource based on the request received at the block 706. In some embodiments, the UE may determine a beginning time and ending time for RAT 1 usage of the shared resource based on expected future requests for usage of the shared resource for the RAT 1. In some embodiments, the UE may determine a beginning time and ending time for RAT 1 usage of the shared resource based on a paging cycle for the RAT 1. The block 710 may include the UE determining a beginning time and ending time for RAT 2 usage of the shared resource based on the CDRx timing information received at the block 708. In some embodiments, the block 710 may include the UE determining a beginning time and ending time for RAT 2 usage of the shared resource based on a request received for the RAT 2. The block 710 may include the UE comparing the beginning time and ending time for the RAT 1 usage of the shared resource with the beginning time and ending time for the RAT 2 usage of the shared resource in order to determine if the two time intervals overlap at any instance in time.

[0160] At block 712, a determination is made as to whether contention will occur during a RAT 2 CDRx ON duration based on the comparison performed at the block 710. The block 712 may include the UE determining that contention will occur during a RAT 2 CDRx ON duration if the comparison performed at the block 710 results in determination that the intervals of usage of the shared resource by the RAT 1 and the RAT 2 overlap at least one instance in time. The block 712 may include the UE determining that contention will occur during a RAT 2 CDRx ON duration if the comparison performed at the block 710 results in determination that the intervals of usage of the shared resource by the RAT 1 and the RAT 2 overlap at least one instance in time including an instance in time during an expected RAT 2 CDRx ON duration. The UE determines whether or not to reset a connection for RAT 2 (or determines whether or not to perform other predefined actions for avoiding contention), based on a result of the UE determining a probability of contention.

[0161] FIG. 8 is a flowchart of a process 800 according to various embodiments. With reference to FIGS. 1-8, the process 800 may be performed by a UE (e.g., the UEs 110, 200, 300).

[0162] At block 802, communication is performed using a RAT 1. The block 802 may include a UE (e.g., the UE 300) communicating using a first radio access technology.

[0163] At block 804, communication is performed using a RAT 2. The block 804 may include the UE communicating using a second radio access technology.

[0164] At block 806, shared resource usage information is received for the RAT 1. The block 806 may include a component of the UE (e.g., the processor 201) receiving shared resource usage information from an internal module for the RAT 1. In some embodiments, the shared resource usage information may include a request for usage of the shared resource (e.g., the shared resource 322, the transceiver 330). In some embodiments, the share resource usage information may include paging cycle information for the RAT 1 (e.g., paging cycle duration, slot cycle index)

[0165] At block 808, CDRx timing information is received for the RAT 2. The block 808 may include a component of the UE (e.g., the processor 201) receiving CDRx timing information from an internal module for the RAT 2. The block 808 may include the UE receiving CDRx timing information from a base station for the RAT 2. In some embodiments, the CDRx timing information may include an inactivity timer duration, a CDRx offset value, a CDRx cycle duration value, and/or a CDRx ON duration value.

[0166] At block 810, shared resource usage times for the RAT 1 are determined for an upcoming time period. The block 810 may include the UE determining beginning and ending times for usage of the shared resource by the RAT 1 based on the shared resource usage information received at the block 806. In some embodiments, the upcoming period of time may be a period of time beginning at some point in the future and continuing for some defined duration. For example, the upcoming period of time may be a duration of ten seconds beginning at the present time (relative to when the block 810 is performed).

[0167] At block 812, shared resource usage times for the RAT 2 are determined for the upcoming time period. The block 812 may include the UE determining beginning and ending times for usage of the shared resource by the RAT 2 based on the CDRx timing information received at the bock 808. The block 812 may include the UE determining beginning and ending times for usage of the shared resource by the RAT 2 based on expected CDRx ON durations for the RAT 2.

[0168] At block 814, the shared resource usage times determined at the block 810 and the block 812 are compared. The block 814 may include the UE comparing the beginning and ending times for the RAT 1 determined at the block 810 with the beginning and ending times for the RAT 2 determined at the block 812 in order to determine when the two sets of intervals overlap. The block 814 may include determining all points in time in which both the RAT 1 and the RAT 2 are expected to attempt usage of the shared resource.

[0169] At block 816, a probability or proportion of contention for CDRx ON durations for the RAT 2 is determined based on the comparison performed at the block 814. The block 816 may include the UE determining the proportion of all CDRx ON durations in the upcoming time period for which at least a portion of the CDRx ON durations overlap with expected shared resource usage by the RAT 1. The block 816 may include the UE determining a probability that any single CDRx ON duration in the upcoming time period will overlap with a shared resource usage by the RAT 1. Upon the UE determining the probability of contention, the UE may perform one or more predefined actions to avoid the contention. For example, the UE may reset a connection between the UE and a base station for the RAT 2.

[0170] FIG. 9 is a flowchart of a process 900 according to various embodiments. With reference to FIGS. 1-9, the process 900 may be performed by a UE (e.g., the UEs 110, 200, 300).

[0171] At block 902, communication is performed using a RAT 1. The block 902 may include a UE (e.g., the UE 300) communicating using a first radio access technology.

[0172] At block 904, communication is performed using a connected mode discontinuous reception for a RAT 2. The block 904 may include a UE (e.g., the UE 300) communicating using CDRx for a second radio access technology.

[0173] At block 906, determination is performed as to whether contention will occur during an ON duration of the RAT 2 CDRx. The block 906 may include a UE (e.g., the UE 300) determining whether contention will occur for a shared resource of the UE (e.g., the share resource 322, the transceiver 330). The block 906 may include the UE determining a proportion of upcoming CDRx ON durations for the RAT 2 for which contention is expected to occur. The block 906 may include the UE determining a probability of contention for upcoming CDRx ON durations for the RAT 2.

[0174] At block 908, a determination is made as to whether to reset a connection for the RAT 2 based on the determination performed at the block 906. The block 908 may include the UE determining to reset the connection for the RAT 2 if the determination performed at the block 906 results in determination that contention will occur for at least one CDRx ON duration. The block 908 may include the UE determining to not reset the connection for the RAT 2 if the determination performed at the block 908 results in determination that contention will not occur for any CDRx ON duration. The block 908 may include the UE determining to reset the connection for the RAT 2 if the determination performed at the block 906 results in determination of a proportion of expected contention for upcoming CDRx ON durations that is greater than a contention threshold. The block 908 may include the UE determining to not reset the connection for the RAT 2 if the determination performed at the block 906 results in determination of a proportion of expected contention for upcoming CDRx ON durations that is less than the contention threshold. The block 908, may include the UE determining to reset the connection for the RAT 2 if the determination performed at the block 906 results in determination of a probability of expected contention for upcoming CDRx ON durations that is greater than a contention threshold. The block 908 may include the UE determining to not reset the connection for the RAT 2 if the determination performed at the block 906 results in determination of a probability of expected contention for upcoming CDRx ON durations that is less than the contention threshold.

[0175] At block 910, the connection for the RAT 2 is reset based on the determination performed at the block 908. If the determination performed at the block 908 results in determination to reset the connection for the RAT 2, then the process 900 continues at the block 912. If the determination performed at the block 908 results in determination to not reset the connection for the RAT 2, then the process 900 continues at the block 914.

[0176] At block 912, the connection for the RAT 2 is reset. The block 912 may include the UE resetting the connection between the UE and a base station for the RAT 2. The block 912 may include the UE declaring a local radio link failure. The block 912 may include the UE performing a radio resource control connection reestablishment procedure. The block 912 may include the UE receiving a new CDRx offset value from a base station for the RAT 2.

[0177] At block 914, communication is continued using the RAT 1 and the RAT 2.

[0178] FIG. 10 illustrates an example of a UE 1000, which may correspond to the UEs 110, 200, 300 in FIGS. 1-3. With reference to FIGS. 1-10, the UE 1000 may include a processor 1002 coupled to a touchscreen controller 1004 and an internal memory 1006. The processor 1002 may correspond to the processor 201. The processor 1002 may be one or more multi-core integrated circuits designated for general or specific processing tasks. The internal memory 1006 may correspond to the memory 202. The memory 1006 may be volatile or non-volatile memory, and may also be secure and/or encrypted memory, or unsecure and/or unencrypted memory, or any combination thereof. The touchscreen controller 1004 and the processor 1002 may also be coupled to a touchscreen panel 1012, such as a resistive-sensing touchscreen, capacitive-sensing touchscreen, infrared sensing touchscreen, etc. Additionally, the display of the UE 1000 need not have touch screen capability. The touch screen controller 1004, the touchscreen panel 1012 may correspond to the user interface 203.

[0179] The UE 1000 may have one or more cellular network transceivers 1008a, 1008b coupled to the processor 1002 and to two or more antennae 1010 and configured for sending and receiving cellular communications. The transceivers 1008 and antennae 1010a, 1010b may be used with the above-mentioned circuitry to implement the various embodiment methods. The UE 1000 may include two or more SIM cards 1016a, 1016b, corresponding to SIM A 206 and SIM B 207, coupled to the transceivers 1008a, 1008b and/or the processor 1002 and configured as described above. The UE 1000 may include a cellular network wireless modem chip 1011 that enables communication via a cellular network and is coupled to the processor. The one or more cellular network transceivers 1008a, 1008b, the cellular network wireless modem chip 1011, and the two or more antennae 1010 may correspond to the RF resources 204.

[0180] The UE 1000 may include a peripheral device connection interface 1018 coupled to the processor 1002. The peripheral device connection interface 1018 may be singularly configured to accept one type of connection, or multiply configured to accept various types of physical and communication connections, common or proprietary, such as USB, FireWire, Thunderbolt, or PCIe. The peripheral device connection interface 1018 may also be coupled to a similarly configured peripheral device connection port (not shown).

[0181] The UE 1000 may also include speakers 1014 for providing audio outputs. The UE 1000 may also include a housing 1020, constructed of a plastic, metal, or a combination of materials, for containing all or some of the components discussed herein. The UE 1000 may include a power source 1022 coupled to the processor 1002, such as a disposable or rechargeable battery. The rechargeable battery may also be coupled to a peripheral device connection port (not shown) to receive a charging current from a source external to the UE 1000. The UE 1000 may also include a physical button 1024 for receiving user inputs. The UE 1000 may also include a power button 1026 for turning the UE 1000 on and off.

[0182] The foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the block of various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of blocks in the foregoing embodiments may be performed in any order. Words such as “thereafter,” “then,” “next,” etc. are not intended to limit the order of the blocks; these words are simply used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles “a,” “an,” or “the” is not to be construed as limiting the element to the singular.

[0183] The various illustrative logical blocks, modules, circuits, and algorithm blocks described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, and circuits have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

[0184] The hardware used to implement the various illustrative logics, logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration). Alternatively, some blocks or methods may be performed by circuitry that is specific to a given function.

[0185] In some exemplary embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable storage medium or non-transitory processor-readable storage medium. The blocks of a method or algorithm disclosed herein may be embodied in a processor-executable software module which may reside on a non-transitory computer-readable or processor-readable storage medium. Non-transitory computer-readable or processor-readable storage media may be any storage media that may be accessed by a computer or a processor. By way of example but not limitation, such non-transitory computer-readable or processor-readable storage media may include

RAM, ROM, EEPROM, FLASH memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of non-transitory computer-readable and processor-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory processor-readable storage medium and/or computer-readable storage medium, which may be incorporated into a computer program product.

[0186] The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the embodiments disclosed herein. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to some embodiments without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A method for managing contention between a first radio access technology (RAT) and a second radio access technology of a user equipment (UE), comprising:

communicating using the first RAT;

communicating using the second RAT, wherein the communicating using the second RAT comprises communicating using a connected mode discontinuous reception (CDRx);

determining whether a contention condition will occur between the first RAT and the second RAT for a shared radio-frequency (RF) resource of the UE during an ON duration of the CDRx; and

resetting a connection for the second RAT in response to determining that the contention condition will occur between the first RAT and the second RAT.

2. The method of claim 1,

wherein the determining whether a contention condition will occur comprises determining whether or not the contention condition will occur during the ON duration, prior to the beginning of the ON duration.

3. The method of claim 1,

wherein the determining whether a contention condition will occur is performed based on a request for the first RAT for the shared RF resource.

4. The method of claim 3,

wherein the determining whether a contention condition will occur is performed based on a CDRx offset value for the CDRx of the second RAT.

5. The method of claim 4,

wherein the CDRx offset value is received by the UE from a base station of the second RAT during a radio resource control connection establishment procedure.

6. The method of claim 4,

wherein the determining whether a contention condition will occur comprises comparing an expected beginning time and an expected ending time for the ON duration based on the CDRx offset value with an expected beginning time and an expected ending time associated with the request for the first RAT for the shared RF resource.

7. The method of claim 3,

wherein the determining whether a contention condition will occur is performed based on expected future requests for the first RAT for the shared RF resource.

8. The method of claim 1,

wherein the determining whether a contention condition will occur is performed based on a paging cycle of the first RAT.

9. The method of claim 1,

wherein the determining whether a contention condition will occur comprises determining a probability of the contention condition for the shared RF resource occurring.

10. The method of claim 9,

wherein the determining a probability of the contention condition for the shared RF resource comprises determining a probability of the contention condition for the shared RF resource occurring during an upcoming duration of time.

11. The method of claim 10,

wherein the upcoming duration of time includes two or more ON durations of the CDRx; and

wherein the determining the probability of the contention condition for the shared RF resource during the upcoming duration of time comprises determining a probability that the contention condition will occur during one or more of the ON durations included in the upcoming duration.

12. The method of claim 1,

wherein the determining whether the contention condition will occur comprises determining a proportion of ON durations for which the contention for the shared RF resource is expected to occur.

13. The method of claim 12,

wherein the determining the proportion of ON durations for which the contention for the shared RF resource is expected to occur comprises determining a proportion of ON durations for which the contention for the shared RF resource is expected to occur during an upcoming duration of time.

14. The method of claim 13,

wherein the upcoming duration of time includes two or more ON durations of the CDRx; and

wherein the determining a proportion of ON durations for which the contention for the shared RF resource is expected to occur during the upcoming duration of time comprises determining a proportion of all ON durations included in the upcoming duration of time for which the contention for the shared RF resource is expected to occur.

15. The method of claim 1,

wherein the determining whether the contention condition will occur comprises determining a proportion of ON durations for which the contention for the shared RF resource is expected to occur; and

wherein the determining whether or not to reset the connection for the second RAT comprises comparing the proportion of ON durations for which the contention for the shared RF resource is expected to occur to the contention threshold.

16. The method of claim 15, further comprising:

resetting the connection for the second RAT if the proportion of ON durations for which the contention for the shared RF resource is expected to occur is greater than or equal to the contention threshold, and

not resetting the connection for the second RAT if the proportion of ON durations for which the contention for the shared RF resource is expected to occur is less than the contention threshold.

17. The method of claim 16,

wherein the resetting the connection for the second RAT comprises the UE declaring a local radio link failure to a base station of the second RAT.

18. The method of claim 17, further comprising:

receiving a new CDRx offset value from the base station of the second RAT during a radio resource control connection reestablishment procedure.

19. The method of claim 18,

wherein the new CDRx offset value is different from a CDRx offset value used by the UE during the determining whether the contention condition will occur.

20. The method of claim 15,

wherein the contention threshold is a predefined value.

21. The method of claim 15,

wherein the contention threshold is dynamically adjusted by the UE.

22. The method of claim 1,

wherein the UE performs the determining whether a contention condition will occur without coordination or instruction from a base station of the first RAT or a base station of the second RAT.

23. The method of claim 1,

wherein the shared RF resource is a radio frequency resource used by the UE to at least receive communications for both the first RAT and the second RAT.

24. The method of claim 1,

further comprising maintaining without resetting the connection for the second RAT in response to determining that a contention condition will not occur between the first RAT and the second RAT.

25. A user equipment apparatus comprising:

a shared radio resource configured to communicate using a first RAT, wherein the shared radio resource is further configured to communicate using a connected mode discontinuous reception (CDRx) for a second RAT; and

one or more processors configured to:

determine whether a contention condition will occur between the first RAT and the second RAT for the shared radio resource during an ON duration of the CDRx; and

reset a connection for the second RAT in response to determining that the contention condition will occur between the first RAT and the second RAT.

26. A user equipment apparatus comprising:

means for communicating using a first RAT;

means for communicating using a connected mode discontinuous reception (CDRx) for a second RAT;

means for determining whether a contention condition will occur between the first RAT and the second RAT for a shared resource during an ON duration of the CDRx; and

means for resetting a connection for the second RAT in response to determining that the contention condition will occur between the first RAT and the second RAT.

27. A non-transitory computer-readable medium, the medium comprising instructions configured to cause one or more computing devices to:

communicate using a first RAT of a UE;

communicate using a connected mode discontinuous reception (CDRx) for a second RAT of the UE;

determine whether a contention condition will occur between the first RAT and the second RAT for a shared resource during an ON duration of the CDRx; and

reset a connection for the second RAT in response to determining that the contention condition will occur between the first RAT and the second RAT.

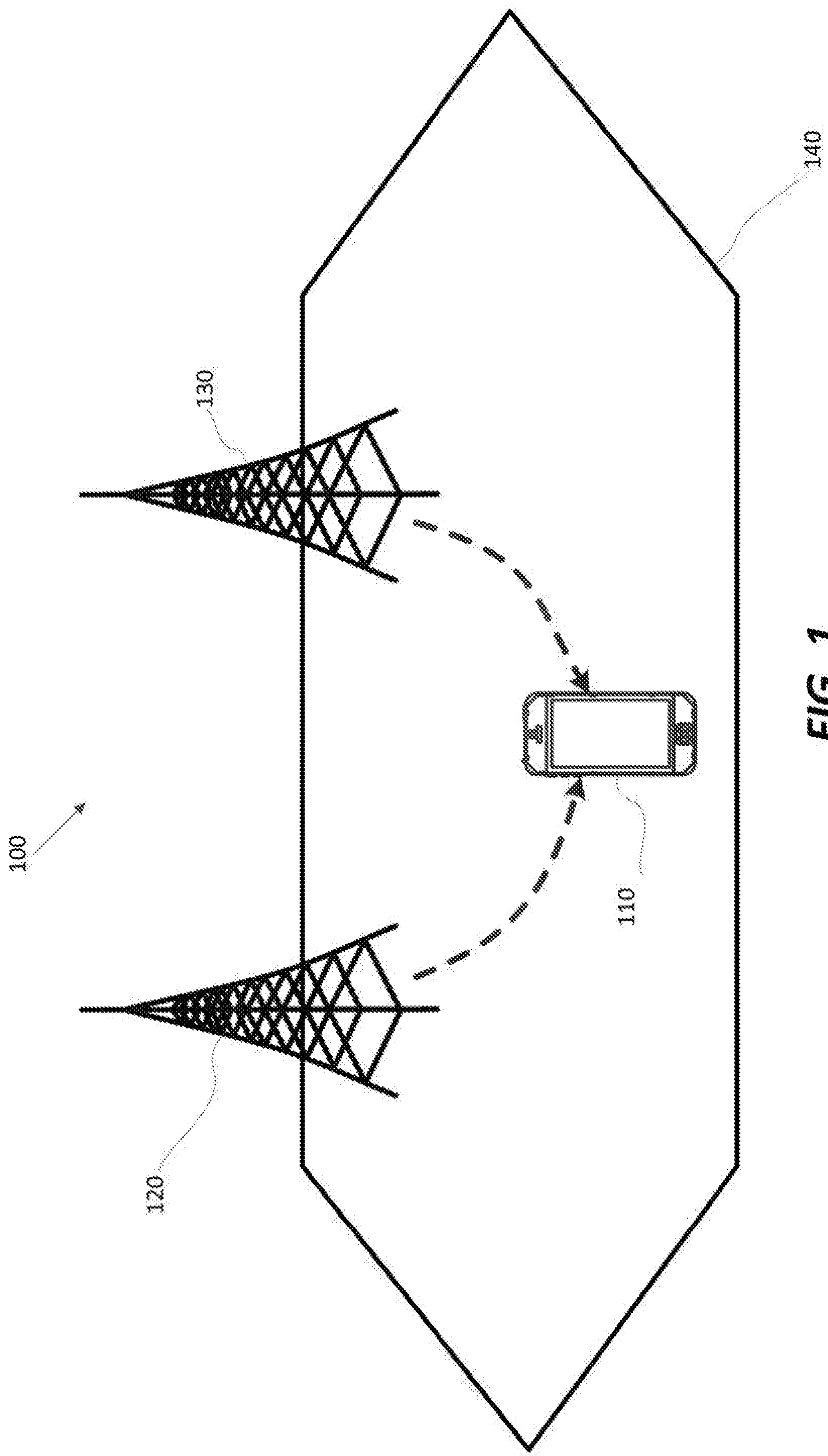

FIG. 1

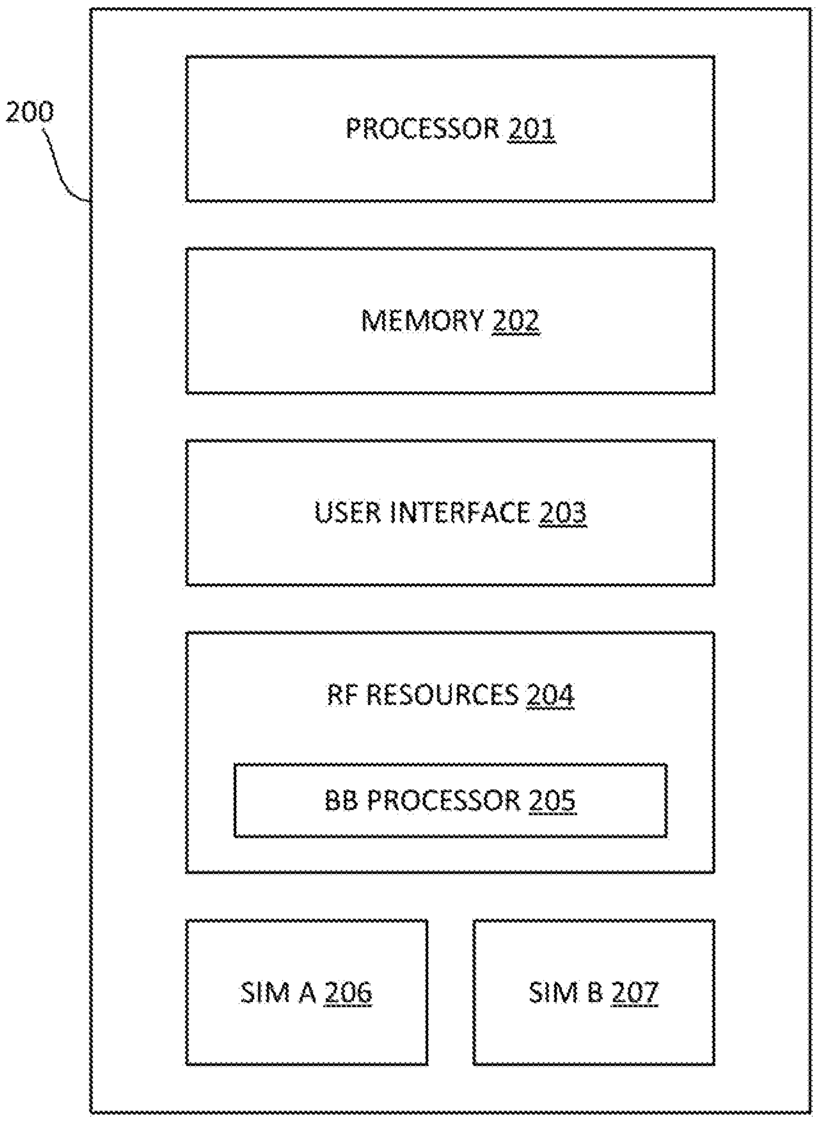
200
PROCESSOR 201
MEMORY 202
USER INTERFACE 203
RF RESOURCES 204
BB PROCESSOR 205
SIM A 206
SIM B 207

FIG. 2

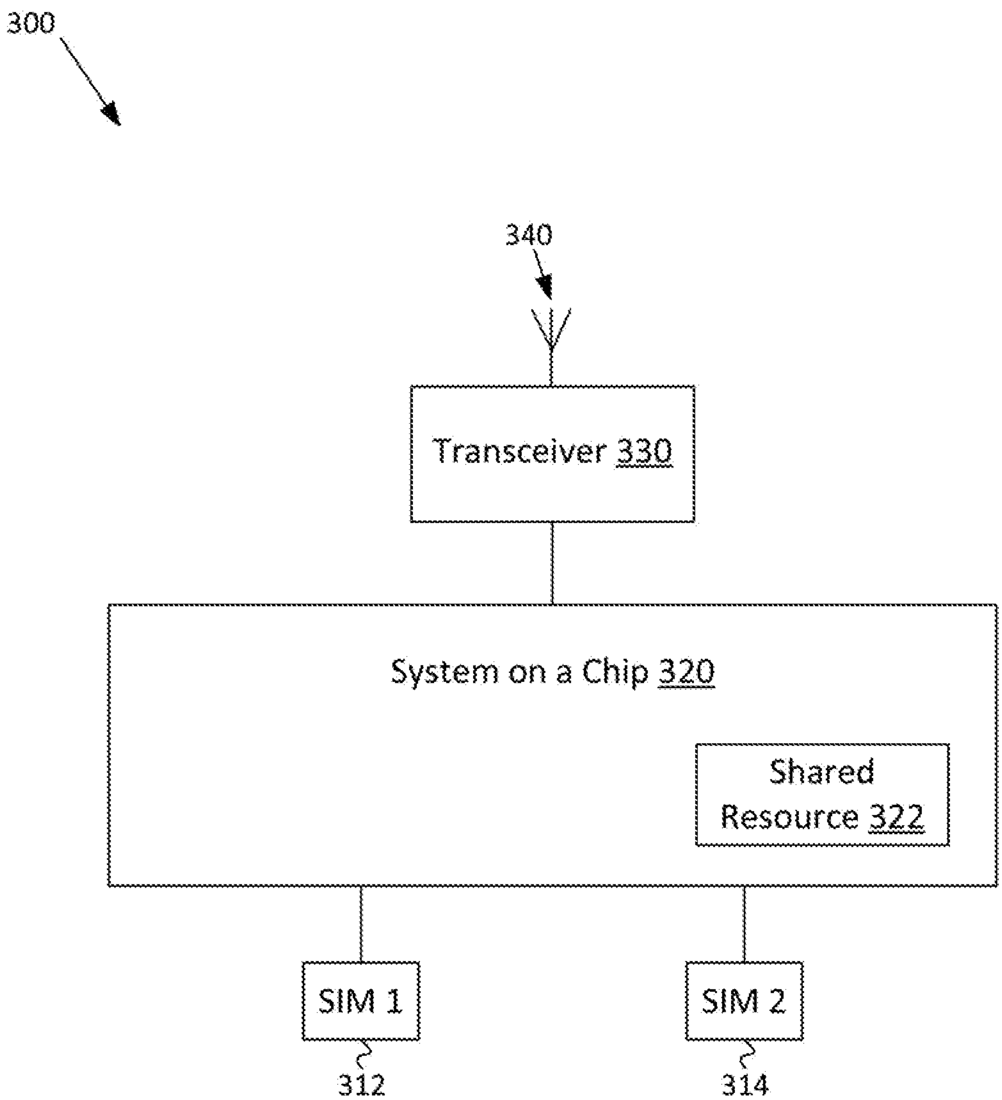
300
340
Transceiver 330
System on a Chip 320
Shared Resource 322
SIM 1
SIM 2
312
314

FIG. 3

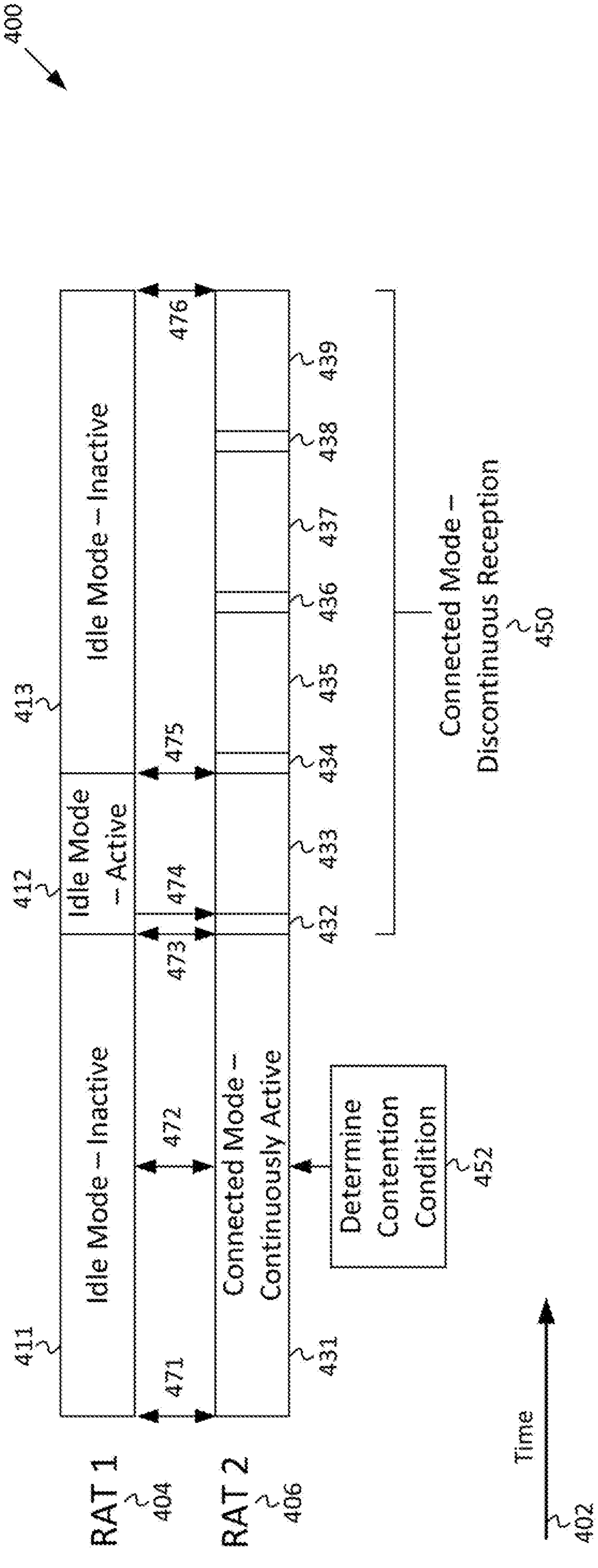
400
RAT 1
404
RAT 2
406
Idle Mode – Inactive
411
Idle Mode – Active
412
Idle Mode – Inactive
413
Connected Mode – Continuously Active
431
432
433
434
435
436
437
438
439
471
472
473
474
475
476
Determine Contention Condition
452
Connected Mode – Discontinuous Reception
450
Time
402

FIG. 4

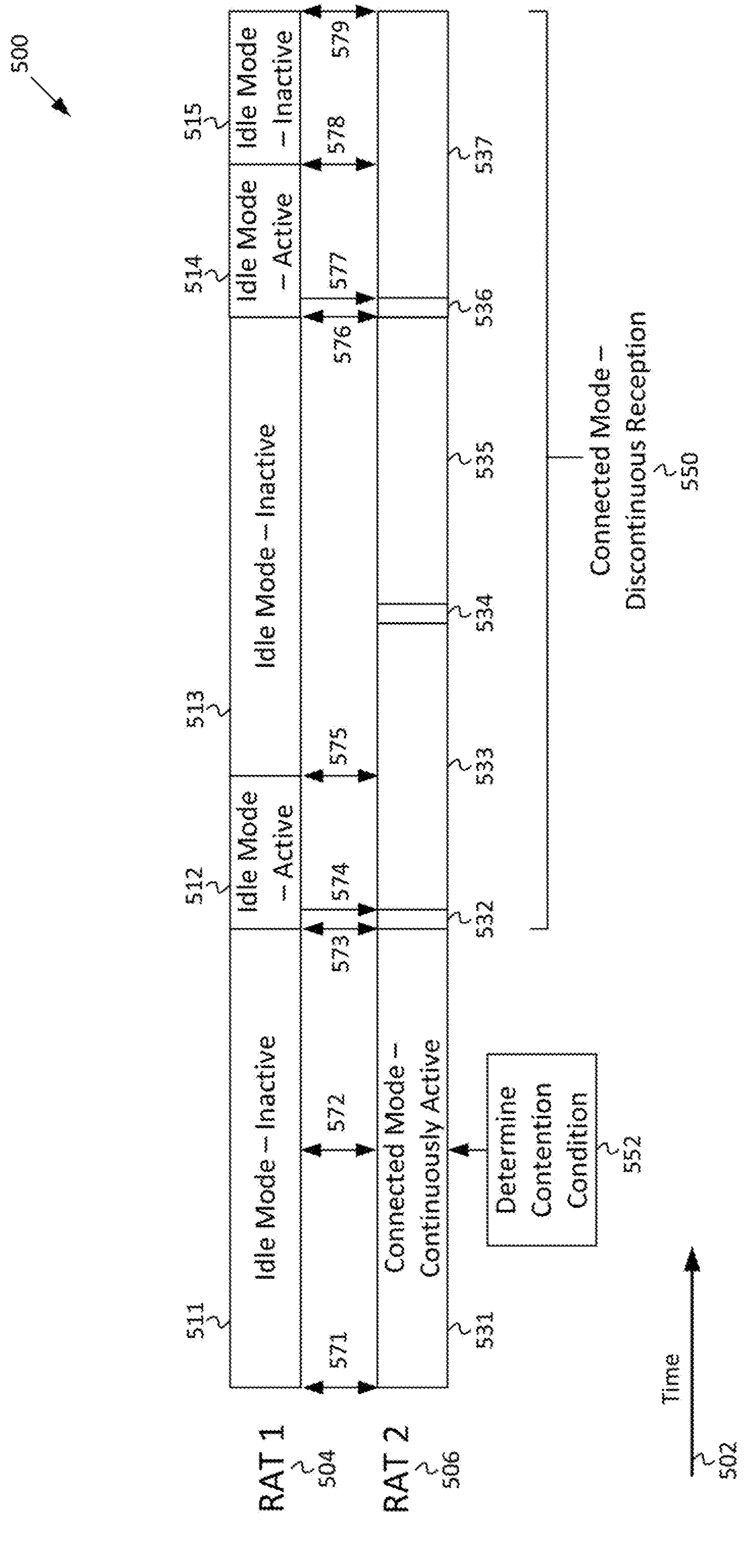
500
RAT 1
504
RAT 2
506
511
512
513
514
515
Idle Mode – Inactive
Idle Mode – Active
Idle Mode – Inactive
Idle Mode – Active
Idle Mode – Inactive
571
572
573
574
575
576
577
578
579
Connected Mode – Continuously Active
531
532
533
534
535
536
537
Determine Contention Condition
552
Connected Mode – Discontinuous Reception
550
Time
502

FIG. 5A

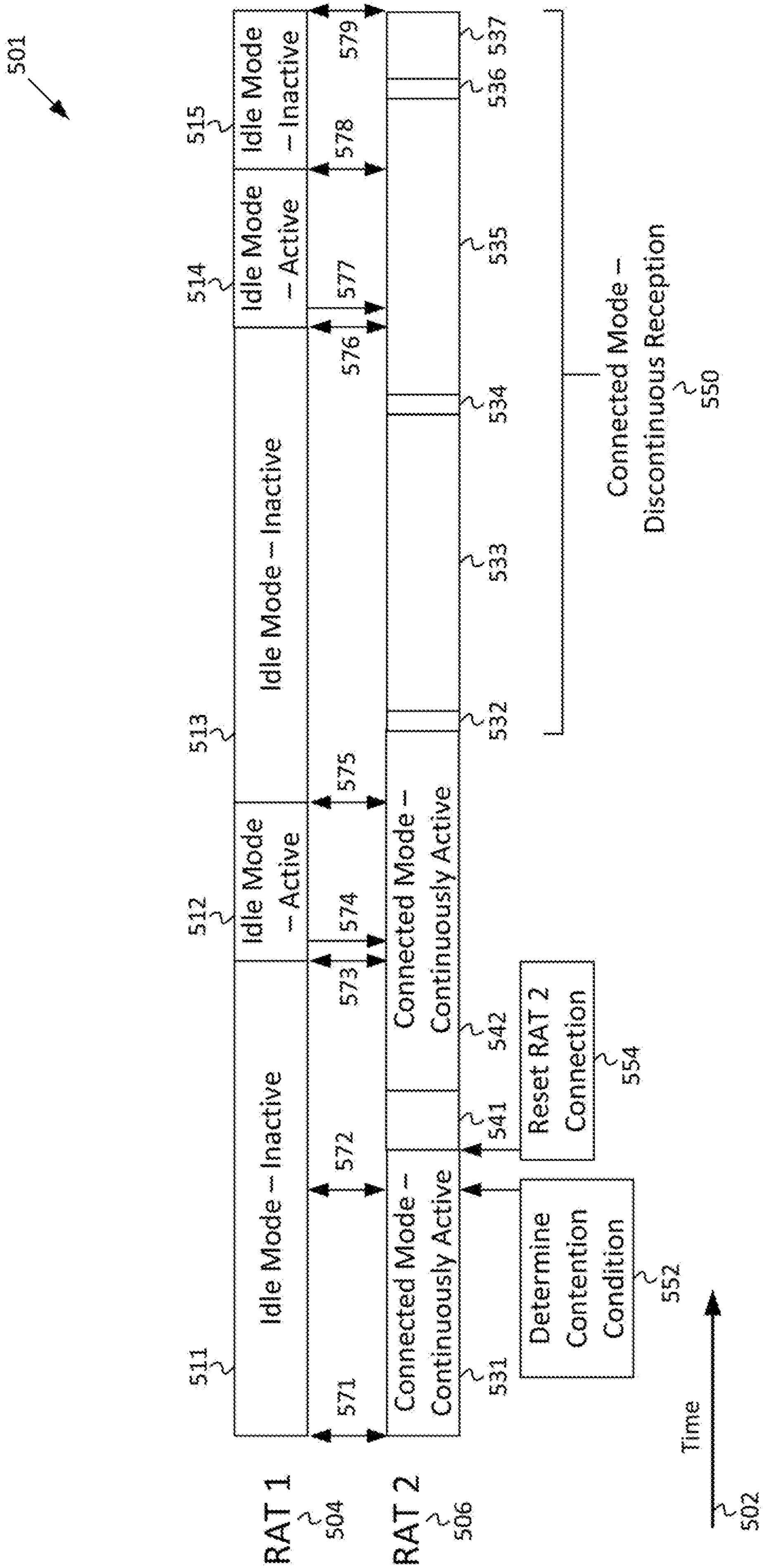
501
RAT 1
504
RAT 2
506
Idle Mode – Inactive
511
Idle Mode – Active
512
Idle Mode – Inactive
513
Idle Mode – Active
514
Idle Mode – Inactive
515
571
572
573
574
575
576
577
578
579
Connected Mode – Continuously Active
531
541
Connected Mode – Continuously Active
542
532
533
534
535
536
537
Connected Mode – Discontinuous Reception
550
Determine Contention Condition
552
Reset RAT 2 Connection
554
Time
502

FIG. 5B

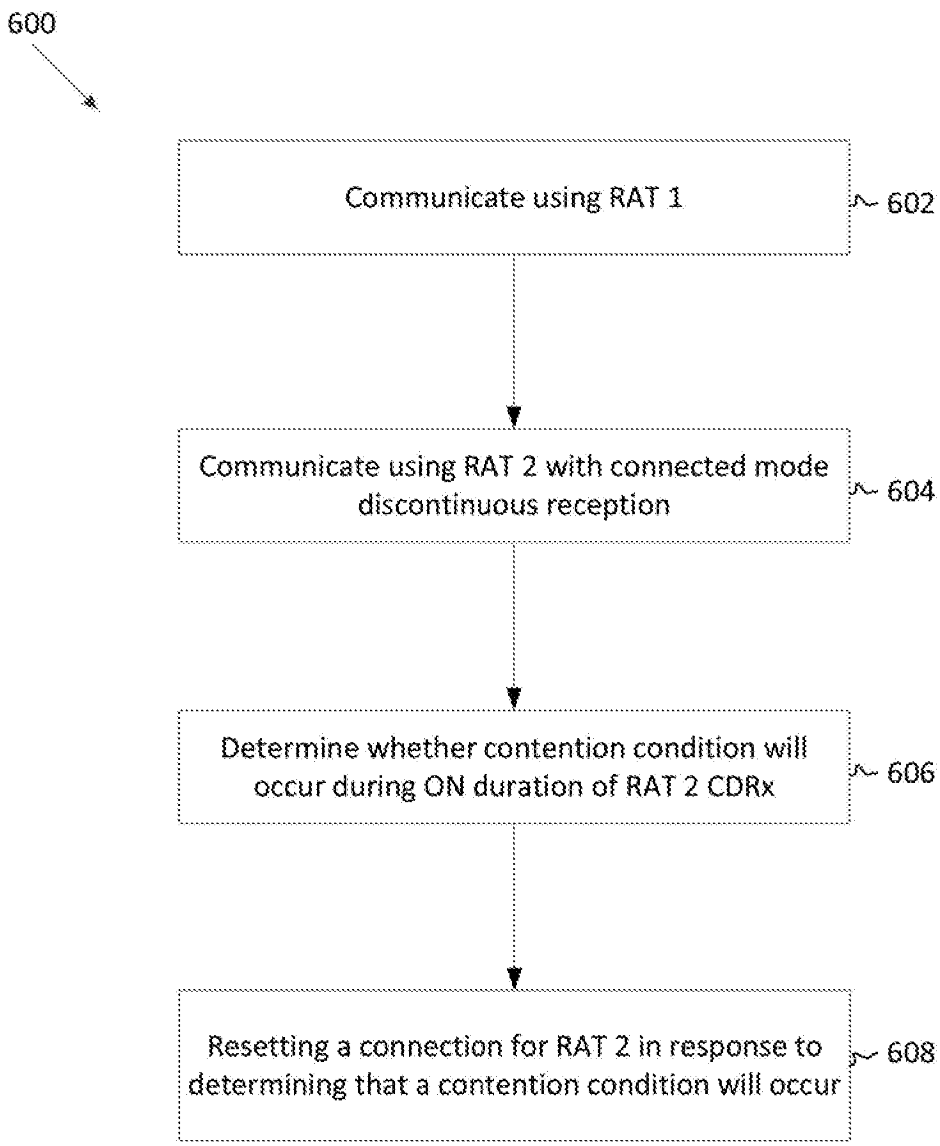
600
Communicate using RAT 1
602
Communicate using RAT 2 with connected mode discontinuous reception
604
Determine whether contention condition will occur during ON duration of RAT 2 CDRx
606
Resetting a connection for RAT 2 in response to determining that a contention condition will occur
608

FIG. 6

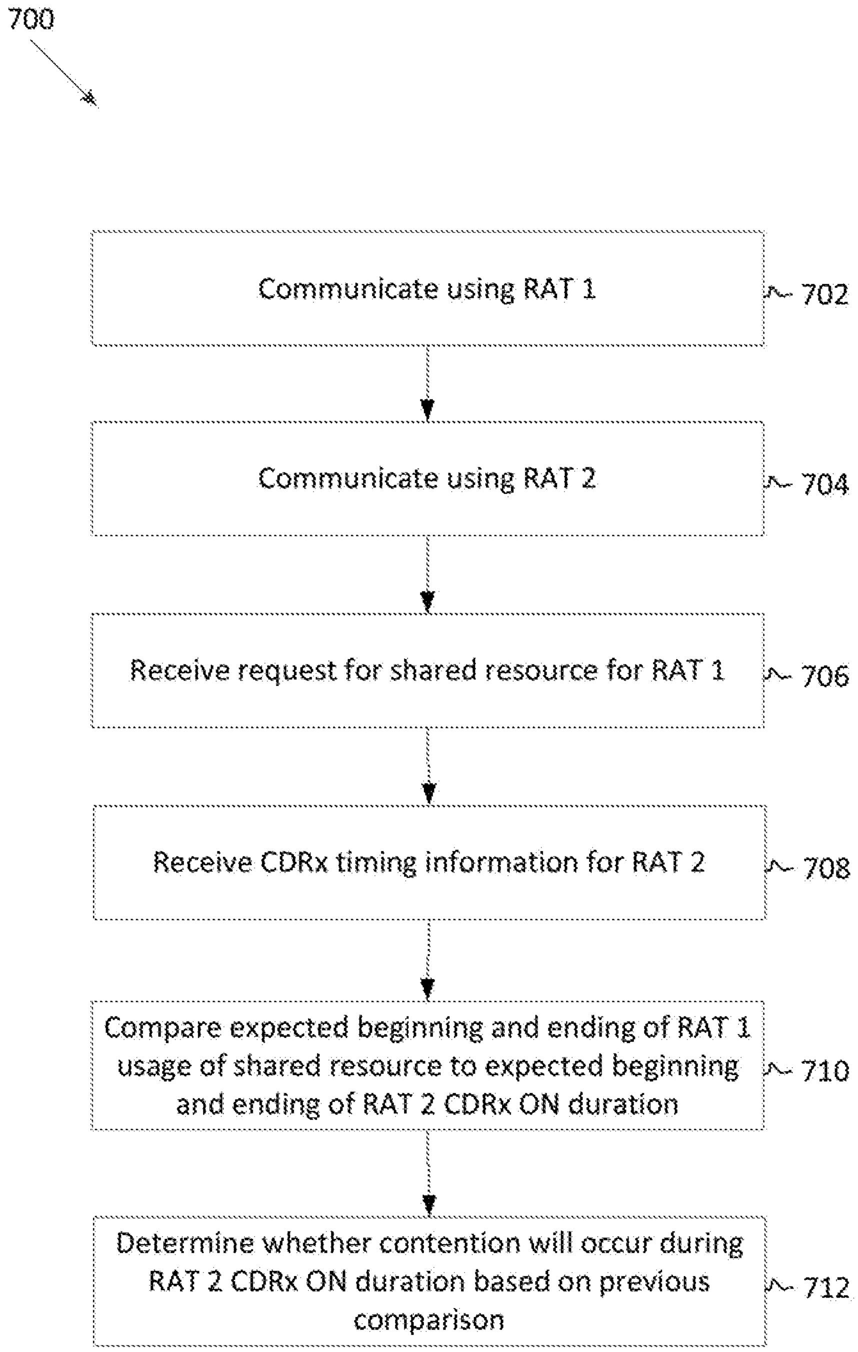
700
Communicate using RAT 1
702
Communicate using RAT 2
704
Receive request for shared resource for RAT 1
706
Receive CDRx timing information for RAT 2
708
Compare expected beginning and ending of RAT 1 usage of shared resource to expected beginning and ending of RAT 2 CDRx ON duration
710
Determine whether contention will occur during RAT 2 CDRx ON duration based on previous comparison
712

FIG. 7

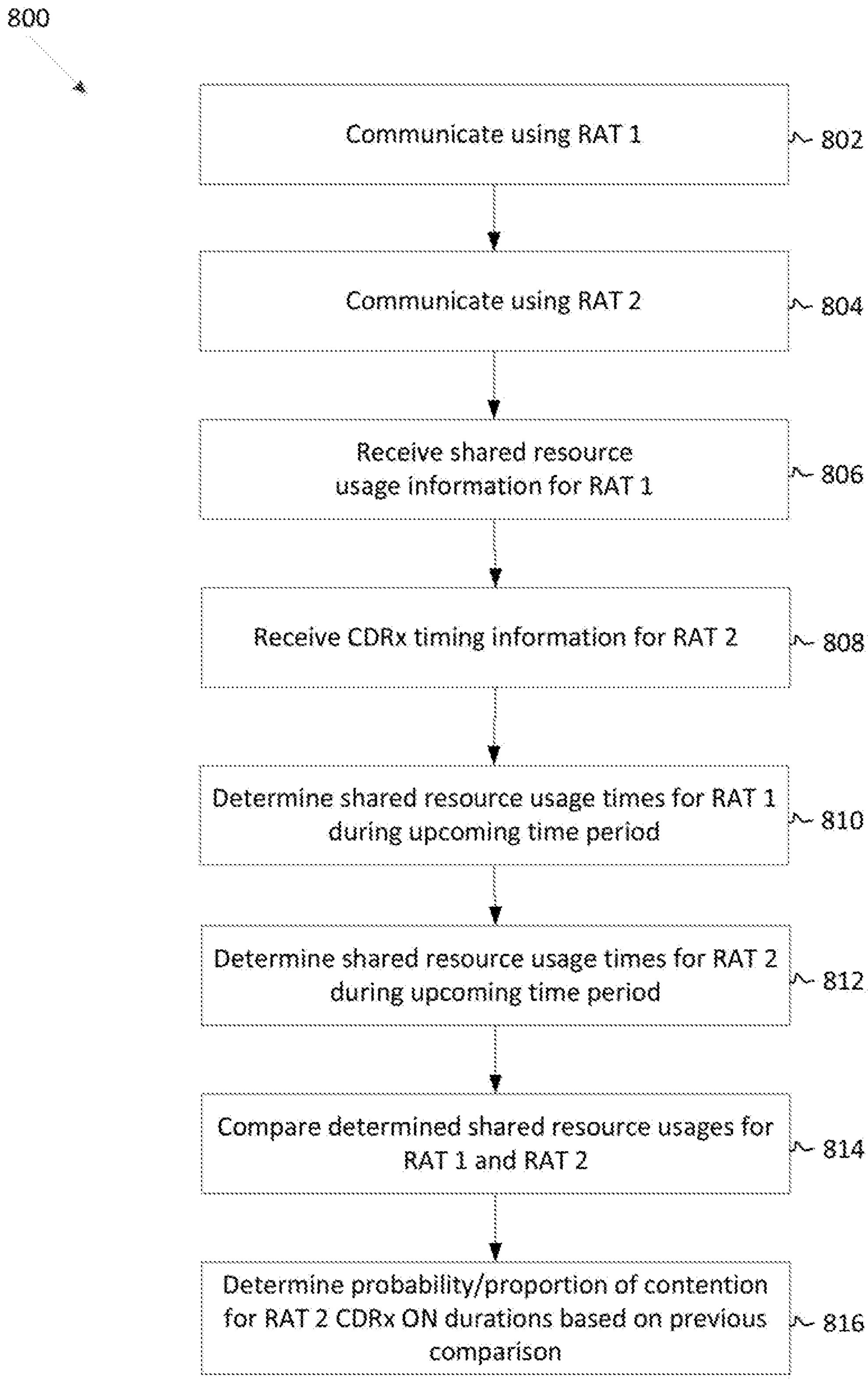
800
Communicate using RAT 1
802
Communicate using RAT 2
804
Receive shared resource usage information for RAT 1
806
Receive CDRx timing information for RAT 2
808
Determine shared resource usage times for RAT 1 during upcoming time period
810
Determine shared resource usage times for RAT 2 during upcoming time period
812
Compare determined shared resource usages for RAT 1 and RAT 2
814
Determine probability/proportion of contention for RAT 2 CDRx ON durations based on previous comparison
816

FIG. 8

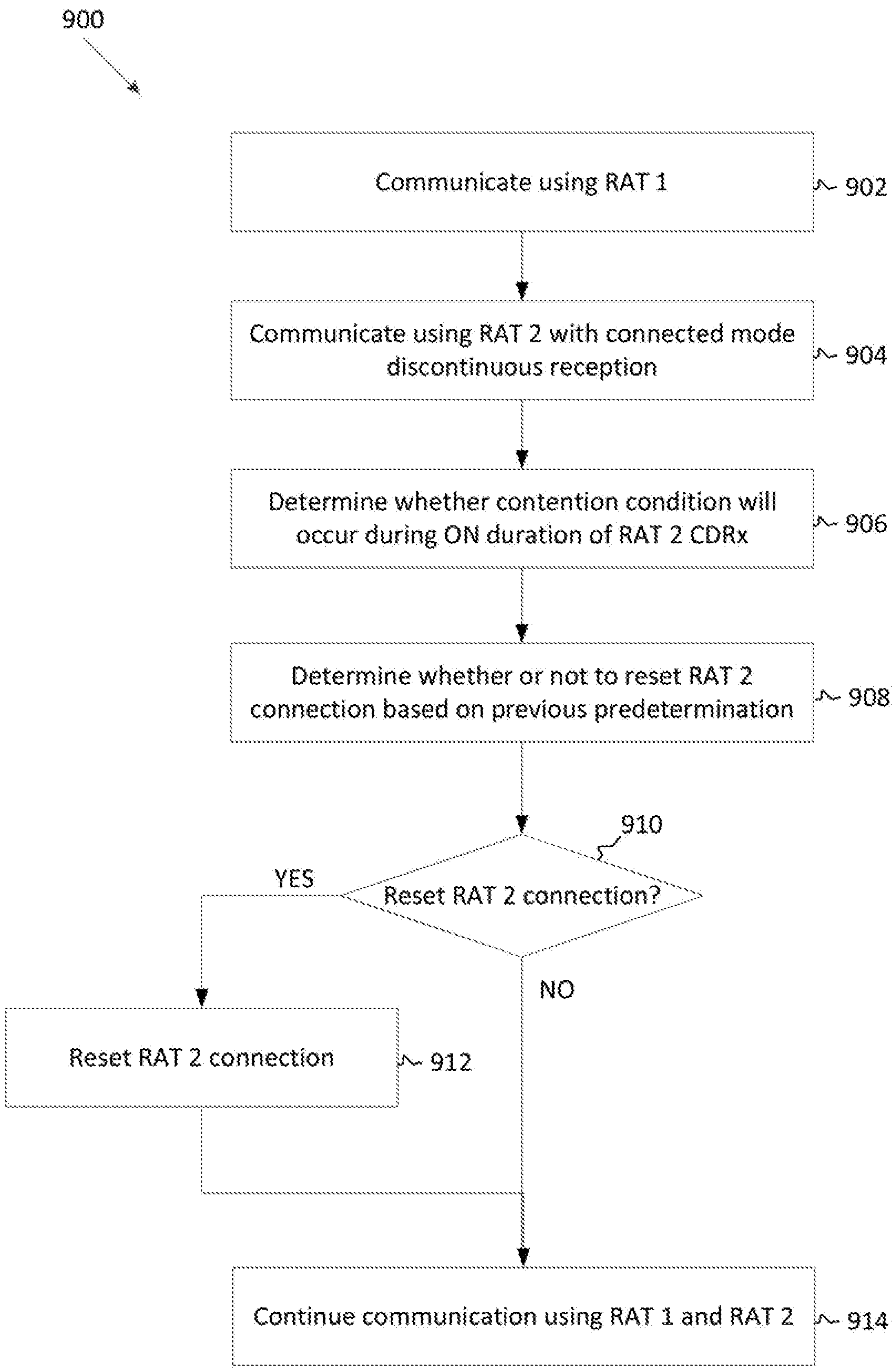
900
Communicate using RAT 1
902
Communicate using RAT 2 with connected mode discontinuous reception
904
Determine whether contention condition will occur during ON duration of RAT 2 CDRx
906
Determine whether or not to reset RAT 2 connection based on previous predetermination
908
910
Reset RAT 2 connection?
YES
NO
Reset RAT 2 connection
912
Continue communication using RAT 1 and RAT 2
914

FIG. 9

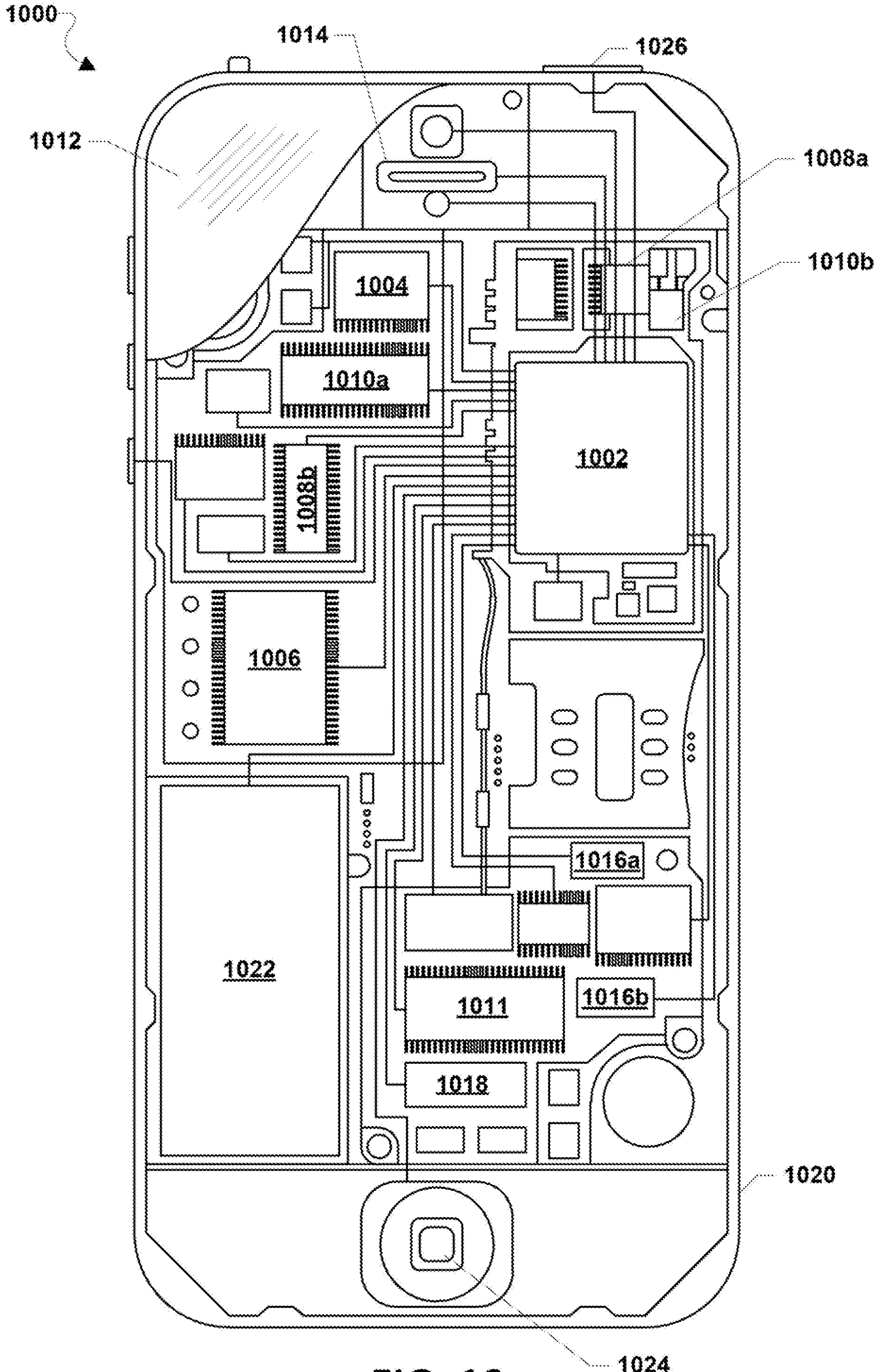
1000
1014
1026
1012
1008a
1010b
1004
1010a
1002
1008b
1006
1016a
1022
1011
1016b
1018
1020
1024

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/086341

A. CLASSIFICATION OF SUBJECT MATTER

H04W 88/06(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q

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)

CNPAT, CNKI, WPI, EPODOC，3GPP： first, second, RAT, contention, conflict, interfere，interference， DRX, CDRX, reset, connection

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 104106308 A (QUALCOMM INC.) 15 October 2014 (2014-10-15) description， paragraphs [0009]， [0045]-[0100]，claims 1-22	1-27
Y	CN 103167473 A (BROADCOM CORPORATION) 19 June 2013 (2013-06-19) description， paragraphs [0065]-[0091]	1-27
Y	US 2013010766 A1 (QUALCOMM INC.) 10 January 2013 (2013-01-10) description， paragraphs [0011]-[0014]，[0117]，claim 1	1-27
Y	CN 103222205 A (INTEL CORPORATION) 24 July 2013 (2013-07-24) description， paragraphs [0020]-[0048]	1-27
A	QUALCOMM INC. "Considerations on access delay to ART_LTE-UED" *3GPP TSG-SA WG4 Meeting #74 Tdoc S4 (13)0671,* 12 July 2013 (2013-07-12), the whole document	1-27

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

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"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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 April 2016	**11 May 2016**

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China

Facsimile No. **(86-10)62019451**

Authorized officer

LI,Wen

Telephone No. **(86-10)62413858**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/086341

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