US 20140362829A1

(19) **United States**

(12) **Patent Application Publication**

Kazmi et al.

(10) **Pub. No.: US 2014/0362829 A1**

(43) **Pub. Date: Dec. 11, 2014**

(54) **EPS BEARER SPLITTING FOR DUAL CONNECTIVITY DEVICES**

(71) Applicants: **Zaigham A. Kazmi**, San Marcos, CA (US); **Ana Lucia Pinheiro**, Breinigsville, PA (US); **Candy Yiu**, Portland, OR (US); **Youn Hyoung Heo**, Seoul (KR); **Yujian Zhang**, Beijing (CN)

(72) Inventors: **Zaigham A. Kazmi**, San Marcos, CA (US); **Ana Lucia Pinheiro**, Breinigsville, PA (US); **Candy Yiu**, Portland, OR (US); **Youn Hyoung Heo**, Seoul (KR); **Yujian Zhang**, Beijing (CN)

(21) Appl. No.: **14/134,985**

(22) Filed: **Dec. 19, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/832,644, filed on Jun. 7, 2013.

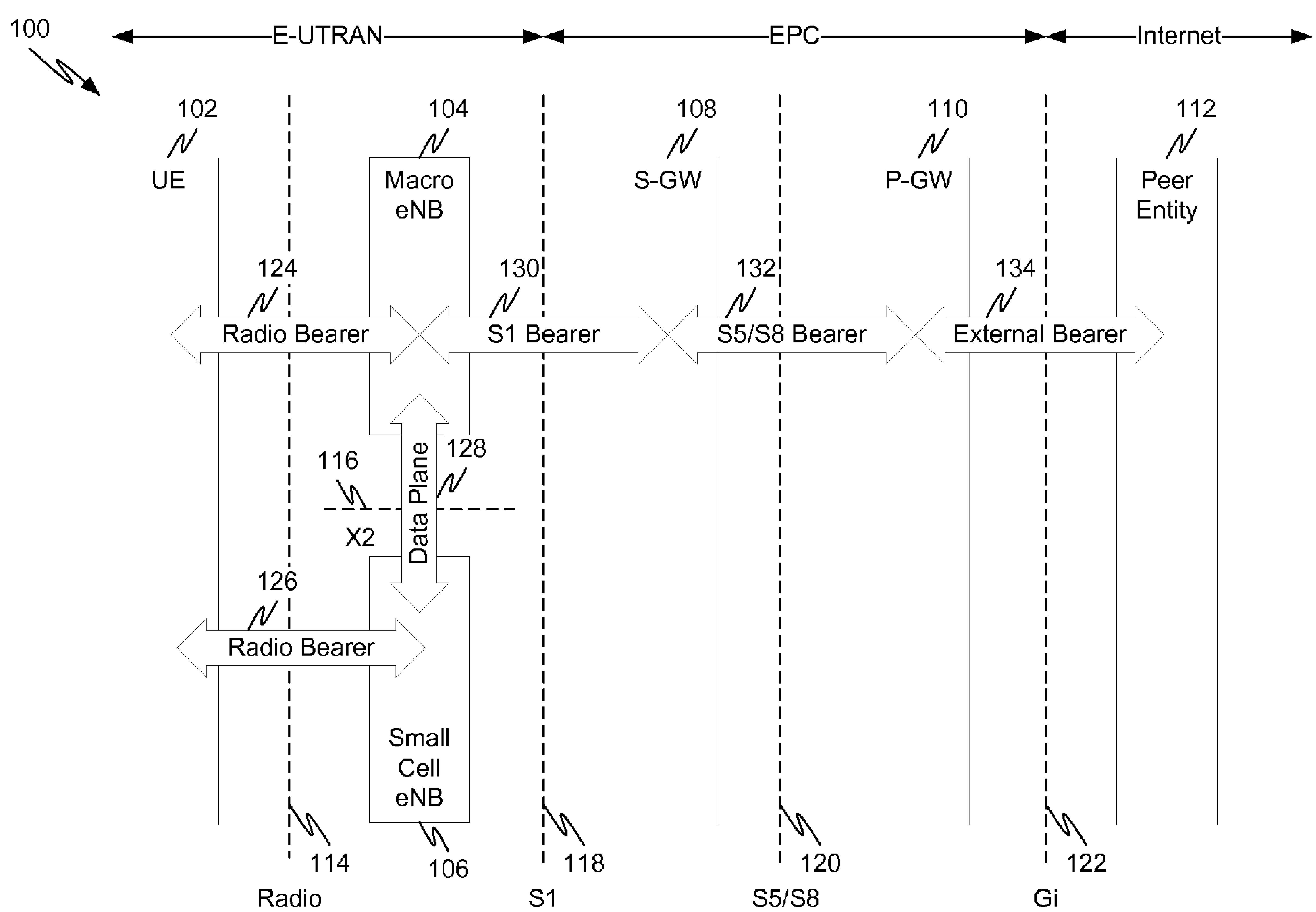
Publication Classification

(51) **Int. Cl.**
H04W 36/30 (2006.01)

(52) **U.S. Cl.**
CPC *H04W 36/30* (2013.01)
USPC **370/332**

(57) **ABSTRACT**

A User Equipment (UE) may be connected to multiple Enhanced Node Bs (eNBs). The multiple connection allows a UE to have an EPS bearer with multiple bearer paths, one routed through each of the eNBs. One eNB may implement a decision module to switch the bearer path to route incoming packets along a selected bearer path in order to achieve objectives such as maintaining Quality of Service (QoS) for the EPS bearer and/or maximizing overall network throughput. The eNB may gather information and metrics influencing these objectives from the other eNB and UE in order to make better bearer path decisions. The split bearer allows the UE to implement reduced protocol layers and reconfigure the protocol layers to match the bearer path selected by the eNB.



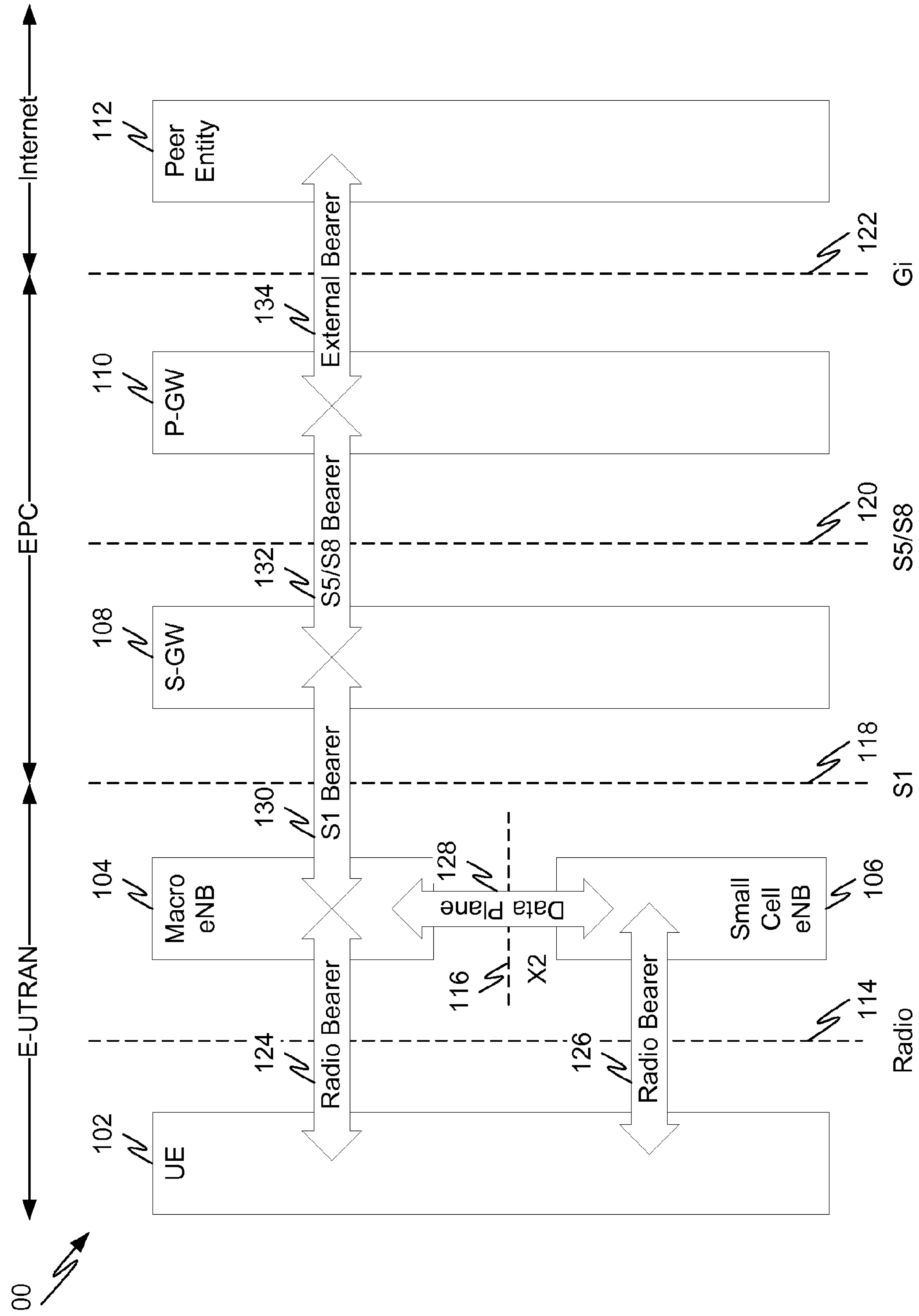
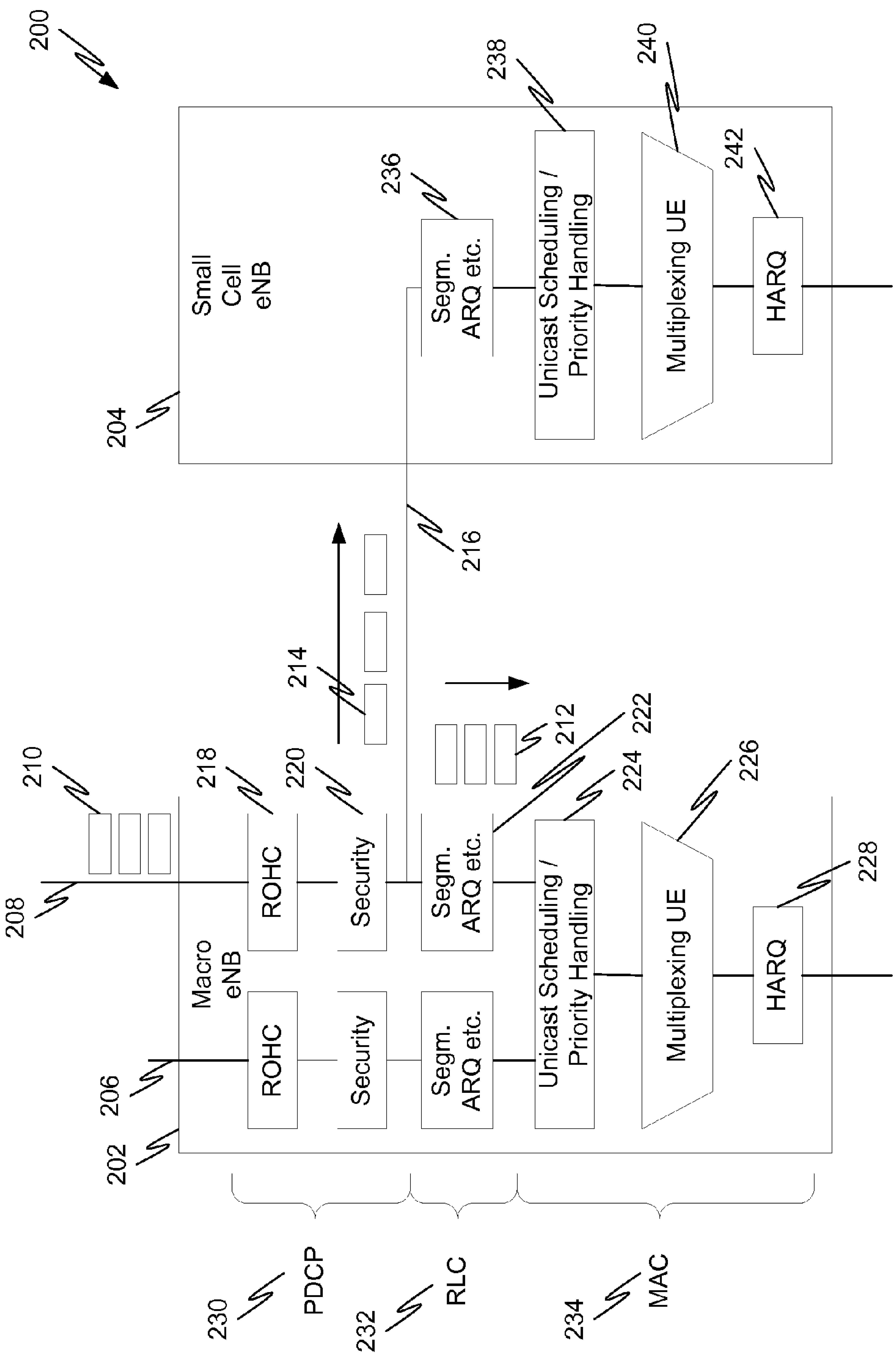

100
E-UTRAN
EPC
Internet
UE
102
Macro
eNB
104
Small
Cell
eNB
106
S-GW
108
P-GW
110
Peer
Entity
112
Radio
114
X2
116
S1
118
S5/S8
120
Gi
122
Radio Bearer
124
Radio Bearer
126
Data Plane
128
S1 Bearer
130
S5/S8 Bearer
132
External Bearer
134

FIG. 1



200
Small Cell eNB
204
Segm. ARQ etc.
236
Unicast Scheduling / Priority Handling
238
Multiplexing UE
240
HARQ
242
216
214
212
222
Macro eNB
202
206
208
210
ROHC
218
Security
220
Segm. ARQ etc.
Unicast Scheduling / Priority Handling
224
Multiplexing UE
226
HARQ
228
PDCP
230
RLC
232
MAC
234

FIG. 2

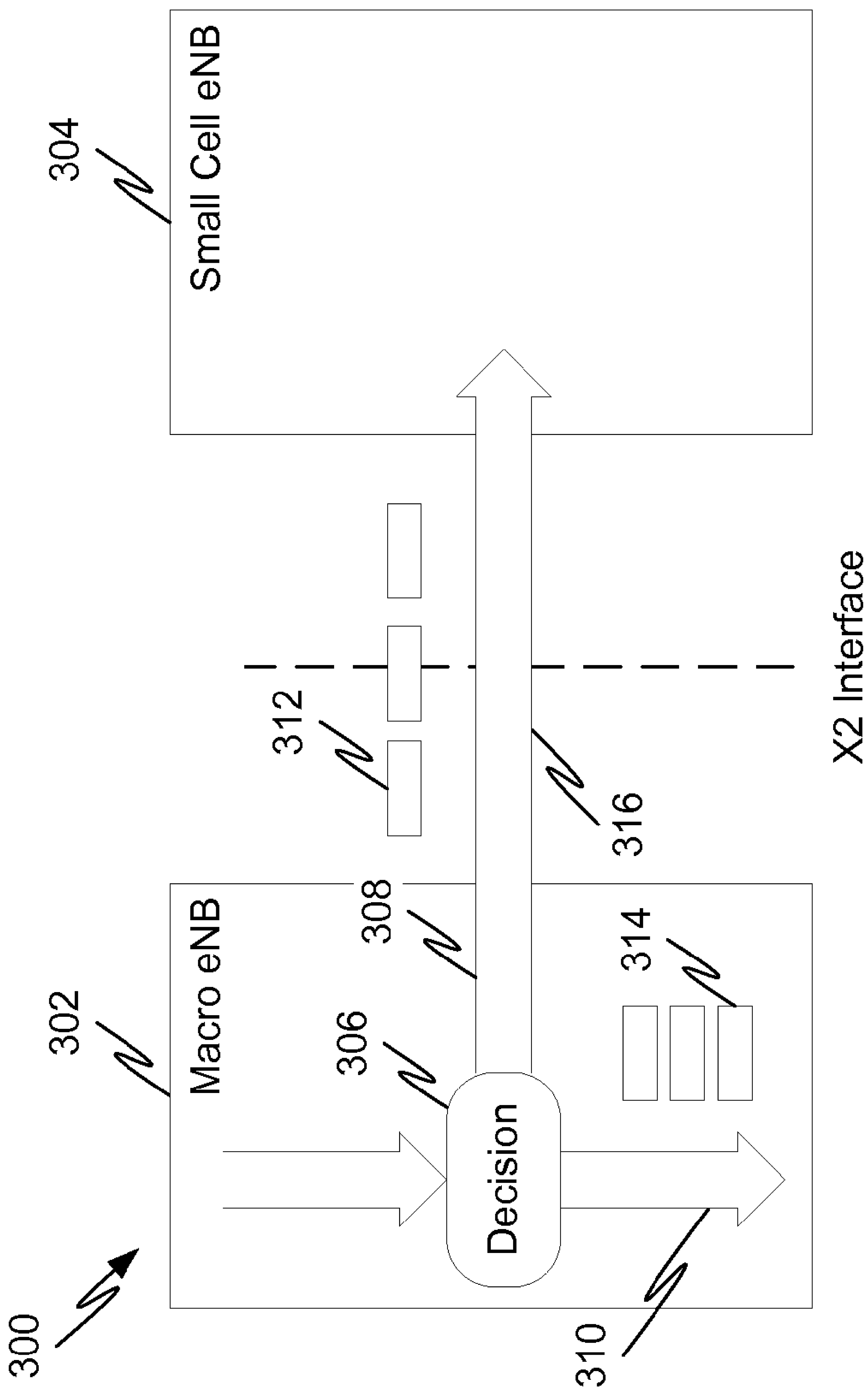

300
302
Macro eNB
304
Small Cell eNB
306
Decision
308
310
312
314
316
X2 Interface

FIG. 3

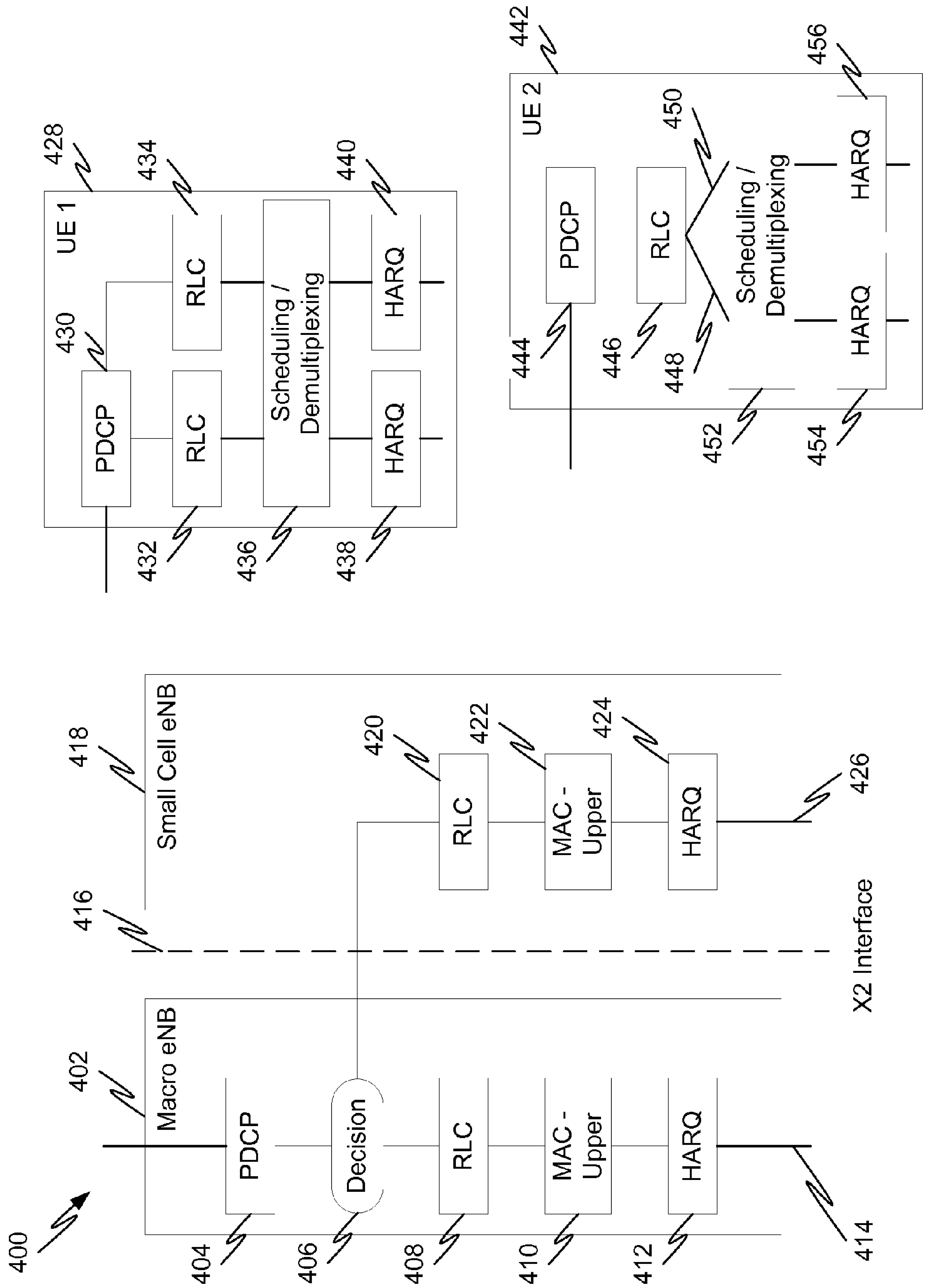

400
Macro eNB
402
PDCP
Decision
RLC
MAC - Upper
HARQ
404
406
408
410
412
414
416
X2 Interface
Small Cell eNB
418
RLC
MAC - Upper
HARQ
420
422
424
426
UE 1
428
PDCP
RLC
RLC
Scheduling / Demultiplexing
HARQ
HARQ
430
432
434
436
438
440
UE 2
442
PDCP
RLC
Scheduling / Demultiplexing
HARQ
HARQ
444
446
448
450
452
454
456

FIG. 4

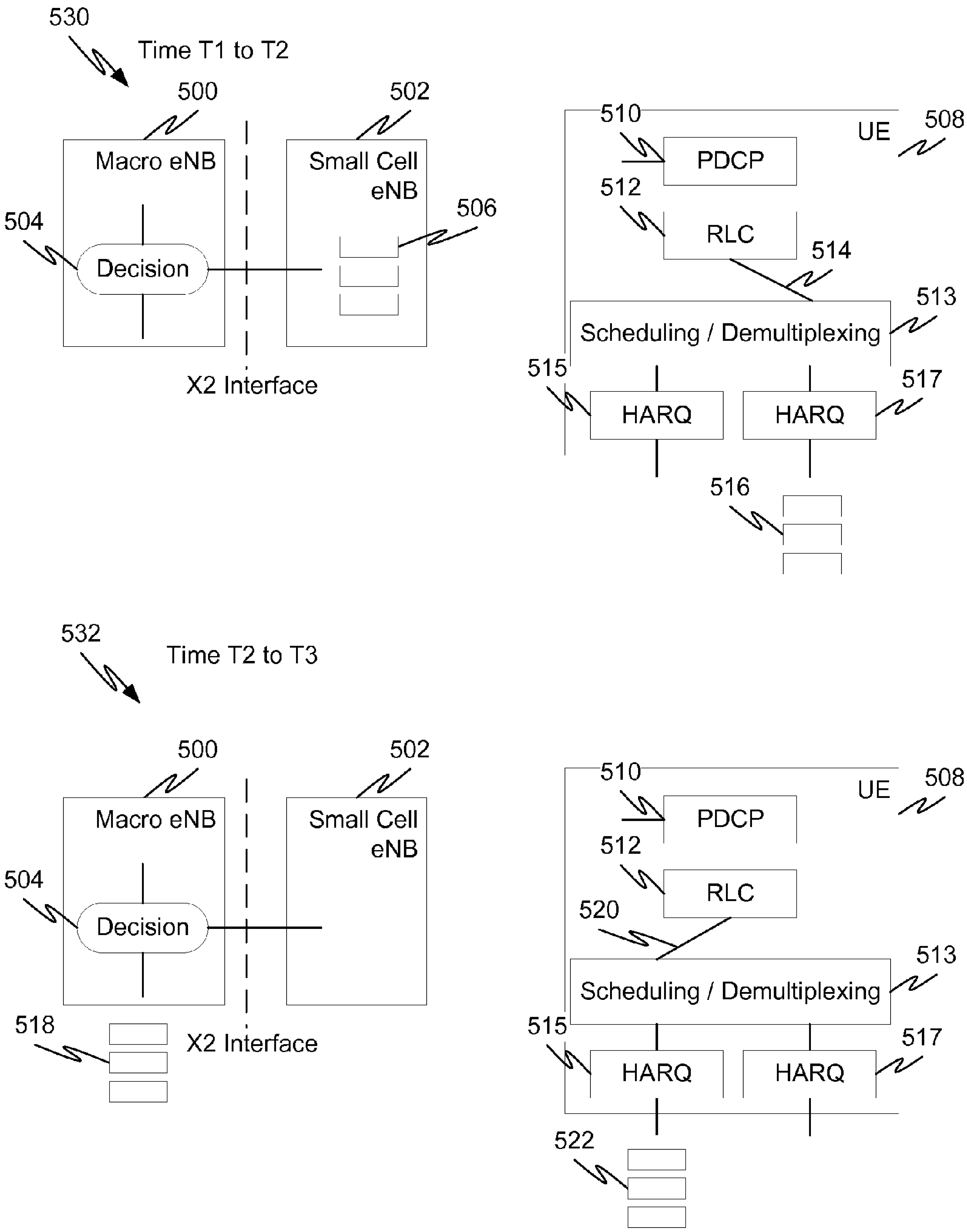

530
Time T1 to T2
500
502
Macro eNB
Small Cell eNB
504
506
Decision
X2 Interface
510
UE
508
PDCP
512
RLC
514
513
Scheduling / Demultiplexing
515
HARQ
HARQ
517
516
532
Time T2 to T3
500
502
Macro eNB
Small Cell eNB
504
Decision
518
X2 Interface
510
UE
508
PDCP
512
RLC
520
513
Scheduling / Demultiplexing
515
HARQ
HARQ
517
522

FIG. 5

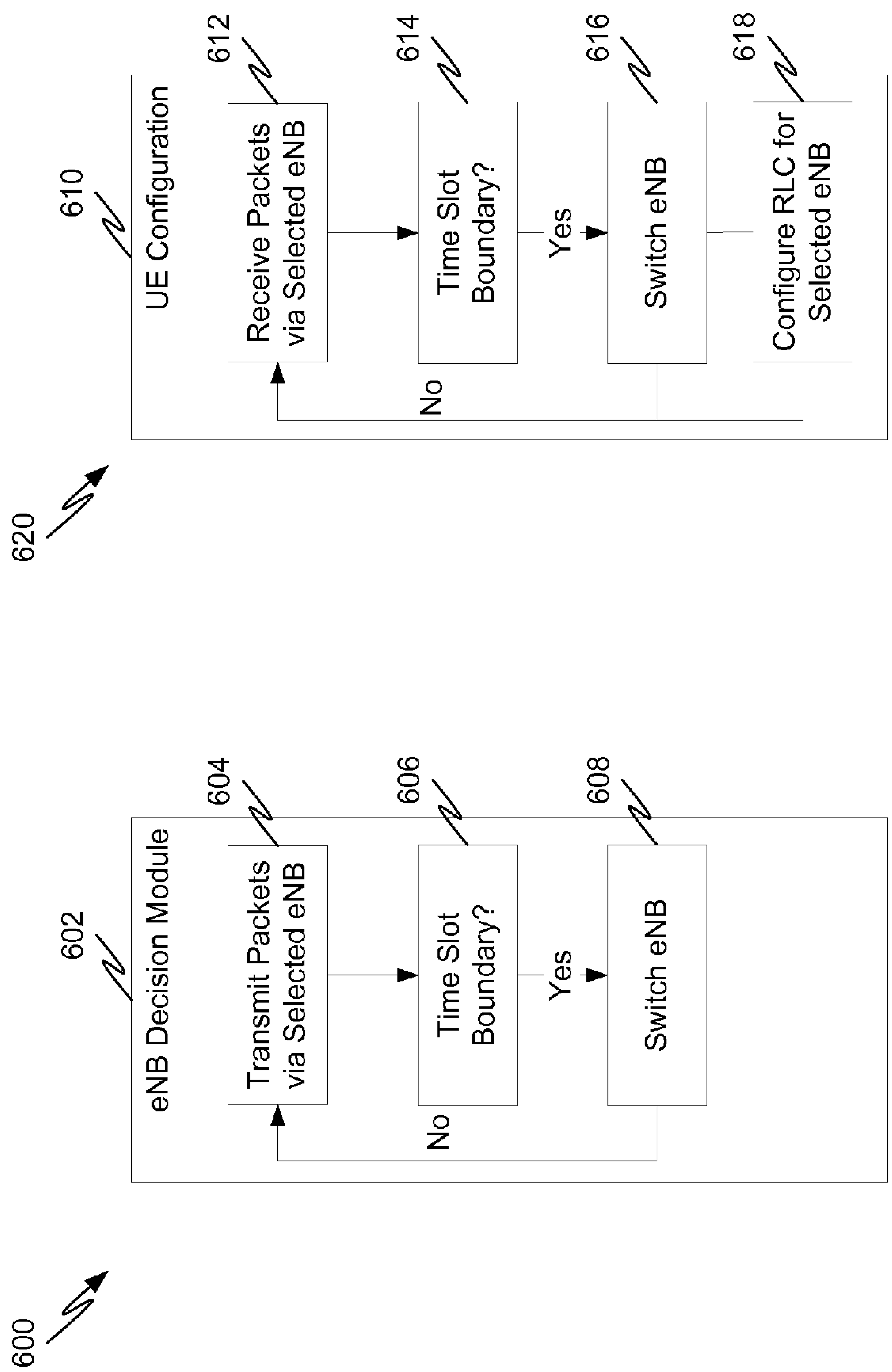

600
602
eNB Decision Module
604
Transmit Packets via Selected eNB
606
Time Slot Boundary?
Yes
608
Switch eNB
No
620
610
UE Configuration
612
Receive Packets via Selected eNB
614
Time Slot Boundary?
Yes
616
Switch eNB
618
Configure RLC for Selected eNB
No

FIG. 6

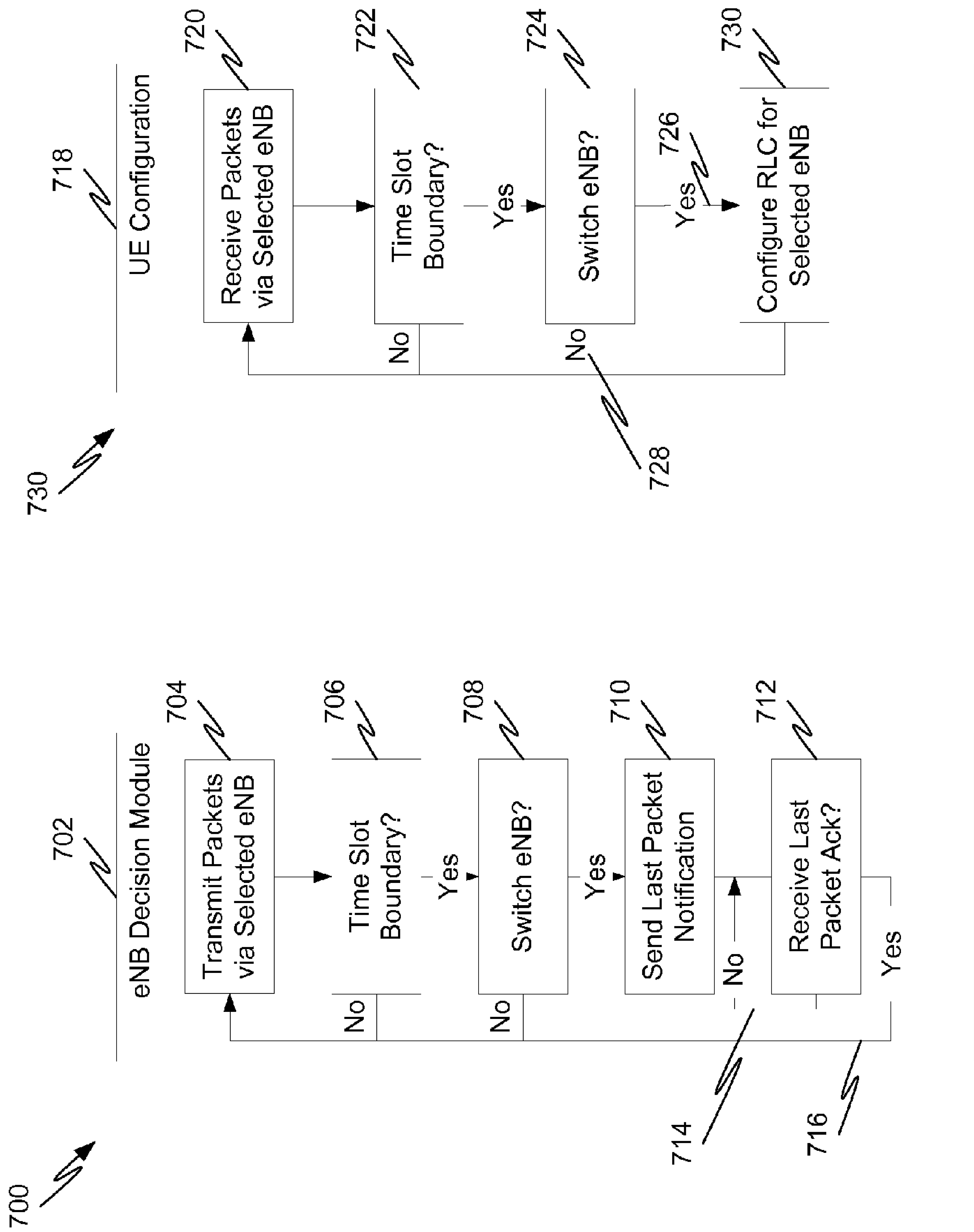

700
702
eNB Decision Module
704
Transmit Packets via Selected eNB
706
Time Slot Boundary?
Yes
No
708
Switch eNB?
Yes
No
710
Send Last Packet Notification
712
Receive Last Packet Ack?
No
Yes
714
716
730
718
UE Configuration
720
Receive Packets via Selected eNB
722
Time Slot Boundary?
Yes
No
724
Switch eNB?
726
Yes
No
730
Configure RLC for Selected eNB
728

FIG. 7

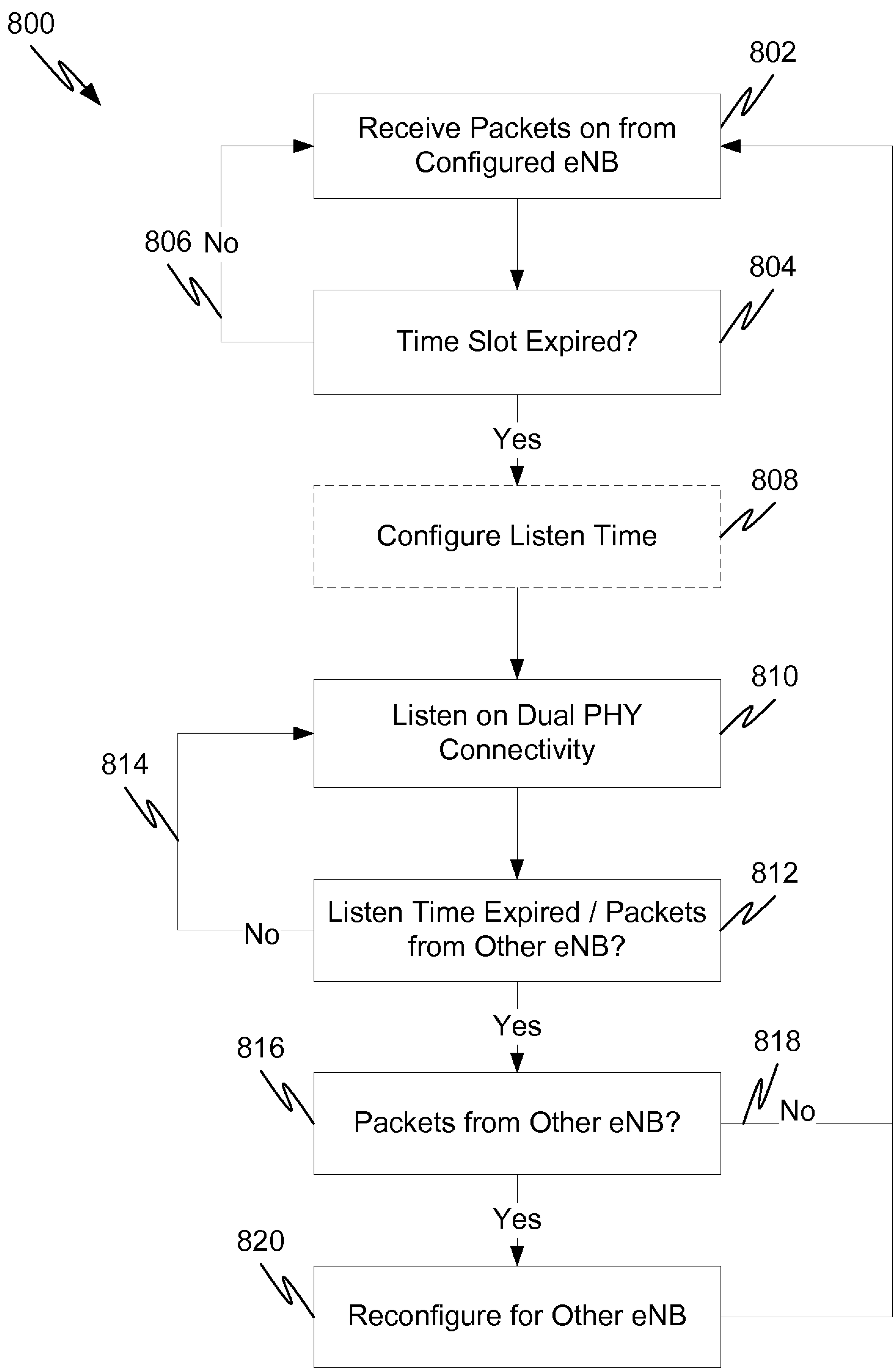

800
802
Receive Packets on from Configured eNB
806 No
804
Time Slot Expired?
Yes
808
Configure Listen Time
810
Listen on Dual PHY Connectivity
814
812
Listen Time Expired / Packets from Other eNB?
No
Yes
816
818
Packets from Other eNB?
No
Yes
820
Reconfigure for Other eNB

FIG. 8

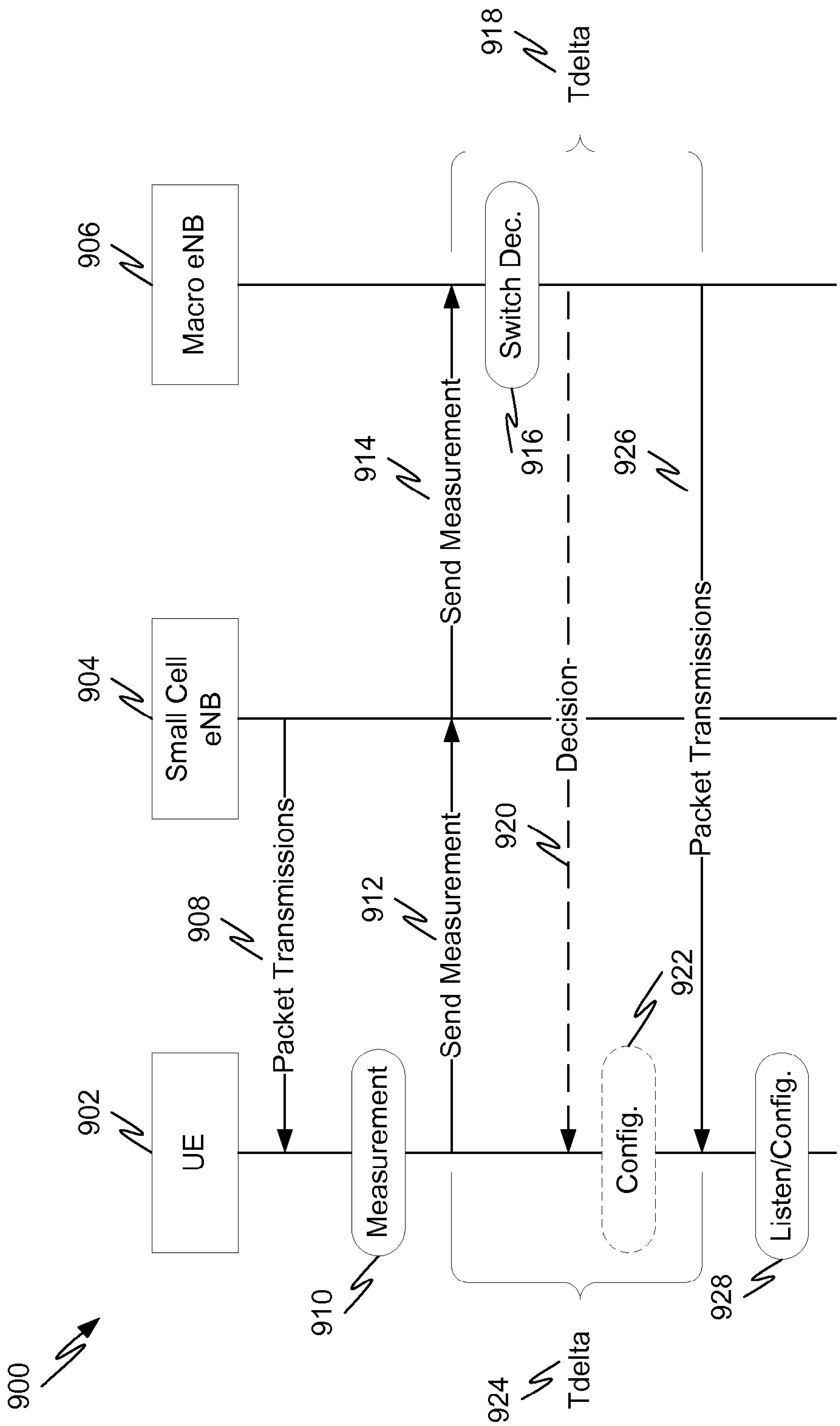

900
902
UE
904
Small Cell eNB
906
Macro eNB
908
Packet Transmissions
910
Measurement
912
Send Measurement
914
Send Measurement
916
Switch Dec.
918
Tdelta
920
Decision
922
Config.
924
Tdelta
926
Packet Transmissions
928
Listen/Config.

FIG. 9

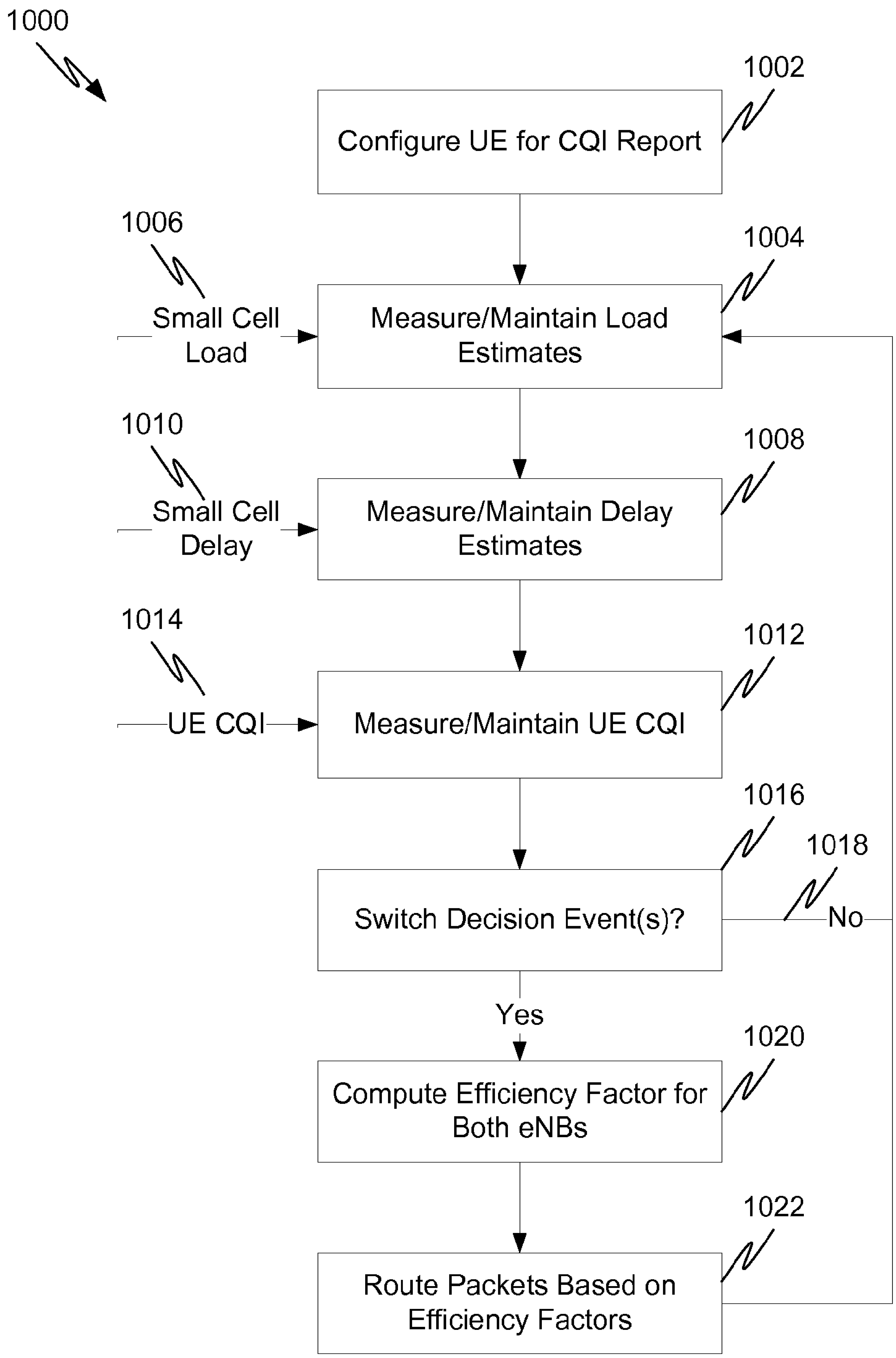

1000
1002
Configure UE for CQI Report
1006
1004
Small Cell Load
Measure/Maintain Load Estimates
1010
1008
Small Cell Delay
Measure/Maintain Delay Estimates
1014
1012
UE CQI
Measure/Maintain UE CQI
1016
1018
Switch Decision Event(s)?
No
Yes
1020
Compute Efficiency Factor for Both eNBs
1022
Route Packets Based on Efficiency Factors

FIG. 10

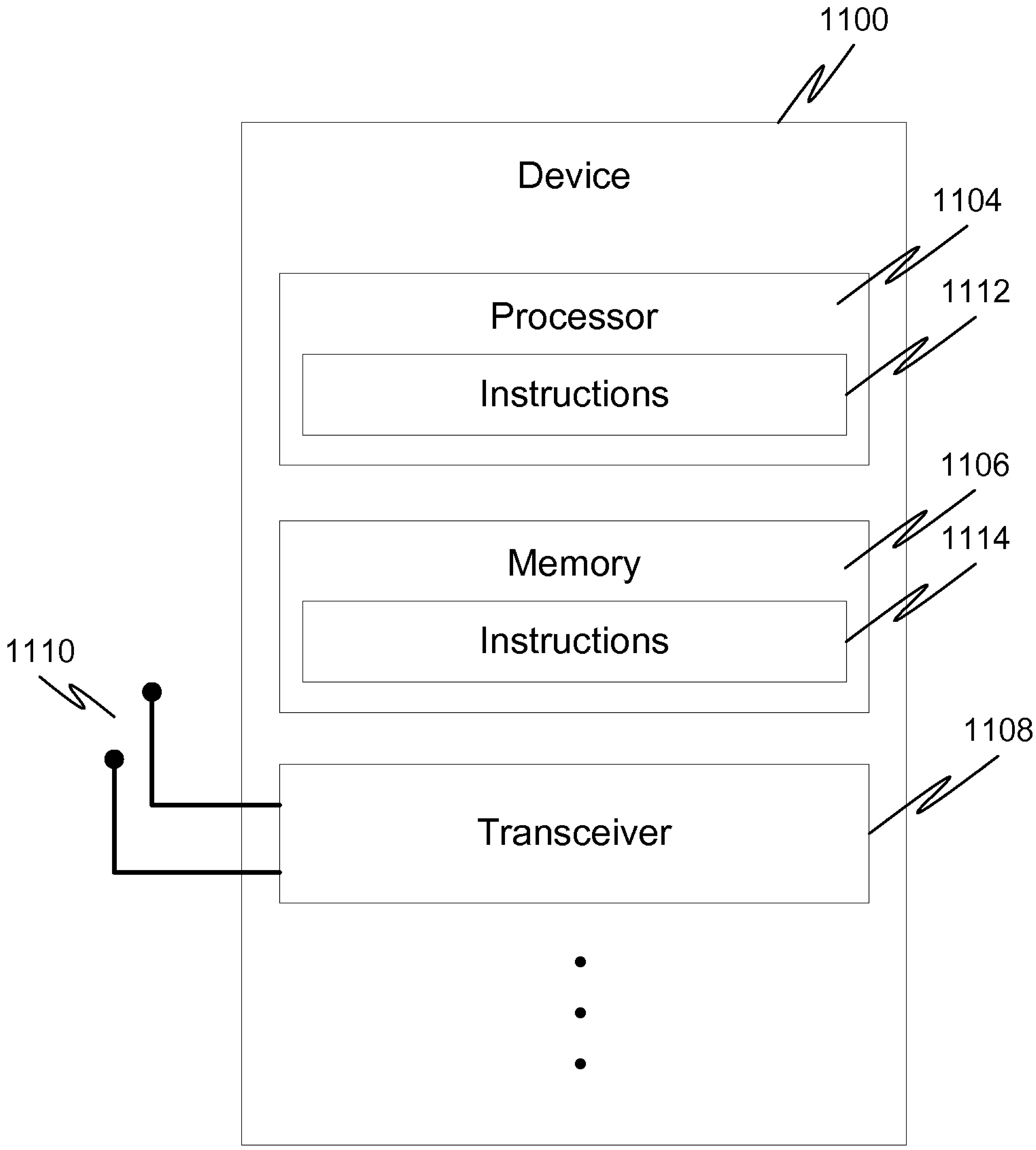

1100
Device
1104
Processor
1112
Instructions
1106
Memory
1114
Instructions
1110
Transceiver
1108

FIG. 11

EPS BEARER SPLITTING FOR DUAL CONNECTIVITY DEVICES

[0001] This application claims the benefit of priority under 35 U.S.C. 119(e) to U.S. Provisional Patent Application Ser. No. 61/832,644, filed on Jun. 7, 2013, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments pertain to multi-connection wireless communications. More particularly, some embodiments relate to selecting which cell coverage should be used to transmit data to a wireless device when the wireless device may communication via multiple cells.

BACKGROUND

[0003] Evolved Packet System (EPS) is a connection-oriented transmission network and allows the establishment of a "virtual" connection between two endpoints such as a User Equipment (UE) and a Packet Data Network Gateway (P-GW) so the UE can send information to and receive information from the Internet. The virtual connection is called an EPS bearer. An EPS bearer provides a bearer service (e.g., transport service) with specific Quality of Service (QoS) attributes. In this disclosure, an EPS Bearer will be referred to as simply a bearer.

[0004] UE may have dual connectivity functionality that allows the UE to be connected to multiple Enhanced Node B (eNB) systems. This provides the opportunity for multiple bearers, one through each of the eNBs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates an example wireless network with a UE having multiple bearers, each connected through a different eNB.

[0006] FIG. **2** illustrates an example system with a macro eNB and a small cell eNB.

[0007] FIG. **3** illustrates an example system with a macro eNB with a decision module and a small cell eNB.

[0008] FIG. **4** illustrates an example system with a macro eNB with a decision module, a small cell eNB and two alternative UE architectures.

[0009] FIG. **5** illustrates an example system showing configuration changes occurring on time slot boundaries.

[0010] FIG. **6** illustrates an example flow diagram of a decision module and UE configuration module.

[0011] FIG. **7** illustrates an example flow diagram of a decision module and UE configuration module.

[0012] FIG. **8** illustrates an example flow diagram of a UE configuration module.

[0013] FIG. **9** illustrates a system with a UE, small cell eNB and macro eNB.

[0014] FIG. **10** illustrates an example flow diagram of a decision module.

[0015] FIG. **11** illustrates a system block diagram for representative UE or eNB according to some embodiments.

DETAILED DESCRIPTION

[0016] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0017] Various modifications to the embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments and applications without departing from the scope of the disclosure. Moreover, in the following description, numerous details are set forth for the purpose of explanation. However, one of ordinary skill in the art will realize that embodiments disclosed herein may be practiced without the use of these specific details. In other instances, well-known structures and processes are not shown in block diagram form in order not to obscure the description of the embodiments of disclosed herein with unnecessary detail. Thus, the present disclosure is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

[0018] Although the embodiments of this disclosure will generally be discussed in terms of UE and other devices that adhere to the LTE standard, the principles herein may be applied to UE and other devices outside of the LTE standard. For example, an embodiment may mention that a UE has channels called PDCCH, DCI, etc. In other systems, devices also have control channels, but they might have different names and the principles discussed herein may be applied to the devices in other systems by using the appropriate control channel(s), even though they are called by a different name.

[0019] FIG. **1** illustrates an example wireless network **100** with a UE **102** having multiple bearers, each connected through a different eNB **104**, **106**. The two eNBs are referred to as a macro eNB **104** and a small cell eNB **106**. Thus, they can represent one eNB with a larger coverage area (macro eNB **104**) and a second eNB with a smaller coverage area (small cell eNB **106**). However, this is only one example. The two eNB may represent any eNB with overlapping coverage. The UE **102** is located so that it is in both the coverage area of both macro eNB **104** and small cell eNB **106**. As indicated in the figure, the UE **102**, the macro eNB **104** and the small cell eNB **106** may be part of the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and comply with the various standards thereof. Thus, the UE **102** may communicate with the macro eNB **104** and the small cell eNB **106** via radio **114**. The macro eNB **104** and the small cell eNB **106** may communicate via an X2 interface **116**.

[0020] Since the UE **102** is connected to both the macro eNB **104** and the small cell eNB **106**, the UE **102** may have two bearer connections, one extending via macro eNB **104** and one extending via small cell eNB **106**. Although numerous bearer configurations may be used, FIG. **1** illustrates only one representative option for these two bearers. The bearer connecting through the macro eNB **104** comprises a radio bearer **124**, an S1 bearer **130**, an S5/S8 bearer **132** and an external bearer **134**. The bearer connecting through the small cell eNB **106** comprises a radio bearer **126**, a data plane bearer/X2 bearer **128**, an S1 bearer **130**, an S5/S8 bearer **132** and an external bearer **134**. Note that data plane bearer **128** may be carried over a radio interface or a physical interface, since the X2 interface between the macro eNB **104** and the small cell eNB **106** may use a wired or a wireless connection. Also note that the two bearers share the S1 bearer **130**, the S5/S8 bearer **132** and the external bearer **134**, although this is only a representative example. Separate bearers may also be used as well as a larger "end to end" type bearer.

[0021] The bearers form two virtual connections from the UE **102** to the Internet (e.g., such as to a peer entity **112**). The bearer that includes the radio bearer **124** extends from the UE **102**, through the macro eNB **104**, the Serving Gateway (S-GW) **108**, the Packet Data Network Gateway (P-GW) **110** and out into the internet (e.g., such as to the peer entity **112**). The bearer that includes the radio bearer **126** extends from the UE **102**, through the small cell eNB **106**, the macro eNB **104**, the S-GW **108**, the P-GW **110** and out into the internet (e.g., such as to the peer entity **112**).

[0022] With multiple bearers, data can be routed along one or both of the bearers to accomplish specific objectives such as maintaining Quality of Service (QoS) or maximizing overall network capacity. While the multiple bearers may be managed as two separate bearers, the two bearers are better thought of as a single "split" bearer connection, with multiple options to route data to accomplish one or more specific objectives, such as those listed above. This single split bearer will be referred to as having multiple bearer paths. In the example of FIG. **1**, one bearer path is routed through the macro eNB **104** to UE **102** (e.g., the radio bearer **124**, the S1 bearer **130**, the S5/S8 bearer **132** and the external bearer **134**). The other bearer path is routed through the small cell eNB **106** to UE **102** (e.g., the radio bearer **126**, the data plane bearer **128**, the S1 bearer **130**, the S5/S8 bearer **132** and the external bearer **134**). In shorthand notation, these can be referred to as routing packets via the macro eNB **104** or routing packets via the small cell eNB **106**. Thus, a single QoS may apply to the bearer connections so that they can be managed to meet the specified QoS.

[0023] FIG. **2** illustrates an example system **200** with a macro eNB **202** and a small cell eNB **204**. The architecture illustrated in FIG. **2** is representative of an architecture for the downlink using a split Packet Data Convergence Protocol (PDCP)/Radio Link Control (RLC). Alternatively, the split may occur at the RLC/Machine Access Control (MAC) boundary rather than the PDCP/RLC boundary. The macro eNB **202** may comprise a plurality of incoming connections such as Radio Resource Control (RRC) connection **206** and a S-GW connection **208**. The RRC connection **206** will not be described as it is of little interest in this disclosure and is shown simply for context. Incoming IP packets **210** arrive over the S-GW connection **208**. The PDCP layer **230** processes these packets **210**. The PDCP layer may comprise Robust Header Compression (ROHC) block **218** and security block **220** that operate according to known methods.

[0024] The architecture splits between the PDCP layer **230** and the RLC layer **232**. In other words, the macro eNB **202** provides the PDCP layer for both the macro eNB **208** and the small cell eNB **204** for IP packets **210** routed along the split bearer to the UE. Then the macro eNB **208** and the small cell eNB **204** provide independent RLC layers **232** and MAC layers **234**. Thus out of the PDCP layer **230** of macro eNB **202**, the PDCP Protocol Data Units (PDU) **214**, **212**, may take one of two paths. The first path follows the remainder of the protocol stack in the macro eNB **202** comprising the RLC layer **232** (e.g., segmentation, Automatic Repeat Request (ARQ), and so forth **222**) and the Medium Access Control (MAC) layer **234** (e.g., unicast scheduling/priority handling **224**, multiplexing for various UE **226**, Hybrid Automatic Repeat Request (HARQ) **228**). The second path **216** follows through the small cell eNB **204**, which has its own RLC layer (e.g., segmentation, ARQ, and so forth **236**) and MAC layer (e.g., unicast scheduling/priority handling **238**, multiplexing for various UE **240**, and HARQ **242**).

[0025] FIG. **3** illustrates an example system **300** with a macro eNB **302** with a decision module **306** and a small cell eNB **304**. The decision module **306** represents the functionality implemented in the macro eNB **304** that decides which path of the split bearer to route packets along. The decision module **306** may reside between the PDCP layer and the RLC layer of the macro eNB **304**. Alternatively, the decision module **306** may reside between the RLC layer and the MAC layer. The PDCP layer of the macro eNB **304** may be implemented as illustrated in PDCP layer **230** of FIG. **2**. The RLC layer of the macro eNB **304** may be implemented as illustrated in RLC layer **232** of FIG. **2**. The MAC layer may be implemented as illustrated in the MAC layer **234** of FIG. **2**.

[0026] The decision module **306** makes a determination whether the packets should be routed through the remainder of the stack as shown by path **310** and packets **314** or whether the packets should be routed through the small cell eNB **304** as indicated by path **316** and packets **312**. Various embodiments and implementations of the decision module **306** may be used, depending on the specific objectives and logic used to decide when bearer path should be used and when the other bearer path should be used. Representative examples of the decision module **306** along with its decision logic and UE configuration and implementation are discussed below.

[0027] FIG. **4** illustrates an example system **400** with a macro eNB **402** with a decision module **406**, a small cell eNB **418** and two alternative UE architectures **428** and **442**. The macro eNB **402** may comprise a plurality of protocol layers, such as the PDCP layer **404**, the RLC layer **408**, the MAC upper layer **410** and the HARQ layer **412**. The decision module **406** resides between the PDCP layer **404** and the RLC layer **408**. The decision module **406** determines whether to route packets (e.g., via X2 interface **416**) to the small cell eNB **418** or whether to transmit them directly (e.g., output **414**) to a UE, such as the UE **418** or the UE **442**.

[0028] If the packets are routed to the small cell eNB **418**, they pass through the protocol layers provided by the small cell eNB **418**. These layers include the RLC layer **420**, the MAC upper layer **422** and the HARQ layer **424**. The PDUs are then transmitted to a UE (such as the UE **418** or the UE **442**) as indicated by output **426**.

[0029] Although the decision module **406** is illustrated as residing between the PDCP layer **404** and the RLC layer **408**, the decision module may also reside between the RLC layer **408** and the MAC-upper layer **410**. In this case, small cell eNB **418** may rely on the RLC layer **408** of the macro eNB **402** and may not need to implement its RLC layer **420**.

[0030] A UE designed to connect through two bearers and/or a split bearer such as discussed herein may provide protocol layers to process received packets through each of the bearers. There are different options that may be used, two of which are illustrated as representative examples in FIG. **4**. The UE **428** illustrates one representative example. The UE **428** provides two parallel paths, one to process packets from one bearer and the other to process packets from the other bearer. Thus, the UE **428** may comprise PDCP layer **430**, which then splits into the two paths. One path comprises the RLC layer **432**, scheduling/(de)multiplexing **436** and the HARQ **438**. The other path comprises the RLC layer **434**, scheduling/(de)multiplexing **436** and the HARQ **440**. Since both paths are independent, there is generally no need to reconfigure UE **428** based on whether the decision module **406** is routing packets through the macro eNB **402** or through the small cell eNB **418**.

[0031] The UE **442** illustrates a different representative example. The UE **442** provides a shared PDCP layer **444** and a shared RLC layer **446**. The shared RLC layer **446** may then be connected either to one path as illustrated by path **448**, scheduling/(de)multiplexing **452** and the HARQ **454**. The shared RLC layer **446** may alternatively be connected to the other path as illustrated by path **450**, scheduling/(de)multiplexing **452** and the HARQ **456**. Thus, the UE **442** may be configured to process received packets through either the first path (the PDCP **444**, the RLC **446**, the scheduling/(de)multiplexing **452**, and the HARQ **454**) or the second path (the PDCP **444**, the RLC **446**, the scheduling/(de)multiplexing **452**, and the HARQ **456**). The UE **442** may be reconfigured depending on whether the decision module **406** is routing packets through the macro eNB **402** or through the small cell eNB **418**.

[0032] One set of embodiments for a decision block that determines when to route packets along one of two bearer paths may rely on a time division multiplex scheme. FIG. **5** illustrates an example system showing configuration changes occurring on time slot boundaries to accommodate such a TDMA type scheme. The configuration shown generally as **530** may comprise a macro eNB **500** having a decision module **504** which decides whether to route packets via the macro eNB **500** or via the small cell eNB **502** according to some selection criteria.

[0033] The UE **508** may comprise a common PDCP layer **510** and a common RLC layer **512** which may be connected to either a first path (e.g., scheduling/(de)multiplexing **513** and the HARQ **515**) or a second path (e.g., scheduling/(de)multiplexing **513** and the HARQ **517**).

[0034] During the first time slot, specified by time T1 to T2, the decision module **504** has selected to route packets **506** through the small cell eNB **502**. UE **508** is configured to receive packets **506** along the second path comprising shared PDCP layer **510**, shared RLC layer **512**, scheduling/(de)multiplexing **513** and the HARQ **517** as indicated by received packets **516**.

[0035] A switch to the other bearer path may occur at the time slot boundary. Thus at time T2, the decision module **504** may decide to send packets via the macro eNB **500** rather than the small cell eNB **502**. Such a switch will cause the UE **508** to reconfigure itself to receive the packets along the other path.

[0036] Assuming such a switch occurs, the system configuration is illustrated generally as **532**. Thus during the next time slot T2 to T3, packets **518** are transmitted via the macro eNB **500**. The UE **508** is reconfigured so that the received packets are processed by the first path comprising shared PDCP layer **510**, shared RLC layer **512**, scheduling/(de)multiplexing **513** and the HARQ **515** as indicated by received packets **522**.

[0037] Different TDMA embodiments may utilize the architecture as reconfigurations shown in FIG. **5**. FIG. **6** illustrates an example flow diagram of a decision module **602** and UE configuration module **610** of one such embodiment. In this embodiment, specific time slots are established where the decision module of the macro eNB will switch between the two bearer paths. Switching always occurs at the expiration of a time slot in this embodiment. The time slots need not be uniform in length and the macro eNB may establish them using any mechanism desired (including making them uniform). Thus, in this embodiment, the time slot boundaries are established for at least some time in the future, for example the next several milliseconds. At a minimum, the boundary of the next time slot should be established. The time slot boundary (or boundaries) are then communicated from the macro eNB to the UE so that the UE knows the upcoming time slot boundary (or boundaries) and knows when to switch.

[0038] The macro eNB may communicate time slot boundaries to the UE in a variety of ways. For example, the macro eNB may use a direct communication to the UE, such as by using the Physical Downlink Control Channel (PDCCH)/Physical Uplink Shared Channel (PDSCH). Alternatively, the macro eNB may communicate using an indication in one of the packets. As yet another example, a specific message may be sent from the macro eNB to the UE. As yet a further example, the UE may know the mechanism the macro eNB uses to select the time slot boundary so that no explicit message need be passed (e.g., the UE has sufficient information to calculate the time slot boundary or boundaries). Slot boundaries could optionally be pre-configured/pre-defined at the UE. At the pre-defined slots both UE and eNB sides switch. This has the advantage of being simpler in design and implementation. However, such a design does not take advantage of some of the additional information described below that may help the macro eNB better accomplish certain objectives.

[0039] Turning now to FIG. **6**, the flow diagram for an eNB decision module **602** is illustrated generally as **600**. The eNB decision module **602** transmits packets using the selected eNB as indicated by operation **604** until the time boundary is reached as illustrated by operation **606**. When the next time slot boundary is reached, the decision module selects the other eNB and then begins transmitting packets via the newly selected eNB.

[0040] Because a switch happens at time slot boundary independent of whether packets remain to be sent, various options may be used to handle the unsent packets. In one embodiment the eNB may simply hold on to the packets until the next time slot boundary and then transmit them during the next time interval. This may be useful, for example, where the bearer split happens at the RLC/MAC boundary rather than the PDCP/RLC boundary (e.g., the decision module resides between the RLC and MAC layers rather than the PDCP and RLC layers).

[0041] In another embodiment, the remaining packets may be transferred to the other eNB for transmission. For example, the eNB where the packets reside may transfer the RLC state information (e.g., sequence number, timer values, etc.) to the other eNB along with the untransmitted packets if they don't reside on the other eNB already. For RLC packets already transmitted to the UE but not yet acknowledged, the eNB could also transfer the RLC packets to the other eNB. Optionally, after the UE switches from one eNB to the other, the UE may perform an RLC reset, so that the RLC state information is not needed by the newly selected eNB. This may be of interest when the decision module resides between the PDCP and RLC layers.

[0042] The UE may reconfigure itself at the time slot boundaries to receive the packets on the correct path as illustrated, for example, in FIG. **5**. A representative process is illustrated in FIG. **6** generally as **620**. The UE receives packets from the active eNB as illustrated in operation **612** until the time slot boundary as illustrated in operation **614**. When the time slot boundary is reached, the UE reconfigures itself for the other eNB as indicated in operation **616**. The reconfiguration may include, for example, connecting a shared RLC layer such as that illustrated by the RLC layer **512** of FIG. **5** to the other path (e.g., the switching connection **514** of FIG. **5** for connection **520** or vice versa). The connections **514** and **520** may not represent physical connections between layers. Such connections may be implemented as a logical interface or in some other fashion. All that need happen is that the configuration for one or the other bearer path be accomplished. The reconfiguration is illustrated by operation **618**. As indicated above, the reconfiguration may also include an RLC reset (not shown). Alternatively, if the macro eNB and the small cell eNB are set up to transfer RLC state information to one another, the UE may not need to perform an RLC reset.

[0043] An alternative embodiment employing a similar TDMA scheme is next discussed in conjunction with FIGS. **5** and **7**. FIG. **7** illustrates an example flow diagram of a decision module **702** and UE configuration module **718**. In this embodiment, specific time slots are established where the decision module of the macro eNB may optionally switch between the two bearer paths. In other words, at the time slot boundary, the decision module may decide to switch to a new bearer path (e.g., switch eNBs) or may decide to keep the existing bearer path (e.g., keep the existing eNB). Switching, if it happens, occurs at the expiration of a time slot in this embodiment. The time slots need not be uniform in length and the macro eNB may establish them using any mechanism desired (including making them uniform). Thus, in this embodiment, the time slot boundaries are established for at least some time in the future, for example the next several milliseconds. At a minimum, the boundary of the next time slot should be established. The time slot boundary (or boundaries) may be communicated from the macro eNB to the UE so that the UE will know the upcoming time slot boundary (or boundaries) in order to determine whether a switch occurred. Alternatively, or additionally, the UE may not need to know the upcoming time slot boundary. If the decision module decides to make a switch, the eNB may communicate the decision to switch to the UE in a variety of ways, such as those outlined below.

[0044] The macro eNB may communicate time slot boundaries and/or decision to switch to the UE in a variety of ways. In one embodiment, the macro eNB may use a direct communication to the UE, such as by using the PDCCH/PDSCH. Alternatively, the macro eNB may communicate using an indication in one of the packets such as a “last packet” indication in the RLC or MAC header (depending on where the split is located). As yet another example, a specific message may be sent from the macro eNB to the UE such as using MAC control elements. Also, as indicated above, slot boundaries could optionally be pre-configured/pre-defined at the UE. At the pre-defined slots both UE and eNB sides switch.

[0045] As a representative example of how this might work, if the macro eNB decides to switch and it is currently transmitting to the UE via the small cell eNB, the macro eNB may send a notification in the last packet directed toward the small cell eNB that no more packets will come for that UE in the next time slot. When the small cell eNB sends that last packet to the UE, the small cell eNB notifies the macro eNB that the last packet has been sent. Alternatively or additionally, the small cell eNB may notify the macro eNB that the last packet has been received by the UE. The small cell eNB may also notify the UE that this is the last packet from the small cell eNB (either via direct connection or by including something indicating the transmitted packet is the last packet to be received from the small cell eNB this time slot). The UE may then reconfigure itself to receive packets from the macro eNB.

[0046] As another representative example, if the macro eNB decides to switch and it is currently transmitting to the UE via the macro eNB itself, then when the last packet is transmitted, the macro eNB may notify the UE that this is the last packet from the macro eNB (either via direct connection or by including something indicating the transmitted packet is the last packet to be received from the macro cell eNB this time slot). The UE may then reconfigure itself to receive packets from the small cell eNB.

[0047] Turning now to FIG. **7**, the eNB decision module flow diagram is illustrated generally as **700**. In this diagram, the eNB transmits packets via the selected eNB as indicated by operation **704** until a time slot boundary arrives as indicated by operation **706**. At the time slot boundary, the eNB decision module determines whether to switch eNBs or not as indicated by **708**. If the decision is not to switch, the “no” branch out of operation **708** is taken and the eNB continues to transmit packets until the next time slot boundary as indicated by operations **704** and **706**.

[0048] If the decision is made to switch eNBs, then the “yes” branch out of operation **708** is taken and the last packet notification is sent as indicated to operation **710**. As described above, this may be via PDCCH/PDSCH, via including something in a packet header to indicate that this is the last packet, or via some other mechanism. If the macro eNB had been transmitting packets via the small cell eNB, then this last packet notification would include notifying the small cell eNB that this is the last packet to be transmitted to that UE this time slot. This can be accomplished in any fashion as described above including via an indication in a packet header transmitted to the small cell eNB or via a dedicate message to the small cell eNB. If the macro eNB had been transmitting packets to the UE via the macro eNB itself, then the macro eNB may notify the UE via PDCCH/PDSCH, via an indication in a packet header, or in some other fashion.

[0049] Operation **712** represents the process of waiting to receive acknowledgment for the last packet as needed. As described above, if the macro eNB decides to switch and it is currently transmitting to the UE via the small cell eNB, the small cell eNB may notify the macro eNB that the last packet has been sent. If the macro eNB decides to switch and it is currently transmitting to the UE via the macro eNB itself, then when the last packet is transmitted, UE may acknowledge receipt of the last packet.

[0050] The UE may reconfigure itself at when the decision to switch has been made by the macro eNB. A representative process is illustrated in FIG. **7** generally as **734**. The UE receives packets via the current eNB until a time slot boundary as indicated by operations **720** and **722**. At the time slot boundary, the UE may determine whether the decision module of the macro eNB has decided to switch eNBs. This is indicated by operation **724**. As previously indicated, the decision to switch may come to the UE via PDCCH/PDSCH, via a last packet indication in a packet header, or via some other mechanism. If the macro eNB has indicated that it has decided not to switch eNBs, the “no” branch **728** is taken out of operation **724** and the UE continues to receive packets via the currently selected bearer path until the next time slot boundary as indicated by operations **720** and **722**.

[0051] If the decision to switch has been received, then the “yes” branch **726** is taken out of operation **724** and the UE reconfigures itself to receive packets from the other eNB (operation **730**). The reconfiguration may include, for example, connecting a shared RLC layer such as that illustrated by the RLC layer **512** of FIG. **5** to the other path (e.g., the switching connection **514** of FIG. **5** for connection **520** or vice versa). The reconfiguration may also include an RLC reset (not shown). Alternatively, if the macro eNB and the small cell eNB are set up to transfer RLC state information to one another, the UE may not need to perform an RLC reset.

[0052] Although the embodiments discussed in conjunction with FIG. **7** indicate that a time slot boundary is the even that triggers evaluation of whether to switch eNBs or not, events other than a time boundary may trigger such an evaluation. In this type of embodiment, a time boundary may be only one type of decision trigger events. Alternatively, decision trigger events may not include a time slot boundary at all. In other words, any triggering event may be used in conjunction with this type of architecture to evaluate wither to switch bearer paths (e.g., switch which eNB packets are routed through). Discussion of representative triggering events is included below.

[0053] The discussion of FIGS. **5-7** presumed that the UE was reconfigured when a decision to switch was made, such as by connecting shared layers to one path or the other. However, if a UE has the ability to listen on multiple bearer paths simultaneously, there may be little or no need to reconfigure the UE differently depending on which eNB the packets are routed through. Alternatively, the ability to listen on multiple bearer paths may be used to detect when a switch has occurred.

[0054] FIG. **8** illustrates an example flow diagram **800** of a UE configuration module that uses the ability to listen on multiple bearer paths to detect when a switch has occurred. The UE receives packets from the configured eNB until a time slot boundary (or other decision event) occurs as indicated by operations **802** and **804**. Upon the occurrence of the time slot boundary or other decision event, the UE begins to listen using dual physical layer connectivity for a period of time after the event. This is indicated by operation **810**. Operation **808** indicates an optional operation that configures the listen time. Such an option may be desirable, for example, when the time that the UE should listen varies according to some factor or another.

[0055] Once the UE begins listening, it will continue to listen until some "stop listening" event occurs. Examples of stop listening events may include the expiration of the listen time, detection of receive packets from one eNB or the other, other events, or some combination thereof. In FIG. **8**, operation **812** indicates that the UE will continue to listen until either the expiration of the listen time or until a packet is detected from the other eNB (e.g., the one that has not been sending packets). When one of these events occur, the "yes" branch out of operation **812** is taken and the UE determines whether to reconfigure for the other eNB or whether to continue receiving packets from the existing eNB.

[0056] Operation **816** indicates that if packets have not been received from the other eNB during the listen time, then the UE retains its existing configuration and continues to receive packets from the current eNB (e.g., operation **802** and operation **804**). On the other hand, if packets from the other eNB have been received during the listen time, then the "yes" branch out of operation **816** is taken and the UE is reconfigured to receive packets from the other eNB as indicated by operation **820**. When the UE is reconfigured, the UE may perform an RLC reset. Alternatively, if the macro eNB and the small cell eNB are set up to transfer RLC state information to one another, the UE may not need to perform an RLC reset.

[0057] A macro eNB and small cell eNB may interact with a UE operating according to FIG. **8** as described in the following examples. The decision module of the macro eNB will make a switch decision in conjunction with a switch event, such as the occurrence of a time slot boundary or other switch events discussed below. If the decision module of the macro eNB decides to switch and it is currently transmitting to the UE via the small cell eNB, the macro eNB may send a notification in the last packet directed toward the small cell eNB that no more packets will come for that UE until at least the next switch event such as the next time slot boundary or other event. When that last packet is transmitted, the small cell eNB may then notify the macro eNB that the last packet was transmitted. The macro eNB may then begin to transmit packets to the UE via the macro eNB.

[0058] If the macro eNB decides to switch and it is currently transmitting to the UE via the macro eNB itself, then when the last packet is transmitted, the macro eNB may begin transmitting packets via the small cell eNB. There is no need to inform the UE of the switch since the UE will detect the switch as indicated in FIG. **8** by listening to both eNB using dual physical layer connectivity.

[0059] The embodiments illustrated above rely on the occurrence of a set time schedule or the occurrence of a switch event such as the expiration of a time slot to identify when to switch from one eNB to the other. However, information may be available to or obtainable by the macro eNB so that the decision module may employ more sophisticated logic when making switching decisions. This allows specific objectives to be pursued such as ensuring QoS for the bearer or maximizing overall network throughput. FIG. **9** illustrates a system **900** with a UE **902**, small cell eNB **904** and macro eNB **906** that uses measurements to make switching decisions. Although the information is described in conjunction with a particular embodiment in FIG. **9**, the measurements may also be used in one or more of the previously described embodiments to help improve the effectiveness of the switching decisions. For example, in the case of pre-defined time slots where the macro eNB decides whether or not to switch on the time slot boundary, the measurement information may be used to make the switching decision at the time slot boundary. Similarly, if the system uses events to determine when to switch, the measurements may also be used to decide whether to switch or not. In other words, the measurements can be used with any of the embodiments described herein, plus systems that are event based.

[0060] The UE **902** is configured to receive packets from one of the eNB, such as the small cell eNB **904** as indicated by packet transmissions **908**. The UE **902** may be configured to report certain measurements to the macro eNB **906** either directly or through small cell eNB **904**. The measurement process is indicated by measurement operation **910**. Sending the measurement to the macro eNB **906** is indicated by send measurement operations **912** and **914**. Measurements sent by the UE **902** may comprise Channel Quality Indicator (CQI) for small cell eNB **904** and/or macro eNB **906**. To the extent that the UE **902** may have other information useful in making the switch decision that information may be sent as well. Such information may include delay information relating to such categories as over the air delay, processing delays, backhaul and/or network delays, and so forth. This type of delay information may be derived from such information as HARQ ACK delay, number of HARQ retransmissions, RLC delay, PDCP delay, backhaul delay or other delay information. HARQ metrics indicate the over the air delay. RLC/PDCP delay indicate overall bearer processing delays. Backhaul delay indicates network delays. Some of this information is known by the small cell eNB and/or the macro eNB rather than the UE **902**. Thus, the small cell eNB **904** may send information relating to delays to the macro eNB **906**.

[0061] Other information may be useful for the macro eNB **906** to make switch decisions. Such information may include loading estimates for the macro eNB **906** and small cell eNB **904**. Thus, information such as radio bearer usage, hardware loading factors, number of bearers being served, and so forth for both the macro eNB **906** and small cell eNB **904** may be sent to the macro eNB **906** (in the case of small cell eNB information) and/or collected/maintained by the macro eNB **906** (in the case of macro eNB information).

[0062] Macro eNB **906** makes a switch decision based on the collected information as indicated by operation **916**. The UE **902** may then reconfigure itself as needed based on the outcome of the switch decision. This may be accomplished in any of the ways previously described. A couple of different options are illustrated in FIG. **9** by way of example, and not limitation.

[0063] In one embodiment, the macro eNB **906** may inform the UE of its switch decision as indicated by decision **920**. This can be accomplished in a variety of ways as previously described. In one embodiment, the macro eNB **906** may include a "last packet" notification either directly to the UE **902** (if the macro eNB **906** has been transmitting packets to the UE **902**). Alternatively, if the macro eNB **906** has been transmitting packets to the UE **902** via the small cell eNB **904**, the macro eNB may include the last packet notification in a packet sent via the small cell eNB **904** (which may then be forwarded to the UE **902**). As yet another alternative, the macro eNB **906** may inform the UE **902** of the switch such as by PDCCH/PDSCH either from the macro eNB **906** or from the small cell eNB **904**. In response to the decision, the UE **902** may configure itself as appropriate as shown by operation **922**.

[0064] As an alternative to the mechanism shown by decision **920** and configuration operation **922**, the UE may use its dual physical connectivity to listen to both eNBs to determine whether a switch decision has been made as previously described. As an example, sending the measurement to the macro eNB **906** (e.g., send measurement operation **912**, **914**) may represent a "start listen time" event for the UE **902**. Beginning with the time that the UE **902** sent its measurement to the macro eNB **906**, the UE may begin listening using its dual physical connectivity to determine which eNB will send packets (e.g., as shown in operations **808**, **810**, **812**, **818** and **820** of FIG. **8**).

[0065] The macro eNB **906** makes its switch decision (e.g., operation **916**) and begins transmitting packets via the selected eNB as indicated by operation **926**. The UE may then detect and configure appropriately as indicated by operation **928**. The UE may perform an RLC reset as appropriate or the macro eNB and small cell eNB may be configured to transfer RLC state as appropriate for the switch decision.

[0066] The embodiments of FIG. **9** may be for any measurement report or for some special measurement report that is sent by the UE **902** to notify that the UE **902** is losing coverage of the eNB that is currently servicing the UE **902**. This could be helpful, for example, if the UE **902** is leaving the coverage of the small cell eNB **904**.

[0067] FIG. **10** illustrates an example flow diagram **1000** of a decision module that takes advantage of one or more measurements to achieve specific objective(s). For example, one objective may be to maintain QoS of the split bearer as things change. Another objective may be to maximize overall network capacity. Other objectives may also be used.

[0068] To make decisions that are in accordance with one or more of these objectives, the decision module of a macro eNB may consider information such as channel conditions for both the macro eNB and/or small cell eNB, load estimates of the macro eNB and/or small cell eNB, delay estimates, QoS requirements of the bearer, and/or other information.

[0069] Channel conditions may help the macro eNB identify which eNB may effectively transmit packets to the UE. Channel conditions may be measured by the UE as part of the CQI report. The CQI report may include information for the macro eNB and/or the small cell eNB. These reports may be sent by the UE directly to the macro eNB or the CQI report may be sent to the small cell eNB which then forwards it to the macro eNB via, for example, the X2 interface. Note that both reports may be sent together (e.g., via the same mechanism) or a CQI report with the macro eNB information may be sent to the macro eNB and a CQI report with the small cell eNB may be sent to the small cell eNB, which forwards it to the macro eNB. Additionally, the CQI may be sent via Physical Uplink Control Channel (PUCCH)/Physical Uplink Shared Channel (PUSCH). The macro eNB may configure the UE either for periodic or aperiodic CQI reports for the serving eNBs.

[0070] Load estimates may help identify which route packets may be sent. Load estimates are generally known by each eNB. The load estimates may be derived from a variety of metrics including radio bearer usage, hardware loading factor (Hardware Load Indicator), number of bearers being served, and so forth. The X2 Resource Status Update message may be used to transmit load information from the small cell eNB to the macro eNB for radio bearer usage and hardware load indicator. The message may be modified for other metrics or new messages may be defined.

[0071] Delay estimates may be used to determine whether a given path will meet the delay requirements of the bearer. For example, higher delay on the small cell eNB may mean that newer packets traveling via the macro eNB may arrive at the UE before older packets from the small cell eNB (or vice versa). The newer packets would have to wait in a reordering buffer in the UE until the older packets arrive. This would result in delays dependent on which eNB was used. Accounting for delays may, therefore, help identify which path will help meet a desired QoS.

[0072] Metrics that may be used to help estimate the total delay include HARQ ACK delay, number of HARQ retransmissions, RLC delay, PDCP delay and/or backhaul delay. Such metrics need to be forward to the macro eNB for consideration from the locations where they are measured. Thus, if the small cell eNB implements a PDCP layer, it needs to send its PDCP delay to the macro eNB, for example. These metrics could be combined together to arrive at various delay components such as over the air delay, overall bearer processing delay and network delays. HARQ related metrics indicate the over the air delay. RLC/PDCP delay metrics indicate the overall bearer processing delay. Backhaul delay indicates network delay.

[0073] The UE may also have metrics that indicates one or more of these delay components. For example, the number of packets that were received out of order, along with the path used to send the packets may give a measure of the relative delays through the different eNBs. The macro eNB may use this information to modify packet distribution.

[0074] Bearer QoS requirements may include various requirements such as packet loss rates, delay requirements, throughput requirements, and so forth. These QoS requirements may be compared to various parameters such as channel conditions, load estimates, delay estimates and so forth to ensure that they are met.

[0075] Returning to FIG. **10**, an example embodiment of how these and other factors may be used by a macro eNB to make decisions. In operation **1002**, the macro eNB may configure the UE for CQI reports as desired. As previously mentioned, the UE may be configured for periodic or aperiodic CQI reports.

[0076] In operations **1004**, and **1008** the macro eNB receives and/or maintains load estimates and delay measurements, respectively. For information that the macro eNB has it may maintain the information, for information about the small cell eNB, it may receive the information from the small cell eNB (e.g., operation **1006** and operation **1010**). To the extent that the UE has information relevant to either the load estimate or delay estimate, the UE information may also be received by macro eNB as described above.

[0077] Operation **1012** represents the macro eNB receiving and/or maintaining channel information from the UE (e.g., operation **1014**) for the macro eNB and/or small cell eNB.

[0078] Operations **1004**, **1006**, **1008**, **1010**, **1012**, and **1014** collectively represent the macro eNB receiving the information it needs to develop the channel condition information, load estimates and delay estimates described above so that the macro eNB may use the information to make decisions as to which eNB to route packets through.

[0079] When a switch event occurs as indicated by operation **1016**, the macro eNB may use the collected information to make a decision as to how to route the packets to accomplish the desired objective(s). Such a switch event may be a time slot boundary, the receipt of a periodic or aperiodic measurement, the expiration of a timer, or any other desired event. Combinations of events may also be used to trigger a decision.

[0080] In operation **1020** macro eNB calculates an efficiency factor for both the macro eNB path and the small cell eNB path. The efficiency factor is a representation of how well a given path helps the eNB meet given objective(s). For example, when considering how well the path meets the QoS requirements of the bearer, the efficiency factor may be a weighted sum (e.g., linear combination) of how well the two paths meet a given QoS requirement. If the QoS requirements include a packet loss requirement, a delay requirement and a throughput requirement, the channel conditions, the load estimate and delay estimates may be evaluated to see how well each path meets the various QoS requirements. As another example, when the objective is to maximize the overall network throughput, the various factors may be evaluated to identify their impact on network throughput. The results may then be summed or some other combination of the results produced to yield the efficiency factor for a given path.

[0081] In operation **1022**, a path is selected based on the efficiency factors. In one embodiment, the path with the highest efficiency factor may be selected. However, in some implementations, such a straight comparison may result in a "ping pong" effect between the two paths where the system switches back and forth at a rate that decreases overall effectiveness. In such a situation, a variety of strategies may be employed to reduce the ping pong effect. One strategy is to lengthen the time between decisions. Another strategy is to allow the switch to occur only when the difference between the two efficiency factors is greater than some threshold or, equivalently, comparing the efficiency factor of the non-selected path to the efficiency factor of the selected path plus a threshold value. The switch occurs only when the efficiency factor of the non-selected path is greater than the selected path plus the threshold value. Another parameter can be added to the comparison by means of a timer so that the switch occurs only when the efficiency factor of the non-selected path is greater than the selected path plus the threshold value for a given period of time (the timer).

[0082] FIG. **11** illustrates a system block diagram a device **1100** suitable for use as a UE or eNB according to some embodiments. Such a device could be, for example, any of the UE or eNB discussed in FIGS. **1-10**. Device **1100** may include processor **1104**, memory **1106**, transceiver **1108**, antennas **1110**, instructions **1112**, **1114**, and possibly other components (not shown).

[0083] Processor **1104** comprises one or more central processing units (CPUs), graphics processing units (GPUs), accelerated processing units (APUs), or various combinations thereof. The processor **1104** provides processing and control functionalities for device **1100**.

[0084] Memory **1106** comprises one or more memory units configured to store instructions and data for device **1100**. Transceiver **1108** comprises one or more transceivers including, for an appropriate station or responder, a multiple-input and multiple-output (MIMO) antenna to support MIMO communications. For device **1100**, transceiver **1108** receives transmissions and transmits transmissions. Transceiver **1108** may be coupled to antennas **1110**, which represent an antenna or multiple antennas, as appropriate to the device.

[0085] The instructions **1112**, **1114** comprise one or more sets of instructions or software executed on a computing device (or machine) to cause such computing device (or machine) to perform any of the methodologies discussed herein. For example, instructions **1112**, **1114** may implement the processing described in FIGS. **2-10** relative to the UEs, macro eNBs, and small cell eNBs illustrated including the various protocol layers, switching decisions, flow diagrams, and so forth. The instructions **1112**, **1114** (also referred to as computer- or machine-executable instructions) may reside, completely or at least partially, within processor **1104** and/or the memory **1106** during execution thereof by device **1100**. While instructions **1112** and **1114** are illustrated as separate, they can be part of the same whole. The processor **1104** and memory **1106** also comprise machine-readable storage media.

[0086] In FIG. **11**, processing and control functionalities are illustrated as being provided by processor **1104** along with associated instructions **1112** and **1114**. However, these are only examples of processing circuitry that comprise programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software or firmware to perform certain operations. In various embodiments, processing circuitry may comprise dedicated circuitry or logic that is permanently configured (e.g., within a special-purpose processor, application specific integrated circuit (ASIC), or array) to perform certain operations. It will be appreciated that a decision to implement a processing circuitry mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by, for example, cost, time, energy-usage, package size, or other considerations.

[0087] Accordingly, the term "processing circuitry" should be understood to encompass a tangible entity, be that an entity that is physically constructed, permanently configured (e.g., hardwired), or temporarily configured (e.g., programmed) to operate in a certain manner or to perform certain operations described herein.

[0088] The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

[0089] The term "computer readable medium," "machine-readable medium" and the like should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The terms shall also be taken to include any medium that is capable of storing, encoding, or carrying a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure. The term "computer readable medium," "machine-readable medium" shall accordingly be taken to include both "computer storage medium," "machine storage medium" and the like (tangible sources including, solid-state memories, optical and magnetic media, or other tangible devices and carriers but excluding signals per se, carrier waves and other intangible sources) and "computer communication medium," "machine communication medium" and the like (intangible sources including, signals per se, carrier wave signals and the like).

[0090] It will be appreciated that, for clarity purposes, the above description describes some embodiments with reference to different functional units or processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processors or domains may be used without detracting from embodiments disclosed herein. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same processor or controller. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[0091] Although the present embodiments have been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. One skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the disclosure. Moreover, it will be appreciated that various modifications and alterations may be made by those skilled in the art without departing from the scope of the disclosure.

What is claimed is:

1. A method performed by user equipment (UE), the method comprising:

receiving information packets over a first bearer path from a first enhanced node B (eNB);

identifying a decision point where a switch from the first bearer path to a second bearer path is possible, a second eNB using the second bearer path; and

responsive to the decision point and to decision logic, reconfiguring the UE to receive packets via the second bearer path when the decision logic indicates that the first eNB will route packets to the second bearer path via the second eNB.

2. The method of claim **1**, wherein the decision logic indicates that the first eNB will route packets to the second bearer path via the second eNB upon expiration of a time slot.

3. The method of claim **1**, wherein the decision logic indicates that the first eNB may route packets to the second bearer path via the second eNB upon expiration of a time slot and wherein the method further comprises listening to both the first and second bearer path upon expiration of the time slot to identify which bearer path is being used by the first eNB to route packets to the UE.

4. The method of claim **1**, further comprising receiving via the first bearer path a last packet indication and wherein the decision logic indicates that the first eNB will route packets to the second bearer path via the second eNB upon.

5. The method of claim **1** further comprising sending to the first eNB at least one of:

a metric relating to channel quality indicator (CQI);

a metric relating to Hybrid Automatic Repeat Request (HARQ); and

a metric relating to a delay estimate.

6. An enhanced Node B (eNB) comprising:

processing circuitry configured to:

obtain Quality of Service (QoS) information for a first bearer path which provides packets to a User Equipment (UE) via the eNB and a second bearer path which provides packets to the UE via a second eNB;

identify a switch event, the occurrence of which causes the eNB to identify a selected bearer path from among the first bearer path or second bearer path to send packets to the UE;

responsive to the switch event and to selection criteria, identify the selected bearer path; and

route packets to the UE via the selected bearer path.

7. The eNB of claim **6**, wherein the switch event comprises the expiration of a time slot and wherein the selection criteria identifies the selected bearer path as a currently non-selected bearer path.

8. The eNB of claim **6**, further comprising:

establishing a schedule to receive at least one metric;

responsive to the switch event and the selection criteria, when the selected bearer path is the first bearer path:

notifying the second eNB of the decision to switch from the second bearer path and the first bearer path; and

receiving from the second eNB a last packet notification indicating that a last packet has been sent to the UE;

responsive to the switch event and the selection criteria, when the selected bearer path is the second bearer path:

sending the last packet notification to the UE upon transmission of the last packet via the first bearer path.

9. The eNB of claim **6**, wherein the selection criteria comprises at least one of:

maintaining QoS of the selected bearer path; and

maximizing overall network capacity.

10. The eNB of claim **6**, wherein the selection criteria considers factors comprising at least one of:

UE channel conditions;

load estimate of at least one of the eNB and second eNB; and

at least one delay estimate.

11. The eNB of claim **10**, wherein the delay estimate comprises at least one of:

an over the air delay from at least one of the eNB and the second eNB to the UE;
an overall bearer processing delay; and
a backhaul delay.

12. A method executed by an enhanced Node B (eNB) comprising:
obtaining metrics influencing at least one bearer path, the metrics comprising at least one of:
a Channel Quality Indicator (CQI);
a load estimate; and
a delay estimate;
obtaining Quality of Service (QoS) requirements for a bearer having a first bearer path and a second bearer path;
calculating an efficiency factor for each of the first bearer path and the second bearer path based on the metrics; and
selecting, based on the efficiency factor, either the first bearer path or the second bearer path to route packets to a User Equipment.

13. The method of claim **12**, further comprising:
identifying a switch event where selection of either the first bearer path or the second bearer path may be changed;
recalculating the efficiency factor for each of the first bearer path and the second bearer path;
responsive to occurrence of the switch event, selecting either the first bearer path or the second bearer path to route packets to the UE based on the recalculated efficiency factor for each of the first bearer path and the second bearer path.

14. The method of claim **12** wherein the CQI is obtained from the UE.

15. The method of claim **12**, wherein the load estimate comprises at least one of:
radio bearer usage;
hardware loading factor; and
number of bearers being served.

16. The method of claim **12**, wherein the delay estimate comprises at least one of:
Hybrid Automatic Repeat Request (HARQ) metrics to indicate over the air delay;
Radio Link Control (RLC) delay;
Packet Data Convergence Protocol (PDCP) delay; and
backhaul delay.

17. The method of claim **12**, wherein selecting either the first bearer path or the second bearer path to route packets to a User Equipment comprises:
setting a selected efficiency factor as the efficiency factor for the selected one of the first bearer path or the second bearer path;
setting a non-selected efficiency factor as the efficiency factor for the non-selected one of the first bearer path or the second bearer path;
comparing the selected efficiency factor to the non-selected efficiency factor plus a threshold value; and
switching to the non-selected one of the first bearer path or the second bearer path when the non-selected efficiency factor plus a threshold exceeds the selected efficiency factor.

18. User Equipment (UE) comprising:
at least one antenna;
transceiver circuitry coupled to the at least one antenna;
memory;
a processor coupled to the memory and transceiver circuitry; and
instructions, stored in the memory, which when executed cause the processor to perform actions comprising:
receive information packets over a first bearer path from a first enhanced node B (eNB);
identify a decision point where a switch from the first bearer path to a second bearer path is possible, a second eNB using the second bearer path; and
responsive to the decision point and to decision logic, reconfigure the UE to receive packets via the second bearer path when the decision logic indicates that the first eNB will route packets to the second bearer path via the second eNB.

19. The UE of claim **18**, wherein the decision logic indicates that the first eNB may route packets to the second bearer path via the second eNB upon occurrence of a switch event and wherein the instructions further cause the processor to listen to both the first and second bearer path upon occurrence of the switch event to identify which bearer path is being used by the first eNB to route packets to the UE.

20. The UE of claim **18**, further comprising receiving via the first bearer path a last packet indication and wherein the decision logic indicates that the first eNB will route packets to the second bearer path via the second eNB upon.

* * * * *