

Adapting a mobile network

Technical field

5 The present embodiments relate to telecommunications and in particular to methods for adapted a mobile network. Nodes and computer programs are also described.

Background

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The present embodiments are described within the context of LTE, i.e. E-UTRAN. It should be understood that the problems and solutions described herein are equally applicable to wireless access networks and user-equipments (UEs) implementing other access technologies and standards. LTE is used as an example technology where the embodiments are suitable, and using LTE in the description therefore is particularly useful for understanding the problem and solutions solving the problem.

20 LTE Mobility is described in the following.

RRC (3GPP TS 36.331) is the main signaling protocol for configuring, re-configuring and general connection handling in the LTE radio access network (E-UTRAN). RRC controls many functions such as connection setup, mobility, measurements, radio link failure and connection recovery. These functions are of relevance for the present embodiments, and are therefore described in some further detail below.

A UE in LTE can be in two RRC states: RRC_CONNECTED and RRC_IDLE. In RRC_CONNECTED state, mobility is network-controlled based on e.g. measurements provided by the UE. I.e. the network decides when and to which cell an UE should be handed over, based on e.g. measurements provided by

the UE. The network, i.e. the LTE radio base station (called eNB in E-UTRAN) configures various measurement events, thresholds etc based on which the UE then sends reports to the network, such that the network can make a wise decision to hand over the UE to a stronger cell as the UE moves away from the present cell.

Figure 1 illustrates a LTE RRC handover procedure according to 3GPP TS 36.300, Fig. 10.1.2.1.1-1.

Figure 2 illustrates a simplified black and white picture of the parts of the LTE HO procedure relevant for the embodiments. (It should be noted that the HO command is in fact prepared in the Target eNB, but the message transmitted via the Source eNB. I.e. the UE sees that the message comes from the Source eNB).

In RRC_IDLE, mobility is handled by UE-based cell-selection, where a nomadic UE selects the "best" cell to camp on, based e.g. on various specified criteria and parameters that are broadcasted in the cells. For example, various cells or frequency layers could be prioritized over other, such that the UE tries to camp on a particular cell as long as the measured quality of a beacon or pilot in that cell is a threshold better than some other beacon or pilot received from other cells.

The present embodiments are primarily focusing on problems associated with network-controlled mobility as described above, i.e. for an LTE UE in RRC_CONNECTED state. The problems associated with failing handovers are therefore described in further detail below.

In a regular situation, and when a RRC_CONNECTED UE is moving out from the coverage of a first cell (also called source cell), it should be handed over to a neighboring cell (also called target cell or second cell) before losing the connection to the first cell. I.e. it is desirable that the connection is maintained

without no or minimal disruption throughout the handover, such that the end-user is unaware of the ongoing handover. In order to succeed with this, it is necessary that

- the measurement report that indicates the need for mobility is transmitted
5 by the UE and received by the Source eNB, and
- the Source eNB has sufficient time to prepare the handover to the target cell (by, among other things, requesting a handover from the Target eNB controlling the target cell), and
- the UE receives the handover command message from the network, as
10 prepared by the Target eNB in control of the target cell and sent via the source cell to the UE, see Figures 1 & 2.

In addition, and in order for the handover to be successful, the UE must finally succeed in establishing a connection to the target cell, which in LTE requires a successful random access request in the target cell, and a subsequent HO
15 complete message. (It should be noted that specifications may differ somewhat in the naming of messages. This does not limit the applicability of the present embodiments).

Thus, it is clear that in order to succeed all this, it is necessary that the
20 sequence of events leading to a successful handover is started sufficiently early, so that the radio link to the first cell (over which this signaling takes place) does not deteriorate too much before completion of the signaling. If such deterioration happens before the handover signaling is completed in the source cell (i.e. first cell), then the handover is likely to fail. Such handover failures are
25 clearly not desirable. The current RRC specification therefore provides various triggers, timers, and thresholds in order to adequately configure measurements, such that the need for handovers can be detected reliably, and sufficiently early. In Figure 2, the exemplified measurement report is triggered by a so called A3 event (in short: A neighbor cell is found to be an offset better than the current
30 serving cell). It should be noted that there are multiple events that can trigger a report.

It may occur that a UE loses coverage to the cell that the UE is currently connected to. This could occur in a situation when a UE enters a fading dip, or that a handover was needed as described above, but the handover failed for one or another reason. This is particularly true if the "handover region" is very short. By constantly monitoring the radio link quality, e.g. on the physical layer as described in 3GPP TS 36.300, TS 36.331 and TS 36.133, the UE itself is able to declare a radio link failure and autonomously start a RRC re-establishment procedure. If the re-establishment is successful (which depends, among other things, if the selected cell and the eNB controlling that cell was prepared to maintain the connection to the UE), then the connection between the UE and the eNB can resume. A failure of a re-establishment means that the UE goes to RRC_IDLE and the connection is released. To continue communication, a brand new RRC connection has then to be requested and established.

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In the following, dual connectivity and RRC diversity is described.

Dual connectivity is a feature defined from the UE perspective wherein the UE may simultaneously receive and transmit to at least two different network points.

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Dual connectivity is one of the features that are being standardized within the umbrella work of small cell enhancements within 3GPP Rel-12.

Dual connectivity is defined for the case when the aggregated network points operate on the same or separate frequency. Each network point that the UE is aggregating may define a stand-alone cell or it may not define a stand-alone cell. It is further foreseen that from the UE perspective, the UE may apply some form of Time Division Multiplex (TDM) scheme between the different network points that the UE is aggregating. This implies that the communication on the physical layer to and from the different aggregated network points may not be truly simultaneous.

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Dual connectivity as a feature bears many similarities with carrier aggregation and CoMP; the main differentiating factor is that dual connectivity is designed considering a relaxed backhaul and less stringent requirements on synchronization requirements between the network points. This is in contrast to
5 carrier aggregation and CoMP wherein tight synchronization and a low-delay backhaul are assumed between connected network points.

Examples of features that dual connectivity will allow in the network are,

- RRC diversity (e.g. handover (HO) command from source and/or target)
- 10 - Radio Link Failure (RLF) robustness (failure only when both links fail)
- Decoupled UL/DL (UL to LPN, DL from macro)
- Aggregation of macro anchor carrier and LPN data booster(s)
- Selective Handover (e.g., data from/to multiple nodes)
- Hide UE mobility between small cells from Core Network (CN) with C-
15 plane in macro
- Network Sharing (Operators might want to always keep the control plane and Voice Over IP (VoIP) terminated in their own macro, but may be willing to offload best effort traffic to a shared network)

20 Figure 3 illustrates dual connectivity to anchor and booster.

A UE in dual connectivity maintains simultaneous connections to anchor and booster nodes. As the name implies, the anchor node terminates the control plane connection towards the UE and is thus the controlling node of the UE.

25 The UE also reads system information from the anchor. In addition to the anchor, the UE may be connected to one or several booster nodes for added user plane support.

The anchor and booster roles are defined from a UE point of view. This means
30 that a node that acts as an anchor to one UE may act as booster to another UE. Similarly, though the UE reads the system information from the anchor node, a

node acting as a booster to one UE, may or may not distribute system information to another UE.

5 The protocol architecture shown in Figure 4 is proposed as a way forward for realizing dual connectivity in LTE Rel-12 in deployments with relaxed backhaul requirements. In the user plane a distributed PDCP/RLC approach is taken where the booster and anchor terminate the user planes of their respective bearers, with a possibility to realize user plane aggregation via MPTCP. In the control plane, the RRC and PDCP are centralized at the anchor, with a
10 possibility to route RRC messages via the anchor, the booster, or even simultaneously at both links.

Figure 4 illustrates a control and user plane termination.

15 Problems described in the following might occur.

In the following, Handover and radio link failure robustness is described.

20 The recent and rapid uptake of Mobile Broadband has led to a need for increasing the capacity of cellular networks. One solution to achieve such a capacity increase is to use denser networks consisting of several "layers" of cells with different "sizes": Macro cells ensure large coverage with cells encompassing large areas, while micro-, pico- and even femto-cells are deployed in hot-spot areas where there is a large demand for capacity. Those
25 cells typically provide connectivity in a much smaller area, but by adding additional cells (and radio base-stations controlling those cells), capacity is increased as the new cells off-load the macros.

Figure 5 illustrates a UE moving out from Pico into Macro cell area.

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The different "layers" of cells can be deployed on the same carrier (i.e. in a reuse-1 fashion), the small-cells could be deployed on a different carrier, and the different cells on the various layers could even be deployed using different

technologies (e.g. 3G/HSPA on the macro- and micro-layer, and LTE on the pico-layer as one non-exclusive example).

There is currently a large interest for investigating the potential of such
5 Heterogeneous Networks, and operators are interested in such deployments.
However, it has also been found that such Heterogeneous Networks may result
in an increased rate of handover failures, as briefly discussed above. One
reason is that the handover region in Heterogeneous Networks may be very
short, meaning that the handover might fail since the UE lost coverage to the
10 source cell before the handover to a target cell could be completed. For
example, when a UE leaves a pico-cell, it may happen that the coverage border
of the pico is so sharp, that the UE fails to receive any handover command
towards a macro before losing coverage to the pico, see figure 4.

15 Figure 6 illustrates a Handover region of pico/macro vs. macro/macro cell
change.

Similar problems could occur when a UE connected to a macro suddenly enters
a pico on the same carrier: It could now happen that the control channels of the
20 pico interferes with the signals that the UE needs to receive from the macro in
order to complete the handover, and the handover thus fails.

In order to investigate the consequences of increased handover failures and
solutions to mitigate those, 3GPP is currently working on evaluations and
25 technical solutions for amendments, as described in TR 36.839.

In the following, Key performance indication degradation and need for drive
testing is described.

30 Today it is very difficult to determine if a KPI problem experienced at a certain
location in a radio network is due to that a Cell does not receive UE
transmission or if it is the UE that does not receive the cell transmission or both.

The current typical way of trouble shooting is to make drive testing and collect both Cell traces with time stamped events/transmissions and UE trace with events/transmissions is collected from the UE's used for drive testing.

5 In 3GPP efforts have been made to support that UE collect some information when experiencing problems with the connection or problems in getting access to the system and then when connectivity is established to the NW at a later time when a connection is established the NW can ask the UE to transmit the collected information. The collected information has time stamp information
10 based on UE internal clock and also location information.

Drive testing and using specific UE's for drive testing may not always be able to discover intermittent faults or drive into locations where the problem actually occurs. If it is a UE vendor specific problem the UE used for drive testing may
15 not have the same kind of fault as some of the UE's used by subscribers in the network. On top of that regular drive testing is typically very expensive. There is a large cost for collecting the data and also a cost when data is analyzed. The data analysis can be costly and difficult due to that drive testers need to collect all data on rather detailed level and hope that the intermittent fault appears and
20 are captured in the data collected during drive testing amongst the large amount of data collected.

Assuming a system where a UE can be simultaneously connected to several cells, it is currently unclear how the UE shall evaluate radio link failures and how
25 the system shall react upon these radio link failures or other connectivity issues of some of the maintained connections.

Moreover, key performance indicator (KPI) evaluation by the radio network for UEs experiencing radio link problems in certain locations at a certain time is
30 problematic due to the degraded connectivity to the UE in these situations. With the current system, the evaluation cannot be done immediately after the fault

and is usually based on reports or (costly) drive tests. An immediate adaption of the system possibly improving the KPIs is thus not possible.

Summary of embodiments

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It is an object to provide measures with which a network adaption in case of degradation of a quality of a connection between an access node of the mobile network and the terminal may have degraded in an improved way. In is a further object to provide corresponding methods, a terminal, nodes, a mobile network, and computer programs.

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The object above is solved by methods, a terminal, nodes, a mobile network, and computer programs as described in the following embodiments.

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The foregoing and other objects, features and advantages will become more apparent in the following detailed description of embodiments as illustrated in the accompanying drawings.

Brief description of the drawings

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Figure 1 is flow diagram illustrating a signaling exchange for a handover procedure.

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Figure 2 is a flow diagram illustrating a signaling exchange for a handover procedure.

Figure 3 is a block diagram illustrating a mobile network used in connection with dual connectivity of a terminal.

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Figure 4 is a diagram illustrating a control plane and user plane terminating in an access node.

Figure 5 is a block diagram illustrating a LTE mobile network.

Figure 6 is a diagram illustrating a signal strength of a LTE mobile network depending on a distance.

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Figure 7 is a flow chart illustrating a method for adapting a mobile network according to an embodiment.

10 Figure 8 is a flow diagram illustrating a method for adapting a mobile network according to another embodiment.

Figure 9 is a flow diagram illustrating a method for adapting a mobile network according to another embodiment.

15 Figure 10 is a block diagram illustrating a terminal for adapting a mobile network according to an embodiment.

Figure 11 is a block diagram illustrating an access node for adapting a mobile network according to an embodiment.

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Figure 12 is a block diagram illustrating an access node for adapting a mobile network according to another embodiment.

Detailed description

25

In the following, methods and devices for providing a media description of a media stream to a client are described in more detail.

30 One or more embodiments are based on the assumption that the UE can communicate independently via two maintained connections. To provide radio link failure (RLF) diversity as well, the UE shall trigger the standardized RLF procedure only if both links are out-of-sync. If only one of the maintained

connections fails, however, a different UE behavior must be enforced. With the
embodiments the UE is able to inform the involved eNBs with the help of a new
RRC RLF warning message about the RLF of one of the links, and the eNBs
are able to quickly react upon this information by stopping the RRC diversity
5 connection and/or handing over the UE completely to one of the involved eNBs.
The eNB may also decide to move potential bearers mapped over the failed link
to another link.

Figure 7 illustrates steps according to an embodiment.

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Moreover, with the information obtained from the RLF-warning of one link and
the information of another maintained connection E-UTRAN is quickly able to
combine these information, learn about UE RLF failure reasons, their statistics
and can apply necessary adaptations.

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Embodiments are based on the assumption that the UE can communicate
independently via two maintained connections. To provide radio link failure
(RLF) diversity as well, the UE shall trigger the standardized RLF procedure
only if both links are out-of-sync. If only one of the maintained connections fails,
20 however, a different UE behavior must be enforced as explained in the
following.

In the following procedures according to embodiments are described.

25 In Figure 8 and Figure 9 the signaling involved in the setup of the RRC
connection as well as the reaction upon RLF of one of the links is described.

The UE is first configured with a measurement configuration (1) issuing an early
measurement report (2). This measurement may relate to source cell, assisting
30 cell or different cells. Upon reception of this measurement report in the source
eNB it will (if required) request an RRC diversity peering (3) with the assisting
eNB, which acknowledges this request (4) and includes the RRC-

reconfiguration for the UE to setup RRC diversity transmission and reception, which the source eNB will forward to the UE (5). At this point the source eNB will go into RRC diversity state where RRC messages are transmitted and received to the UE directly and additionally send to/received from the assisting eNB for relaying to/from the UE. The UE will start a RACH procedure towards the assisting eNB to become synchronized to it (6).

In Figure 8 the reaction procedure for RLF to the assisting cell is described, while in Figure 9 the procedure for RLF to the source cell is described.

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In the following, a reaction to the assisting eNB out-of-sync is described.

After the UE has measured a Layer-3 RLF (i.e. timer T310 expired) towards the assisting cell (Fig. 8), it will stop the transmission on this link and trigger the transmission of the (7) RLF warning message, as further described below, towards the source eNB. The source eNB will send an indication to the assisting eNB to stop the RRC relaying functionality (8) for the UE, since it is aware of the UE having triggered RLF to the assisting eNB. This way the assisting eNB is informed about the radio link failure to the UE immediately, which would not have been possible with the currently standardized solution, where this state could only be estimated based on timers etc. At this point RRC diversity should be deactivated in both source eNB and assisting eNB. Only the connection between source eNB and UE should be maintained, thus the UE is configured to stop RRC diversity, but maintain the connection to the UE. The source eNB uses the RRC reconfiguration procedure (10, 11) to reconfigure the UE to leave RRC diversity mode and be solely connected to the source cell.

Provided the system is capable of dual connectivity for the UE, also potential bearers terminated at the assisting eNB would be reconfigured to terminate at the source eNB. For this, the source eNB also sends a path switch command towards the core network so that the packets are routed to the source eNB.

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Figure 8: illustrates a Radio link failure (RLF) warning for the assisting eNB out-of-sync.

In the following, a reaction to a source eNB out-of-sync is described.

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In Fig. 9 RLF on the link to the source eNB occurs and is registered within the UE. It will stop its transmission on this link and transmit an RLF warning indication towards the assisting eNB (7) which will (since it is in RRC relaying mode) further forward this indication towards the source eNB. The source eNB will then handover the UE completely to the assisting eNB since it can be sure the connection source-UE is lost. Therefore, it will send the handover request indication (8) to the assisting eNB, which is acknowledged (9) by the assisting eNB. The acknowledgment also includes the handover command for the UE, which the source eNB is supposed to send to the UE. The source eNB will send the handover command (RRC reconfiguration (11)) via the RRC relay, i.e. the assisting eNB, to the UE. Therefore, it is important that the assisting eNB still remains in RRC relaying mode, even though it received and acknowledges the complete handover of the UE already. After relaying the handover command to the UE, the assisting eNB can upgrade itself to be the RRC anchor for the UE. The source eNB can stop RRC diversity. Both nodes will now follow the standardized HO procedure, i.e. source eNB will send sequence number status transfer (12) to the assisting eNB and forward buffered packets. The UE will confirm the RRC reconfiguration to be solely connected to the assisting (now anchor) eNB (13), and eventually the assisting eNB will send the UE context release indication to the source eNB (14).

In another embodiment, the assisting eNB being in RRC relaying mode for the UE, will transmit the handover command to the UE (11) itself in case the source requests a complete handover. In this variant, the handover request acknowledge message does not need to include the handover command for the UE, since the source eNB is not supposed to transmit it anyway. However, the

source eNB needs to be informed that the UE is handed over to the assisting eNB and that SN status transfer and buffered data transfer needs to be initiated.

In another embodiment, the assisting eNB could also inspect the RLF warning it forwards and directly send handover acknowledgment to the source eNB, as well as handover command to the UE itself.

Figure 9 illustrates a radio link failure (RLF) warning for the source eNB out-of-sync.

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In the following, radio link failure related actions according to embodiments are described.

It is assumed that the current RLF procedure is only triggered if the conditions for RLF on all links are fulfilled simultaneously. Therefore, RRC needs to evaluate physical layer problems of all links separately.

The timers and constants for the UE to evaluate physical layer problems shall be configurable on a per link basis, thus multiple instances of the IE rlf-TimersAndConstants (or at least a subset of the corresponding timers/constants, e.g. T310, N310, N311) shall exist and be configurable in the UE. In another embodiment, the same values are applied to the each of the links, but evaluation is still done independently.

25 In the following a RLF-TimersAndConstants information element per maintained connection is illustrated:

-- ASN1START

RLF-TimersAndConstants-r9 ::= CHOICE {

30 release NULL,
 setup SEQUENCE {
 t301-r9 ENUMERATED {

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ms100, ms200, ms300, ms400,  
ms600, ms1000, ms1500,  
ms2000},  
5 t310-r9 ENUMERATED {  
ms0, ms50, ms100, ms200,  
ms500, ms1000, ms2000},  
n310-r9 ENUMERATED {  
n1, n2, n3, n4, n6, n8, n10,  
n20},  
10 t311-r9 ENUMERATED {  
ms1000, ms3000, ms5000,  
ms10000, ms15000,  
ms20000, ms30000},  
n311-r9 ENUMERATED {  
15 n1, n2, n3, n4, n5, n6, n8, n10},  
...  
}
```

```
}  
-- ASN1STOP
```

20 To detect a physical layer problem in RRC_CONNECTED, the UE evaluates separately per connected cell *i* if N310_{*i*} consecutive “out-of-sync” indications are received from lower layers while neither in T300 _{*i*}, T301 _{*i*}, T304 _{*i*}, T311 _{*i*} and then starts timer T310 _{*i*}. Upon receiving N311 _{*i*} consecutive “in-sync” indications from lower layers while T310 _{*i*} is running, the UE shall stop timer T310 _{*i*}. The
25 separate evaluation on a per link basis shall also apply if further advanced techniques of “out-of-sync”/“in-sync” evaluations are applied, .e.g. additionally evaluating whether a measurement report was sent.

30 In the following a RLF-warning procedure according to embodiments is described.

Upon T310 expiry of a certain cell, or maximum number of scheduling requests is reached, or RLC maximum number of retransmissions reached indication for this cell, the UE shall trigger the new RLF-warning procedure as defined in the following.

5

The UE shall trigger the following modified actions and prepare the RLF-warning indication to be sent directly via a second maintained connection. Additionally the legacy RLF-Report is prepared in a modified way.

10 Alternative 1:

2> don't consider radio link failure to be detected;
2> store the following radio link failure information in the modified VarRLF-Report according to the selection of links to transmit the RLF warning described below

15 2> if AS security has not been activated:

3> don't perform the actions upon leaving RRC_CONNECTED as specified in 36.331 / 5.3.12, with release cause 'other';

2> else:

3> don't initiate the connection re-establishment procedure as

20 specified in 36.331 / 5.3.7;

2> stop transmission and reception on the link for which RLF is detected

2> trigger transmission of the new RLF-warning indication from the UE to E-UTRA via one or multiple of the other maintained connections

25 Alternative 2:

2> don't consider radio link failure to be detected;

2> store the following radio link failure information in the modified VarRLF-Report according to the RLF warning contents described below

2> if AS security has not been activated:

30 3> don't perform the actions upon leaving RRC_CONNECTED as specified in 36.331 / 5.3.12, with release cause 'other';

2> else:

3> don't initiate the connection re-establishment procedure as specified in 36.331 / 5.3.7;

2> trigger transmission of the new RLF-warning indication from the UE to E-UTRA via one or multiple of the other maintained connections

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With alternative 2 the terminal does not stop transmission/reception on the link for which T310 has expired. Expiry of T310 only means that the downlink channel has problem due to poor channel quality but this does not mean that there are any problems in uplink. The uplink transmissions may therefore
10 successfully reach the base station. This is expected to be beneficial especially in case the acknowledgements for the terminal's uplink transmissions can be transmitted from the network to the terminal on an alternative link, for example a link for which RLF has not been detected.

15

If the terminal continues to transmit and receive (attempt to receive) on the link for which T310 has expired then it is possible that if the link later becomes better after RLF has been detected the terminal can resume use of that link.

20

In the following a selection of links to transmit the RLF-warning according to embodiments is described.

25

The terminal may select a set of configured links on which it sends the RLF-warning on. For example, it may send the RLF-warning to all cells or a subset of all configured links such as only on the source link.

30

If the terminal knows that it has one or more alternative links to the node offering the link for which T310 has expired, for example if there are two links from a node to a terminal and T310 expires only for one of these links then it would be beneficial to transmit the RLF-warning on one or more alternative links.

The terminal may even send the RLF-warning on the link for which the T310 has expired. The benefit of sending the RLF-warning on the link for which T310 has expired is that the concerned node may need to be informed about the expiration of T310. The expiration of T310 indicates that the downlink quality is poor however the uplink may still have sufficiently good quality allowing the RLF-warning to reach the concerned node.

In the following, RLF-warning contents according to embodiments are described.

10

(1) This RLF-warning message indicates to E-UTRA that one of the maintained connections is lost. It can optionally include a subset of the information from the legacy RLF-Report, as well as details of the failure reason.. It may further include an indicator to which connection the RFL-warning belongs. A non-exhaustive list of potential fields for the RLF-warning is given in the following. Information of the cell the RLF-warning belongs to

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- PCell ID, cell global ID, physical cell ID, carrier frequency of this cell

(2) Latest or historic measurement results for the cell the RLF-warning belongs to

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- RSRP, RSRQ, or other.

(3) Latest or historic measurement results for other serving cells

- RSRP, RSRQ, etc., cell identifiers for the respective measurements

(4) Latest or historic measurement results for non-serving neighbor cells

- E-UTRA, UTRA, GERAN, CDMA2000, or other systems measurements

25

(5) Time of failure

(6) Detailed failure type and reason

- Out-of-sync, maximum number of scheduling requests, RLF retransmissions reached, etc.

(7) UE state information, list of current events, e.g. measurement events.

30

(8) Buffer status

In the following Modified RLF-reporting according to embodiments is described.

In the original RLF reporting, the UE stores RLF related information for the (single) link where the failure occurred and sends the report to E-UTRAN upon request. The report is overridden when another RLF occurs. In RRC diversity,
5 the UE shall trigger the original RLF procedure as well as the original RLF report only if all links fail. So, this reporting can to be modified to convey information about multiple links.

10 In one embodiment, the single modified RLF report can include information about multiple or all links.

In another embodiment, multiple RLF reports, so one per link can be created and requested independently or collectively by E-UTRA.

15 In the following, CQI monitoring in network is described.

As an alternative to using RLF-warnings in the network to trigger RRC-reconfigurations for the UE as explained above, CQI reports received for each link in the respective network node can be forwarded to another node, which is
20 also currently connected to the UE. In one embodiment the network will monitor the received CQI reports received from the terminal regarding the terminal's different connections. If the reported CQI indicates a channel quality for one connection below a certain threshold the network will consider that connection unfit for use by the terminal.

25 In case the network considers the quality of a connection is not good enough and unfit for use by the terminal it may take actions such as the following. Note that different behavior may be applied depending on which type of connection is concerned:

30

(1) Trigger a handover – The network can order the terminal to perform a handover to another, probably better quality, cell. If the connection with bad

quality is the source cell this is one alternative to ensuring that another cell becomes the source connection. In case the assisting cell has been identified to be of better quality than the source cell, a similar procedure such as described above for the reaction to a source eNB out-of-syn can be envisaged.

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(2) Source and assisting cell switch - If the network detects that the source cell's quality is below a certain threshold while the quality of an assisting cell is acceptable the network could trigger a switch so that an assisting cell instead becomes the source cell and the source cell instead becomes an assisting cell.

10 This is similar to a handover however it may not include the RRC-reconfiguration in the UE, since the UE can be oblivious of the network element acting as the RRC anchor.

(3) Deconfigure the assisting cell – If the quality of a cell which is serving as an assisting cell is bad the motivation to keep the assisting cell. The network may therefore deconfigure the assisting cell. In case after the deconfiguration of the assisting cell the terminal is only configured with the source cell RRC diversity may be de-configured. This behavior is similar to the procedure described above for a reaction to a assisting eNB out-of-sync.

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In the following, RLF-warnings for UL/DL trouble shooting in E-UTRAN according to embodiments are described.

Whenever an RLF warning occurs for one link of the connection (triggered e.g. by out-of-sync, maximum number of scheduling requests reached or maximum number of RLC retransmission reached) the receiving eNB can utilize the information about failure reason and UE measurements etc. as given in the warning message by combining it with its own information about the working link, e.g. about current events and transmissions done to UE. So, with the RLF warning procedure, E-UTRAN is able to combine UE and eNB information to determine if the problem was related to that eNB did not receive the UE on the link where problems was indicated or vice versa or both.

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- Also the eNB may experience similar faults as the UE e.g. maximum number of resynch attempts reached, maximum number of scheduling requests reached or maximum number of RLC retransmission reached and then eNB could ask the
- 5 UE to provide historic data about UE events and transmissions done. This functionality can be established with another request/response message exchange triggered by the eNB and transmitted via one of the maintained connections.
- 10 With the combined information E-UTRAN is able to quickly react upon these connectivity problems and adapt its system settings to improve the performance for the UE and the overall system, e.g. certain key performance indicators.

Further embodiments are as follows:

- 15 In an embodiment, instead of triggering the RLF warning transmission depending on the existing T310 timer for this respective link, a new timer per link is used, which is started simultaneously with the T310 timer, but has a different expiry time. This way, RLF warning indication transmission can be
- 20 triggered independently of the existing RLF evaluation per link, thus the RLF warning can be transmitted e.g. earlier than RLF on that link is triggered. Also, second N310 and N311 constants per link can be used for this evaluation.

In the following advantages of one or more embodiments are described.

- 25 With the provided solution unnecessary transmissions between UE and eNB are avoided in RRC diversity mode. This way interference and battery consumption are decreased. With the discussed procedures the UE is able to maintain an RRC connection when experiencing RLF on one link in a diversity
- 30 transmission mode. A fast fallback (or fast fall-forward) to one of the maintained connections if one of the connections fails is ensured.

Moreover, this solution will allow an operator to understand the root cause for intermittent performance degradations in a radio network and especially understand if it is a network problem or a UE problem or both. The method will also work in rather poor conditions since only one out of several connections to
5 the network need to work.

With this solution the system is able to very quickly adapt to UE connectivity problems and adapt the system to improve the system's performance.

- 10 The following abbreviations are used
RRC Radio resource control
PDCP Packet data convergence protocol
CRE Cell range extension
CSO Cell selection offset
15 PDU Protocol data unit
UE User equipment
eNB evolved node base station
HO Handover
HOF Handover failure
20 RLF Radio link failure

Referring to Figure 10, a terminal for adapting a mobile network is described. The terminal is connected to a first access node of the mobile network via a first connection and to a second access node via a second connection. The first
25 access node controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal. The terminal comprises a determination unit adapted to determining whether a quality of at least one of the first connection and the second connection is degraded, and an acquiring unit adapted to acquire quality degradation
30 information about the degradation of the quality of at least one of the first connection and the second connection based on the determination for adapting the mobile network based on the acquired quality degradation information.

The terminal is adapted to perform a method according to embodiments described above and comprises respective functionality based units imbedded in respective physical units illustrated in Figure 10.

5

Referring to Figure 11, an access node for adapting a mobile network is illustrated. A terminal is connected to the access node of the mobile network via a connection and to another access node via another second connection. The access node controls a data transmission for the terminal and the another
10 access node assists in the data transmission for the terminal. The access node comprises an acquiring unit adapted to acquire quality degradation information about a degradation of a quality of at least one of the first connection and the second connection based on a determination whether the quality of at least one of the first connection and the second connection is degraded, and an adapting
15 unit adapted to adapt the mobile network based on the acquired quality degradation information.

The access node is adapted to perform a method according to embodiments described above and comprises respective functionality based units imbedded
20 in respective physical units illustrated in Figure 11.

Referring to Figure 12, an access node for adapting a mobile network is illustrated. A terminal is connected to the access node of the mobile network via a connection and to another access node via another connection. The another
25 access node controls a data transmission for the terminal and the access node assists in the data transmission for the terminal. The access node comprises an adapting unit adapted to adapt the mobile network based on acquired quality degradation information about a degradation of a quality of at least one of the connection and the another connection, the acquiring of the quality degradation
30 unit being based on a determination whether a quality of at least one of the connection and the another connection is degraded.

The access node is adapted to perform a method according to embodiments described above and comprises respective functionality based units imbedded in respective physical units illustrated in Figure 12.

- 5 It is noted that an association between the physical units of the terminal and access nodes illustrated in Figures 10 to 12, respectively, and the functionality based units of the terminal and access nodes illustrated these Figures, respectively, may differ from the described embodiments. For example, the acquiring unit of the terminal illustrated in Figure 10 may be part of the interface,
10 the processor, and the memory of the terminal.

It is noted that the embodiments are applicable to LTE and radio access networks of GSM and UMTS.

15

EMBODIMENTS

1. A method for adapting a mobile network, wherein a terminal is connected to a first access node of the mobile network via a first connection and to a
5 second access node via a second connection, wherein the first access node controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal, the method comprising:
- determining whether a quality of at least one of the first connection and the second connection is degraded,
 - 10 - acquiring quality degradation information about the degradation of the quality of at least one of the first connection and the second connection based on the step of determining, and
 - adapting the mobile network based on the step of acquiring.
- 15 In particular, the terminal is part of the mobile network.

In particular, the term “the first access node controlling a data transmission of the terminal” may particularly denote to control, by the first access node, of resource allocation for uplink and/or downlink data transmission for the terminal
20 and/or a connectivity state of the terminal. In particular, the first access node can be referred to as an anchor node for the data transmission of the terminal, for example, always being employed for the data transmission for the terminal. For example, in LTE the controlling of the data transmission may comprise terminating a protocol related to the allocation of resources via the air interface
25 between the terminal and the first access node, particularly a RRC protocol, in the first access node.

In particular, the term “the second access node assisting in the data transmission for the terminal” may particularly denote that the second access
30 node may be free of a capability of controlling the data transmission to the terminal by may relay the uplink and/or downlink data transmission between the access node and the terminal. In particular, the second access node can be

referred to as a booster node for the data transmission of the terminal, for example, being employed for the data transmission for the terminal as relay node. Hence, information sent between the first access node and the terminal may be duplicatedly sent between the first access node and the terminal via the
5 second access node.

In particular, the term "data transmission" may comprise transmission of signaling data and/or payload data in the uplink direction from the terminal to the mobile network and/or downlink direction from the mobile network to the
10 terminal.

In particular, the first connection and the second connection may be independent from one another and may comprise respective radio bearers to be established related to the data transmission.

15 In particular, the first access node is referred in described embodiments as "Source eNB" and the first connection is labeled in Figure 4 by "anchor". In particular, the second access node is referenced in described embodiments as "Assisting eNB". The second connection is labeled in Figure 4 by "booster" It is
20 noted that the target eNB described in connection with Figures 1 and 2 also represents an access node adapted to control the data transmission for the terminal.

In particular, in the data transmission for the terminal, data are sent from the
25 first access node to the terminal and data duplicates are sent from the second access node to the terminal. The first access node may have duplicated the respective data and may have sent the data duplicates to the second access node.

30 2. The method according to embodiment 1, wherein the step of determining results in the first connection having failed, wherein the step of adapting comprises:

-- maintaining the connection which is not failed.

3. The method according to any preceding embodiment, wherein the step of determining results in the first connection having failed, wherein the step of
5 adapting comprises:

-- handing, by the first access node, the terminal over from the first access node to the second access node and disconnecting the first connection.

For example, the first access node may initiate the handover of the terminal by
10 sending a handover request to the second access node. The second access node may forward or relay the handover request to the terminal. The first access node may stop controlling the data transmission of the terminal. In LTE the latter may relate to stop RRC diversity. In RRC diversity employed in the first access node may relate to a sending of data directly to the terminal and to
15 a sending of duplicates of the data, which are sent by the first access node to the terminal, to the second access node for relaying them by the second access node to the terminal. Accordingly, stopping RRC diversity may refer to not duplicating the sent data anymore, thus maintaining only the direct connection to the terminal to keep a legacy functionality. Or in other words, particularly with
20 respect to LTE, the latter may relate to stopping RRC signal duplication and forwarding to the second access node.

4. The method according to embodiment 3, wherein the step of adapting further comprises:
25 -- transferring, by the first access node, control capabilities for controlling the data transmission of the terminal from the first access node to the second access node.

In particular, embodiments 3 and 4 are described with reference to Figure 9.
30

5. The method according to any preceding embodiment, wherein the step of determining results in the second connection having failed, wherein the step of adapting comprises:

- requesting, by the first access node, to disconnect the second
5 connection, and
- stopping to employ the second access node for the data transmission for
10 the terminal.

In particular, the step of stopping to employ the second access node for the
10 data transmission may comprise stopping to duplicate the data sent from the
first access node to the terminal and stopping to send the duplicated data to the
second access node. In particular, this step may be embodied as stopping RRC
diversity, relating to not duplicating the data or messages anymore which may
15 be to be sent to the second access node. Thus only a direct connection from
the first access node to the UE may be maintained, the latter referring to as
legacy functionality of the first access node of the mobile network.

In particular, embodiment 5 is described with reference to Figure 8.

20 6. The method according to any preceding embodiment, wherein the step of determining results in one connection of the first connection and the second connection having failed, wherein the step of acquiring comprises:

- sending, by the terminal, the quality degradation information to the
25 access node of the first access node and the second access node whose
connection to the terminal has not failed.

In particular, the quality degradation information may be sent to the first access
node, if the second connection may have failed, as explained with reference to
Figure 8. The quality degradation information may be sent to the second access
30 node, if the first connection may have failed, and may be relayed or forwarded
by the second access node to the first access node.

7. The method according the embodiment 6, wherein the quality degradation information comprises a failure notification indication, particularly a RLF warning indication as explained above.

5 In particular, the failure notification indication may represent an individual indication, particularly included in a conventional message or a new type message, or may be a specific type of message.

In particular, in accordance with any preceding embodiment, the quality
10 degradation information may comprise at least one information selected from the group of:

- a cell identification indication indicative of an identification of an area, particularly a cell, being served by the access node associated with the failed connection, particularly an PCell Identification (ID), a cell global ID, a physical
15 cell ID, a carrier frequency of the cell,
- information about measurement results obtained for the area served by the access node associated with the failed connection and obtained for a previous time period,
- information about measurement result obtained for an area, particularly a
20 cell, served by the access node associated with the not failed connection and obtained for a previous time period,
- information about a measurement result obtained for at least one further area, particularly a further cell, served by a further access node distinct from the first access node and second access node and obtained for a previous time
25 period, particularly an identifier for the measurement
- a connection indication indicative of the failed connection,
- a timer of the failure of the failed connection, and
- a failure reason.

30 In particular, the failure reason may comprise at least one of the following:
-- an expiration of a timer, the timer being started after a predetermined number of a counter fulfillments of a condition and the timer being stopped after

a predetermined number of counter fulfillments of another condition; for example in LTE the latter may correspond to "Out of sync" referring to a RLF timer expiry,

- 5 -- a maximum of scheduling requests having been sent over the respective connection; for example in LTE the latter may correspond to a maximum number of RLC retransmissions having been reached,
- a maximum of retransmission of data having been sent by the terminal over the respective connection; for example in LTE the latter may correspond a maximum number of scheduling requests having been reached; and
- 10 -- a maximum of unsuccessful random access attempts having been sent by the terminal over the respective connection without receiving a data transmission over the respective connection; for example in LTE the latter may correspond to a Random Access Channel (RACH) failure.

15 In particular, the at least one information mentioned above may be sent together with the failure notification indication in one message or may be sent subsequent to the sent failure notification indication for the step of acquiring.

8. The method according to any preceding embodiment, wherein the step of
- 20 determining results in the first connection and the second connection having failed, wherein the step of adapting comprises
- establishing a further connection between the terminal and a further access node of the mobile network.

25 In particular, in accordance with the preceding embodiment, the step of acquiring may be performed by the terminal. The step of establishing may be initiated by the terminal. The further access node may be distinct from the first access node and the second access node or may be one of the first and second access nodes.

30

9. The method according to any preceding embodiment, the method further comprising:

- determining at least one a key performance indication for the mobile network,
wherein the step of adapting comprises adapting at least one system setting of the mobile network based on the at least one key performance indication.

5

In particular, the step of adapting of the system settings may be alternatively or additionally based on quality degradation information obtained, particularly sent in RLF reports. An objective of this adaption may be the improvement of one of the key performance indicators in the network.

10

In particular, the system setting may relate to a characteristic of the first and/or second access node or may relate to a characteristic of a further access node of the mobile network.

15

In particular, embodiments 2 to 8 may describe an immediate or ad hoc adapted of the mobile network. Embodiments 9 may describe an overall adaption of the mobile network on an intermediate or long term time scale.

10. The method according to any preceding embodiment, wherein the step of determining is performed by the terminal and comprises evaluating the quality of the first connection and evaluating the quality of the second connection.

In particular, the step of evaluating of the quality of the first connection and the step of evaluating the quality of the second connection is performed independently of one another.

11. The method according to the preceding embodiment, wherein the respective step of evaluating comprises evaluating a synchronization of the terminal with the respective access node with respect to the data transmission over the respective connection.

In particular, a degradation of the quality of the respective connection may be determined, if the terminal may be not suitably synchronized for the data transmission over the respective connection. In particular, the determined degradation of the quality of the connection may correspond to a connection
5 failure.

12. The method according to the preceding embodiment, wherein the step of determining comprises, particularly for each of the first and second connections, using a timer in the terminal and a counter in the terminal, the counter being
10 associated with fulfillment of a condition, wherein a degradation of the quality of the respective connection is determined, if the timer expires, the timer being started after a predetermined number of the counter fulfillments of the condition, and the timer being stopped after a predetermined number of counter fulfillments of another condition.

15 In particular, the timer may correspond to the T310 timer and the counter may correspond to the constant N310 both described above. In particular, the same or different type of timers and/or counters can be employed for the first and second connections.

20 In particular, in accordance with any preceding embodiment, the step of determining comprises, particularly for each of the first and second connections, using a timer in the terminal and counters in the terminal, one counter being associated with fulfillment of a condition, wherein a degradation of the quality of
25 the respective connection is determined, if the timer expires, the timer being started after a predetermined number of the counter fulfillments of the condition, and the timer being stopped after a predetermined number of another counter fulfillments of another condition.

30 In particular, the timer may correspond to the T310 timer and the counters may correspond to the constants N310, N311 as described above. In particular, the

same or different type of timers and/or counters can be employed for the first and second connections.

13. The method according to the embodiments 10 to 12, wherein the
5 respective step of evaluating comprises evaluating whether a maximum of scheduling requests has been sent over the respective connection.

14. The method according to the embodiments 10 to 13, wherein the
10 respective step of evaluating comprises evaluating whether a maximum of retransmission of data has been sent by the terminal over the respective connection.

15. The method according to the embodiments 10 to 14, wherein the
15 respective step of evaluating comprises evaluating whether a maximum of unsuccessful random access attempts has been sent by the terminal over the respective connection without receiving a data transmission over the respective connection.

20 16. The method according to any preceding embodiment, wherein the step of acquiring comprises sending by the second access node to the first access the quality degradation information.

In particular, the latter embodiment may apply in a case in which at least one of
25 the first and second connections may comprise a degraded or low quality but might not have failed. For example, the quality degradation information may comprise a channel quality indication. The step of determining may be performed by the second access node which may monitor a parameter associated with the channel quality information and/or may determine a value of
30 the parameter.

In particular, the latter embodiment may apply to the embodiment related to handing over the terminal and to the embodiment related to the handover combined with the transfer of the control capabilities.

- 5 17. A method for adapting a mobile network, wherein a terminal is connected to a first access node of the mobile network via a first connection and to a second access node via a second connection, wherein the first access node controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal, the method being
- 10 performed by the terminal and comprising:
- determining whether a quality of at least one of the first connection and the second connection is degraded,
 - acquiring quality degradation information about the degradation of the quality of at least one of the first connection and the second connection based

15 on the step of determining for adapting the mobile network based on the step of acquiring.
18. A method for adapting a mobile network, wherein a terminal is connected to a first access node of the mobile network via a first connection
- 20 and to a second access node via a second connection, wherein the first access node controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal, the method being performed by the first access node and comprising:
- acquiring quality degradation information about a degradation of a quality

25 of at least one of the first connection and the second connection based on a determination whether the quality of at least one of the first connection and the second connection is degraded, and - adapting the mobile network based on the step of acquiring.
- 30 19. A method for adapting a mobile network, wherein a terminal is connected to a first access node of the mobile network via a first connection and to a second access node via a second connection, wherein the first access node

controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal, the method being performed by the second access node and comprising:

- adapting the mobile network based on acquired quality degradation information about a degradation of a quality of at least one of the first connection and the second connection, the acquiring being based on a determination whether a quality of at least one of the first connection and the second connection is degraded.

20. A terminal for adapting a mobile network, wherein the terminal is connected to a first access node of the mobile network via a first connection and to a second access node via a second connection, wherein the first access node controls a data transmission for the terminal and wherein the second access node assists in the data transmission for the terminal, the terminal comprising:

- a determination unit adapted to determining whether a quality of at least one of the first connection and the second connection is degraded,
- an acquiring unit adapted to acquire quality degradation information about the degradation of the quality of at least one of the first connection and the second connection based on the determination for adapting the mobile network based on the acquired quality degradation information.

In particular, the terminal may be adapted to perform a method according to any one of embodiments 1 to 18.

21. An access node for adapting a mobile network, wherein a terminal is connected to the access node of the mobile network via a connection and to another access node via another second connection, wherein the access node controls a data transmission for the terminal and wherein the another access node assists in the data transmission for the terminal, the access node comprising:

- an acquiring unit adapted to acquire quality degradation information about a degradation of a quality of at least one of the first connection and the second connection based on a determination whether the quality of at least one of the first connection and the second connection is degraded, and
- 5 - an adapting unit adapted to adapt the mobile network based on the acquired quality degradation information.

In particular, the access node may be adapted to perform a method according to any one of embodiments 1 to 17 and 19.

10

22. An access node for adapting a mobile network, wherein a terminal is connected to the access node of the mobile network via a connection and to another access node via another connection, wherein the another access node controls a data transmission for the terminal and wherein the access node assists in the data transmission for the terminal, the access node comprising:
- 15 - an adapting unit adapted to adapt the mobile network based on acquired quality degradation information about a degradation of a quality of at least one of the connection and the another connection, the acquiring of the quality degradation unit being based on a determination whether a quality of at least
 - 20 one of the connection and the another connection is degraded.

In particular, the access node may be adapted to perform a method according to anyone of embodiments 1 to 17 and 19.

23. A mobile network, comprising a terminal according to embodiment 20, a
- 25 first access node according to embodiment 21, and a second access node according to embodiment 22.

24. A computer program, which, when being executed by a processor, is adapted to carry out or control a method for handling a terminating circuit
- 30 switched signaling service to a terminal in a mobile network according to any one of embodiments 1 to 19.

It is noted that the above described embodiments related to method according to embodiments 1 to 16 apply to the embodiments related to other methods according to embodiments 17 to 19, the terminal, the first access node, the second access node, a mobile network and the computer programs.

5

Modifications and other embodiments of the disclosed embodiments will come to mind to one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the embodiments are not to be limited to the specific

10 embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of this disclosure. Although specific terms may be employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Abstract

5

Methods, nodes, computer programs and a mobile network for adapting a mobile network are described.

Figure 9

10

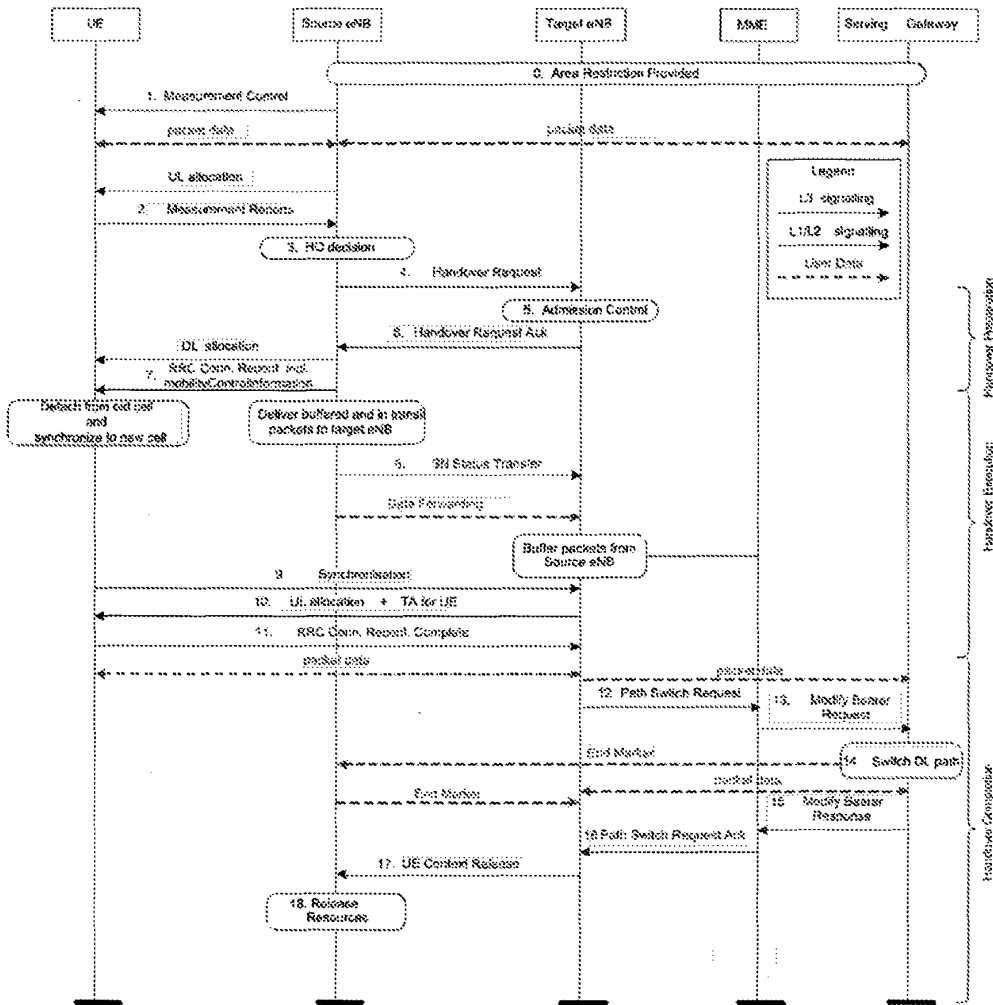


Figure 1

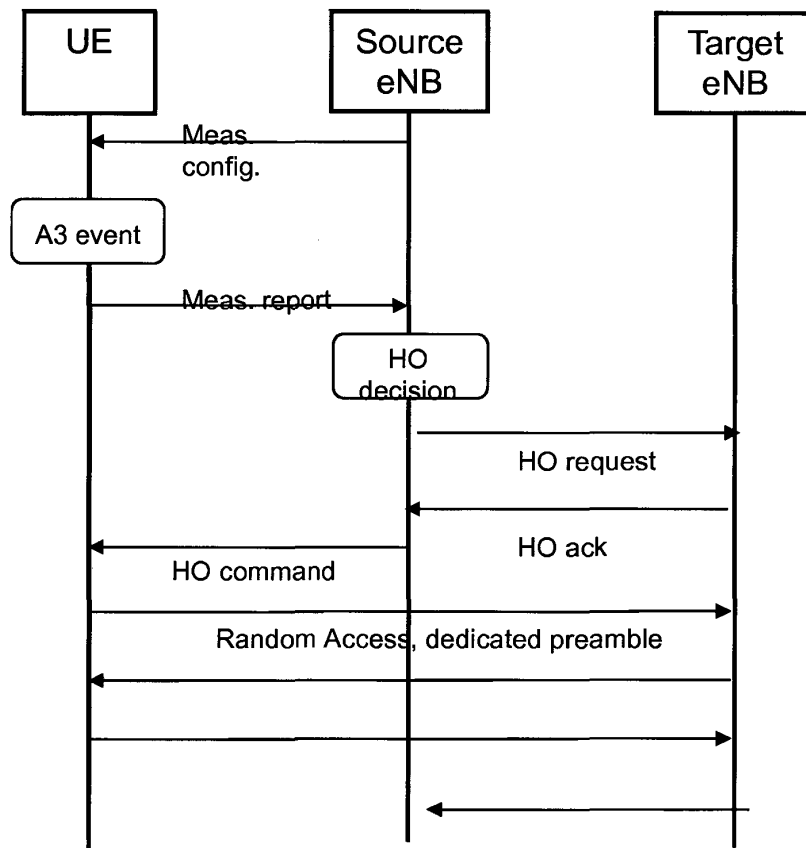


Figure 2

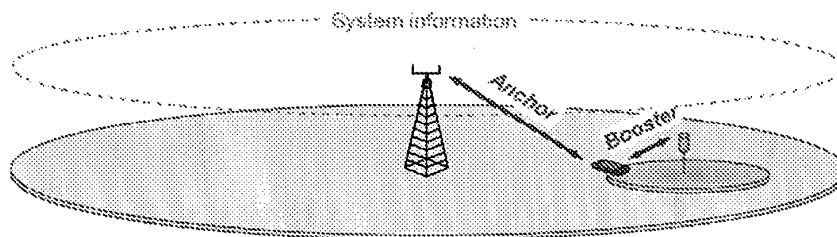


Figure 3

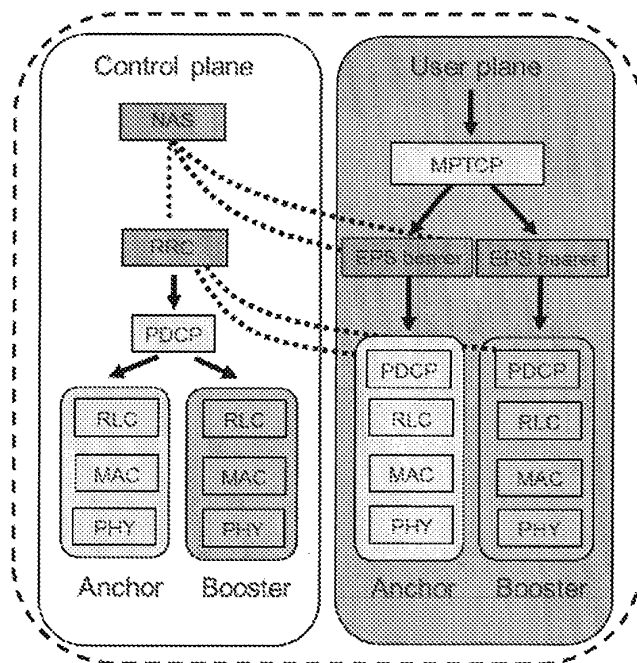


Figure 4

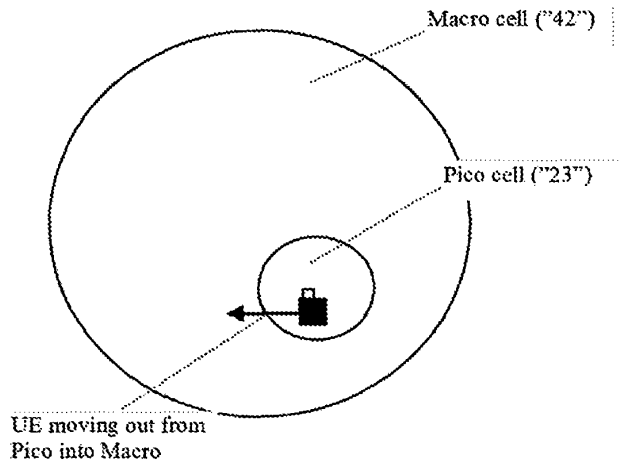


Figure 5

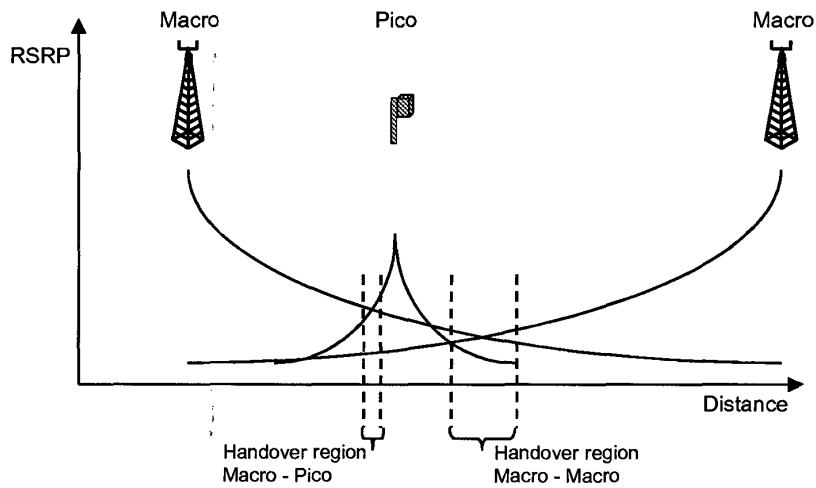


Figure 6

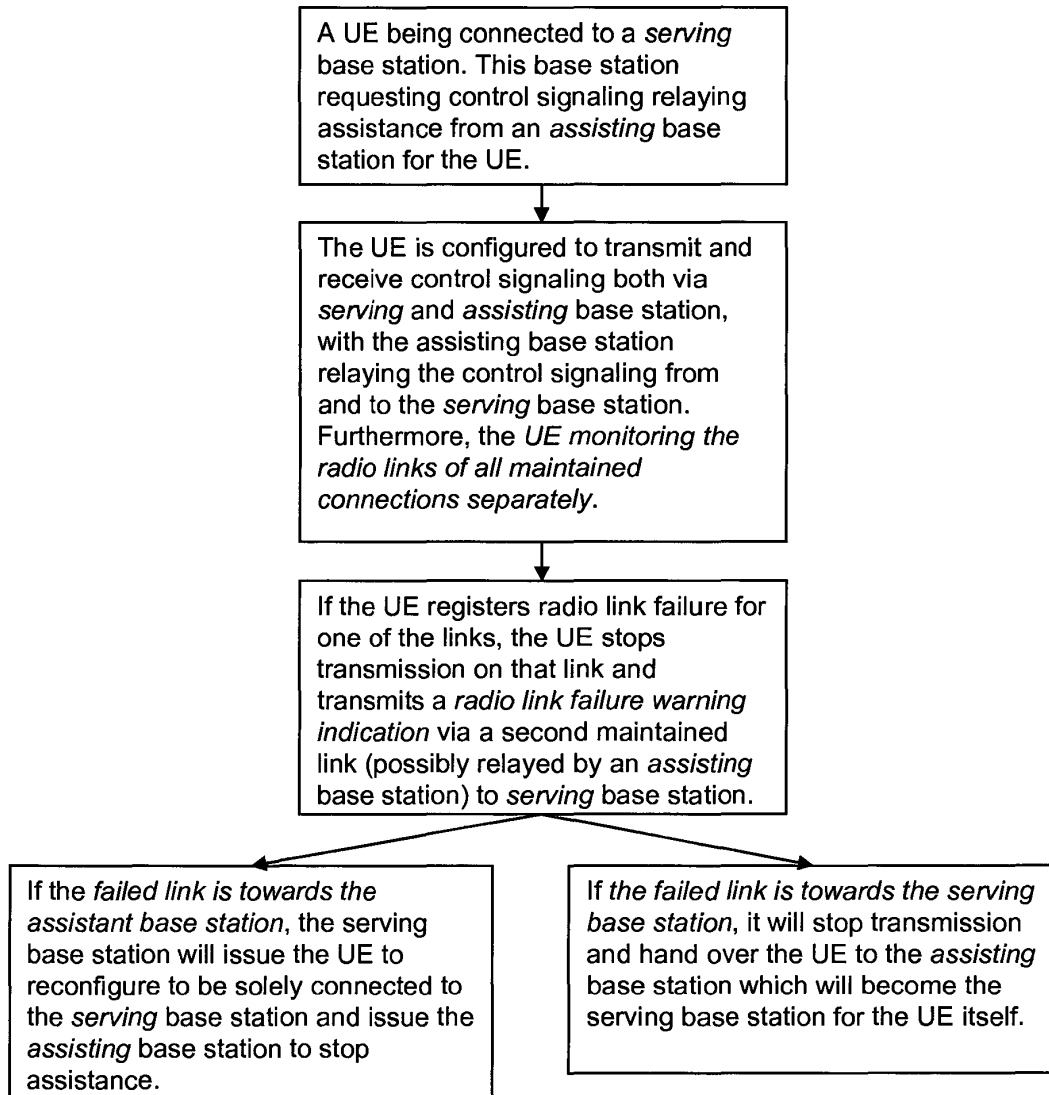


Figure 7

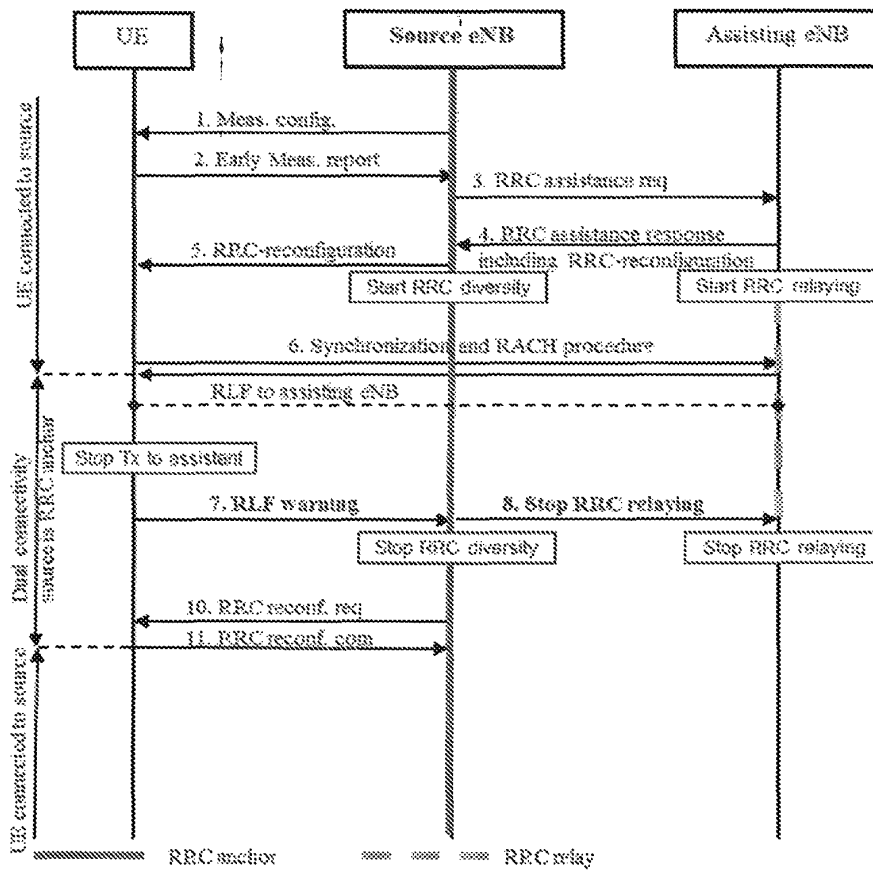


Figure 8

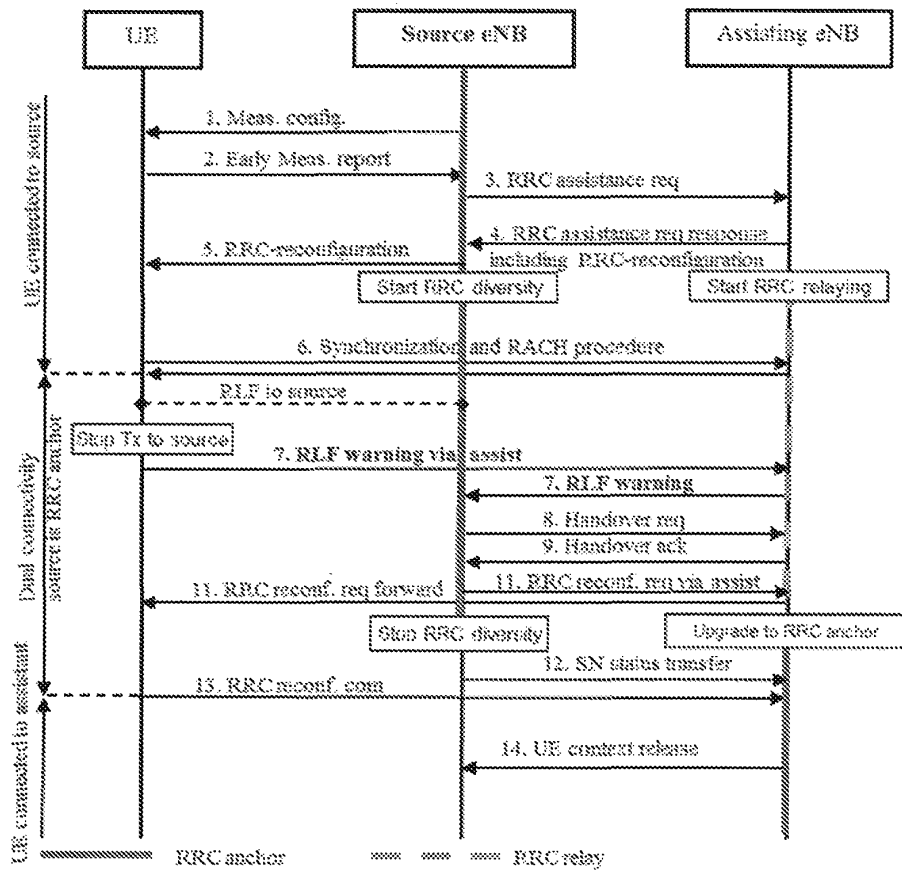


Figure 9

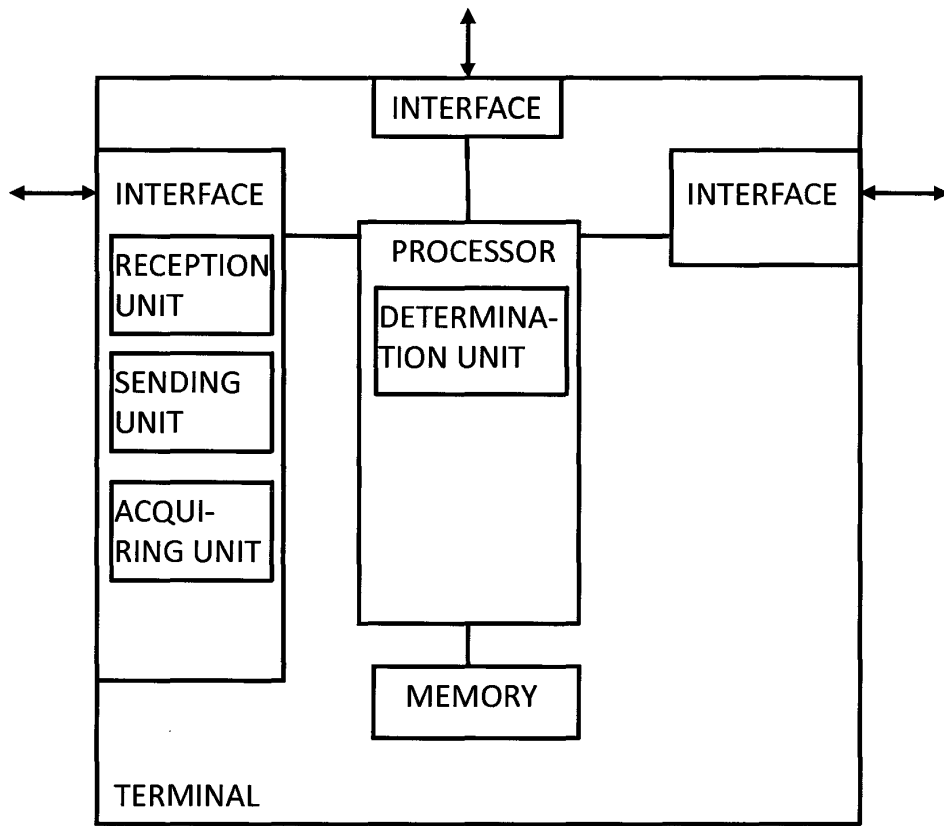


Figure 10

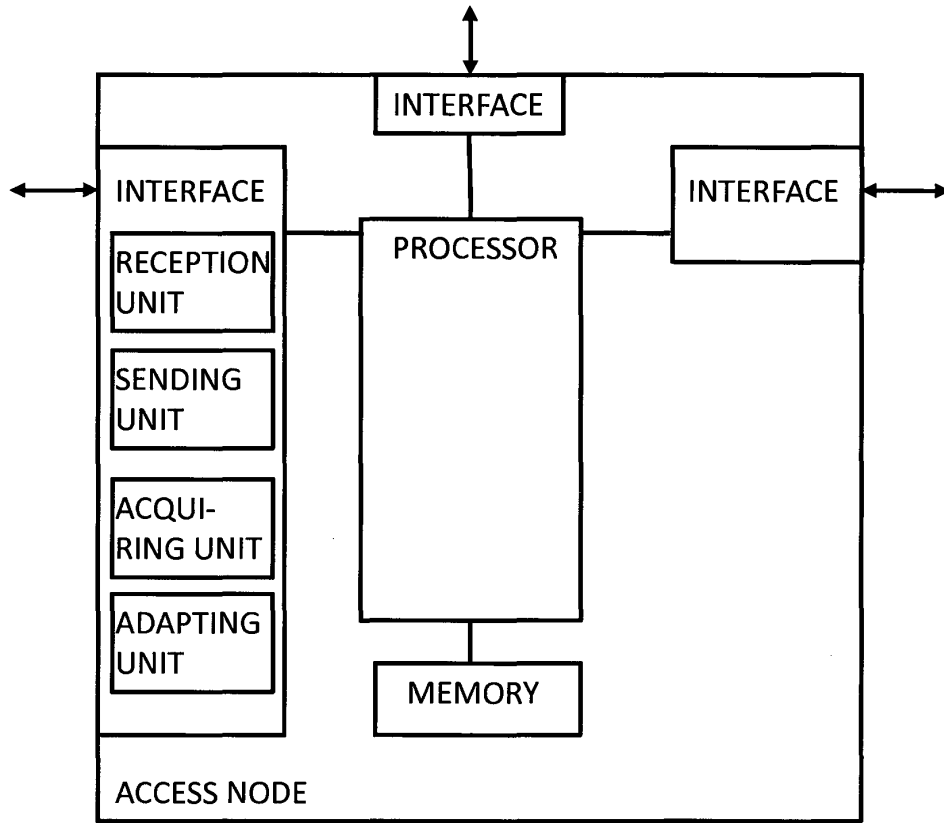


Figure 11

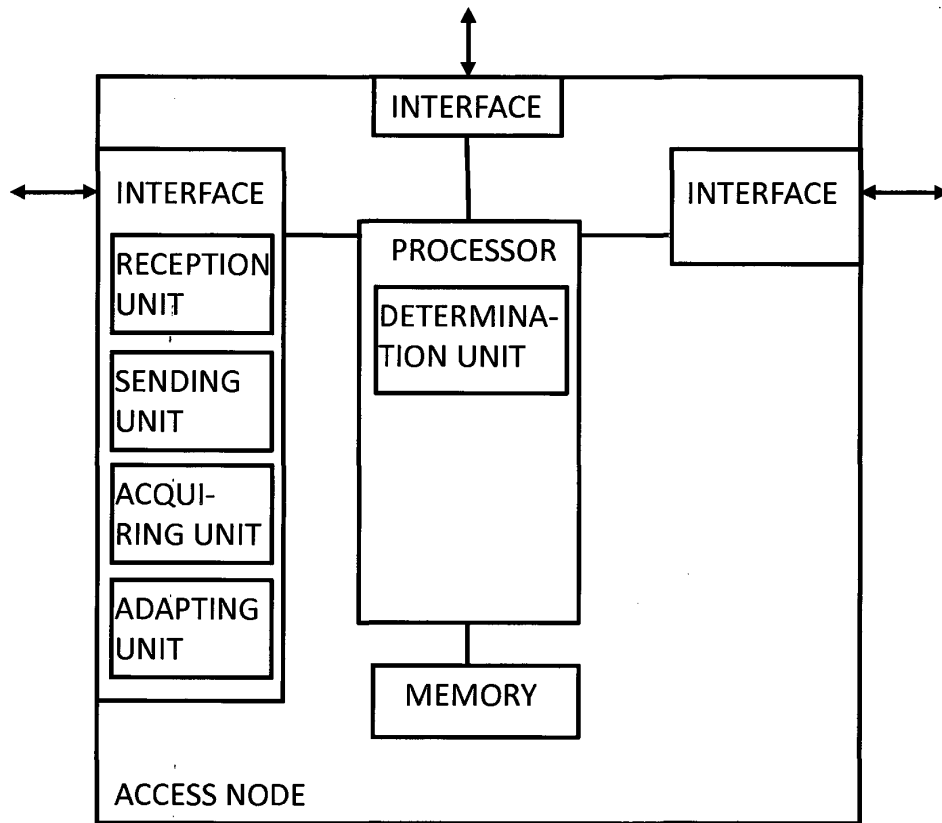


Figure 12