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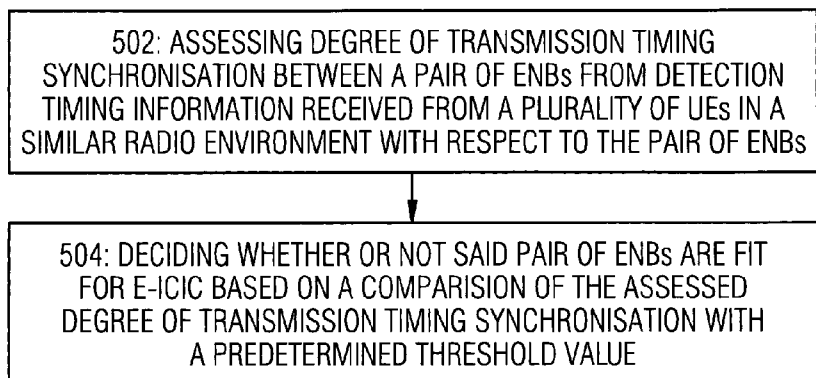
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(54) Title: ASSESSING TIMING SYNCHRONISATION

FIG 4



(57) Abstract: A technique comprising, assessing at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.



ASSESSING TIMING SYNCHRONISATION

An access network typically comprises a coordinated collection of transceiver nodes whose coordinated operation can rely on a close degree of transmission timing synchronisation between the transceiver nodes.

A conventional technique aimed at achieving good transmission timing synchronisation involves configuring the transceiver nodes of an access network to make their transmissions with reference to external timing signals such as GPS timing signals or internet protocol (IP) communications according to the IEEE 1588 precision time protocol.

The inventors for the present application have identified advantages in assessing the actual degree of timing synchronisation between transceiver nodes of the access network, and have identified the challenge of providing a mechanism for assessing the actual degree of transmission timing synchronisation between transceiver nodes of the access network.

There is hereby provided a method comprising, assessing at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.

According to one embodiment, wherein said timing information includes information from one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes.

According to one embodiment, said timing information includes information from said one or more communication devices about one or more respective measurements at

said one or more communication devices of the respective detection time difference between detecting reference signals from said two transmission nodes.

According to one embodiment, said timing information includes information from a plurality of communication devices about one or more respective measurements at said plurality of communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes; and the method further comprises calculating an average detection time difference for the two transmission nodes from the plurality of time difference measurements received from the plurality of communication devices; and using said calculated average detection time difference as an indicator of the degree of transmission timing synchronisation between two transmission nodes.

According to one embodiment, the method further comprises deciding whether to adopt a coordinated operation mode for said two transmission nodes at least partly on the basis of the result of said assessing the degree of transmission timing synchronisation between said two transmission nodes.

According to one embodiment, said coordinated operation mode comprises muting one of said transmission nodes at predetermined times.

According to one embodiment, the method further comprises triggering a correction to the transmission timing of least one of said two transmission nodes if the degree of transmission timing synchronisation between two transmission nodes is assessed to be below a predetermined threshold.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: assess at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.

According to one embodiment, said timing information includes information from one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes.

According to one embodiment, said timing information includes information from said one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting reference signals from said two transmission nodes.

According to one embodiment, said timing information includes information from a plurality of communication devices about one or more respective measurements at said plurality of communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes; and the memory and computer program code are further configured to, with the processor, cause the apparatus to: calculate an average detection time difference for the two transmission nodes from the plurality of time difference measurements received from the plurality of communication devices; and use said calculated average detection time difference as an indicator of the degree of transmission timing synchronisation between two transmission nodes.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: decide whether to adopt a coordinated operation mode for said two transmission nodes at least partly on the basis of the result of said assessing the degree of transmission timing synchronisation between said two transmission nodes.

According to one embodiment, said coordinated operation mode comprises muting one of said transmission nodes at predetermined times.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: trigger a correction to the transmission timing of least one of said two transmission nodes if the degree of

transmission timing synchronisation between two transmission nodes is assessed to be below a predetermined threshold.

There is also hereby provided a computer program product comprising program code means which when loaded into a computer controls the computer to: assess at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.

Embodiments of the present invention are described in detail hereunder, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates an example of an access network in which embodiments of the present invention are implemented;

Figure 2 illustrates an example of apparatus for use at user equipment in Figure 1;

Figure 3 illustrates an example of apparatus for use at the eNodeBs in Figure 1;

Figures 4 and 5 illustrate examples of operations at the access network in accordance with an embodiment of the present invention.

Embodiments of the invention are described in detail below, by way of example only, in the context of a cellular network operating in accordance with an E-UTRAN standard.

Figure 1 illustrates an example of an access network in which embodiments of the present invention can be implemented. The access network includes an array of macro eNodeBs (eNBs) 2 each operating one or more cells. Only eight macro eNBs are shown in Figure 1, but a mobile telecommunication network will typically comprise thousands of macro eNBs 2. The access network also includes other non-macro eNBs 4 (such as e.g. femto eNBs and pico eNBs) that operate cells whose coverage areas are smaller than the cells of the macro eNBs 2, and which typically overlap with the coverage areas of one or more cells of one or more macro eNBs 2. Figure 1 only shows three non-macro eNBs in the vicinity of UE 8, but an access network will typically contain a large number of non-macro eNBs. Due to the combination of access nodes with different coverage areas in the network, such

networks are typically denoted heterogeneous networks (HetNet). Also, Figure 1 only shows one UE 8, but the combined coverage area of the access network will typically be occupied by a large number of UEs, each served by one of the eNBs. Each of the eNBs 2, 4 is connected by a wired link to a core network (not shown) of the access network.

Figure 2 shows a schematic view of an example of user equipment 8 that may be used for communicating with the eNBs 2, 4 of Figure 1 via a wireless interface. The user equipment (UE) 8 may be used for various tasks such as making and receiving phone calls, for receiving and sending data from and to a data network and for experiencing, for example, multimedia or other content.

The UE 8 may be any device capable of at least sending or receiving radio signals to or from the eNBs 2, 4 of Figure 1. Non-limiting examples include a mobile station (MS), a portable computer provided with a wireless interface card or other wireless interface facility, personal data assistant (PDA) provided with wireless communication capabilities, or any combinations of these or the like. The UE 8 may communicate via an appropriate radio interface arrangement of the UE 8. The interface arrangement may be provided for example by means of a radio part and associated antenna arrangement. The antenna arrangement may be arranged internally or externally to the UE 8, and may include a plurality of antennas capable of operating in the kind of multi-layer transmission scheme described below.

The UE 8 may be provided with at least one data processing entity 203 and at least one memory or data storage entity 217 for use in tasks it is designed to perform. The data processor 213 and memory 217 may be provided on an appropriate circuit board 219 and/or in chipsets.

The user may control the operation of the UE 8 by means of a suitable user interface such as key pad 201, voice commands, touch sensitive screen or pad, combinations thereof or the like. A display 215, a speaker and a microphone may also be provided. Furthermore, the UE 8 may comprise appropriate connectors (either wired or wireless) to other devices and/or for connecting external accessories, for example hands-free equipment, thereto.

UE 8 may also be a relay node configured to relay transmissions from eNB 2 to one or more communication devices.

Figure 3 shows an example of apparatus for use at the eNBs 2, 4 of Figure 1. The apparatus comprises a radio frequency antenna array 301 configured to receive and transmit radio frequency signals; radio frequency interface circuitry 303 configured to interface the radio frequency signals received and transmitted by the 8-antenna array 301 and the data processor 306. The radio frequency interface circuitry 303 may also be known as a transceiver. The apparatus also comprises an interface 309 via which it can send and receive information to and from one or more other network nodes. The data processor 306 is configured to process signals from the radio frequency interface circuitry 303, control the radio frequency interface circuitry 303 to generate suitable RF signals to communicate information to the UE 8 via the wireless communications link, and also to exchange information with other network nodes via the interface 309. The memory 307 is used for storing data, parameters and instructions for use by the data processor 306.

It would be appreciated that the apparatus shown in each of figures 2 and 3 described above may comprise further elements which are not directly involved with the embodiments of the invention described hereafter.

With the aim of achieving good synchronisation of the timing of downlink transmissions in the access network, the eNBs 2, 4 are configured to time their downlink transmissions with reference to external timing signals such as GPS timing signals or internet protocol (IP) communications according to the IEEE 1588 precision time protocol.

At the request of the serving eNB, UE 8 provides the serving eNB with time difference information about the time difference between detecting, at UE 8 from e.g. three eNBs, signals that should have been made at the same time from each of the e.g. three eNBs 2, 4 (including the serving eNB). This time difference information can, for example, be provided by RRC (Radio Resource Control) signalling.

This detection time difference information provides serving eNB with an indicator of the degree of transmission timing synchronisation between any two of the e.g. three eNBs. In a typical cellular network (where any cell extends no more than about 2km from the operating eNB, and often no more than about 1km from the operating eNB), the measured detection time difference for any two eNBs will differ from the actual transmission time difference between those two eNBs by no more than about 7 microseconds; and this degree of accuracy is sufficient for some purposes, such as those discussed below.

Where necessary, an even more accurate indicator of the transmission timing difference between two eNBs can be obtained by requesting a measurement of the detection time difference for those two transmission nodes from a plurality of UEs that are in the same kind of radio environment with respect to those two eNBs (e.g. whose radio links with the two eNBs exhibit similar average path loss differences, and/or for which the difference in detected reference signal received power (RSRP) is similar), and using an average of the plurality of measurements from the plurality of UEs as an indicator of the degree of transmission timing synchronisation between the two eNBs.

Reference signal time difference (RSTD) measurements of the kind already used for the different purpose of determining the position of an UE (by Observed Time Difference Of Arrival (OTDOA) Positioning) is one example of detection time difference information that the serving eNB could use to assess the degree of transmission timing synchronisation between two eNBs. One example of RSTD measurements is described at Section 9.1.10 of 3GPP TS 36.133 V.10.7.0. In one example, each RSTD measurement indicates the OTDOA for a cell not operated by the serving eNB and a cell operated by the Serving eNB (i.e. the cell via which UE has established a RRC connection with the serving eNB) as a reference cell. The OTDOA for two cells other than the reference cell can be calculated from the RSTD measurements for those two cells.

UE Rx-Tx time difference measurements of the kind already used for the different purpose of determining the position of an UE (by Enhanced Cell-ID (E-CID) Positioning) is another example of detection time difference information that the

serving eNB could use to assess the degree of transmission timing synchronisation between two eNBs. UE Rx-Tx time difference measurements are measurements at a UE of the time difference between detecting a reference signal at the UE and making a transmission from the UE to the serving eNB. The serving eNB can assess the degree of transmission timing synchronisation for any pair of eNBs whose reference signals are detected by the UE, by requesting the UE to make and report respective UE Rx-TX time difference measurements for cells of that pair of eNBs for transmissions (e.g. reference signals) that should have been transmitted from that pair of eNBs at the same time. One example of UE Rx-TX time difference measurements is described at Section 9.1.9 of 3GPP TS 36.133 Version 10.7.0.

One example of a way in which the serving eNB could advantageously use this assessment of the degree of transmission synchronisation is to use it to at least assist a decision as to whether a pair of eNBs are fit for an inter-eNB operation that requires tight time synchronisation between eNBs. One example of such an operation is Time-Domain Enhanced Inter-Cell Interference Coordination (TDM eICIC). TDM eICIC is an operation mode aimed at enhancing the operation of an eNB. For example, the effective coverage area of a non-macro eNB in the vicinity of a macro eNB can be enhanced by configuring the macro eNB to mute a set of subframes in the time domain. For this period of muting, there can be observed a large reduction in the downlink interference observed by UEs served by the non-macro eNB, particularly those close to the edge of the coverage area of the non-macro eNB. Another example of using eICIC is to enhance the performance of a macro eNB whose coverage area overlaps with the coverage area of a non-macro eNB (such as a closed subscriber group (CSG) Home eNB (HeNB)) at a location close to the edge of the coverage area of the macro eNB. Muting such a non-macro eNB for some sub-frames can enhance the capability of the macro eNB to serve UEs that happen to be within the coverage area of the non-macro eNB. With reference to Figure 5, the serving eNB estimates the degree of transmission timing synchronisation for a pair of eNBs that are under consideration for eICIC (STEP 502), and makes a decision about whether the pair of eNBs are fit for eICIC at least partly on the basis of a comparison of the estimate with a predetermined threshold value (STEP 504). The degree of accuracy at which the transmission timing synchronisation can be assessed using the technique described above is sufficient

for the purposes of determining whether or not two eNBs are sufficiently synchronised for eICIC.

Another example of a way in which the serving eNB could advantageously use the estimate of the degree of transmission synchronisation is to alert the operation and management (O&M) system of the access network to what are determined to be synchronisation failures in the access network. For example, the serving eNB could determine that a synchronisation failure has occurred when the estimate of the degree of synchronisation between a pair of eNBs falls below a predetermined threshold value. With reference to Figure 5, the serving eNB continually estimates the degree of transmission timing synchronisation for each pair of eNBs for which it has a sufficient amount of timing information from UEs served by the serving eNB (STEP 602), and alerts O&M system to a synchronisation failure (STEP 606), if the result of a comparison of an estimated value with a predetermined threshold value (STEP 604) is negative. In response to such an alert, the O&M system could, for example, restart an eNB whose transmission timing is determined to be poor, and/or reconfigure the eNB to time its transmissions with reference to a different external timing signal.

The above-described operations may require data processing in the various entities. The data processing may be provided by means of one or more data processors. Similarly various entities described in the above embodiments may be implemented within a single or a plurality of data processing entities and/or data processors. Appropriately adapted computer program code product may be used for implementing the embodiments, when loaded to a computer. The program code product for providing the operation may be stored on and provided by means of a carrier medium such as a carrier disc, card or tape. A possibility is to download the program code product via a data network. Implementation may be provided with appropriate software in a server.

For example the embodiments of the invention may be implemented as a chipset, in other words a series of integrated circuits communicating among each other. The chipset may comprise microprocessors arranged to run code, application specific

integrated circuits (ASICs), or programmable digital signal processors for performing the operations described above.

Embodiments of the invention may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

Programs, such as those provided by Synopsys, Inc. of Mountain View, California and Cadence Design, of San Jose, California automatically route conductors and locate components on a semiconductor chip using well established rules of design as well as libraries of pre stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

In addition to the modifications explicitly mentioned above, it will be evident to a person skilled in the art that various other modifications of the described embodiment may be made within the scope of the invention.

CLAIMS

1. A method comprising, assessing at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.
2. A method according to claim 1, wherein said timing information includes information from one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes.
3. A method according to claim 2, wherein said timing information includes information from said one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting reference signals from said two transmission nodes.
4. A method according to any of claims 1 to 3, wherein said timing information includes information from a plurality of communication devices about one or more respective measurements at said plurality of communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes; and further comprising calculating an average detection time difference for the two transmission nodes from the plurality of time difference measurements received from the plurality of communication devices; and using said calculated average detection time difference as an indicator of the degree of transmission timing synchronisation between two transmission nodes.
5. A method according to any preceding claim, comprising: deciding whether to adopt a coordinated operation mode for said two transmission nodes at least partly on the basis of the result of said assessing the degree of transmission timing synchronisation between said two transmission nodes.

6. A method according to claim 5, wherein said coordinated operation mode comprises muting one of said transmission nodes at predetermined times.
7. A method according to any of claims 1 to 4, comprising triggering a correction to the transmission timing of least one of said two transmission nodes if the degree of transmission timing synchronisation between two transmission nodes is assessed to be below a predetermined threshold.
8. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: assess at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.
9. An apparatus according to claim 8, wherein said timing information includes information from one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes.
10. An apparatus according to claim 9, wherein said timing information includes information from said one or more communication devices about one or more respective measurements at said one or more communication devices of the respective detection time difference between detecting reference signals from said two transmission nodes.
11. An apparatus according to any of claims 8 to 10, wherein said timing information includes information from a plurality of communication devices about one or more respective measurements at said plurality of communication devices of the respective detection time difference between detecting transmissions from said two transmission nodes; and wherein the memory and computer program code are

further configured to, with the processor, cause the apparatus to: calculate an average detection time difference for the two transmission nodes from the plurality of time difference measurements received from the plurality of communication devices; and use said calculated average detection time difference as an indicator of the degree of transmission timing synchronisation between two transmission nodes.

12. An apparatus according to any of claims 8 to 11, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: decide whether to adopt a coordinated operation mode for said two transmission nodes at least partly on the basis of the result of said assessing the degree of transmission timing synchronisation between said two transmission nodes.

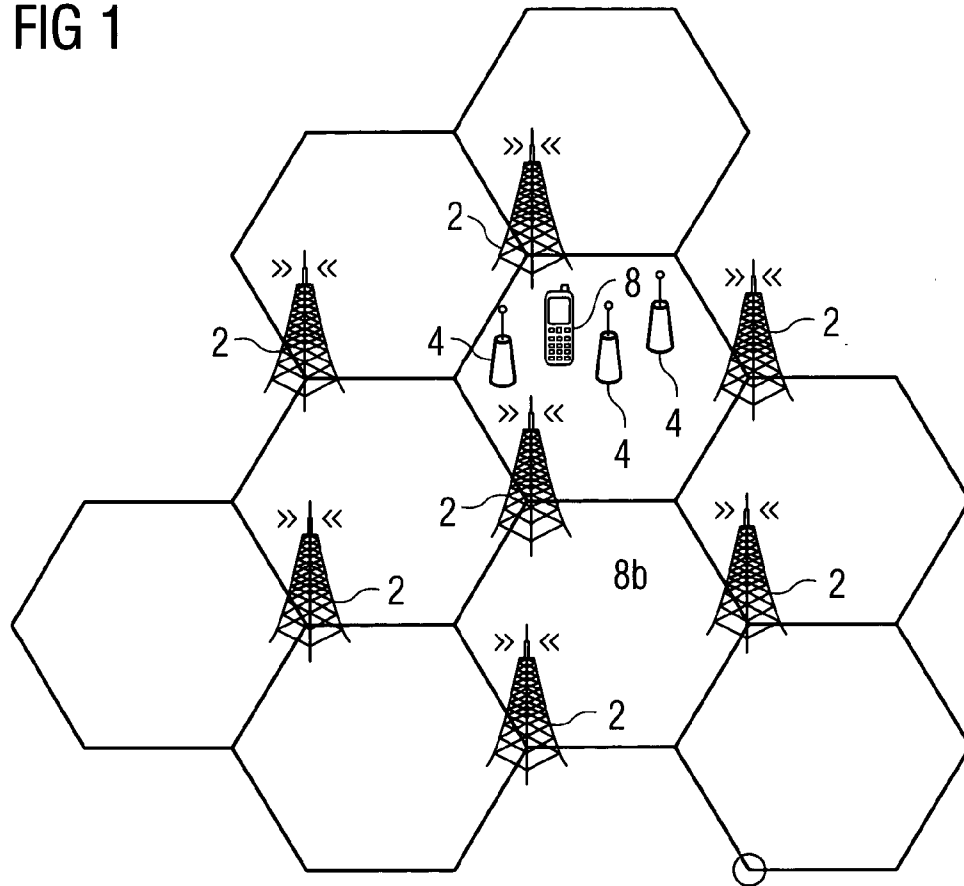
13. An apparatus according to claim 12, wherein said coordinated operation mode comprises muting one of said transmission nodes at predetermined times.

14. An apparatus according to any of claims 8 to 11, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: trigger a correction to the transmission timing of least one of said two transmission nodes if the degree of transmission timing synchronisation between two transmission nodes is assessed to be below a predetermined threshold.

15. A computer program product comprising program code means which when loaded into a computer controls the computer to: assess at an access network a degree of transmission timing synchronisation between two transmission nodes, from timing information received at said access network from one or more communication devices detecting transmissions by said two transmission nodes.

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FIG 1



2/3

FIG 2

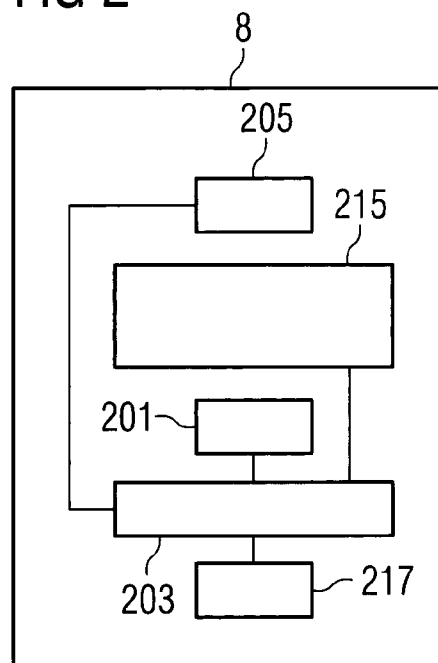
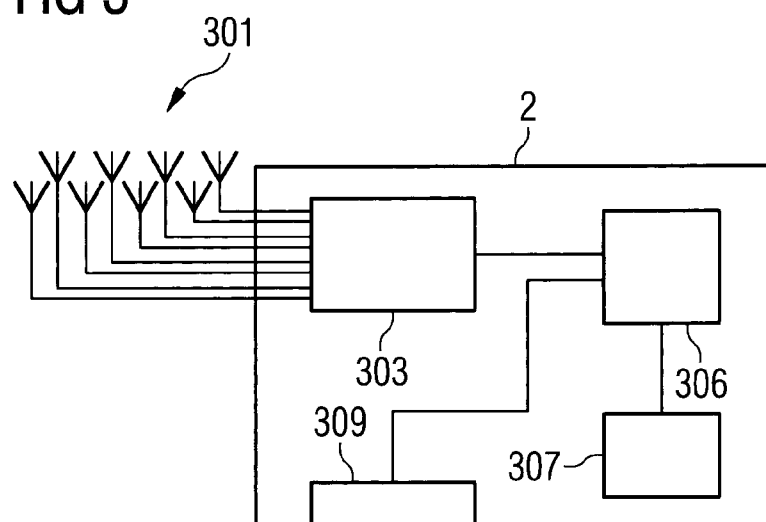


FIG 3



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FIG 4

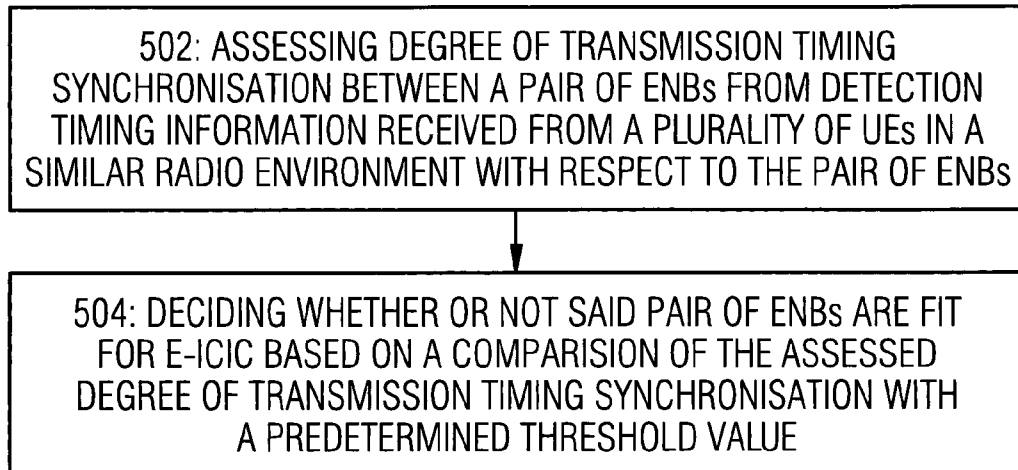
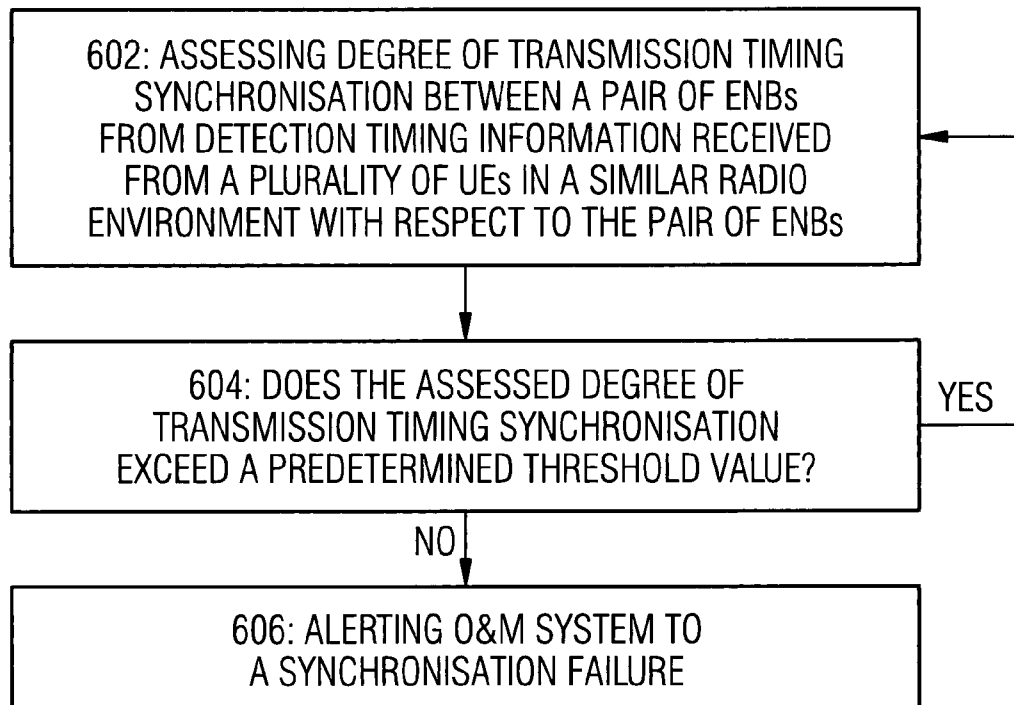


FIG 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/068960

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W56/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LG ELECTRONICS: "Methods to facilitate the inter-cell coordination in heterogeneous networks", 3GPP DRAFT; R1-105358 COORDINATION METHOD, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Xi'an; 20101011, 5 October 2010 (2010-10-05), XP050450509, [retrieved on 2010-10-05]	1,4-8, 11-15
Y	paragraph [02.1]; figures 1,2 ----- -/-	2,3,9,10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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Date of mailing of the international search report

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Name and mailing address of the ISA/

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Bohnhoff, Peter

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/068960

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements (Release 11)", 3GPP STANDARD; 3GPP TS 36.214, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. V11.0.0, 18 September 2012 (2012-09-18), pages 1-14, XP050649203, [retrieved on 2012-09-18] paragraphs [0004], [5.1.12] -----	2,3,9,10
A	LG ELECTRONICS: "Comparison of Time-domain eICIC Solutions", 3GPP DRAFT; R1-104661 TIME DOMAIN EICIC, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Madrid, Spain; 20100823, 17 August 2010 (2010-08-17), XP050449939, [retrieved on 2010-08-17] page 1 - page 8 -----	1-15
A	ERICSSON: "Summary of the offline discussion about exchanging synchronization info between eNBs", 3GPP DRAFT; R3-110286, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG3, no. Dublin, Ireland; 20110117, 11 January 2011 (2011-01-11), XP050497224, [retrieved on 2011-01-11] paragraph [0001] - paragraph [0003] -----	1-15