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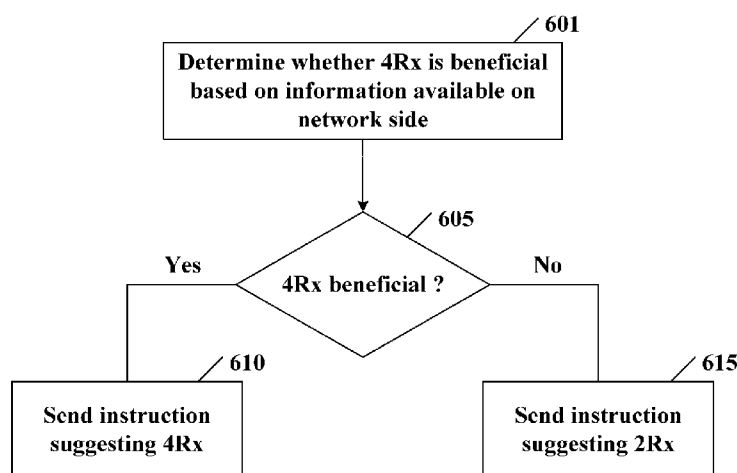


FIG. 6

- (57) **Abstract:** Method, network element, user equipment and system are disclosed for optimal use of high-number receive antennas (Rx) in a wireless network. The network has a network element and a user equipment (UE). The UE is operable with the high number and a low number Rx. The method comprises: determining whether the high number Rx is beneficial based on information available at the network element; and sending a first instruction to the UE, wherein the first instruction includes information about use of the high number Rx.

**METHOD, NETWORK ELEMENT, USER EQUIPMENT AND SYSTEM
FOR OPTIMAL USE OF HIGH-NUMBER RX**

Field of the Invention

[0001] Embodiments of the disclosure generally relate to wireless communications, and, more particularly, to optimal use of high-number receive antennas (Rx) in a wireless network.

Background

[0002] Universal Mobile Telecommunications System (UMTS) is an exemplary implementation of a "third-generation" or "3G" cellular telephone technology. The UMTS standard is specified by a collaborative body referred to as the 3rd Generation Partnership Project (3GPP). The 3GPP has adopted UMTS as a 3G cellular radio system targeted for inter alia European markets, in response to requirements set forth by the International Telecommunications Union (ITU). The ITU standardizes and regulates international radio and telecommunications. Further enhancements to UMTS have been summarized under the Long Term Evolution (LTE) radio standard, as fourth generation (4G) technology. LTE-Advanced (LTE-A), an evolution of LTE, is being standardized in LTE Release 10 and beyond.

[0003] With new technologies developed, user equipment (UE) using a higher number of receive antennas (Rx) has become realistic. The performance requirements for 4Rx UE have been proposed, for example, as described in 3GPP Work Item Description RP-150427. While the high-number Rx can bring diversity gain, it also has disadvantages. For example, 4Rx increases the UE power consumption compared to traditional 2Rx. The existing solutions for optimal use of high-number Rx are limited. It is desirable to provide more practical solutions.

Summary

[0004] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not

intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0005] According to one aspect of the disclosure, it is provided a method for optimal use of high-number receive antennas (Rx) in a wireless network. The network has a network element and a user equipment (UE). The UE is operable with the high number and a low number Rx. The method comprises: determining whether the high number Rx is beneficial based on information available at the network element; and sending a first instruction to the UE, wherein the first instruction includes information about use of the high number Rx.

[0006] According to another aspect of the disclosure, it is provided a method for optimal use of a high number receive antennas (Rx) in a wireless network having a network element and a user equipment (UE). The UE is operable with the high number and a low number Rx. The method comprises: receiving a first instruction from the network element, wherein the first instruction includes information about use of the high number Rx; and using the high number Rx based on the first instruction.

[0007] According to another aspect of the disclosure, it is provided a method for optimal use of a high number receive antennas (Rx) in a wireless network having a network element and a user equipment (UE). The UE is operable with the high number and a low number Rx. The method comprising: sending a report to the network element indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

[0008] According to still another aspect of the disclosure, it is provided a network element configured to work in a wireless network having a user equipment (UE) operable with a high number and a low number Rx. The network element comprises: a determining means configured to determine whether the high number Rx is beneficial based on information available at the network element; and a sending means configured to send a first instruction to the UE, wherein the first instruction includes information about use of the high number Rx.

[0009] According to another aspect of the disclosure, it is provided a user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element. The UE comprises: a receiving means configured to receive a first instruction from the network element, wherein the first instruction includes information about use of the high number Rx. The UE is configured to use the high number Rx based on the first instruction.

[0010] According to another aspect of the disclosure, it is provided a user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element. The UE comprising: a sending means configured to send a report to the network element indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

[0011] According to another aspect of the disclosure, it is provided a network element configured to work in a wireless network having a user equipment (UE) operable with a high number and a low number Rx. The network element comprises: at least one processor; and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the network element to perform the above-described method.

[0012] According to another aspect of the disclosure, it is provided a user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element. The UE comprising: at least one processor; and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the UE to perform the above-described method.

[0013] According to another aspect of the disclosure, it is provided a system for optimal use of high-number Rx. The system includes at least one above-described network element and at least one above-described UE.

[0014] These and other objects, features and advantages of the disclosure will become apparent from the following detailed description of illustrative embodiments, which are to be read in connection with the accompanying drawings.

Brief Description of the Drawings

[0015] Figure 1 shows a wireless communication system in which embodiments of the present disclosure may be implemented;

[0016] Figure 2 is a simplified block diagram illustrating a network element according to an embodiment;

[0017] Figure 3 is a simplified block diagram illustrating a user equipment (UE) according to an embodiment;

[0018] Figure 4 is a simplified block diagram illustrating a network element according to an embodiment;

[0019] Figure 5 is a simplified block diagram illustrating a user equipment (UE) according to an embodiment;

[0020] Figure 6 is a flowchart depicting the process for optimal use of 4Rx according to an embodiment;

[0021] Figure 7 is a flowchart depicting the process for optimal use of 4Rx according to an embodiment; and

[0022] Figure 8 shows the effects of 4Rx use in radio link monitoring (RLM) according to an embodiment.

Detailed Description

[0023] For the purpose of explanation, details are set forth in the following description in order to provide a thorough understanding of the embodiments

disclosed. It is apparent, however, to those skilled in the art that the embodiments may be implemented without these specific details or with an equivalent arrangement.

[0024] Figure 1 shows a wireless communication system in which embodiments of the present disclosure may be implemented. As shown in Figure 1, the wireless communication system 100 includes a base station 120 supporting services in a coverage area 122 (also referred to as a cell). The base station 120 is also capable of communicating with wireless devices, such as user equipment (UE) 110A, 110B, within the coverage area. Although Figure 1 depicts one base station 120 and two UEs 110A, 110B, other quantities of base stations and UEs may be implemented as well.

[0025] While this and other embodiments below are primarily discussed in the context of a fourth generation UMTS LTE network, it will be recognized by those of ordinary skill that the disclosure is not so limited. In fact, the various aspects of this disclosure are useful in any wireless network that can benefit from the method as is described herein, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other networks. The terms "network" and "system" are often used interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. Cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDMA, etc. Further, the term "wireless" means any wireless signal, data, communication, or other interface including without limitation Wi-Fi, Bluetooth, 3G (e.g., 3GPP, 3GPP2, and UMTS), HSDPA/HSUPA, TDMA, CDMA (e.g., IS-95A, WCDMA, etc.), FHSS, DSSS, GSM, PAN/802.15, WiMAX (802.16), 802.20, narrowband/FDMA, OFDM, PCS/DCS, analog cellular, CDPD, satellite systems, millimeter wave or microwave systems, acoustic, and infrared (i.e., IrDA).

[0026] In some implementations, the base station 120 may be implemented as an evolved Node B (eNB) type base station consistent with standards, including the LTE standards. The UE 110A, 110B may be mobile and/or stationary. Moreover, the UE 110A, 110B may be referred to as, for example, devices, mobile stations, mobile units, subscriber stations, wireless terminals, terminals, or the like. The UE may be implemented as, for example, a wireless handheld device, a wireless plug-in accessory, or the like. For example, the UE may take the form of a wireless phone, a computer with a wireless connection to a network, or the like. In some cases, the UE may include one or more of the following: at least one processor, at least one computer-readable storage medium (e.g., memory, storage, and the like), a radio access mechanism, and a user interface. The wireless communication system 100 may include a core network 130. The core network 130 may comprise conventional network elements and functions of a cellular communication network, such as MME 132 (Mobility Management Entity), HSS (Home Subscriber Server) 134, etc.

[0027] The UE 110A or 110B is capable of working with a high number and a low number Rx. In this embodiment, the high number Rx is 4Rx and the low number Rx is 2Rx. It is noted that this and below embodiments are not limited to the specific numbers of Rx. Instead, the embodiments can apply to other numbers of Rx, as long as the high-number Rx has more receive antennas than the low-number Rx.

[0028] It is known that a higher number of Rx (e.g. 4Rx) can improve performance of the UE due to a better diversity gain. However, one important consideration, which was raised by chipset vendors and was also recognized by other companies, is that 4Rx would increase the UE power consumption compared to 2RX. This may become a problem where 4Rx are used continuously for a long period of time. Therefore, it would be preferable if 4Rx are used opportunistically by the UE. For example, 4Rx should be used only when the performance gain is large enough to justify the disadvantages such as the increased UE power consumption; otherwise, the UE should be allowed to fall back to 2Rx in order to enable power savings.

[0029] A straightforward solution is that the UE solely determines and activates 4Rx use based on information available to it such as channel condition. However, the problem with this solution is that some possible system performance gains may be lost because the UE, although having the best knowledge of its downlink (DL) channel conditions, does not have the full system-level or cell-level information such as information about e.g. traffic status, immediate cell load or interference situation. Thus, the UE may be unable to make an optimal decision on 4Rx usage.

[0030] For example, in a medium loaded network, using 4Rx in an upcoming bursty traffic can improve user experience because of shorter packet delay. This can also result in a shorter active time at both UE and eNB. As a consequence, the UE power consumption may not be increased much due to use of additional Rx, because UE Rx time including re-transmissions is shortened. Moreover, the inter-cell interference can be reduced because eNB Tx time is also shortened. Therefore, it is beneficial to use 4Rx from the perspective of overall system. However, an individual UE does not have necessary information to make an optimal decision in such scenario.

[0031] Figure 2 shows a network element according to an embodiment; while Figure 3 shows a user equipment (UE) according to an embodiment. The network element 200 and the UE 110 can operate in a wireless network, such as the network of Figure 1. Specifically, the UE 110 can operate as UE 110A or 110B as shown in Figure 1. The UE 110 can work with a high number Rx (4Rx) and a low number Rx (2Rx). The network element 200 can be implemented as a part of the core network 130 or eNB 120, for example, integrated with an existing network element. Alternatively, the network element 200 can be physically separate from the other components of the system 100 and functionally operate with them.

[0032] As shown in Figure 2, the network element 200 has a determining means 203 configured to determine whether the high number Rx is beneficial based on information available at the network element. As discussed above, the network element 200, on the network side, has the full information about traffic status, load or interference situation at cell level, as well as some of the UE channel conditions such

as those obtained from CSI feedback. The network element 200 can make an optimal decision on the 4Rx usage in the sense of the overall system performance. Compared to the UE 110, the network element 200 can strike a better balance between the disadvantages of using 4Rx like power consumption and the advantages, such as the improved throughput/latency, lower interference and enhanced coverage.

[0033] The network element 200 may determine whether 4Rx is beneficial based on any information available including, but not limited to, scheduled activities associated with the UE, e.g. UE traffic type, Immediate or expected Buffer Status Reportings for the UE and buffer status in eNB, condition of the network and/or the UE. For example, where a burst of DL traffic is scheduled to the UE 110, it is usually preferable to use 4Rx. Moreover, use of 4Rx may significantly improve cell coverage and cell edge performance compared to 2Rx. Thus, where the UE 110 is located near the border of a cell or is moving from one cell to another, it may be beneficial to use 4Rx instead of 2Rx. Network knowledge about load in serving and neighbour cells as well as the capabilities of other UEs in the cell can also help to make the optimal decision in the system level if using 4 Rx by the specific UE is beneficial. It is noted that these are only examples showing how the network element 200 can determine whether use of 4Rx is beneficial. Embodiments of the present disclosure are applicable to other scenarios.

[0034] Further, the network element 200 comprises a sending means 201 configured to send a first instruction to the UE 110. The first instruction includes information about use of the high number Rx. In this embodiment, if the network element 200 determines that 4Rx is beneficial, then the sending means 201 sends an instruction suggesting use of 4Rx to the UE 110. The instruction can be sent from the network element 200 to the UE 110 e.g. through RRC signaling, MAC signaling like a MAC Control Element, or any other forms of signaling and/or transmission, such as, physical downlink control channel (PDCCH), physical downlink shared channel (PDSCH), physical broadcast channel (PBCH), physical multicast channel (PMCH), etc. Besides, the instruction can be either semi-static or dynamic. The semi-static

instruction indicates that the network element 200 sends the 4Rx/2RX instruction to the UE 110 over long period of time. The dynamic instruction means that the 4Rx/2Rx instruction can be applicable for data demodulation in the TTI where the instruction is received, or for all receiving operations from the n TTI after the the TTI where the instruction is received.

[0035] As shown in Figure 3, the UE 110 comprises a receiving means 1101 configured to receive instructions from the network element 200. According to this embodiment, when the instruction received from the network element 200 suggests using 4Rx, the UE 110 will determine whether use of 4Rx is beneficial based on information available to it. For example, the UE 110 may take its battery level into consideration. Where the battery level is critically low, the UE 110 can determine that use of 4Rx is not beneficial because it will accelerate power consumption. In this case, the UE 110 can refuse to use 4Rx and keep using 2Rx and report its decision to the networks; or alternatively UE can still follow the instructions from the networks but indicate its intention or recommendation to the networks by a third instruction. Otherwise, the UE 110 may use 4Rx as the network element 200 suggests.

[0036] In another embodiment, the UE 110 may skip its own determination and simply adopt the suggestion of the network element 200. In this embodiment, the determining means 1103 can be omitted.

[0037] In another embodiment, the sending means 201 of the network element 200 is further configured to send a second instruction to the UE 110 if it is determined that 4Rx is not beneficial based on the information available at the network side. The second instruction suggests not using 4Rx. When receiving the second instruction, the UE 110 stops or may stop using 4Rx accordingly.

[0038] In another embodiment, the first instruction sent from the network element 200 to the UE 110 includes a condition requirement for 4Rx use. The network element 200 may configure one or more requirements or certain metrics. This can be done by setting one or more thresholds on the relevant metrics. The determining

means 1103 of the UE 110 is configured to determine whether the condition requirement is satisfied. If yes, the UE 110 should start to use 4Rx. Otherwise, the UE 110 is no longer required to use 4Rx. Examples of metrics may include: CQI ratio (computed with 2Rx or 4Rx), RSRP, RSRQ, and scheduling activity.

[0039] For example, the condition requirement can be a threshold of RSRP. Namely, the UE 110 should use 4Rx if RSRP is lower than a first threshold, i.e. enter condition. If at a later point the RSRP becomes higher than a second threshold, i.e. leave condition, then the UE 110 may stop using 4Rx.

[0040] Additionally, the condition requirement can be based on a scheduling activity, for example, measured by the number of scheduled subframes within a time window, transport block size (TBS), and/or the size of physical resource block (PRB). If the UE 110 is scheduled, then the UE 110 should use 4Rx. Otherwise, UE may stop using 4Rx. This could be combined with a timer. For example, if the UE 110 is not scheduled for a given time period before a configured deactivation timer expires, the UE can stop using 4Rx; afterwards the UE 110 is no longer required to use 4Rx. While the timer is running and UE is scheduled the UE will use 4Rx. Such timer could be started/re-started/re-initialized each time UE receives scheduling event. This could be combined with other conditions e.g. such as threshold conditions.

[0041] It is noted that the network element 200 can use any of these and other condition requirements, or their combinations. For example, the requirement on scheduling activity can be combined with RSRP thresholds.

[0042] According to the embodiment shown in Figure 3, the UE 110 further comprises a sending means 1102 configured to send a report to the network element 200, indicating whether the UE is operating with 4Rx or 2Rx. The report can be sent through L1 reporting like CSI reporting. It can also be included in the CSI reporting (e.g. the one with RI or wideband CQI for periodic CSI, or in aperiodic CSI when the networks need the information about 4/2 Rx and trigger the report), in MAC layer (as new MAC report or included in existing reports like BSR or PHR) or RRC layer (e.g. as measurement report). In this embodiment, the UE 110 reports to the network

element 200 e.g. each time when the UE 110 changes the number of Rx. Alternatively, the UE may also include the number of Rx in each BSR, CSI, RRC or PHR. Other reporting rules could also apply.

[0043] In the embodiment of Figure 2, the network element 200 comprises a receiving means configured to receive the report from the UE 110, and an adjusting means 204 configured to potentially adjust at least one transmission or mobility related parameter for the UE based on the report.

[0044] Due to the better diversity gain, 4Rx can provide better coverage and cell edge performance than 2RX. Accordingly, the parameters or parameters used for determining, Q_{in}/Q_{out} , for 4Rx can be lower than or be different from those for 2Rx in the same control channel transmission setup and/or conditions. More details about parameters Q_{in}/Q_{out} , and radio link monitoring (RLM) are disclosed in section 7.6 of 3GPP TS 36.133, which is incorporated here by reference in its entirety.

[0045] In other words, a UE using 4Rx for radio link monitoring (RLM) can have the operation point in lower SNR than a UE using 2Rx. Thus, the 4Rx UE can stay in the cell with an extended range. Figure 8 shows the effect of 4Rx on cell range and handover region. As shown in Figure 8, the traditional cell planning is based on 2RX. The cell of eNB 120A is 122A and eNB 120B is 122B. When a UE is using 4Rx, the cell range would be extended to 122A' and 122B'. Accordingly, there would be a larger handover region for the 4Rx UE. If the network knows a UE is using 4Rx for Q_{in}/Q_{out} evaluation, depending on its mobility strategy, the network may be able to configure a cell individual offset (CIO) different from a 2Rx UE. By adjusting the CIO, the network can control the UE's behavior. A larger CIO would result in that the 4Rx UE is more likely to stay in the initial cell; while a smaller CIO would result in that the 4Rx UE is more likely to be handed over to a neighbor cell.

[0046] Alternatively, when knowing that a UE is using 4Rx for Q_{in}/Q_{out} evaluation, the network may assume or try to keep same cell coverage area for 4Rx and 2Rx UEs. For example, the network may use lower Tx power for the 4Rx UE and, thus, could

improve inter-cell interference at least for PDSCH. This would result in improved throughput for others UEs, i.e. a system level throughput improvement.

[0047] Additionally, the knowledge of 4Rx/2Rx usage can be used to schedule one or more UEs using 4Rx in certain transmission time intervals (TTIs) to utilize the better cell edge performance provided by 4Rx. The knowledge may also be used for MU-MIMO user pairing or interference coordination.

[0048] In another embodiment, the information of 4Rx/2Rx usage may be used to schedule the 4Rx UE more aggressively with the help of UE CSI feedback. The MCS level, transmission rank, and/or power control may be scheduled for 4Rx UE with the 4Rx reporting information. For example, utilization of 4Rx may allow the network to select higher order of MCS levels, higher transmission rank, and/or lower PDSCH Tx power, compared to the 2Rx.

[0049] In this embodiment, the UE reporting is only an indication of Q_{in}/Q_{out} calculation assumption. This does not force the UE 110 to keep using the reported number of Rx for control channel demodulation. The UE 110 indicating using 4Rx, however, may have to use 4Rx for control channel monitoring when it is in the extended area, which can be derived by comparing the Q_{in}/Q_{out} for 4Rx and 2Rx. The reported number of Rx used for RLM needs to be consistent with the number of Rx actually used for DL reception.

[0050] In another embodiment, the sending means 1102 of the UE 110 is further configured to send a third instruction to the network element 200. The third instruction indicates the UE's intention to use 4Rx or 2Rx when 4Rx favorable or unfavorable condition is observed at the UE side. After receiving the third instruction, the network element 200 determines whether 4Rx or 2Rx is beneficial based on the information available at the network side, and then potentially instructs the UE 110. In this way, the UE 110 will be able to initiate the process of deciding use of the high-number Rx. The UE and network can collaborate in the decision making process taking into consideration the information from two sides. It is noted that this embodiment can be combined with other embodiments.

[0051] In another embodiment, the first instruction sent from the network element 200 to the UE 110 may include information indicating whether the instruction is optional or binding. When the instruction is optional, the UE 110 is not forced by the network to use the suggested Rx. However, when the instruction is binding, the UE 110 must use the suggested Rx. This is useful in certain circumstances. For example, where the UE is operating in an indoor environment, the network may send the binding instruction to force the UE to use 4Rx.

[0052] Figure 6 is a flowchart depicting the process for optimal 4Rx use according to an embodiment. This process can be performed by the network element 200. As shown in Figure 6, the process starts at step 601 where it is determined whether 4Rx is beneficial based on information available at the network side. As described above, any information available at the network side may be used to determine whether 4Rx is beneficial, including, but not limited to, scheduled activities associated with the UE, condition of the network and/or the UE.

[0053] The process proceeds to step 610 if it is determined that 4Rx is beneficial; otherwise it proceeds to step 615. At step 610, a first instruction is sent to the UE 110. As described above, the first instruction may including information suggesting 4Rx or condition requirements for 4Rx use. At step 615, a second instruction is sent to the UE 110. The second instruction suggests not using 4Rx.

[0054] Figure 7 is a flowchart depicting the process for optimal 4Rx use according to an embodiment. This process can be performed by the UE 110. As shown in Figure 7, the process starts at step 701 where a first instruction is received from the network element 200. As described above, the first instruction may including information suggesting 4Rx or condition requirements for 4Rx use.

[0055] Then at step 705, it is determined whether 4Rx is beneficial based on information available at the UE 110. As described above, the information available at the UE may include power consumption, battery level and/or channel condition of the UE. When the first instruction includes condition requirements for 4Rx use, the

information used for the determination may include: reference signal received power (RSRP), reference signal received quality (RSRQ), channel quality indicator (CQI) and/or ratios of CQIs.

[0056] If it is determined that 4Rx is beneficial, then the process proceeds to step 715 where the UE uses 4Rx. Otherwise, the process proceeds to step 720 where the UE uses 2Rx and report its decision to the networks; or alternatively UE can still follow the instructions from the networks but indicate its intention or recommendation to the networks by a third instruction.

[0057] Further, as described in the above embodiments, the UE 110 may send a report to the network element 200 informing the number of Rx being used. After receiving the report, the network element 200 may adjust one or more transmission or mobility related parameters for the UE 110 based on the report.

[0058] Moreover, the UE 110 may send a third instruction to the network element 200, indicating its intention or recommendation to use 4Rx or 2Rx, when 4Rx favorable or unfavorable condition is observed at the UE side. After receiving the third instruction, the network element 200 determines whether 4Rx or 2Rx is beneficial based on the information available at the network side, and then instructs the UE 110.

[0059] The components of the network element 200 and UE 110 can be implemented as hardware, software or their combination. In the case of software, they can be embodied on a tangible computer-readable recordable storage medium. The software can run, for example, on a hardware processor. Figure 4 shows the structure of network element 200 that can run the software, while Figure 5 shows the structure of UE 110, according to an embodiment.

[0060] As shown in Figure 4, the network element 200 comprises a processing device 220, a memory 230, and a radio modem subsystem 210 in operative communication with the processor 220. The radio modem subsystem 210 comprises at least one

transmitter 211 and at least one receiver 212. While only one processor is illustrated in Figure 4, the processing device 220 may comprises a plurality of processors or multi-core processor(s). Additionally, the processing device 220 may also comprise cache to facilitate processing operations. Computer-executable instructions can be loaded in the memory 230 and, when executed by the processing device 220, cause the network element 100 to perform the above-described processes and functions. As described above, the network element 200 can be integrated with an existing network element of the system. In this case, some of the components such as the modem subsystem 210 may be omitted.

[0061] As shown in Figure 5, the UE 110 comprises a processing device 1120, a memory 1130, and a radio modem subsystem 1110 in operative communication with the processor 1120. The radio modem subsystem 1110 comprises at least one transmitter 1111 and at least one receiver 1112. The receiver 1112 is operable with a high-number Rx and a low-number Rx. While only one processor is illustrated in Figure 5, the processing device 1120 may comprises a plurality of processors or multi-core processor(s). Additionally, the processing device 1120 may also comprise cache to facilitate processing operations. Computer-executable instructions can be loaded in the memory 1130 and, when executed by the processing device 1120, cause the UE 100 to perform the above-described processes and functions.

[0062] According to another aspect of the disclosure, it is provided a system for optimal use of high-number Rx. The system includes at least one above-described network element and at least one above-described UE.

[0063] The term "computer program" or "software" is meant to include any sequence or human or machine cognizable steps which perform a function. Such program may be rendered in virtually any programming language or environment including, for example, C/C++, Fortran, COBOL, PASCAL, assembly language, markup languages (e.g., HTML, SGML, XML), and the like, as well as object-oriented environments such as the Common Object Request Broker Architecture (CORBA), Java™

(including J2ME, Java Beans, etc.), Binary Runtime Environment (BREW), and the like.

[0064] The term “storage device” is meant to include, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[0065] In any case, it should be understood that the components illustrated herein may be implemented in various forms of hardware, software, or combinations thereof, for example, application specific integrated circuit(s) (ASICs), functional circuitry, an appropriately programmed general purpose digital computer with associated memory, and the like. Given the teachings of the disclosure provided herein, one of ordinary skill in the related art will be able to contemplate other implementations of the components of the disclosure.

[0066] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of another feature, integer, step, operation, element, component, and/or group thereof.

[0067] The descriptions of the various embodiments have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments

disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments.

Claims

What is claimed is:

1. A method for optimal use of a high number receive antennas (Rx) in a wireless network having a network element and a user equipment (UE), wherein said UE is operable with the high number and a low number Rx, the method comprising:

determining whether the high number Rx is beneficial based on information available at the network element; and

sending a first instruction to the UE, wherein the first instruction includes information about use of the high number Rx.

2. The method according to claim 1, wherein the information available at the network element includes a scheduled activity associated with the UE.

3. The method according to claim 1 or 2, wherein the information available at the network element includes condition related to the UE.

4. The method according to claim 2, wherein the scheduled activity is measured by the number of scheduled subframes within a certain time, transport block size (TBS), and/or the size of physical resource block (PRB).

5. The method according to claim 3, wherein the condition related to the UE is measured by reference signal received power (RSRP), reference signal received quality (RSRQ), channel quality indicator (CQI) and/or ratio of CQI.

6. The method according to any one of claims 1 to 5, further comprising:
sending a second instruction to the UE if it is determined that the high number Rx is not beneficial, wherein the second instruction suggests not using the high number Rx.

7. The method according to any one of claims 1 to 6, the first and/or second instruction is sent to the UE through RRC signaling, MAC signaling, physical downlink control channel (PDCCH), physical downlink shared channel (PDSCH), physical broadcast channel (PBCH), or physical multicast channel (PMCH).

8. The method according to any one of claims 1 to 7, the first and/or second instruction is sent to the UE by semi-static or dynamic signaling.

9. The method according to any one of claims 1 to 8, further comprising:
receiving a third instruction from the UE, wherein the third instruction indicates the UE's intention to use the high number Rx;
wherein the step of determining is performed based on the third instruction.

10. The method according to any one of claims 1 to 9, wherein the first and/or second instruction includes information about a condition requirement for use of the high number Rx.

11. The network element according to claim 10, wherein the condition requirement includes a requirement for RSRP, RSRQ, CQI, or ratio of CQI.

12. The method according to any one of claims 1 to 11, further comprising:

receiving a report from the UE indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

13. The method according to claim 12, wherein the report is received through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

14. The method according to claim 12 or 13, further comprising:
adjusting at least one transmission or mobility related parameter for the UE based on the report.

15. The method according to any one of claims 1 to 14, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

16. A method for optimal use of a high number receive antennas (Rx) in a wireless network having a network element and a user equipment (UE), wherein said UE is operable with the high number and a low number Rx, the method comprising:

receiving a first instruction from the network element, wherein the first instruction includes information about use of the high number Rx; and

using the high number Rx based on the first instruction.

17. The method according to claim 16, further comprising:

determining whether the high number Rx is beneficial based on information available at the UE.

18. The method according to claim 17, wherein the information available at the UE includes power consumption, battery level and/or channel condition of the UE.

19. The method according to any one of claims 16 to 18, further comprising:

receiving a second instruction from the network element, wherein the second instruction suggests not using the high number Rx; and

using the low number Rx based on the second instruction.

20. The method according to any one of claims 16 to 19, further comprising:

sending a third instruction to the network element, wherein the third instruction indicates the UE's intention to use the high number Rx.

21. The method according to any one of claims 16 to 20, wherein the first and/or second instruction includes information about a condition requirement for use of the high number Rx.

22. The method according to claim 21, wherein the condition requirement includes a requirement for RSRP, RSRQ, CQI, or ratio of CQI.

23. The method according to any one of claims 16 to 22, further comprising:

sending a report to the network element indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

24. The method according to claim 23, wherein the report is sent through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

25. The method according to any one of claims 16 to 24, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

26. A method for optimal use of a high number receive antennas (Rx) in a wireless network having a network element and a user equipment (UE), wherein said UE is operable with the high number and a low number Rx, the method comprising:

sending a report to the network element indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

27. The method according to claim 26, wherein the report is sent through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

28. The method according to claim 26 or 27, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

29. The method according to any one of claims 26 to 28, further comprising:

determining whether the high number Rx is beneficial based on information available at the UE; and

using the high number Rx if it is determined that the high number Rx is beneficial.

30. A network element configured to work in a wireless network having a user equipment (UE) operable with a high number and a low number Rx, the network element comprising:

a determining means configured to determine whether the high number Rx is beneficial based on information available at the network element; and

a sending means configured to send a first instruction to the UE, wherein the first instruction includes information about use of the high number Rx.

31. The network element according to claim 30, wherein the information available at the network element includes a scheduled activity associated with the UE.

32. The network element according to claim 30 or 31, wherein the information available at the network element includes condition related to the UE.

33. The network element according to claim 31, wherein the scheduled activity is measured by the number of scheduled subframes within a certain time, transport block size (TBS), and/or the size of physical resource block (PRB).

34. The network element according to claim 32, wherein the condition related to the UE is measured by reference signal received power (RSRP), reference signal received quality (RSRQ), channel quality indicator (CQI) and/or ratio of CQI.

35. The network element according to any one of claims 30 to 34, wherein the sending means is further configured to sending a second instruction to the UE if it is determined that the high number Rx is not beneficial, wherein the second instruction suggests not using the high number Rx.

36. The network element according to any one of claims 30 to 35, the first and/or second instruction is sent to the UE through RRC signaling, MAC signaling, physical downlink control channel (PDCCH), physical downlink shared channel (PDSCH), physical broadcast channel (PBCH), or physical multicast channel (PMCH).

37. The network element according to any one of claims 30 to 36, the first and/or second instruction is sent to the UE by semi-static or dynamic signaling.

38. The network element according to any one of claims 30 to 37, wherein the receiving means is further configured to receive a third instruction from the UE, wherein the third instruction indicates the UE's intention to use the high number Rx.

39. The network element according to any one of claims 30 to 38, wherein the first and/or second instruction includes information about a condition requirement for use of the high number Rx.

40. The network element according to claim 39, wherein the condition requirement includes a requirement for RSRP, RSRQ, CQI, or ratio of CQI.

41. The network element according to any one of claims 30 to 40, further comprising:

a receiving means configured to receive a report from the UE indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

42. The network element according to claim 41, wherein the report is received through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

43. The network element to claim 41 or 42, further comprising:

an adjusting means configured to adjust at least one transmission or mobility related parameter for the UE based on the report.

44. The network element according to any one of claims 30 to 43, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

45. A user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element, the UE comprising:

a receiving means configured to receive a first instruction from the network element, wherein the first instruction includes information about use of the high number Rx;

wherein the UE is configured to use the high number Rx based on the first instruction.

46. The UE according to claim 45, further comprising:

a determining means configured to determine whether the high number Rx is beneficial based on information available at the UE.

47. The UE according to claim 46, wherein the information available at the UE includes power consumption, battery level and/or channel condition of the UE.

48. The UE according to any one of claims 45 to 47, wherein the receiving means is further configured to receive a second instruction from the network element, the second instruction suggests not using the high number Rx; and

the UE is configured to use the low number Rx based on the second instruction.

49. The UE according to any one of claims 45 to 48, further comprising:

a sending means configured to send a third instruction to the network element, wherein the third instruction indicates the UE's intention to use the high number Rx.

50. The UE according to any one of claims 45 to 49, wherein the first and/or second instruction includes information about a condition requirement for use of the high number Rx.

51. The UE according to claim 50, wherein the condition requirement includes a requirement for RSRP, RSRQ, CQI, or ratio of CQI.

52. The UE according to any one of claims 45 to 51, wherein the sending means is further configured to send a report to the network element indicating

whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

53. The UE according to claim 52, wherein the report is sent through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

54. The UE according to any one of claims 45 to 53, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

55. A user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element, the UE comprising:

a sending means configured to send a report to the network element indicating whether the UE is operating with the high number or low number Rx at least for the radio link monitoring.

56. The method according to claim 55, wherein the report is sent through PHY layer reporting, MAC layer reporting, or RRC layer reporting.

57. The method according to claim 55 or 56, wherein the high number Rx is 4Rx and the low number Rx is 2Rx.

58. The method according to any one of claims 55 to 57, further comprising:

a determining means configured to determine whether the high number Rx is beneficial based on information available at the UE;

wherein the UE is configured to use the high number Rx if it is determined that the high number Rx is beneficial.

59. A network element configured to work in a wireless network having a user equipment (UE) operable with a high number and a low number Rx, the network element comprising:

at least one processor; and

at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the network element to perform the process according to any one of claims 1 to 15.

60. A user equipment (UE) operable with a high number and a low number Rx in a wireless network having a network element, the UE comprising:

at least one processor; and

at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the UE to perform the process according to any one of claims 16 to 29.

61. A system comprising:

a network element according to any one of claims 30-44 and 59; and

a UE according to any one of claims 45-58 and 60.

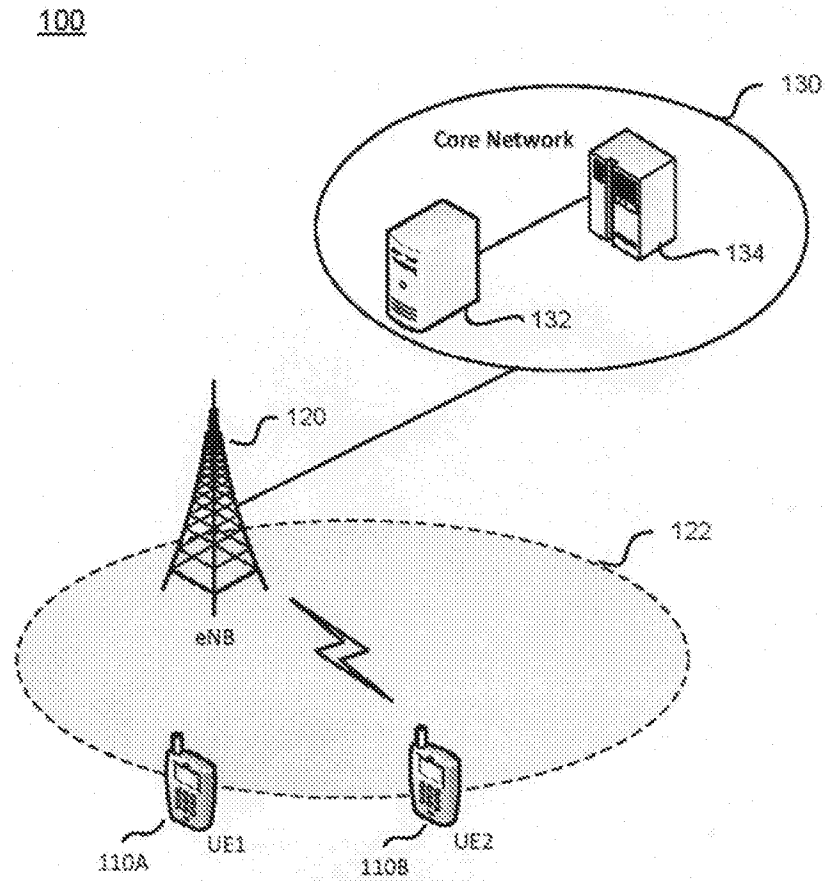


FIG. 1

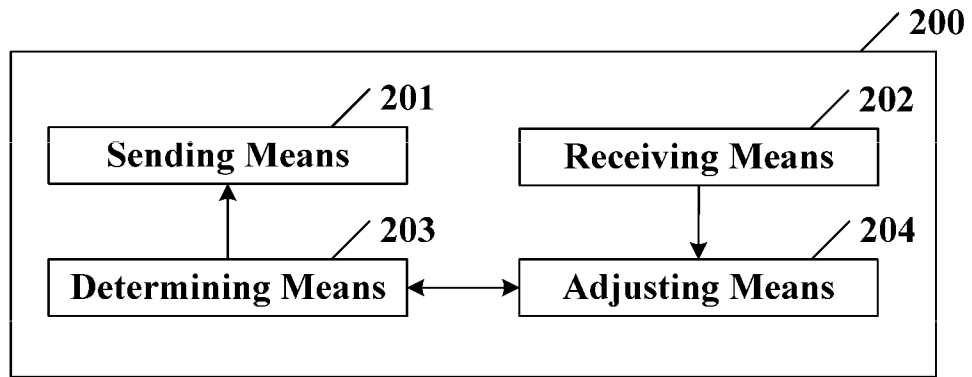


FIG. 2

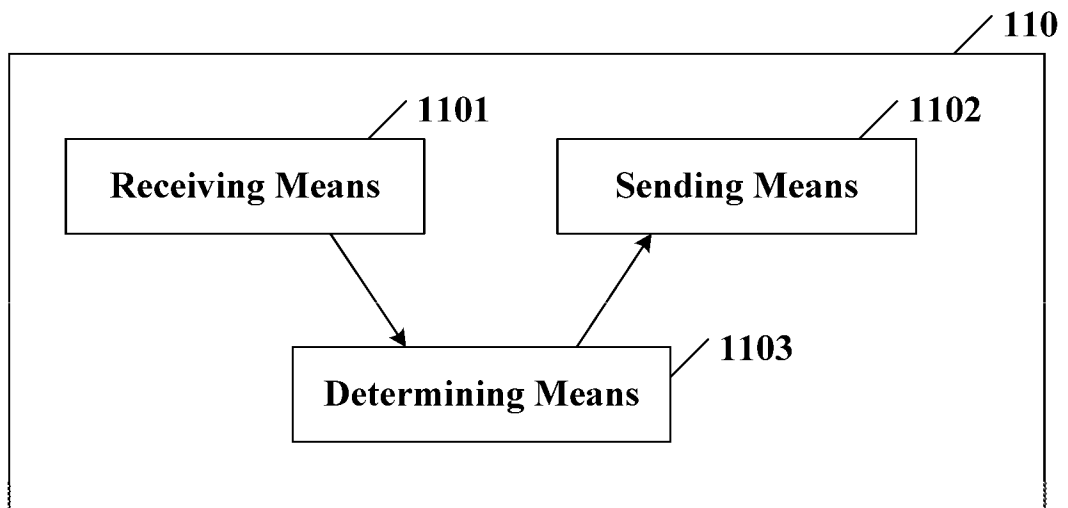


FIG. 3

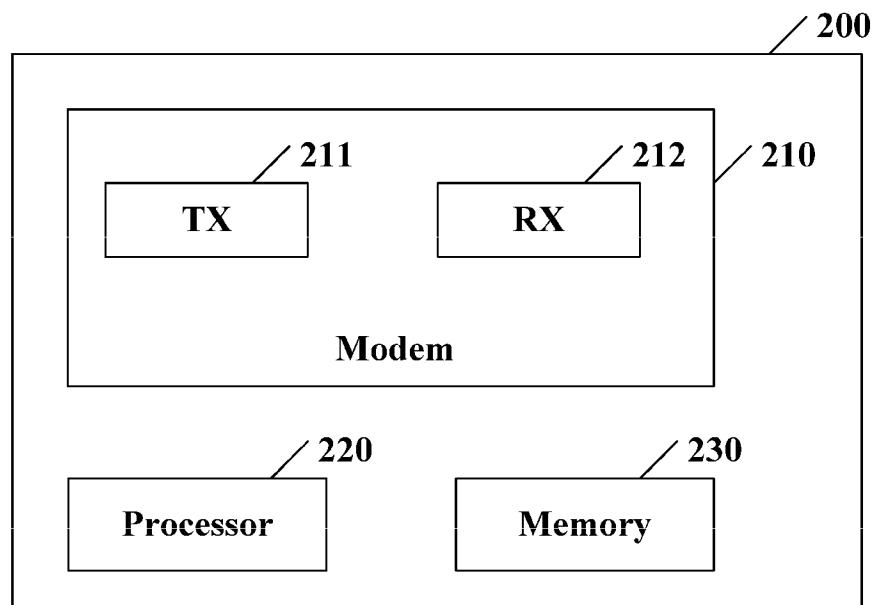


FIG. 4

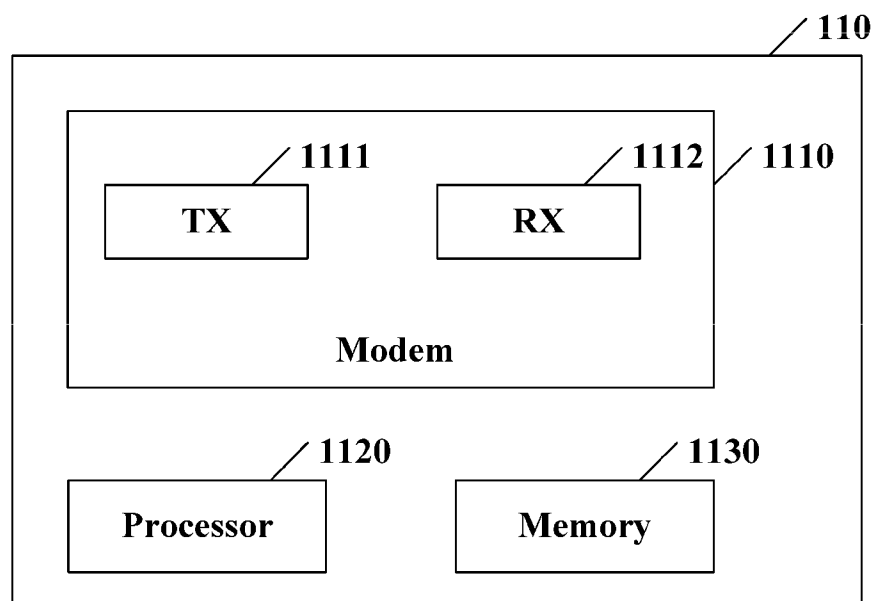


FIG. 5

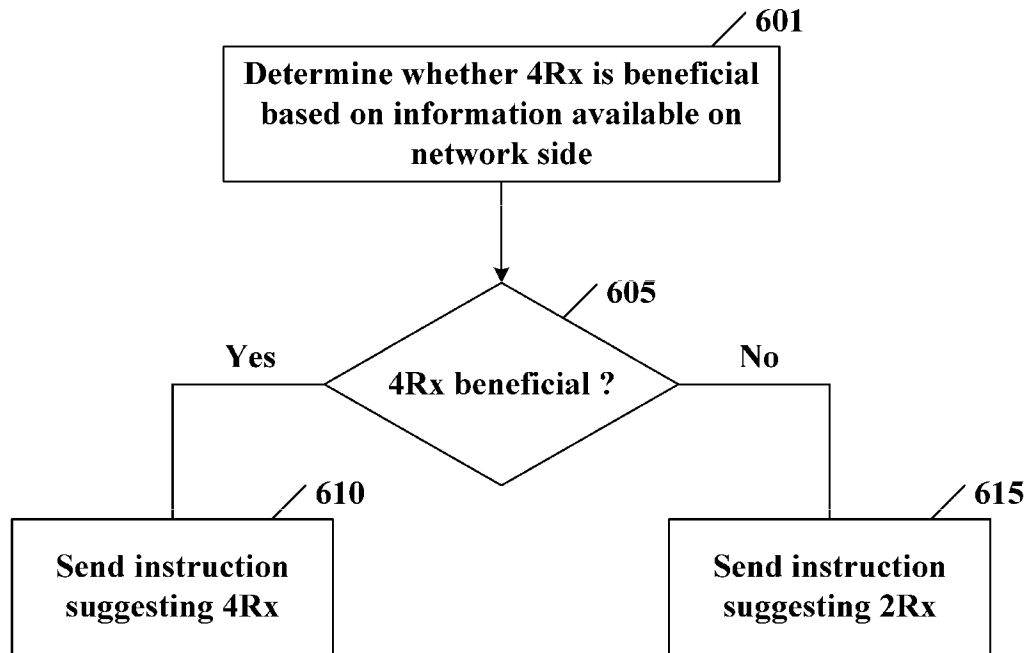


FIG. 6

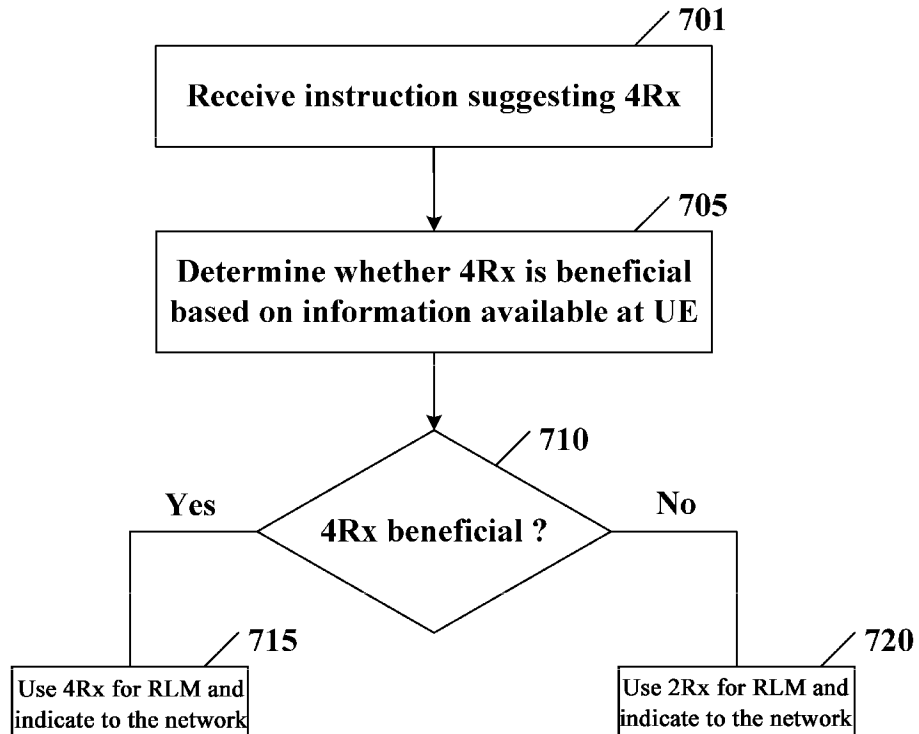


FIG. 7

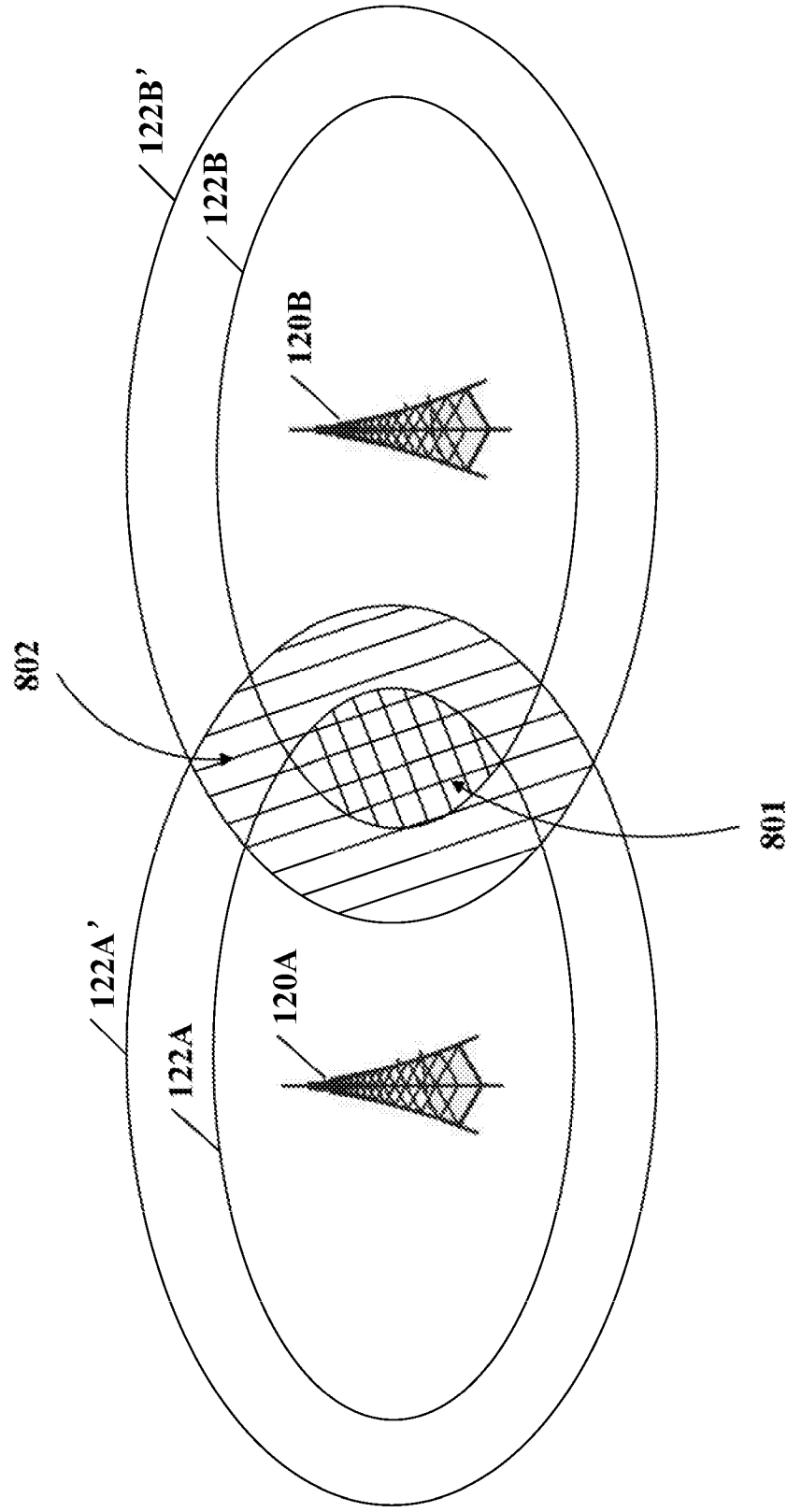


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/076457

A. CLASSIFICATION OF SUBJECT MATTER

H04W 4/00(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

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,WPI,EPODOC,USTXT:receive,antenna,add,increase,additional,user,equipment,UE,phone,telephone,mobile

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012063341 A1 (HAMAGUCHI YASUHIRO ET AL.) 15 March 2012 (2012-03-15) description, paragraphs 39-45, 47 and figures 1-3	1-61
Y	US 2009093281 A1 (DEMIRHAN MUSTAFA ET AL.) 09 April 2009 (2009-04-09) description, paragraphs 13 and 23	1-61
A	US 2013039349 A1 (EBRAHIMI TAZEY MAHALLEH MASOUD ET AL.) 14 February 2013 (2013-02-14) the whole document	1-61

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

26 December 2015

Date of mailing of the international search report

18 January 2016

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/076457

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				IN	8562CHENP2011	A	17 May 2013
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				WO	2013023291	A1	21 February 2013
				WO	2013023290	A1	21 February 2013
				KR	20140061449	A	21 May 2014
				EP	2742714	A1	18 June 2014
				EP	2742714	A4	18 June 2014
				CN	103959839	A	30 July 2014