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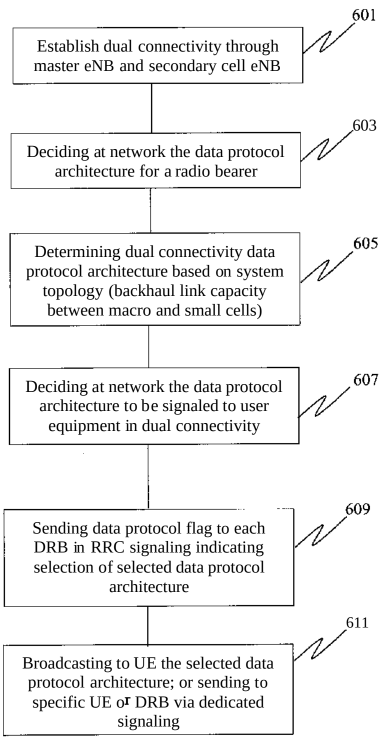

FIG. 6

(57) **Abstract:** A method, apparatus and computer program product are provided for establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell and for causing a data protocol indication to be sent to each data radio bearer during radio resource control (RRC) signaling. The data protocol indication signals a selected one of a set of data protocol architectures. A first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in the macro cell. The data protocol indication for the selected one of the data protocol architectures may be caused to be broadcast from the small cell for use in dual connectivity communication.

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CONFIGURABLE PROTOCOL STACK FOR DUAL CONNECTIVITY

Technological Field

This disclosure is related to an on-going wireless small cell network enhancement. More specifically, it is related to a higher layer aspect of the data protocol architecture.

Background

Dual connectivity is a promising technology for small cell enhancement. Small cell evolved Node Bs (eNBs) are low-power network nodes that function as serving cells for as few as one mobile terminal (such as a cell phone) to many mobile devices in a small local area (such as a shopping mall or library). The main target of dual connectivity is to utilize the small cell to provide a high frequency resource reuse factor and to ensure the mobility performance via connection with a macro cell. The scenario is somewhat like carrier aggregation or Coordinated Multipoint (CoMP), though there is no ideal backhaul link between macro evolved node B (eNB) and small cell eNB. However, due to the sometime non-ideal backhaul link, there needs to be some change to the system and protocol architecture.

There are two main promising architectures which are shown by way of example in Fig. 1. The main difference between these two architectures (Figs. la, lb) is whether to let the macro eNB route the data packets (Fig. lb). If both macro eNB and small cell eNB (sometimes referred to as "master cell eNB" and "secondary cell eNB", respectively) could connect to the core network (CN) as shown in Fig. 1a (that is, through a serving-gateway (S-GW), or some enhanced gateway to handle the data), both macro and small cell eNB would need the full protocol stack and the same traffic could only be served on one leg. However, if the macro eNB is used to route the packets as in Fig. lb, it is possible to simplify the protocol at the small cell eNB and let only macro eNB have the packet data convergence protocol (PDCP) layer and make the path switch decision.

The benefit of the first architecture (Fig. la) is that it could enable local breakout and might be a relatively simpler implementation such that user equipment (UE) could duplicate the protocol design. However, it also has the disadvantage of losing flexibility. The network (NW) may need a hard split between different traffic so that the UE cannot fully enjoy the increased frequency resource on two cells. Also, the security aspect may need some modification if there is an independent PDCP entity at the macro and small cells, respectively.

The architecture of Fig. 1b also has its advantages and disadvantages. On one hand, it could provide the flexibility of data routing to better utilize the load balancing between macro and small cells. It could avoid too much path switch signaling to the CN. On the other hand, it could cause some burden on the backhaul link between the macro and small cells and also reduce the scalability of the network.

Clearly each of these architectures has benefits and detriments. The choice of architecture, whether one of these or some other concept, is related to the practicality of deployment and hardware availability. These data protocol architectures may be two of a set of potential architectures from which the network may select.

Brief Summary

In a first embodiment, a method is provided that includes establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell (e.g., a macro eNB) and a small cell (e.g., a local eNB), and causing a data protocol indication to be sent to each data radio bearer during radio resource control (RRC) signaling. The data protocol indication signals a selected one of set of data protocol architectures. The method may include causing the data protocol indication for the selected one of the first and second data protocol architectures to be broadcast from the small cell for use in dual connectivity communication. Alternatively, a small cell eNB may determine to send the selected protocol architecture indication to particular UE and to a radio bearer by dedicated signaling.

The method may include determining which of the set of data architectures to employ in dual connectivity communication based on system topology. A first data architecture may be selected where the system topology provides poor backhaul link between the macro and small cells. A second data architecture may be selected where the system topology provides at least a good backhaul link between the macro and small cells. The method may further include deciding at the network the data protocol architecture for a radio bearer and deciding at the network the data protocol architecture to be signaled to user equipment in dual connectivity.

In a second embodiment, a method is provided that includes accessing a wireless network using legacy mobile device signaling, receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol, receiving dual connectivity establishment downlink signaling, and receiving an indication of data protocol architecture selection. This method may include building a data protocol stack according to the data protocol architecture selection indication, replacing the default architecture.

In another embodiment is an apparatus comprising at least a processor, a memory in communication with the processor and having computer coded instructions stored therein, said instructions, when executed by the processor, configured to cause the apparatus to perform establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell, and causing a data protocol indicator to be sent to each data radio bearer during radio resource control (RRC) signaling, said data protocol indicator signaling a selected data protocol architecture of a set of data protocol architectures. The apparatus further comprises instructions to cause determining at the network the data protocol architecture for a radio bearer and determining at the network the data protocol architecture to be signaled to user equipment in dual connectivity. More instructions are configured to determine which of the set of data protocol architectures to employ in dual connectivity communication based on system topology.

The apparatus further comprises instructions configured for causing the data protocol indicator for the selected one of the set of data protocol architectures to be broadcast from the small cell for use in dual connectivity communication, causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to target user equipment for use in dual connectivity communication, and for causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to a target radio bearer for use in dual connectivity communication. In this apparatus a protocol stack in a network node, whether macro or small cell, comprises at least a packet data convergence protocol (PDCP) function and a radio link control (RLC) function, a first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in said macro cell. The apparatus may embody a first data protocol architecture selected where the system topology provides poor backhaul link between the macro and small cells, and a second data architecture selected where the system topology provides at least a good backhaul link between the macro and small cells.

In another embodiment is an apparatus comprising at least a processor, a memory in communication with the processor and having computer coded instructions stored therein, said instructions, when executed by the processor, configured to cause the apparatus to perform accessing a wireless network using legacy mobile device signaling; receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol; receiving dual connectivity establishment downlink signaling; and receiving an indicator of data protocol architecture selection. The apparatus further comprises instructions configured to cause the apparatus to perform building a data protocol stack according to the data protocol architecture selection indicator, replacing said default architecture.

A computer program product embodiment comprises a computer readable storage medium having computer coded instructions stored therein, said instructions, when executed by a processor, causing an apparatus to perform establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell; and causing a data protocol indicator to be sent to each data radio bearer during radio resource control (RRC) signaling, the data protocol indicator signaling a selected data protocol architecture of a set of data protocol architectures. The computer program product further comprises instructions causing an apparatus to perform determining at the network the data protocol architecture for a radio bearer, and determining at the network the data protocol architecture to be signaled to user equipment in dual connectivity, and determining which of the set of data protocol architectures to employ in dual connectivity communication based on system topology.

The computer program product has instructions causing an apparatus to perform causing the data protocol indicator for the selected one of the set of data protocol architectures to be broadcast from the small cell for use in dual connectivity communication, and causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to target user equipment for use in dual connectivity communication, or causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to a target radio bearer for use in dual connectivity communication.

The computer program product may have a protocol stack in a network node, whether macro or small cell, that comprises at least a packet data convergence protocol (PDCP) function and a radio link control (RLC) function, wherein a first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in said macro cell. The computer program product is one wherein a first data protocol architecture is selected where the system topology provides poor backhaul link between the macro and small cells, and wherein a second data architecture is selected where the system topology provides at least a good backhaul link between the macro and small cells.

Another computer program product comprises a computer readable storage medium having computer coded instructions stored therein, said instructions, when executed by a processor, causing an apparatus to perform accessing a wireless network using legacy mobile device signaling, receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol, receiving dual connectivity establishment downlink signaling, and receiving an indicator of data protocol architecture selection. The product further comprises instructions causing an apparatus to perform building a data protocol stack according to the data protocol architecture selection indicator, replacing said default architecture.

Brief Description of the Drawings

Having thus described example embodiments in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Fig. 1 is a schematic representation of a wireless core network dual connectivity model between macro cell and small cell nodes and user equipment.

Fig. 2 is a block diagram of a wireless network and its basic components.

Fig. 3 is a block diagram of the components of network nodes and mobile terminals in a wireless network that may be specifically configured in accordance with an example embodiment of the present invention.

Fig. 4 is a schematic diagram of a first data protocol architecture in a local area network node (small cell) and a macro cell network node.

Fig. 5 is a schematic diagram of a second data protocol architecture in a local area network node (small cell) and a macro cell network node.

Fig. 6 is a flow diagram of a method for establishing dual connectivity and appropriate data protocol architecture in wireless network nodes in accordance with an example embodiment of the present invention.

Fig. 7 is a flow diagram of a method for establishing dual connectivity data protocol architecture in user equipment in accordance with an example embodiment of the present invention.

Detailed Description

Various embodiments now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the inventions are shown. Indeed, these embodiments may take different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

As used in this application, the term "circuitry" refers to all of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of "circuitry" applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or application specific integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

Although the method, apparatus and computer program product of example embodiments of the present invention may be implemented in a variety of different systems, one example of such a system is shown in Fig. 2, which includes a mobile terminal 8 that is capable of communication with a network 6 (e.g., a core network) via, for example, an access point 2 (AP). While the network may be configured in accordance with Global System for Mobile communications (GSM) / Enhanced Data rates for Global Evolution (EDGE) Radio Access Network (GERAN), the network may employ other mobile access mechanisms such as a Universal Mobile Telecommunications System

(UMTS) Terrestrial Radio Access Network (UTRAN), Long Term Evolution (LTE), LTE-Advanced (LTE-A), wideband code division multiple access (W-CDMA), CDMA2000, and/or the like. The embodiments of the present invention may also be implemented in future LTE based technologies and subsequently developed mobile networks.

The network 6 may include a collection of various different nodes, devices or functions that may be in communication with each other via corresponding wired and/or wireless interfaces. For example, the network may include one or more base stations, such as one or more Base Transceiver Stations (BTSs) and Base Station Controllers (BSCs), node Bs, evolved node Bs (eNBs), access points (AP), relay nodes or the like (all of which being hereinafter generically referenced as an access point (AP)), each of which may serve a coverage area divided into one or more cells. For example, the network may include one or more cells, including, for example, the AP 2, each of which may serve a respective coverage area. The serving cell could be, for example, part of one or more cellular or mobile networks or public land mobile networks (PLMNs). In turn, other devices such as processing devices (e.g., personal computers, server computers or the like) may be coupled to the mobile terminal and/or the second communication device via the network.

The mobile terminals 8 may be in communication with each other or other devices via the network 6. In some cases, each of the mobile terminals may include an antenna or antennas for transmitting signals to and for receiving signals from a base station. In some example embodiments, the mobile terminal 8, also known as a client device, may be a mobile communication device or user equipment (UE) such as, for example, a mobile telephone, portable digital assistant (PDA), pager, laptop computer, tablet computer, or any of numerous other hand held or portable communication devices, computation devices, content generation devices, content consumption devices, universal serial bus (USB) dongles, data cards or combinations thereof. As such, the mobile terminal 8 may include one or more processors that may define processing circuitry either alone or in combination with one or more memories. The processing circuitry may utilize instructions stored in the memory to cause the mobile terminal to operate in a particular way or execute specific functionality when the instructions are executed by the one or more processors. The mobile terminal 8 may also include communication circuitry and corresponding hardware/software to enable communication with other devices and/or the network 6.

Referring now to Fig. 3, an apparatus 20 that may be embodied by or otherwise associated with a mobile terminal 8 (e.g., a cellular phone, a personal digital assistant (PDA), smartphone, tablet computer or the like) or an AP 2 may include or otherwise be in communication with a processor 22, a memory device 24, a communication interface 28, and a user interface 30.

In some example embodiments, the processor 22 (and/or co-processors or any other processing circuitry assisting or otherwise associated with the processor) may be in communication with the memory device 24 via a bus for passing information among components of the apparatus 20. The memory device 24 may include, for example, one or more non-transitory volatile and/or non-volatile memories. In other words, for example, the memory device 24 may be an electronic storage device (e.g., a computer readable storage medium) comprising gates configured to store data (e.g., bits) that may be retrievable by a machine (e.g., a computing device like the processor). The memory device 24 may be configured to store information, data, content, applications, instructions, or the like for enabling the apparatus to carry out various functions in accordance with an example embodiment of the present invention. For example, the memory device could be configured to buffer input data for processing by the processor. Additionally or alternatively, the memory device 24 could be configured to store instructions for execution by the processor 22.

As noted above, the apparatus 20 may, in some embodiments, be embodied by a mobile terminal 8 or an AP 2. However, in some embodiments, the apparatus may be embodied as a chip or chip set. In other words, the apparatus may comprise one or more physical packages (e.g., chips) including materials, components and/or wires on a structural assembly (e.g., a baseboard). The structural assembly may provide physical strength, conservation of size, and/or limitation of electrical interaction for component circuitry included thereon. The apparatus may therefore, in some cases, be configured to implement an embodiment of the present invention on a single chip or as a single "system on a chip." As such, in some cases, a chip or chipset may constitute means for performing one or more operations for providing the functionalities described herein.

The processor 22 may be embodied in a number of different ways. For example, the processor may be embodied as one or more of various hardware processing means such as a coprocessor, a microprocessor, a controller, a digital signal processor (DSP), a processing element with or without an accompanying DSP, or various other processing circuitry including integrated circuits such as, for example, an ASIC (application specific integrated circuit), an FPGA (field programmable gate array), a microcontroller unit (MCU), a hardware accelerator, a special-purpose computer chip, or the like. As such, in some embodiments, the processor may include one or more processing cores configured to perform independently. A multi-core processor may enable multiprocessing within a single physical package. Additionally or alternatively, the processor may include one or more processors configured in tandem via the bus to enable independent execution of instructions, pipelining and/or multithreading. In the embodiment in which the apparatus 20 is embodied as a mobile terminal 8, the processor may be embodied by the processor of the mobile terminal.

In an example embodiment, the processor 22 may be configured to execute instructions stored in the memory device 24 or otherwise accessible to the processor. Alternatively or additionally, the processor may be configured to execute hard coded functionality. As such, whether configured by hardware or software methods, or by a combination thereof, the processor may represent an entity (e.g., physically embodied in circuitry) capable of performing operations according to an embodiment of the present invention while configured accordingly. Thus, for example, when the processor is embodied as an ASIC, FPGA or the like, the processor may be specifically configured hardware for conducting the operations described herein. Alternatively, as another example, when the processor is embodied as an executor of software instructions, the instructions may specifically configure the processor to perform the algorithms and/or operations described herein when the instructions are executed. However, in some cases, the processor may be a processor of a specific device (e.g., a mobile terminal 8) configured to employ an embodiment of the present invention by further configuration of the processor by instructions for performing the algorithms and/or operations described herein. The processor may include, among other things, a clock, an arithmetic logic unit (ALU) and logic gates configured to support operation of the processor.

Meanwhile, the communication interface 28 may be any means such as a device or circuitry embodied in either hardware or a combination of hardware and software that is configured to receive and/or transmit data from/to a network and/or any other device or module in communication with the apparatus 20. In this regard, the communication interface may include, for example, an antenna (or multiple antennas) and supporting hardware and/or software for enabling communications with a wireless communication network. Additionally or alternatively, the communication interface may include the circuitry for interacting with the antenna(s) to cause transmission of signals via the antenna(s) or to handle receipt of signals received via the antenna(s). In order to support multiple active connections simultaneously, such as in conjunction with a digital super directional array (DSDA) device, the communications interface of one embodiment may include a plurality of cellular radios, such as a plurality of radio front ends and a plurality of base band chains. In some environments, the communication interface may alternatively or also support wired communication. As such, for example, the communication interface may include a communication modem and/or other hardware/software for supporting communication via cable, digital subscriber line (DSL), universal serial bus (USB) or other mechanisms.

In some example embodiments, such as instances in which the apparatus 20 is embodied by a mobile terminal 8, the apparatus may include a user interface 30 that may, in turn, be in communication with the processor 22 to receive an indication of a user input and/or to cause provision of an audible, visual, mechanical or other output to the user. As such, the user interface may include, for example, a keyboard, a mouse, a joystick, a display, a touch screen(s), touch areas, soft keys, a microphone, a speaker, or other input/output mechanisms. Alternatively or additionally, the processor may comprise user interface circuitry configured to control at least some functions of one or more user interface elements such as, for example, a speaker, ringer, microphone, display, and/or the like. The processor and/or user interface circuitry comprising the processor may be configured to control one or more functions of one or more user interface elements through computer program instructions (e.g., software and/or firmware) stored on a memory accessible to the processor (e.g., memory device and/or the like).

Addressing the data protocol issue, in a first approach the network (NW) could configure the protocol architecture type on an EPS radio bearer (E-RAB) (or radio bearer from the radio aspect) basis. Once the mobile device is known in the core network the following radio bearers are established automatically:

- A low priority signaling (message) bearer (SRB1)
- A high priority signaling (message) bearer (SRB2)
- A data radio bearer (DRB), i.e. a bearer for IP packets

Authentication and activation of encryption are begun in the bearer establishment procedure. The base station, e.g., the NodeB or eNB, retrieves the required data for this process from the S-GW, or more accurately from the network Mobility Management Entity (MME). The MME also delivers all necessary information that is required to configure the data radio bearer, such as for example minimum/maximum bandwidth, and quality of service.

In a first embodiment, during the Radio Bearer (RB) establishment procedure, eNB could insert a flag about the actual protocol for this RB.

1. eNB inserts the protocol architecture flag into the radio resource control (RRC) signaling when establishing an RB; different RBs could have different protocol architectures.

2. UE builds its protocol according to the indication from eNB;
3. There should be default protocol architecture at both eNB and UE for the signaling radio bearers (SRBO and SRB1). SRB1 may re-configure the protocol architecture for itself in the later stage.

As a potential conservative choice, if the NW decides the protocol purely according to the system topology (other factors may be considered), the NW may choose to route the data in an instance in which the system topology has at least good backhaul from the macro eNB. In an instance in which the system topology does not have a good backhaul, the NW may choose to utilize the local breakout. In regards to the backhaul being considered by the NW to be good, or not, the NW may compare the backhaul of the system topology to a predefined threshold that serves to distinguish a good backhaul from one that is not considered good.

Once dual connectivity is established, the small cell eNB may indicate the selected protocol architecture flag in a system information broadcast to all UEs it serves. The UEs receiving the protocol architecture flag indicator may follow the indication, building their data protocol stacks according to the selected architecture. If, however, the small cell determines that each UE or DRB should be configured individually, then the small cell will send the selected data protocol architecture indication via dedicated signaling to each affected UE or DRB.

An example of the protocol architecture signaling approaches are shown in Tables 1 and 2. The examples show how an example embodiment of the approach works from the specification point of view and considers the related likely eNB decision.

For example deployments of a macro cell and a small cell, there is a backhaul link between them and the capacity / delay performance of this backhaul link is "medium." There are two data radio bearers (DRBs) that need to be established to the UE in this example, but according to the backhaul link capacity, the macro eNB could only forward one of these, DRBl.

In this example, UE first accesses the NW as a legacy UE (e.g. per 3GPP Specification Rel-8 UE procedures), so that SRBO and SRB1 both use the legacy protocol. After NW establishes dual connectivity to this UE, NW establishes DRBl and DRB2 with different protocol stacks. The detailed signaling could be arranged as shown in Table 1 below.

Table 1

```
DRB-ToAddMod  ::=    SEQUENCE  {
    Protocol-Flag              ENUMERATED (pa1, pa2, pa3, spare)
    eps-Bearerldentity         INTEGER  (0..15)          OPTIONAL,         -- Cond DRB-Setup
    drb-Identity                   DRB-Identity ,
    pdcp-Config                PDCP-Config               OPTIONAL,         -- Cond PDC
    rlc-Config                 RLC-Config                OPTIONAL,         -- Cond Setup
    logicalChannelldentity     INTEGER  (3.. 10)         OPTIONAL,         -- Cond DRB-Setup
    logicalChannelConf ig      LogicalChannelConf ig     OPTIONAL,         -- Cond Setup
    ...
}
```

The highlighted "Protocol-Flag" part shows an added signaling flag. Flag "pal" means protocol architecture alternative 1 which could be predefined, and "pa2" means protocol architecture alternative 2. There may be a set of several data protocol architectures from which to choose.

Figures 4 and 5 illustrate the two detailed protocols in an example embodiment. In a dual connectivity scenario, there could be at least two potential architectures for protocol stack, which could be:

1. [pal] Data split above the PDCP 401 so there will be complete U-plane protocol for both small cell 403 and macro cell 405 legs (Fig. 4);
2. [pa2] Data split between PDCP 401 and RLC 407, so that macro eNB 405 has common PDCP (Fig. 5).

After UE builds the protocol stack for the related DRB, the UE performs the corresponding behavior for the given radio bearer (RB). Although the standards organization (3GPP) has yet to specify the corresponding behavior, it may be suggested that if a common PDCP structure is built, UE would need to perform packet reordering at the PDCP layer and UE could assume the same security handing as set forth in 3GPP, Release 8. This may cause impact to the UL logical channel prioritization, buffer status report, etc.

The NW could still modify the SRB 1 itself, so the signaling may look like the example shown in Table 2 below.

Table 2

```
SRB-ToAddMool ::=     SEQUENCE {
    Protocol-Flag                          ENUMERATED (pa1, pa2, pa3, spare)
    srb-Identity                           INTEGER (1..2),
    rlc-Config                             CHOICE {
        explicitValue                          RLC-Config,
        defaultValue                           NULL
    }       OPTIONAL,                                                      -- Cond Setup
    logicalChannelConfig                   CHOICE {
        explicitValue                          LogicalChannelConfig,
        defaultValue                           NULL
    }       OPTIONAL,                                                      -- Cond Setup
    ...
}
```

Figs. 6 and 7 illustrate processes involved in establishing dual connectivity and selection of the appropriate data protocol for use in the macro and small cell network nodes and user equipment, respectively. Regarding Fig. 6, a process comprises an apparatus 20 embodied by a network node and, more particularly, the processor 22, the communications interface 28 or the like for establishing dual connectivity 601 through macro (master) cell eNB and small (secondary) cell eNB. The apparatus embodied by the network node, such as the processor, decides the data protocol architecture for a radio bearer 603 in dual connectivity. The data protocol architecture determination is based 605 on system topology, wherein at least a good backhaul link between macro and small cells decides the second data protocol architecture while a poor backhaul link leads to selection of the first architecture. A first architecture splits the data path above PDCP while a second architecture splits the data path between PDCP and RLC in the macro cell. The apparatus embodied by the network node, such as the processor, may also decide the architecture to be signaled 607 to user equipment in dual connectivity. The process includes the apparatus, such as the processor, the communications interface or the like, causing a data protocol flag 609 to be sent to each DRB in RRC signaling to indicate selection of the first or second data protocol architecture. The processor, the communications interface or the like may cause broadcasting 611 from the network node(s) to UE the selected protocol, or may cause the small cell eNB to send the protocol indicator to particular UE or DRB via dedicated signaling.

Referring to Fig. 7, another process operates in UE and, more particularly, an apparatus 20 embodied by the UE wherein the processor 22 and/or the communications interface 28 of the apparatus accesses 701 the wireless network using legacy signaling. The apparatus embodied by the UE, such as the processor, the communications interface or the like, receives signaling from the network initially 703 in a default data protocol architecture including receiving downlink signals 705 indicating the establishment of dual connectivity. The process continues with the apparatus, such as the processor, the communications interface or the like, receiving an indicator of the selected data protocol architecture 707. Then the apparatus embodied by the UE, such as the processor the othe like, builds its data protocol stack 709 according to the selected data protocol architecture.

As described above, the processes shown in Figs. 6 and 7 may each be performed in an apparatus comprising means for performing each of the listed functions. In regards to the process of Fig. 7, the apparatus may be embodied by a mobile terminal 8 (Fig. 2) in communication with an access point 2 to the network 6. The mobile terminal may comprise (Fig. 3) a processor 22, a memory 24 and communications interface 28. Alternatively, in conjunction with the process of Fig. 6, the process may be embodied in an access point 2 (network node or base station) that comprises a macro or small cell eNB having the same components, as shown in Fig. 3. The means for performing the listed functions includes, for example, a processor 22 and a memory 24 containing computer coded instructions for carrying out the functions, and a communications interface 28 for sending and/or receiving network signaling.

As described above, Figures 6-7 are flowcharts of a method, apparatus and program product according to example embodiments of the invention. It will be understood that each block of the flowcharts, and combinations of blocks in the flowcharts, may be implemented by various means, such as hardware, firmware, processor, circuitry and/or other device associated with execution of software including one or more computer program instructions. For example, one or more of the procedures described above may be embodied by computer program instructions. In this regard, the computer program instructions which embody the procedures described above may be stored by a memory device 24 of an apparatus 20 employing an embodiment of the present invention and executed by a processor 22 in the apparatus. As will be appreciated, any such computer program instructions may be loaded onto a computer or other programmable apparatus (e.g., hardware) to produce a machine, such that the resulting computer or other programmable apparatus embody a mechanism for implementing the functions specified in the flowchart blocks. These computer program instructions may also be stored in a non-transitory computer-readable storage memory (as opposed to a transmission medium such as a carrier wave or electromagnetic signal) that may direct a computer or other programmable apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture the execution of which implements the function specified in the flowchart blocks. The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operations to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide operations for implementing the functions specified in the flowchart block(s). As such, the operations of Figures 6-7, when executed, convert a computer or processing circuitry into a particular machine configured to perform an example embodiment of the present invention. Accordingly, the operations of Figures 6-7 define an algorithm for configuring a computer or processing circuitry (e.g., processor) to perform an example embodiment. In some cases, a general purpose computer may be configured to perform the functions shown in Figures 6-7 (e.g., via configuration of the processor), thereby transforming the general purpose computer into a particular machine configured to perform an example embodiment.

Accordingly, blocks of the flowcharts support combinations of means for performing the specified functions, combinations of operations for performing the specified functions and program instructions for performing the specified functions. It will also be understood that one or more blocks of the flowcharts, and combinations of blocks in the flowcharts, can be implemented by special purpose hardware-based computer systems which perform the specified functions or operations, or combinations of special purpose hardware and computer instructions.

The following list of abbreviations and acronyms is provided as a reference for terms appearing in this description that may also appear in the claims to follow.

CN	Core Network
CoMP	Coordinated Multipoint
DRB	Data Radio Bearer
eNB	evolved NodeB
EPS	Evolved Packet System
LTE	Long Term Evolution
MAC	Medium Access Control
MME	Mobility Management Entity
NW	NetWork
PDCP	Packet Data Convergence Protocol
RB	Radio Bearer
RLC	Radio Link Control
S-GW	Serving Gateway
SRB	Signaling Radio Bearer
UE	User Equipment

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A method comprising:

establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell; and

causing a data protocol indicator to be sent to each data radio bearer during radio resource control (RRC) signaling, said data protocol indicator signaling a selected data protocol architecture of a set of data protocol architectures.

2. The method of claim 1, further comprising:

determining at the network the data protocol architecture for a radio bearer.

3. The method of claims 1 or 2, further comprising:

determining at the network the data protocol architecture to be signaled to user equipment in dual connectivity.

4. The method of any of claims 1 to 3, further comprising:

determining which of the set of data protocol architectures to employ in dual connectivity communication based on system topology.

5. The method of claim 1, further comprising:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be broadcast from the small cell for use in dual connectivity communication.

6. The method of claim 1, further comprising:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to target user equipment for use in dual connectivity communication.

7. The method of claim 1, further comprising:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to a target radio bearer for use in dual connectivity communication.

8. The method of any of claims 1 and 5 to 7, wherein a protocol stack in a network node, whether macro or small cell, comprises at least a packet data convergence protocol (PDCP) function and a radio link control (RLC) function, a first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in said macro cell.

9. The method of claim 4, wherein a first data protocol architecture is selected where the system topology provides poor backhaul link between the macro and small cells.

10. The method of claim 4, wherein a second data architecture is selected where the system topology provides at least a good backhaul link between the macro and small cells.

11. A method comprising:

accessing a wireless network using legacy mobile device signaling;

receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol;

receiving dual connectivity establishment downlink signaling; and

receiving an indicator of data protocol architecture selection.

12. The method of claim 11, further comprising:

building a data protocol stack according to the data protocol architecture selection indicator, replacing said default architecture.

13. An apparatus comprising at least a processor, a memory in communication with the processor and having computer coded instructions stored therein, said instructions, when executed by the processor, configured to cause the apparatus to perform:

establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell; and

causing a data protocol indicator to be sent to each data radio bearer during radio resource control (RRC) signaling, said data protocol indicator signaling a selected data protocol architecture of a set of data protocol architectures.

14. The apparatus of claim 13, further comprising instructions configured to cause the apparatus to perform:

determining at the network the data protocol architecture for a radio bearer.

15. The apparatus of claim 13 or 14, further comprising instructions configured to cause the apparatus to perform:

determining at the network the data protocol architecture to be signaled to user equipment in dual connectivity.

16. The apparatus of any of claims 13 to 15, further comprising instructions configured to cause the apparatus to perform:

determining which of the set of data protocol architectures to employ in dual connectivity communication based on system topology.

17. The apparatus of claim 13, further comprising instructions configured to cause the apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be broadcast from the small cell for use in dual connectivity communication.

18. The computer program product of claim 24, further comprising instructions causing an apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to target user equipment for use in dual connectivity communication.

19. The apparatus of claim 13, further comprising instructions configured to cause the apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to a target radio bearer for use in dual connectivity communication.

20. The apparatus of any of claims 13 and 17 to 19, wherein a protocol stack in a network node, whether macro or small cell, comprises at least a packet data convergence protocol (PDCP) function and a radio link control (RLC) function, a first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in said macro cell.

21. The apparatus of claim 16, wherein a first data protocol architecture is selected where the system topology provides poor backhaul link between the macro and small cells.

22. The apparatus of claim 16, wherein a second data architecture is selected where the system topology provides at least a good backhaul link between the macro and small cells.

23. An apparatus comprising at least a processor, a memory in communication with the processor and having computer coded instructions stored therein, said instructions, when executed by the processor, configured to cause the apparatus to perform:

accessing a wireless network using legacy mobile device signaling;

receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol;

receiving dual connectivity establishment downlink signaling; and

receiving an indicator of data protocol architecture selection.

24. The apparatus of claim 23, further comprising instructions configured to cause the apparatus to perform:

building a data protocol stack according to the data protocol architecture selection indicator, replacing said default architecture.

25. A computer program product comprising a computer readable storage medium having computer coded instructions stored therein, said instructions, when executed by a processor, causing an apparatus to perform:

establishing dual connectivity in a mobile network wherein the dual connectivity is to a mobile wireless network through both a macro cell and a small cell; and

causing a data protocol indicator to be sent to each data radio bearer during radio resource control (RRC) signaling, said data protocol indicator signaling a selected data protocol architecture of a set of data protocol architectures.

26. The computer program product of claim 25, further comprising instructions causing an apparatus to perform:

determining at the network the data protocol architecture for a radio bearer.

27. The computer program product of claim 25 or 26, further comprising instructions causing an apparatus to perform:

determining at the network the data protocol architecture to be signaled to user equipment in dual connectivity.

28. The computer program product of any of claims 25 to 27, further comprising instructions causing an apparatus to perform:

determining which of the set of data protocol architectures to employ in dual connectivity communication based on system topology.

29. The computer program product of claim 25, further comprising instructions causing an apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be broadcast from the small cell for use in dual connectivity communication.

30. The computer program product of claim 25, further comprising instructions causing an apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to target user equipment for use in dual connectivity communication.

31. The computer program product of claim 25, further comprising instructions causing an apparatus to perform:

causing the data protocol indicator for the selected one of the set of data protocol architectures to be sent from the small cell via dedicated signaling to a target radio bearer for use in dual connectivity communication.

32. The computer program product of any of claims 25 and 29-3 1, wherein a protocol stack in a network node, whether macro or small cell, comprises at least a packet data convergence protocol (PDCP) function and a radio link control (RLC) function, a first data protocol architecture splits data above the PDCP and a second protocol architecture splits data between PDCP and RLC in said macro cell.

33. The computer program product of claim 28, wherein a first data protocol architecture is selected where the system topology provides poor backhaul link between the macro and small cells.

34. The computer program product of claim 28, wherein a second data architecture is selected where the system topology provides at least a good backhaul link between the macro and small cells.

35. A computer program product comprising a computer readable storage medium having computer coded instructions stored therein, said instructions, when executed by a processor, causing an apparatus to perform:

accessing a wireless network using legacy mobile device signaling;

receiving signaling from a wireless network using a default data protocol architecture in the absence of a configured protocol;

receiving dual connectivity establishment downlink signaling; and

receiving an indicator of data protocol architecture selection.

36. The computer program product of claim 35, further comprising instructions causing an apparatus to perform:

building a data protocol stack according to the data protocol architecture selection indicator, replacing said default architecture.

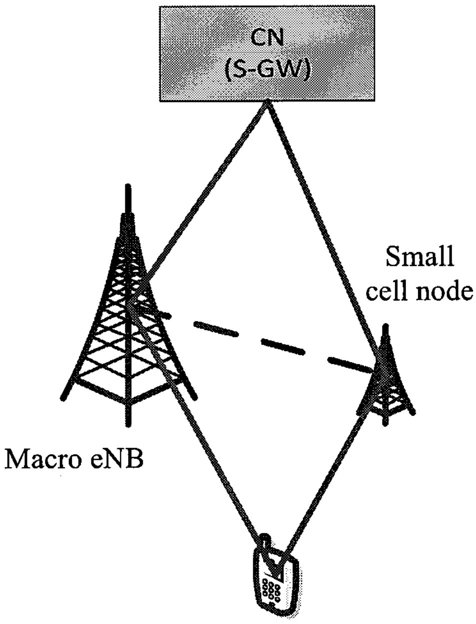

Fig. 1a

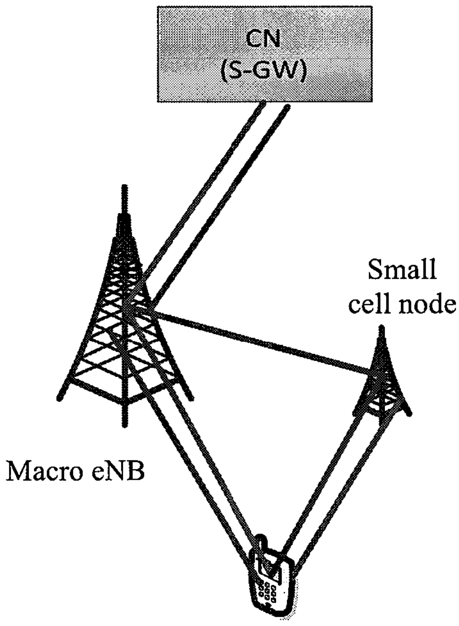

Fig. 1b

FIG. 1

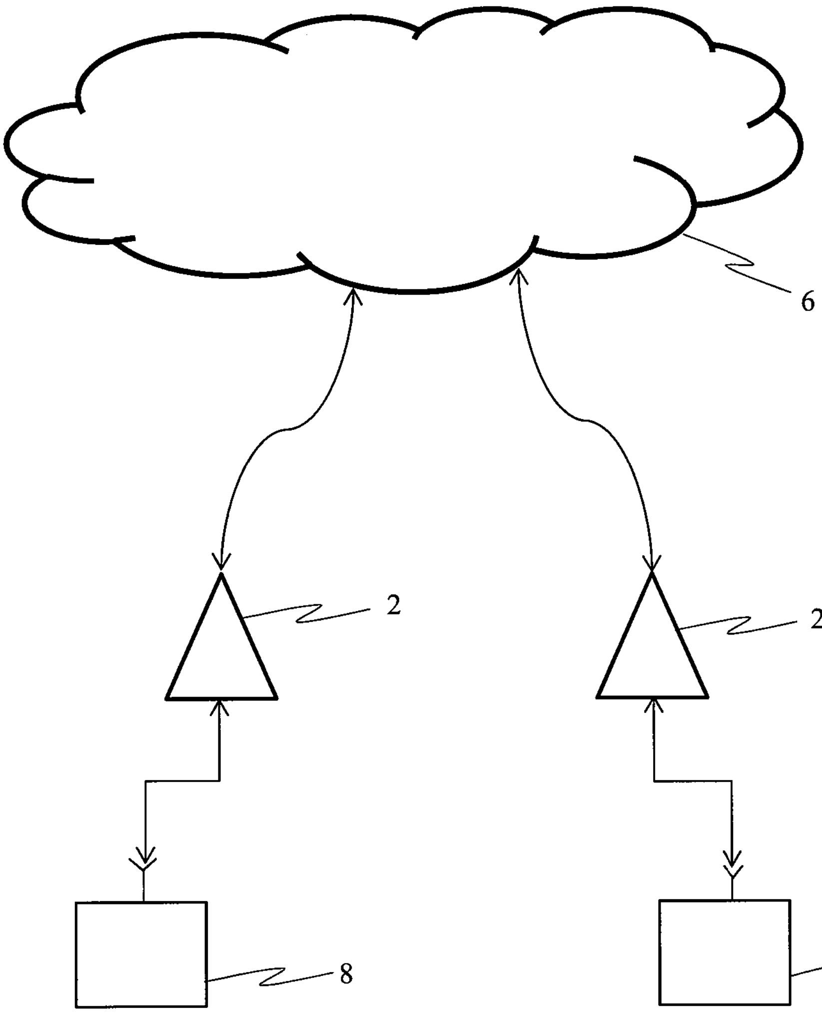

FIG. 2

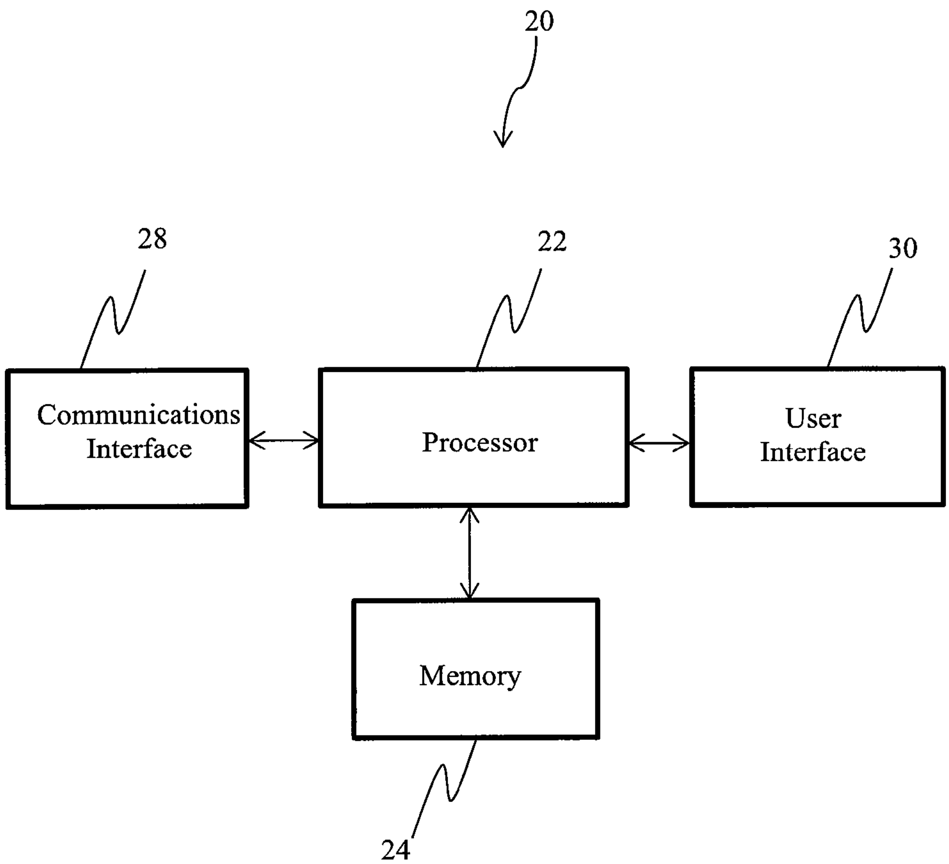
20
28
22
30
Communications Interface
Processor
User Interface
Memory
24

FIG. 3

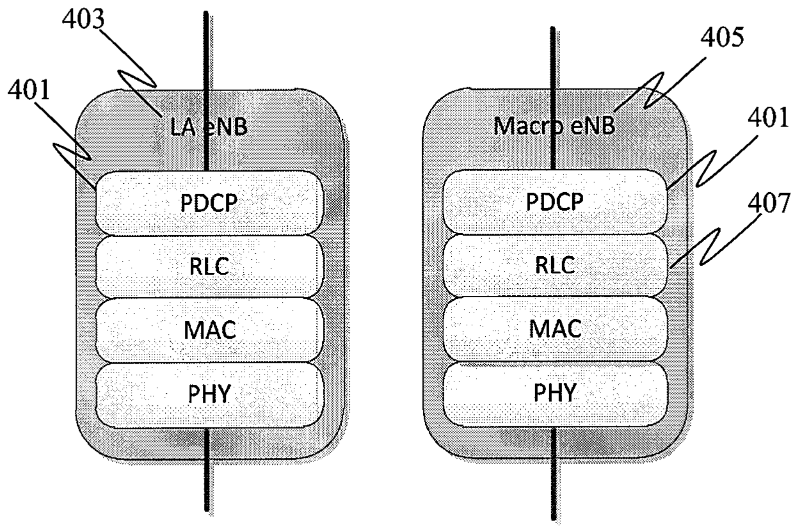
403
401
LA eNB
PDCP
RLC
MAC
PHY
405
Macro eNB
401
407
PDCP
RLC
MAC
PHY

FIG. 4

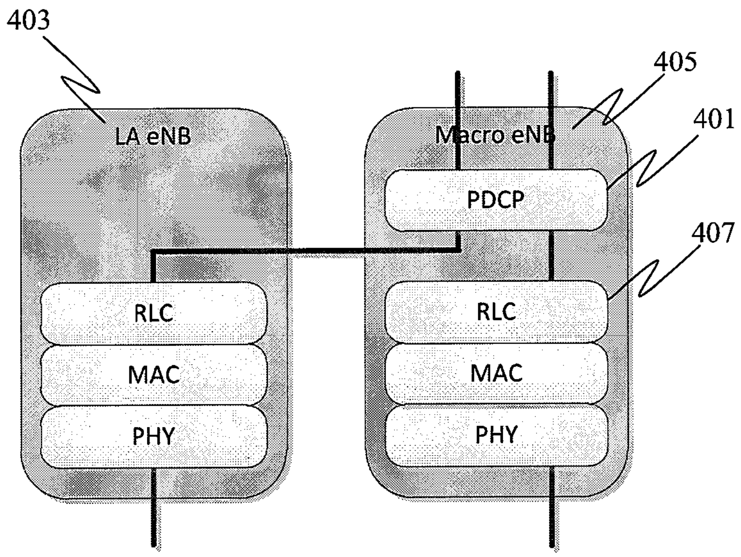

FIG. 5

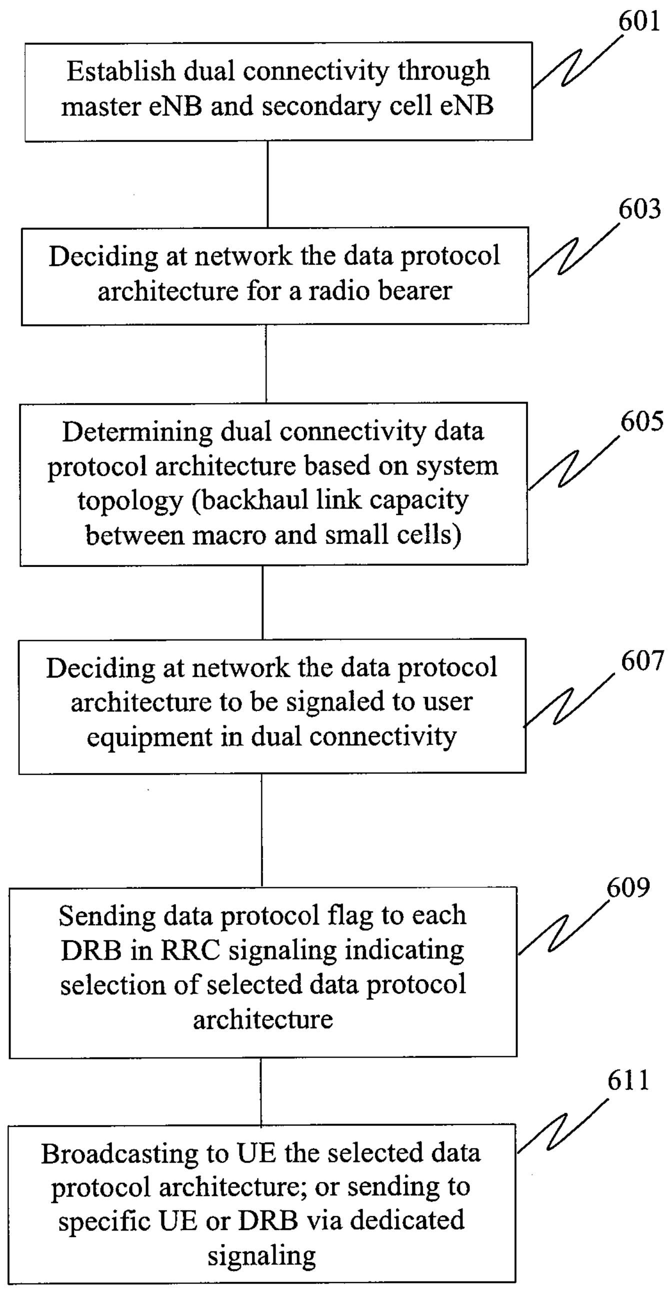
601
Establish dual connectivity through master eNB and secondary cell eNB
603
Deciding at network the data protocol architecture for a radio bearer
605
Determining dual connectivity data protocol architecture based on system topology (backhaul link capacity between macro and small cells)
607
Deciding at network the data protocol architecture to be signaled to user equipment in dual connectivity
609
Sending data protocol flag to each DRB in RRC signaling indicating selection of selected data protocol architecture
611
Broadcasting to UE the selected data protocol architecture; or sending to specific UE or DRB via dedicated signaling

FIG. 6

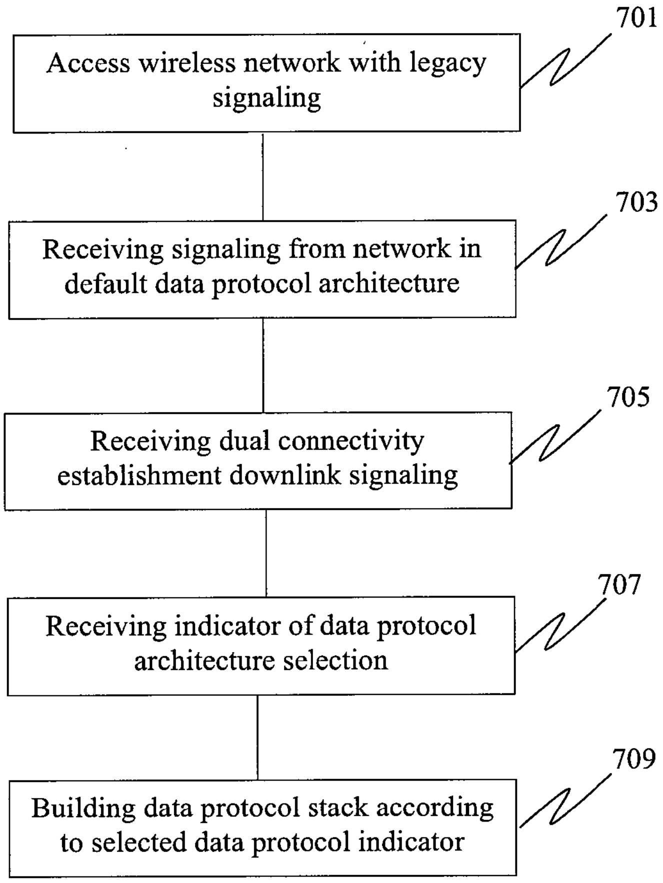
Access wireless network with legacy signaling
701
Receiving signaling from network in default data protocol architecture
703
Receiving dual connectivity establishment downlink signaling
705
Receiving indicator of data protocol architecture selection
707
Building data protocol stack according to selected data protocol indicator
709

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/075458

A. CLASSIFICATION OF SUBJECT MATTER

H04W 76/02 (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

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, VEN, WOTXT, 3GPP: dual connectivity, macro cell, small cell, radio resource control, RRC, data protocol architecture

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	What is Dual Connectivity. 3GPP TSG RAN WG2 Meeting #81 St. Julian's, Malta. January 28 - February 1, 2013. the whole document. Retrieved from the internet URL: http://isearch.3gpp.Org/isysquery/fe316632-4d5b-4b7c-b451-0dl76aed515c/l/doc/ [retrieved on 2014-1-17]	1-36
A	Discussion about Dual Connectivity. 3GPP TSG-RAN WG2 Meeting #81 Malta. January 28 - February 1, 2013. the whole document. Retrieved from the internet URL: http://isearch.3gpp.Org/isysquery/08510a6c-4444-4de6-ad6a-47a23452f058/5/doc/ [retrieved on 2014-1-17]	1-36
A	Mobility for Dual Connectivity. 3GPP TSG RAN WG2 Meeting #8Ibis Chicago, USA. April 15- April 19, 2013. the whole document. Retrieved from the internet URL: http://isearch.3gpp.Org/isysquery/lae72521-d274-46a5-9993-8382c9a27a7b/7/doc/ [retrieved on 2014-1-17]	1-36

☒ 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

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

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

"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
17 January 2014(17.01.2014)	**20 Feb. 2014 (20.02.2014)**

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

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Telephone No. (86-10)62089373

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/075458

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	[Discussion on Dual Connectivity. 3GPP TSG RAN WGl Meeting #79bits Chicago, US. April 15- April 19, 2013. the whole document. Retrieved from the internet URL: http://www.3gpp.org/ftp/TSG_RANAVGl_RLl/TSGRl_72b/Docs/Rl-131138.zip [retrieved on 2014-1-17]	1-36
A	Protocol Architecture for Dual Connectivity. 3GPP TSG-RAN WG2 Meeting #81bis Chicago. April 15- April 19, 2013. the whole document. Retrieved from the internet URL: http://isearch.3gpp.Org/isysquery/08510a6c-4444-4de6-ad6a-47a23452f058/7/doc/ [retrieved on 2014-1-17]	1-36