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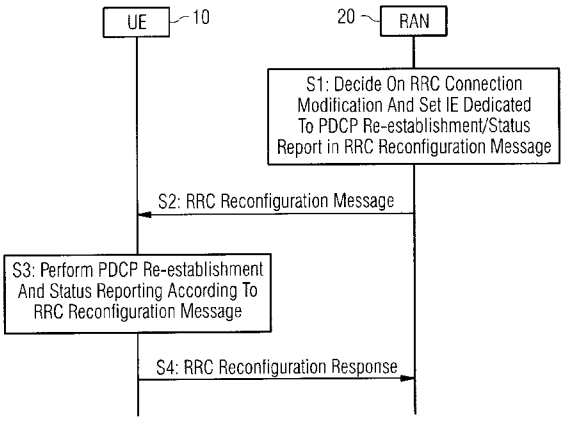
FIG 5



(57) Abstract: An apparatus of a communication network (20) detects (S1) that a modification of a radio resource control connection for a user equipment (10) is required. The apparatus decides (S1), based on the detected modification requirement, if a re-establishment of a packet data convergence protocol is required for a first radio bearer and/or a second radio bearer, and indicates, in a radio resource control reconfiguration message (S2), the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required. The user equipment (10) detects (S3), from the radio resource control reconfiguration message (S2), that a modification of a radio resource control connection between the user equipment (10) and the communication network (20) is required, and re-establishes the packet data convergence protocol for the first radio bearer and/or the second radio bearer in accordance with the indication set in the radio resource control reconfiguration message (S1).

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PDCP OPERATION FOR DUAL CONNECTION

DESCRIPTION

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a communication system such as LTE-A, and in particular to a PDCP operation when a user equipment has a dual connection, i.e., is connected to different base stations of a communication network, which serve different radio bearers.

Related background Art

The following meanings for the abbreviations used in this specification apply:

CA	carrier aggregation
CN	core network
CP	control plane
eNB	evolved NodeB
EPS	evolved packet system
GPRS	general packet radio service
GTP	GPRS tunneling protocol
GW	gateway
HO	hand over
IP	internet protocol
L1L2	layer 1 layer 2
LCH	logical channel
LCP	logical channel prioritization
LTE	long term evolution
LTE-A	LTE advanced
MAC	medium access control
RAN	radio access network
RLC	radio link control

RRC	radio resource control
S	serving
SRB	signaling resource block
PDCP	packet data convergence protocol
PHY	physical layer
UDP	user datagram protocol
UE	user equipment
UP	user plane
Uu	air interface between UE and eNB
X2	interface between eNBs

A dual connection comprises e.g. dual connectivity of a UE to both macro eNB and pico eNB of a communication network. In addition, inter-site CA introduces the possibility of carrier aggregation between different eNBs, which also requires dual connectivity to multiple eNBs from UE point of view.

Fig. 1 shows a dual connection of a UE to a macro eNB serving a radio bearer F1 in a macro cell 1, and to a pico eNB serving a radio bearer F2 in a pico cell 2. The pico eNB and the macro eNB may communicate over an X2 interface. PDCP for different EPS bearers could be terminated differently at macro eNB or pico eNB. Fig. 1 shows further pico eNBs of pico cells in the macro cell 1, to which the UE may hand over, which is indicated by the dashed line in Fig. 1.

A handover or RRC reconfiguration of the UE may occur from one pico eNB to another while the UE is still connected to the macro eNB. However, current PDCP operation (no PDCP reset for RRC reconfiguration or full PDCP reset for Handover) is not efficient for this event.

SUMMARY OF THE INVENTION

The present invention aims at overcoming the above drawback and at providing a PDCP operation for dual connection. For example, the invention aims at providing PDCP operation enhancement for RRC reconfiguration procedure for both independent PDCP and master/slave PDCP structure.

This is at least in part achieved by the methods and apparatuses defined in the appended claims. The invention may also be implemented by a computer program product.

According to an exemplary embodiment of the invention, a per-bearer PDCP re-establishment is introduced in LTE-A, when a UE is connected to different eNBs and each eNB serves different radio bearers. For example, the UE has a dual connection to a macro eNB and a pico eNB. A handover/reconfiguration may occur from one pico eNB to another while the UE is still connected to the macro eNB. In such a case only a partial re-establishment is required. A new information element is added in an RRC reconfiguration message (e.g. "RRCConnectionReconfiguration" defined in 3GPP TS 36.331 v11.3.0) that indicates if a PDCP re-establishment/status report is to be triggered or not.

In the following the invention will be described by way of embodiments thereof with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic diagram illustrating a dual connection of a UE to a macro eNB and a pico eNB.

Figs. 2A to 2C show UP layer structures for different data splitting approaches.

Figs. 3A to 3D show schematic diagrams illustrating alternatives for data splitting at CN or RAN.

Figs. 4A and 4B show flowcharts illustrating processes of PDCP operation for dual connection according to exemplary embodiments of the invention.

Fig. 5 shows a signaling diagram illustrating an implementation example of the PDCP operation for dual connection according to the present invention.

Fig. 6 shows a schematic block diagram illustrating a configuration of control units in which examples of embodiments of the invention are implementable.

DESCRIPTION OF THE EMBODIMENTS

One of the main issues for dual connectivity is how to perform data splitting between different eNBs. For example, data splitting may be performed at CN, at PDCP layer as depicted in Fig. 2A, with master PDCP in macro eNB and slave PDCP in pico eNB as depicted in Fig. 2B, or at RLC layer as depicted in Fig. 2C.

Fig. 2A shows a UP structure with independent PDCP entities (on top of layers PHY, MAC and RLC) at macro eNB and small cell eNB. The macro eNB and the small cell eNB may communicate over an Xn interface. In case data splitting is performed in the CN as illustrated in Fig. 3B, communication over the Xn interface is not required for PDCP operation.

Fig. 2B shows a UP structure with master and slave PDCP entities. In this case, the macro eNB comprises a master PDCP entity (M)-PDCP, and the small cell eNB comprises a slave PDCP entity S-PDCP, where the (M)-PDCP performs SN allocation, head compression, ciphering/integrity protection and re-ordering for UL data. The macro eNB and the small cell eNB communicate over an Xn interface for PDCP operation.

Fig. 2C shows a UP structure with a centralized PDCP entity at the macro eNB. In this case, a UE is connected to the small cell eNB via RLC layer. The macro eNB and the small cell eNB communicate over an Xn interface for PDCP operation.

Figs. 3B, 3Cand 3D show data splitting at RAN. The macro eNB receives data from a gateway and forwards data intended for the small cell eNB over the Xn interface to the small cell eNB. The UE and the macro eNB communicate data on an EPS bearer # 1, and the UE and the small cell eNB communicate data on an EPS bearer # 2 (as shown in Fig. 3B), or all the bearers are communicated via small cell eNB (as shown in Fig. 3D).

Fig. 3A shows data splitting at CN. The gateway forwards data intended for the macro eNB to the macro eNB and data intended for the small cell eNB to the

small cell eNB. The UE and the macro eNB communicate data on an EPS bearer #1, and the UE and the small cell eNB communicate data on an EPS bearer #2.

Concerning backhaul capacity and delay, the independent PDCP approach shown in Fig. 2A is an appealing option for dual connectivity, as it is applicable to data splitting at either CN or RAN or local breakout with loose delay requirement between eNBs. In other words, the independent PDCP approach is applicable to the alternatives illustrated in Figs. 3A and 3B with different eNBs serving different radio bearers.

The master/slave PDCP approach shown in Fig. 2B makes it possible to serve same or different bearer with different eNBs and is applicable to the alternatives shown in Figs. 3B, 3C and 3D. The alternative shown in Fig. 3D in which all bearers are communicated via the small cell eNB is a special case of the alternative shown in Fig. 3B.

According to an exemplary embodiment of the invention, PDCP operation enhancement for RRC reconfiguration procedure is provided for both the independent PDCP approach and the master/slave PDCP approach.

The purpose of an RRC connection reconfiguration is to modify an RRC connection, e.g. to establish/ modify/ release RBs, to perform handover, to setup/ modify/ release measurements, to add/ modify/ release SCells (serving cells).

Fig. 4A shows a flowchart illustrating process 1 of a PDCP operation for dual connection according to an exemplary embodiment of the invention. The process 1 may be performed by a RAN of a communication network, e.g. by an eNB as shown in Figs. 1, 2A-C and 3A-3D.

In step S41, it is detected that a modification of a RRC connection for a UE (e.g. the UE illustrated in Figs. 1, 2A-C and 3A-3D) is required.

According to an exemplary embodiment of the invention, the UE communicates with the communication network by using the second radio bearer.

According to an alternative exemplary embodiment of the invention, the UE communicates with the communication network by using a first radio bearer and the second radio bearer.

According to an exemplary embodiment of the invention, a PDCP for the second radio bearer is terminated in a second base station (e.g. pico eNB) of the communication network, and a PDCP for the first radio bearer is terminated in a first base station (e.g. macro eNB) of the communication network, as shown e.g. in Figs. 3A and 3B.

According to an alternative embodiment of the invention, PDCP for the second radio bearer is terminated in the second base station and PDCP for the first radio bearer is terminated in the second base station of the communication network, as shown e.g. in Fig. 3D.

For example, the second base station is to be changed to a third base station.

In step S42, it is decided, based on the detected modification requirement, if a re-establishment of the PDCP is required for the first radio bearer and/or the second radio bearer.

In step S43, in an RRC reconfiguration message, the first radio bearer and/or the second radio bearer is indicated, for which re-establishment of the PDCP is required.

According to an exemplary embodiment of the invention, in step S42 it is decided, based on the detected modification requirement, that a PDCP status report for the first radio bearer and/or the second radio bearer is to be sent by the UE, and in step S43 it is indicated, in the RRC reconfiguration message, that the status report is to be sent.

According to an exemplary embodiment of the invention, in step S42 it is decided to which base station of the communication network the status report is to be sent, and in step S43 the base station is indicated in the RRC reconfiguration

message. The base station may comprise the first base station, the second base station or a third base station of the communication network.

According to an exemplary embodiment of the invention, a dedicated information element is added to the RRC reconfiguration message, in which the indications of step S43 are set.

According to an exemplary embodiment of the invention, a status report received from the UE is forwarded to the first or second base station or to a third base station of the communication network, e.g. via an X2 interface.

According to an exemplary embodiment of the invention, the first base station comprises at least a part of functionalities of the PDCP for the second radio bearer. These functionalities for the second radio bearer may comprise any of sequence number allocation, header compression, ciphering, integrity protection and/or reordering for uplink data.

Fig. 4B shows a flowchart illustrating a process 2 of a PDCP operation for dual connection according to an exemplary embodiment of the invention. The process 2 may be performed by a UE, e.g. by the UE as shown in Figs. 1, 2A-C and 3A-3D. The UE communicates with a communication network via a first radio bearer and a second radio bearer, or only via the second radio bearer. PDCP for the first radio bearer is terminated in a first base station (e.g. macro eNB) of the communication network as illustrated e.g. in Figs. 3A and 3B, or is terminated in a second base station (e.g. pico eNB) of the communication network as illustrated e.g. in Fig. 3D, and PDCP for the second radio bearer is terminated in the second base station.

In step S51, it is detected, from an RRC reconfiguration message, that a modification of an RRC connection between the UE and the communication network is required.

In step S52, the PDCP is re-established for the first radio bearer and/or the second radio bearer in accordance with an indication set in the RRC reconfiguration message.

According to an exemplary embodiment of the invention, in step S51 it is detected, from the indication, that a PDCP status report for the first radio bearer and or the second radio bearer is to be sent.

According to an exemplary embodiment of the invention, in step S51 it is detected, from the indication, to which base station of the communication network the status report is to be sent. The base station may comprise the first base station, the second base station or a third base station of the communication network.

According to an exemplary embodiment of the invention, the indication comprises a dedicated information element added to the RRC reconfiguration message.

Fig. 5 shows a signaling diagram illustrating an implementation example of a PDCP operation for dual connection according to the present invention. A UE 10 has a dual connection to eNBs of a RAN 20, which serve different radio bearers. The independent PDCP approach as shown in Fig. 2A or the master/slave PDCP approach shown in Fig. 2B may be adopted by the UE 10 and the RAN 20.

The RAN 20, e.g. an apparatus of the RAN 20 such as an eNB shown in Figs. 1, 2A-C and 3A-3D, decides in step S1 on an RRC connection modification and sets an IE dedicated to PDCP re-establishment/status report in an RRC reconfiguration message in accordance with the decided modification. The processing in step S1 corresponds to that in steps S41-S43 of Fig. 4A.

In step S2, the RAN 20 sends the RRC reconfiguration message to the UE 10, e.g. the UE as shown in Figs. 1, 2A-C and 3A-3D, via a Uu interface.

In step S3, the UE 10 performs PDCP re-establishment and status reporting according to the received RRC reconfiguration message, and replies to the RAN 20 with a RRC reconfiguration response in step S4. The processing in step S3 corresponds to that in steps S51-S52 of Fig. 4B.

According to an implementation example of the invention, for inter-site CA a PDCP re-establishment/PDCP status report is triggered upon SCell reconfiguration, if requested by the RAN 20 in the RRC reconfiguration message. It is possible to explicitly configure only certain radio bearer(s) and/or to which base station/cell the status report should be sent to.

According to an implementation example of the invention, in case the UE 10 is connected to a pico eNB and a macro eNB as shown in Fig. 1, for SRBs there is no need to perform PDCP re-establishment as they are likely to be served via the macro cell (e.g. CP in macro cell and UP in pico cell).

In order to direct a status report to a given cell, a UE MAC layer needs to know to which serving cell a status report received on a logical channel needs to be sent. According to an implementation example of the invention, this relationship between a logical channel and a serving cell is configured by the eNB of the RAN 20 and requires the UE 10 to be aware of incoming status reports. According to an alternative implementation example of the invention, the first MAC PDU(s) after SCell reconfiguration are always directed towards that preferred serving cell in order to guarantee the delivery of the status report to the correct cell (as status reports are prioritized). Here, too, the correspondence between a logical channel and a preferred cell is configured by the RAN 20.

According to an implementation example of the invention, if prioritization on the UE side is not desirable (e.g. to avoid LCH awareness in LCP procedure) or possible, the UE 10 sends the status report to any base station/cell. Then the status report is delivered between eNBs via X2 interface or the data forwarding may take the status report into account.

According to an implementation example of the invention, for single radio with CP in macro cell and UP in pico cell, similarly, upon RRC reconfiguration the eNB can explicitly indicate PDCP re-establishment and PDCP status report for a certain PDCP entity to be triggered even without HO.

According to an implementation example of the invention, data forwarding is performed between two pico cells/eNBs even if the macro cell/eNB does not

change (i.e. without HO, as illustrated by the dashed line in Fig. 1). According to an alternative implementation example of the invention, data forwarding is done via the macro cell/eNB or between pico eNBs according to (S)cell de-configuration and (S)cell configuration. This is applicable for both CA and non-CA cases.

According to an implementation example of the invention, the IE is added in a message "RRCConnectionReconfiguration" (possible with or without mobility information) of 3GPP TS 36.331 v11.3.0, to indicate if PDCP re-establishment/PDCP status report is to be triggered or not. Optionally, the IE indicates to which radio bearers the PDCP re-establishment is limited. Optionally, the IE includes to which cell/eNB the status report should be sent. Alternatively, the eNB of the RAN 20 may configure the UE 10 to always send the first MAC PDU after (S)cell reconfiguration to a preferred cell/eNB, e.g. a newly configured (S)cell.

Upon reception of the RRC connection reconfiguration message, the UE 10 re-establishes the PDCP for the concerned radio bearers and sends the PDCP status report (or the first MAC PDU) to the indicated cell/eNB.

Now reference is made to Fig. 6 for illustrating a simplified block diagram of various electronic devices that are suitable for use in practicing the exemplary embodiments of this invention.

A control unit 100 which may be part of or used by a UE e.g. to execute process 2 of Fig. 4B comprises processing resources 11, memory resources 12 and interfaces 14 which are connected via a link 14. The memory resources 12 may store a program.

The control unit 100 is connected to a control unit 200 through a link 15. The control unit 200 may be part of or used by an apparatus of a communication network, such as an apparatus of a RAN, e.g. a base station, eNB or the like, and may execute process 1 of Fig. 4A.

The control unit 200 comprises processing resources 21, memory resources 22 and interfaces 24 which are connected via a link 24. The memory resources 22 may store a program.

The interfaces 13, 23 each may include suitable radio frequency (RF) transceivers coupled to one or more antennas (not shown) for bidirectional wireless communications over the link 15.

The terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as non-limiting examples.

At least one of the programs stored in the memory resources 12, 22 is assumed to include program instructions that, when executed by the associated processing resources 11, 21, enable the electronic device to operate in accordance with the exemplary embodiments of this invention, as detailed above. Inherent in the processing resources 11, 21 is a clock to enable synchronism among the various apparatus for transmissions and receptions within the appropriate time intervals and slots required, as the scheduling grants and the granted resources/subframes are time dependent. The transceivers include both transmitter and receiver, and inherent in each is a modulator/demodulator commonly known as a modem. The processing resources 21 are assumed to include a modem to facilitate communication over a (hardwire) link (not shown) between the control unit 200 and a GW (not shown).

In general, the exemplary embodiments of this invention may be implemented by computer software stored in the memory resources 12, 22 and executable by

the associated processing resources 11, 21, or by hardware, or by a combination of software and/or firmware and hardware in any or all of the devices shown.

In general, the various embodiments of the UE 10 can include, but are not limited to, mobile stations, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

The memory resources 12, 22 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The processing resources 11, 21 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples.

According to an aspect of the invention, an apparatus of a communication network is provided. The apparatus comprises means for detecting that a modification of a radio resource control connection for a user equipment is required, means for deciding, based on the detected modification requirement, if a re-establishment of a packet data convergence protocol is required for a first radio bearer and/or a second radio bearer, and means for indicating, in a radio resource control reconfiguration message, the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required.

A packet data convergence protocol for the second radio bearer may be terminated in a second base station of the communication network, and a packet

data convergence protocol for the first radio bearer may be terminated in a first base station of the communication network. Alternatively, the packet data convergence protocol for the first radio bearer may be terminated in the second base station of the communication network.

The means for deciding may decide, based on the detected modification requirement, that a packet data convergence protocol status report for the first radio bearer and/or the second radio bearer is to be sent by the user equipment, and the means for indicating may indicate, in the radio resource control reconfiguration message, that the status report is to be sent.

The means for deciding may decide to which base station of the communication network the status report is to be sent, and the means for indicating may indicate the base station in the radio resource control reconfiguration message.

The indicating means may add a dedicated information element to the radio resource control reconfiguration message to indicate the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required, and/or to indicate that the status report is to be sent, and/or to indicate the base station to which the status report is to be sent.

The apparatus may comprises a first base station, e.g. a macro eNB, via which the user equipment communicates using the first radio bearer, or a second base station, e.g. a pico eNB, via which the user equipment communicates using the second radio bearer.

The apparatus may comprise means for forwarding a status report received from the user equipment to the first or second base station or to a third base station of the communication network.

The apparatus may comprise the first base station and comprise at least a part of functionalities of the packet data convergence protocol for the second radio bearer.

The functionalities for the second radio bearer may comprise any of sequence number allocation, header compression, ciphering, integrity protection and/or reordering for uplink data.

The apparatus may be part of the RAN 20 shown in Fig. 5, and may execute process 1 shown in Fig. 4A. The apparatus may comprise or use the control unit 200 of Fig. 6. The detecting, deciding, indicating and forwarding means may be implemented by the processing resources 21, memory resources 22 and interfaces 23 of the control unit 200.

According to another aspect of the invention, a user equipment is provided, which comprises means for detecting, from a radio resource control reconfiguration message, that a modification of a radio resource control connection between the user equipment and a communication network is required, and means for re-establishing a packet data convergence protocol for a first radio bearer and/or a second radio bearer in accordance with an indication set in the radio resource control reconfiguration message.

The user equipment may communicate with the communication network by using the second radio bearer, or the user equipment may communicate with the communication network by using the first radio bearer and the second radio bearer.

The detecting means may detect, from the indication, that a packet data convergence protocol status report for the first radio bearer and or the second radio bearer is to be sent.

The detecting means may detect, from the indication, to which base station of the communication network the status report is to be sent.

The indication may comprise a dedicated information element added to the radio resource control reconfiguration message.

The user equipment may comprise the UE 10 shown in Fig. 5, and may execute process 2 shown in Fig. 4B. The user equipment may comprise or use the control

unit 100 of Fig. 6. The detecting and re-establishing means and the communicating may be implemented by the processing resources 11, memory resources 12 and interfaces 13 of the control unit 100.

It is to be understood that the above description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method for use by an apparatus of a communication network, the method comprising:

detecting that a modification of a radio resource control connection for a user equipment is required;

deciding, based on the detected modification requirement, if a re-establishment of a packet data convergence protocol is required for a first radio bearer and/or a second radio bearer; and

indicating, in a radio resource control reconfiguration message, the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required.

2. The method of claim 1, wherein the user equipment communicates with the communication network by using the second radio bearer.

3. The method of claim 1, wherein the user equipment communicates with the communication network by using the first radio bearer and the second radio bearer.

4. The method of any one of claims 1 to 3, wherein a packet data convergence protocol for the second radio bearer is terminated in a second base station of the communication network.

5. The method of claim 4, wherein a packet data convergence protocol for the first radio bearer is terminated in a first base station of the communication network.

6. The method of claim 4, wherein a packet data convergence protocol for the first radio bearer is terminated in the second base station of the communication network.

7. The method of any one of claims 1 to 6, comprising:

deciding, based on the detected modification requirement, that a packet data convergence protocol status report for the first radio bearer and/or the second radio bearer is to be sent by the user equipment; and

indicating, in the radio resource control reconfiguration message, that the status report is to be sent.

8. The method of claim 7, the deciding comprising:

deciding to which base station of the communication network the status report is to be sent; and

indicating the base station in the radio resource control reconfiguration message.

9. The method of any one of claims 1 to 8, the indicating comprising:

adding a dedicated information element to the radio resource control reconfiguration message.

10. The method of any one of claims 4 to 6, wherein the apparatus comprises the first base station or the second base station.

11. The method of any one of claims 4 to 6 and 10, comprising:

forwarding a status report received from the user equipment to the first or second base station or to a third base station of the communication network.

12. The method of claim 5 or 6, wherein the first base station comprises at least a part of functionalities of the packet data convergence protocol for the second radio bearer.

13. The method of claim 12, said functionalities for the second radio bearer comprising any of sequence number allocation, header compression, ciphering, integrity protection and/or reordering for uplink data.

14. A method for use by a user equipment comprising:

detecting, from a radio resource control reconfiguration message, that a modification of a radio resource control connection between the user equipment and a communication network is required; and

re-establishing a packet data convergence protocol for a first radio bearer and/or a second radio bearer in accordance with an indication set in the radio resource control reconfiguration message.

15. The method of claim 14, wherein the user equipment communicates with the communication network by using the second radio bearer.

16. The method of claim 14, wherein the user equipment communicates with the communication network by using the first radio bearer and the second radio bearer.

17. The method of any one of claims 1 to 3, wherein a packet data convergence protocol for the second radio bearer is terminated in a second base station of the communication network.

18. The method of claim 17, wherein a packet data convergence protocol for the first radio bearer is terminated in a first base station of the communication network.

19. The method of claim 17, wherein a packet data convergence protocol for the first radio bearer is terminated in the second base station of the communication network.

20. The method of any one of claims 14 to 19, comprising:

detecting, from the indication, that a packet data convergence protocol status report for the first radio bearer and or the second radio bearer is to be sent.

21. The method of claim 20, comprising:

detecting, from the indication, to which base station of the communication network the status report is to be sent.

22. The method of any one of claims 14 to 21, wherein the indication comprises a dedicated information element added to the radio resource control reconfiguration message.

23. The method of any one of claims 4 to 6 and 17 to 19, wherein the first base station comprises a macro cell base station and the second base station comprises a pico cell base station.

24. The method of claim 11 or 21, wherein the base station comprises at least one of the first and second base stations and/or a third base station of the communication network.

25. A computer program product including a program for a processing device, comprising software code portions for performing the steps of any one of claims 1 to 24 when the program is run on the processing device.

26. The computer program product according to claim 25, wherein the computer program product comprises a computer-readable medium on which the software code portions are stored.

27. The computer program product according to claim 25, wherein the program is directly loadable into an internal memory of the processing device.

28. An apparatus of a communication network, the apparatus comprising processing resources, memory resources and interfaces, which cause the apparatus to:

detect that a modification of a radio resource control connection for a user equipment is required;

decide, based on the detected modification requirement, if a re-establishment of a packet data convergence protocol is required for a first radio bearer and/or a second radio bearer; and

indicate, in a radio resource control reconfiguration message, the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required.

29. The apparatus of claim 28, wherein a packet data convergence protocol for the second radio bearer is terminated in a second base station of the communication network.

30. The apparatus of claim 29, wherein a packet data convergence protocol for the first radio bearer is terminated in a first base station of the communication network.

31. The apparatus of claim 29, wherein a packet data convergence protocol for the first radio bearer is terminated in the second base station of the communication network.

32. The apparatus of any one of claims 28 to 31, wherein the processing resources, memory resources and interfaces cause the apparatus to:

decide, based on the detected modification requirement, that a packet data convergence protocol status report for the first radio bearer and/or the second radio bearer is to be sent by the user equipment; and

indicate, in the radio resource control reconfiguration message, that the status report is to be sent.

33. The apparatus of claim 32, wherein the processing resources, memory resources and interfaces cause the apparatus to:

decide to which base station of the communication network the status report is to be sent; and

indicate the base station in the radio resource control reconfiguration message.

34. The apparatus of any one of claims 28 to 33, wherein the processing resources, memory resources and interfaces cause the apparatus to:

add a dedicated information element to the radio resource control reconfiguration message to indicate the first radio bearer and/or the second radio bearer for which re-establishment of the packet data convergence protocol is required, and/or to indicate that the status report is to be sent, and/or to indicate the base station to which the status report is to be sent.

35. The apparatus of any one of claims 28 to 34, wherein the apparatus comprises a first base station via which the user equipment communicates using

the first radio bearer, or a second base station via which the user equipment communicates using the second radio bearer.

36. The apparatus of claim 35, wherein the processing resources, memory resources and interfaces cause the apparatus to:

forward a status report received from the user equipment to the first or second base station or to a third base station of the communication network.

37. The apparatus of claim 35 or 36, wherein the apparatus comprises the first base station and comprises at least a part of functionalities of the packet data convergence protocol for the second radio bearer.

38. The apparatus of claim 37, said functionalities for the second radio bearer comprising any of sequence number allocation, header compression, ciphering, integrity protection and/or reordering for uplink data.

39. A user equipment comprising processing resources, memory resources and interfaces, which cause the user equipment to:

detect, from a radio resource control reconfiguration message, that a modification of a radio resource control connection between the user equipment and a communication network is required; and

re-establish a packet data convergence protocol for a first radio bearer and/or a second radio bearer in accordance with an indication set in the radio resource control reconfiguration message.

40. The user equipment of claim 39, wherein the processing resources, memory resources and interfaces cause the user equipment to communicate with the communication network by using the second radio bearer.

41. The user equipment of claim 40, wherein the processing resources, memory resources and interfaces cause the user equipment to communicate with the communication network by using the first radio bearer and the second radio bearer.

42. The user equipment of any one of claims 39 to 41, wherein the processing resources, memory resources and interfaces cause the user equipment to:

detect, from the indication, that a packet data convergence protocol status report for the first radio bearer and or the second radio bearer is to be sent.

43. The user equipment of claim 42, wherein the processing resources, memory resources and interfaces cause the user equipment to:

detect, from the indication, to which base station of the communication network the status report is to be sent.

44. The user equipment of any one of claims 39 to 43, wherein the indication comprises a dedicated information element added to the radio resource control reconfiguration message.

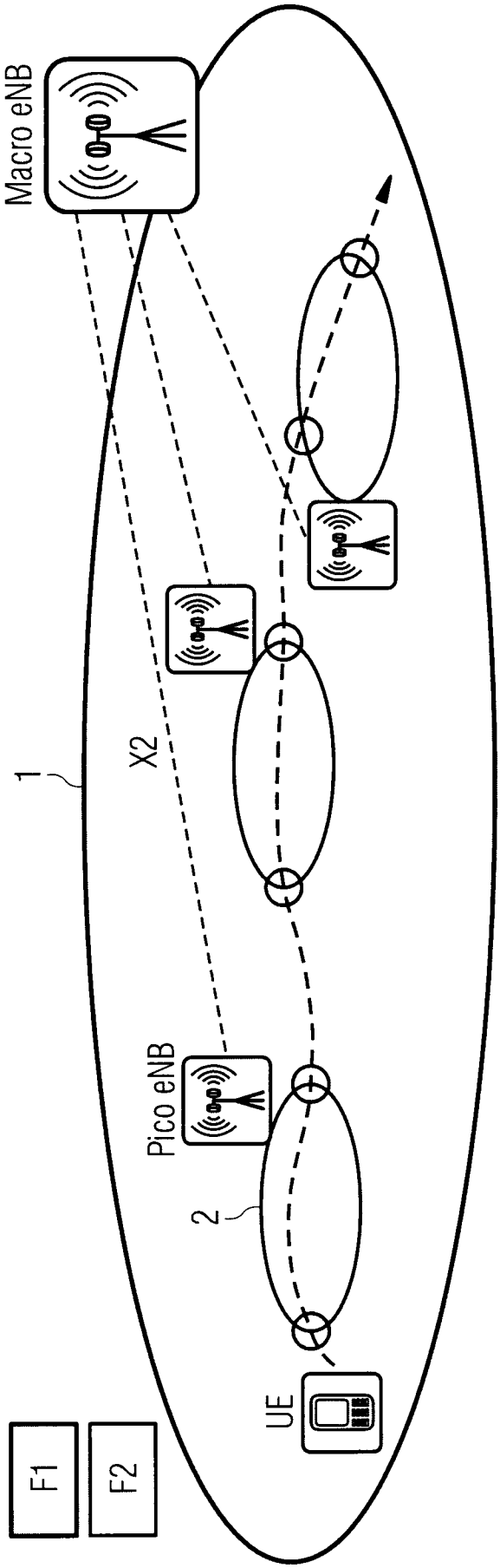
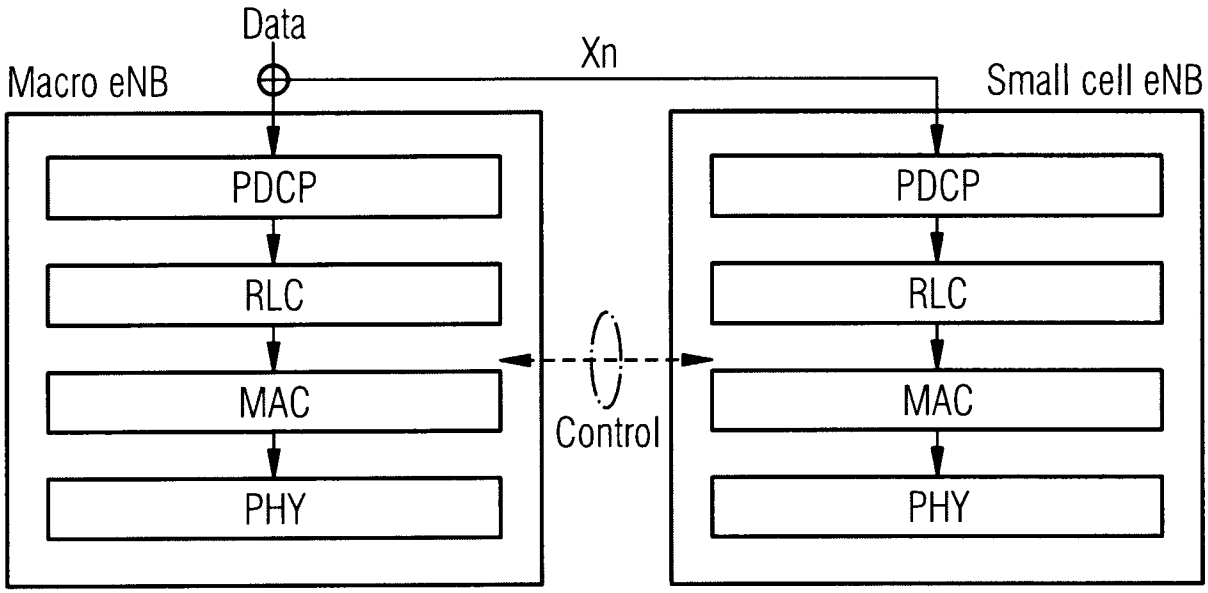


FIG 1

FIG 2A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Small cell eNB
PDCP
RLC
MAC
PHY
Control
PDCP
RLC
MAC
PHY

FIG 2B

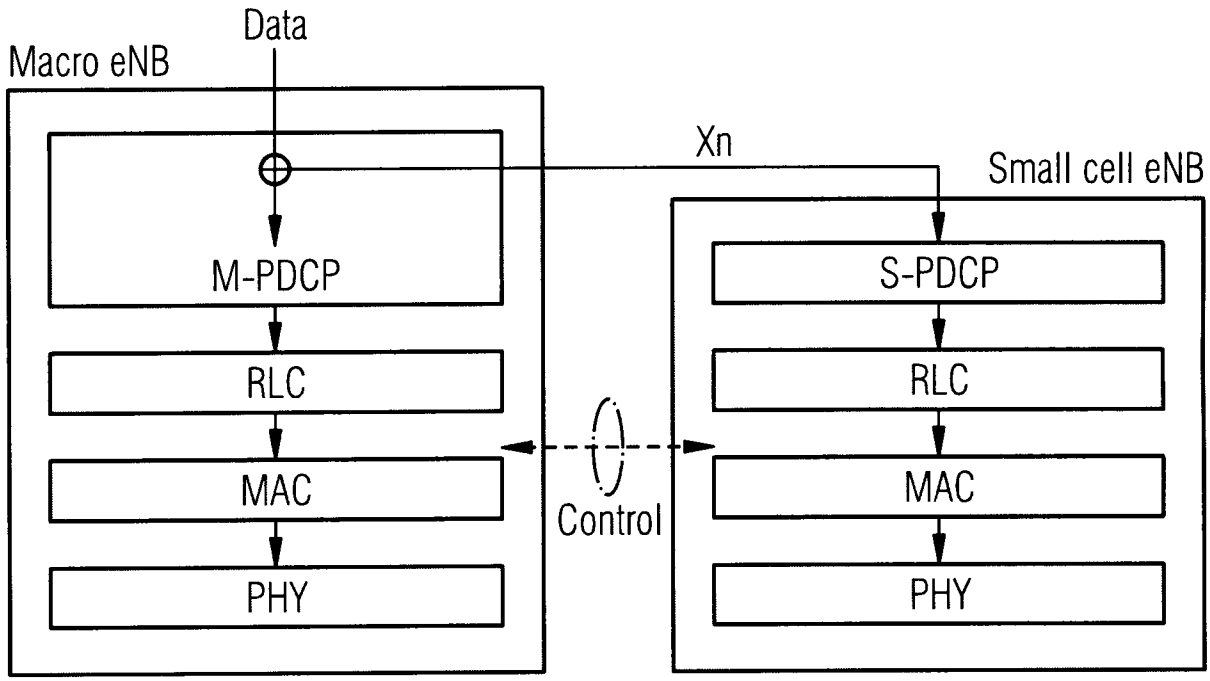

Data
Macro eNB
Xn
Small cell eNB
M-PDCP
RLC
MAC
PHY
Control
S-PDCP
RLC
MAC
PHY

FIG 2C

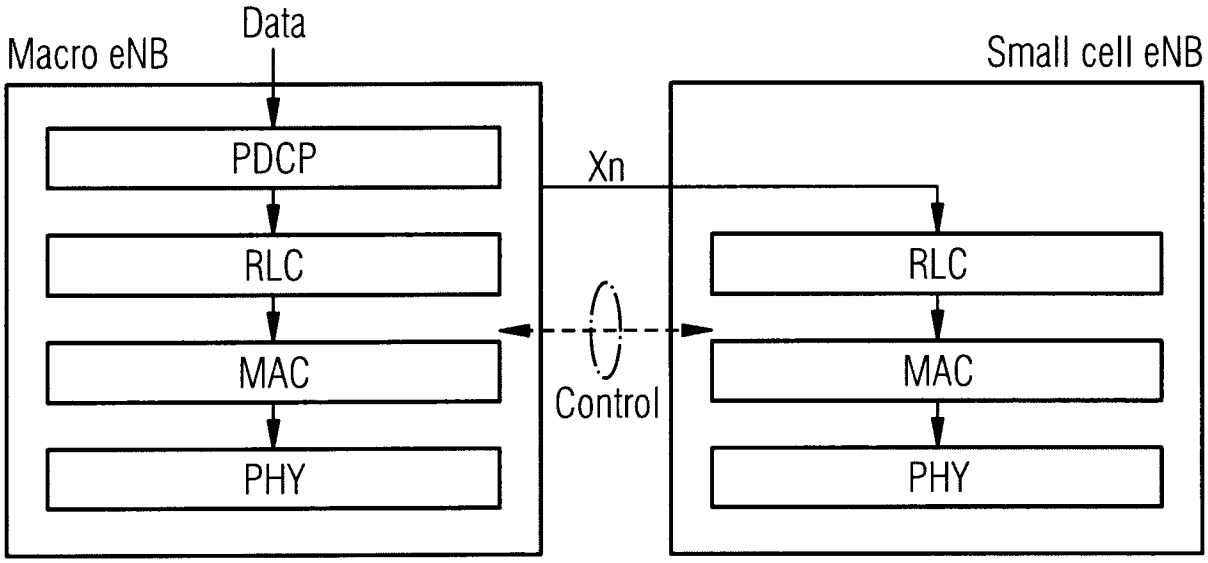

Data
Macro eNB
Small cell eNB
PDCP
RLC
MAC
PHY
Xn
Control
RLC
MAC
PHY

FIG 3A

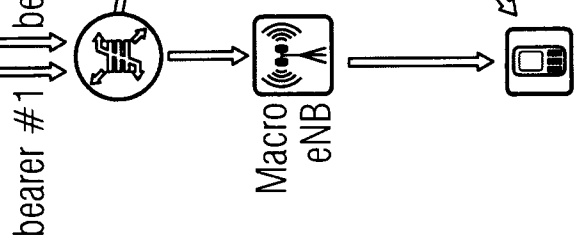


FIG 3B

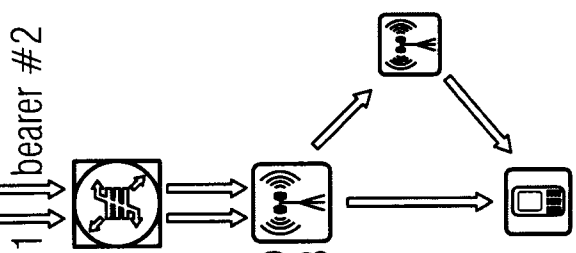


FIG 3C

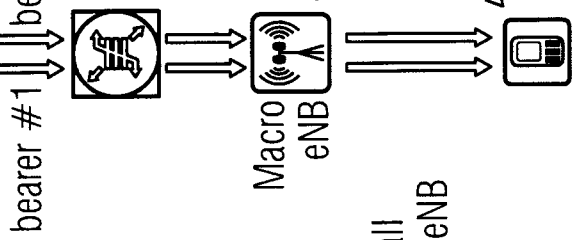


FIG 3D

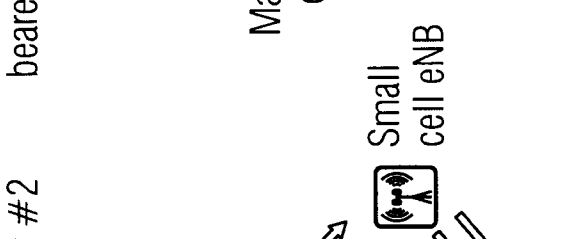


FIG 4A

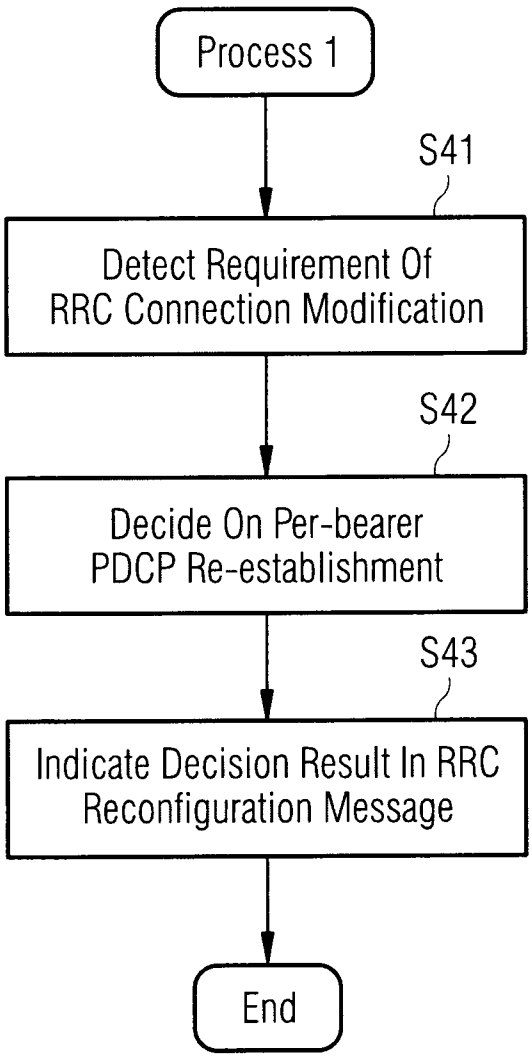

Process 1
S41
Detect Requirement Of RRC Connection Modification
S42
Decide On Per-bearer PDCP Re-establishment
S43
Indicate Decision Result In RRC Reconfiguration Message
End

FIG 4B

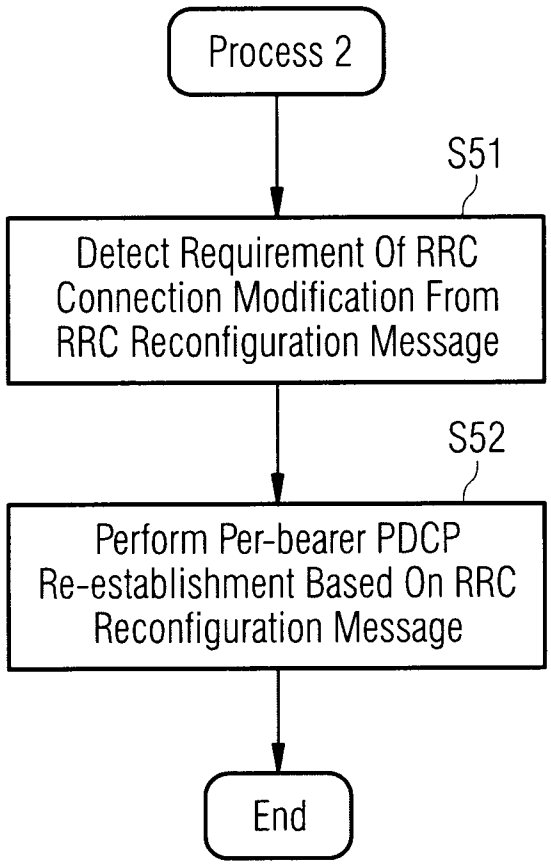

Process 2
S51
Detect Requirement Of RRC Connection Modification From RRC Reconfiguration Message
S52
Perform Per-bearer PDCP Re-establishment Based On RRC Reconfiguration Message
End

FIG 5

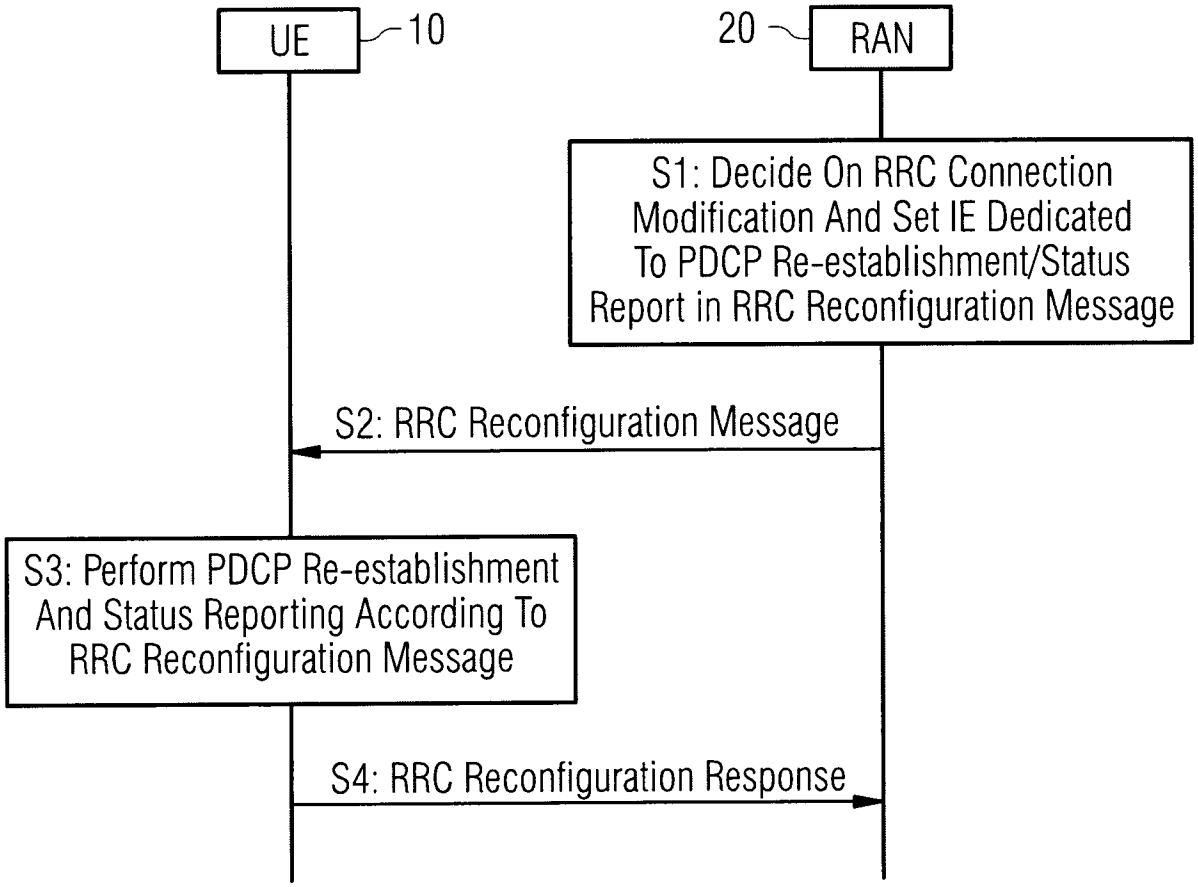
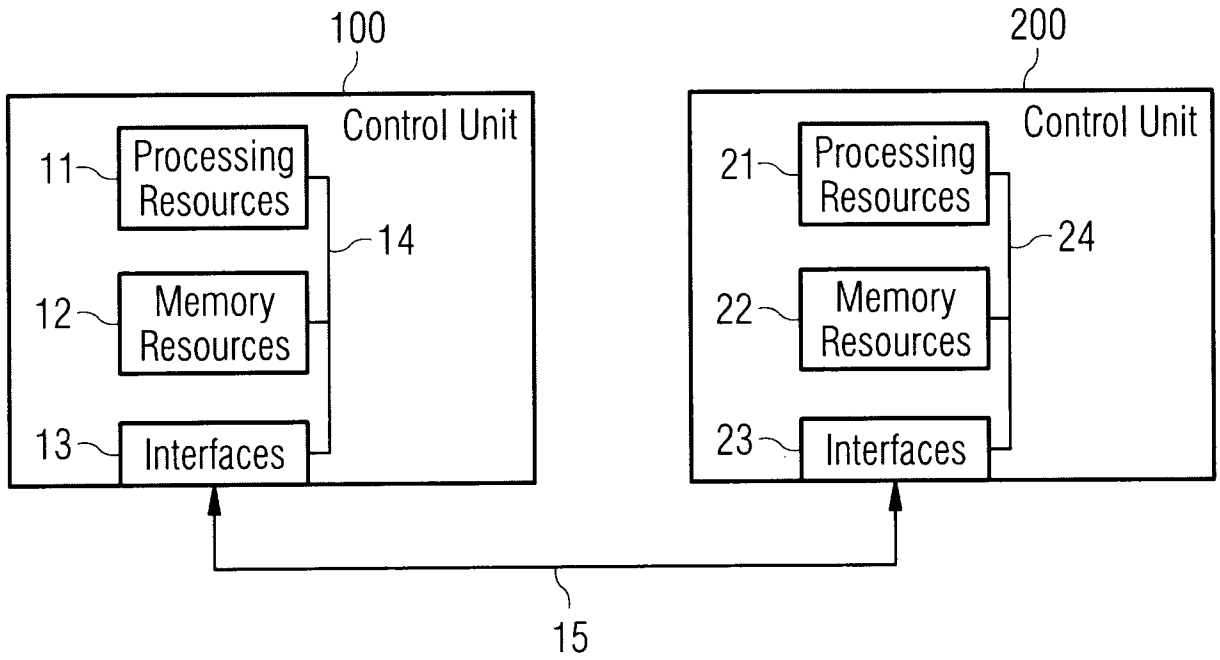

UE
10
20
RAN
S1: Decide On RRC Connection Modification And Set IE Dedicated To PDCP Re-establishment/Status Report in RRC Reconfiguration Message
S2: RRC Reconfiguration Message
S3: Perform PDCP Re-establishment And Status Reporting According To RRC Reconfiguration Message
S4: RRC Reconfiguration Response

FIG 6


100
Control Unit
11
Processing Resources
14
12
Memory Resources
13
Interfaces
200
Control Unit
21
Processing Resources
24
22
Memory Resources
23
Interfaces
15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/074140

A. CLASSIFICATION OF SUBJECT MATTER

H04W 36/22 (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)

IPC: H04W; H04L

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, CNKI, VEN: PDCP, packet data convergence protocol, RRC, radio resource control, re-configure, re-establish, bearer, base station, status report

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN102026324A(DATANG MOBILE COMMUNICATION EQUIP CO LTD) 20 April 2011(20.04.2011) description page 12, line 8 – page 15, line 24	1-6, 10, 12-19, 23, 25-31, 35, 37-41
A	CN101729396A(HUAWEI TECHNOLOGIES CO LTD) 09 June 2010(09.06.2010) the whole document	1-44
A	CN101997660A(ZTE CORP) 30 March 2011(30.03.2011) the whole document	1-44

☐ 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	Date of mailing of the international search report
02 January 2014(02.01.2014)	**23 Jan. 2014 (23.01.2014)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer LIU, Dan Telephone No. (86-10)62411509

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/074140

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN102026324A	20.04.2011	WO2011032497A1	24.03.2011
		US2012142361A1	07.06.2012
		EP2480025A1	25.07.2012
CN101729396A	09.06.2010	WO2010048850A1	06.05.2010
CN101997660A	30.03.2011	None	