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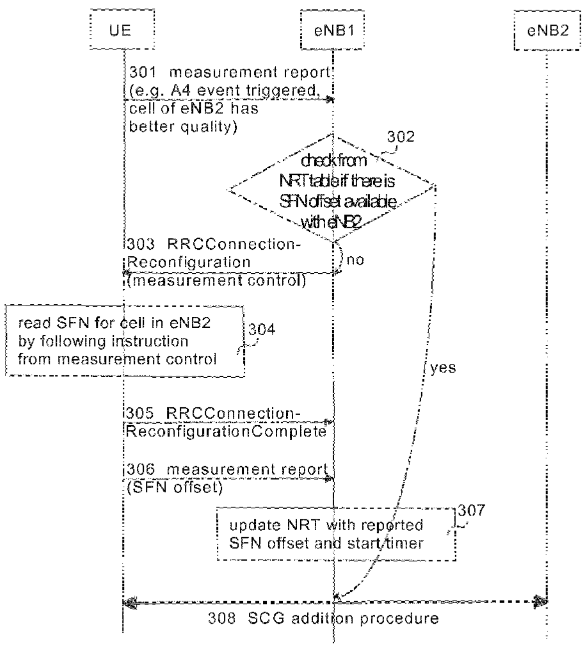

Fig. 3

(57) Abstract: A network node stores dual connectivity capability information on a cell, a system frame number offset for each neighbouring dual connectivity capable cell, and optionally a system frame number offset timer. If required, the network node requests (303) a terminal device to provide a system frame number offset for a secondary base station, and acquires (306), from the terminal device, a report message comprising information indicating the updated system frame number offset for the secondary base station.

WO 2016/020000 A1

DESCRIPTION

TITLE

SIGNALLING OF SYSTEM FRAME NUMBER OFFSET

TECHNICAL FIELD

The invention relates to the field of cellular communication systems and, particularly, signalling of system frame number offset.

BACKGROUND

A communication system may be seen as a facility that enables communication sessions between two or more nodes such as fixed or mobile communication devices, access points such as nodes, base stations, servers, hosts, machine type servers, routers, and so on. A communication system and compatible communicating devices typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. For example, the standards, specifications and related protocols may define the manner how communication devices communicate with the access points, how various aspects of the communications are implemented and how the devices and functionalities thereof are configured.

An example of cellular communication systems is an architecture that is being standardized by the 3rd generation partnership project (3GPP). A recent development in this field is often referred to as the long-term evolution (LTE) or long-term evolution advanced (LTE advanced) of the universal mobile telecommunications system (UMTS) radio-access technology. In LTE, base stations providing the cells are commonly referred to as enhanced node-Bs (eNB). eNBs may provide coverage for an entire cell or similar radio service area.

BRIEF DESCRIPTION

The invention is defined by the independent claims.

Embodiments are defined in the dependent claims.

Although the various aspects, embodiments and features of the invention are recited independently, it should be appreciated that all combinations of the various aspects, embodiments and features of the invention are possible and within the scope of the present invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which

Figure 1 is illustrates a wireless communication system to which embodiments of the invention may be applied;

Figure 2 illustrates a signalling diagram of a procedure for exchanging dual connectivity capability information according to an embodiment of the invention;

Figure 3 illustrates a signalling diagram of a procedure for secondary base station addition according to an embodiment of the invention;

Figure 4 illustrates a signalling diagram of a procedure for updating system frame number offset information according to an embodiment of the invention;

Figures 5-10 illustrate processes for frame number offset handling according to an embodiment of the invention;

Figures 11 and 12 illustrate blocks diagrams of apparatuses according to some embodiments of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

The following embodiments are exemplary. Although the specification may refer to “an”, “one”, or “some” embodiment(s) in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words “comprising” and “including” should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

Figure 1 illustrates a wireless communication scenario to which embodiments of the invention may be applied. Referring to Figure 1, a cellular communication system may comprise a radio access network comprising base stations disposed to provide radio coverage in a determined geographical area. The base stations may comprise macro cell base stations 102 arranged to provide terminal devices 104, 106 with the radio coverage over a relatively large area spanning even over several square miles, for example. In densely populated hotspots where improved capacity is required, small area cell base stations 100 may be deployed to provide terminal devices 104 with high data rate services. Such small area cell base stations may be called micro cell base stations, pico cell base stations, or femto cell base stations. The small area cell base stations typically have significantly smaller coverage area than the macro base stations 102. The cellular communication system may operate according to specifications of the 3rd generation partnership project (3GPP) long term evolution (LTE) advanced or its evolution version.

Dual connectivity in higher layer enhancements for small cells refers to a technique where the terminal device is simultaneously able to be connected with a master base station (e.g. a macro base station, abbreviated as MeNB) and a secondary base station (e.g. a small cell base station, abbreviated as SeNB) to achieve throughput and mobility robustness gains. A single RRC between MeNB and the terminal device is a baseline assumption for control plane architecture for the dual connectivity. Since some system functionality depends on a system number frame (SFN) of the base station, and dual connectivity is supposed to be applicable to networks where SFNs are not aligned between MeNB and SeNB, coordination between MeNB and SeNB is required for good operation of the system. Therefore, in order to e.g. align DRX occasions or measurement gaps between MeNB and SeNB, SeNB is to be able to acquire an SFN offset to MCG of the terminal device.

In 3GPP RAN2, in order SeNB to acquire the SFN offset, the terminal device acquires MIB on PSCell to get SFN of SCG and to learn the offset between SFN on MCG and SFN on SCG (if any). The SFN offset measured by UE may then be reported from UE to MeNB which may then report the offset to SeNB. Alternatively, the SFN offset may be acquired by a network based mechanism and be conveyed to SeNB via an X2 procedure.

For a terminal device reporting approach, when the terminal device starts the acquisition of SFN from a broadcast channel of the cell in SeNB and how the terminal device reports the SFN offset, the overall signaling overhead and the latency may impact at least the initial establishment of the dual connectivity significantly. For example, if the terminal device acquires SFN of SeNB by following a legacy HO procedure, which means the terminal device starts reading MIB of the cell in SeNB after a successful RA procedure during SeNB addition, SeNB may not get the SFN offset in time for configuring DRX. In this case, additional SeNB modification procedure may be needed to inform the terminal device about the DRX configuration after SeNB gets the reported SFN offset. These aspects cause additional X2/Uu signaling and increase the latency for the dual connectivity operation.

Modern cellular communication systems are wideband systems where a large bandwidth may be scheduled to a single terminal device for the transmission of data. The scheduled resources may be indicated in terms of physical resource blocks or frequency resource blocks. Each frequency resource block has a determined bandwidth and a centre frequency and one or more frequency resource blocks may be scheduled to the terminal device at a time. The frequency resource blocks scheduled to the terminal device may be contiguous and, thus, form a continuous scheduled band for the terminal device. However, the resource blocks may be non-contiguous in which case the form a non-contiguous band fragmented into a plurality of smaller bands.

Let us now describe an embodiment of the invention for determining and signalling system frame number offset parameters with reference to Figures 2, 3 and 4.

Figure 2 illustrates a signalling diagram illustrating a method for signalling dual connectivity capability parameters between base stations of a cellular communication system, e.g. base stations 102 and 106. In another embodiment, the procedure of Figure 2 may be carried out between access nodes or, more generally, network nodes. The network node may be a server computer or a host computer. For example, the server computer or the host computer may generate a virtual network through which the host computer communicates with the terminal device. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer. External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

Referring to Figure 2, an additional IE of dual connectivity capability is exchanged between the macro base station and the secondary base station during a X2 setup procedure (steps 201, 202). Alternatively, the dual connectivity capability information may be exchanged during an eNB configuration update procedure, or obtained by O&M configuration. In block 203, the macro base station updates a corresponding NR in an NRT table based on the received information, but the SFN offset is not available for this neighbour base stationyet. eNB1 and eNB2 are in an eNB role from UE point of view only when the dual connection is configured. At this phase, communication is only between eNB1 and its neighbour eNB2 to exchange the cell capability.

Figure 3 illustrates a signalling diagram illustrating a method for signalling system frame number offset parameters between a base station of a cellular communication system, e.g. base station 100 or 102, and a terminal device of the cellular communication system, e.g. the terminal device 104 or 106. In another embodiment, the procedure of Figure 3 may be carried out between the terminal device and an access node or, more generally, a network node. The network node may be a server computer or a host computer. For example, the server computer or the host computer may generate a virtual network through which the host computer communicates with the terminal device. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer. External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

Referring to Figure 3, for SFN offset handling during a eNB2 addition procedure, the terminal device reports (step 301) a measurement result based on configured reporting criteria, if a quality of the cell belonging to eNB2 is better than a predefined threshold. eNB1 checks (block 302) the corresponding NR in NRT of eNB2, wherein if there is a valid SFN offset available (e.g. a validity timer may be configured to assure that the SFN offset is still valid), eNB1 (as MeNB) may directly initiate the SeNB addition procedure towards eNB2 (step 308). If there is no valid SFN offset available, eNB1 requests (step 303) the terminal device to acquire SFN of the cell to be added by signaling an additional measurement configuration for the terminal device (RRCConnectionReconfiguration). This may be achieved by utilizing an existing measurement configuration for ANR or by adding an additional indicator to the measurement configuration. After receiving the measurement configuration from eNB1, the terminal device starts (block 304) acquiring SFN offset by reading MIB of the requested cell, and responds the measurement configuration in step 305. The order of steps 304 and 305 may be reversed. In step 306, the terminal device reports the measurement result including the SFN offset between PCell of eNB1 and the requested cell of eNB2. If the existing measurement configuration for ANR is used, UEs that are capable to support dual connectivity, report the SFN offset in addition to other ANR related parameters. In step 307, eNB1 updates NR with the reported SFN offset and optionally starts an associated timer. In step 308, if eNB1 (as MeNB) starts an SeNB addition procedure, eNB2 is able to get the SFN offset. Steps 303 to 307 do not necessarily need to happen during an SeNB addition procedure. If eNB decides to perform SFN offset acquisition during the SeNB addition procedure, it may do so, but eNB may also decide to keep the valid SFN offset, for instance. Then eNB may trigger the SFN offset acquisition procedure at any time regardless of the SeNB addition process. The use of the validity timer is optional, and the SFN offset may be valid as long as the offset value is available.

Figure 4 illustrates a signalling diagram illustrating a method for signalling updated system frame number offset parameters between a base station of a cellular communication system, e.g. base station 100 or 102, and a terminal device of the cellular communication system, e.g. the terminal device 104 or 106. In another embodiment, the procedure of Figure 4 may be carried out between the terminal device and an access node or, more generally, a network node. The network node may be a server computer or a host computer. For example, the server computer or the host computer may generate a virtual network through which the host computer communicates with the terminal device. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer. External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

Referring to Figure 4, in response to the SFN offset associated timer of NR in NRT expiring (block 401), eNB1 requests, in step 402, the terminal device to acquire the SFN offset of the cell corresponding to NR, by signaling an additional indicator when configuring the measurement for the terminal device (RRCConnectionReconfiguration). eNB1 may request the terminal device to acquire the SFN offset of the cell corresponding to NR at any time based on other criteria regardless of the status of any validity timer for the SFN offset. After receiving the measurement configuration from the base station, the terminal device may start (block 403) acquiring SFN by reading MIB of the indicated cell in the measurement configuration, and responds the measurement configuration in step 404. The order of steps 403 and 404 may be reversed. In steps 405, the terminal device reports to eNB1 the measurement result including the SFN offset between PCell of eNB1 and the requested cell of eNB2. eNB1 updates (block 406) NR with the reported SFN offset and optionally re-starts the associated timer. In step 407, an SeNB modification procedure is triggered to inform the updated SFN offset to eNB2.

eNB2 gets the accurate SFN offset during the initial SeNB addition procedure and periodically maintains the accurate SFN offset to keep the parameter configuration (DRX, measurement gap, etc.) aligned with eNB1 in the dual connectivity. Further, the SFN offset is determined via the ANR-like terminal device action where the terminal device reads and reports the SFN difference to eNB1 or eNB2. The management of an existing NRT is enhanced to assist the acquisition of the SFN offset from the terminal device (while in an existing ANR procedure, eNB manages NRT to maintain the key parameters of the neighboring cell).

In an embodiment, the SFN offset is reported by the terminal device such that SeNB gets the SFN offset reliably and timely to keep the configuration of the required parameters aligned with MeNB and to avoid unnecessary message exchanges over X2 and Uu interfaces.

In an embodiment, an additional measurement configuration (indicator) is established during the RRC procedure to request the SFN offset of the requested cell. The SFN offset is added in the measurement report of the requested cell.

In an embodiment, a dual connectivity capability parameter is added for NR of NRT maintained in eNB. The SFN offset parameter, and optionally an associated timer parameter, are only needed for a dual connectivity capable eNB.

In an embodiment, during the X2 setup procedure or an eNB configuration update procedure, eNBs may exchange the dual connectivity capability via the X2 procedure.

In an embodiment, MeNB updates the corresponding NR in an NRT table based on the received information.

In an embodiment, for SFN offset handling during the SeNB addition procedure, the terminal device reports the measurement result based on the configured reporting criteria, if a quality of the cell belonging to SeNB is better than a predefined threshold.

In an embodiment, MeNB checks the corresponding NR in NRT of SeNB, wherein if there is a valid SFN offset available and an associated timer is still running, MeNB may directly initiate the SeNB addition procedure towards the SeNB.

In an embodiment, if there is no valid SFN offset available or the associated timer has expired, MeNB requests the terminal device to acquire SFN of the cell to be added by signaling an additional indicator when configuring the measurement for the terminal device (RRCConnectionReconfiguration).

In an embodiment, after receiving the measurement configuration from eNB, the terminal device starts acquiring SFN by reading MIB of the configured cell.

In an embodiment, the terminal device reports the measurement result including the SFN offset between PCell of MeNB and the requested cell of SeNB.

In an embodiment, MeNB updates NR with the reported SFN offset and optionally starts an associated timer.

In an embodiment, an SeNB addition procedure is triggered by which SeNB is able to get the SFN offset.

In an embodiment, as the SFN offset may change in time, the SFN offset may be regularly updated to maintain synchronization accuracy, e.g. at predetermined time intervals, or the updating may be triggered by MeNB internal decisions. The updating may be implementation specific, and MeNB may decide the timer based on the practical synchronization situation.

In an embodiment, when the SFN offset associated timer of NR in NRT expires, MeNB requests the terminal device to acquire the SFN offset of the cell corresponding to NR, by signaling an additional indicator when configuring the measurement for the terminal device (RRCConnectionReconfiguration).

In an embodiment, after receiving the measurement configuration from the base station, the terminal device may start acquiring SFN by reading MIB of the indicated cell in the measurement configuration.

In an embodiment, the terminal device reports the measurement result including the SFN offset between PCell of MeNB and the requested cell of SeNB.

In an embodiment, MeNB updates NR with the reported SFN offset and re-starts the associated timer.

In an embodiment, an SeNB modification procedure is triggered to inform the updated SFN offset.

In an embodiment, MeNB manages the established parameters (the dual connectivity capability parameter, the SFN offset, and optionally an associated timer) of NR in NRT for a specific dual connectivity capable base station.

In an embodiment, the associated timer is (re)started when the reported SFN offset is received from the terminal device.

In an embodiment, if there is no valid SFN offset or the SFN offset associated timer expires for a specific NR, the base station requests the SFN offset for a specific cell from the terminal device by setting the optional indicator in the measurement configuration.

In an embodiment, MeNB initiates an SeNB addition procedure towards SeNB, for initiating the dual connectivity feature for the terminal device including the SFN offset.

In an embodiment, MeNB initiates an SeNB modification procedure for updating the SFN offset towards SeNB.

In an embodiment, the terminal device acquires SFN by reading MIB from the requested cell and includes the SFN offset between this cell and PCell of MeNB in the measurement report.

Thus, the SFN offset may reliably and efficiently be acquired and reported to the network (to SeNB) without causing extra signalling overhead and without additional delay when configuring the dual connectivity features.

Let us now describe some embodiments with reference to Figures 5-10.

Referring to Figure 5, the base station may exchange the additional IE of dual connectivity capability with the secondary base station during a X2 setup procedure (steps 501, 502), wherein the base station eNB1 (e.g. MeNB) transmits an X2 setup request to eNB2 (e.g. SeNB) (block 501) and receives a X2 setup response from eNB2 (block 502). Alternatively, the dual connectivity capability information may be exchanged during an eNB configuration update procedure, or obtained by O&M configuration. In block 203, the macro base station updates (block 503) a corresponding NR in an NRT table based on the received information, but the SFN offset is not available for this eNB2 yet.

Referring to Figure 6, the base station may exchange the additional IE of dual connectivity capability with the macro base station during a X2 setup procedure (steps 601, 602), wherein the base station eNB2 receives an X2 setup request from eNB1 (block 601) and transmits a X2 setup response to eNB2 (block 602). Alternatively, the dual connectivity capability information may be exchanged during an eNB configuration update procedure, or obtained by O&M configuration.

Referring to Figure 7, for SFN offset handling during a eNB2 addition procedure, the terminal device reports (block 701) a measurement result (transmits a measurement report) based on configured reporting criteria, if a quality of the cell belonging to eNB2 is better than a predefined threshold. The terminal device receives an additional indicator for measurement configuration (RRCConnectionReconfiguration) from eNB1 (block 702). After receiving the measurement configuration from eNB1, the terminal device starts (block 703) acquiring SFN offset by reading MIB of the configured cell based on instructions received in step 702, and responds the measurement configuration in step 704. The order of steps 703 and 704 may be reversed. In step 705, the terminal device reports the measurement result including the SFN offset between PCell of eNB1 and the requested cell of eNB2. An eNB2 addition procedure is triggered by which eNB2 is able to get the SFN offset (block 706).

Referring to Figure 8, for SFN offset handling during an eNB2 addition procedure, the base station receives (block 801) a measurement result (a measurement report) from the terminal device. eNB1 checks (block 802) the corresponding NR in NRT of eNB2, wherein if there is a valid SFN offset available, eNB1 may directly initiate the eNB2 addition procedure towards eNB2 (block 807). If there is no valid SFN offset available (e.g. the validity timer has expired), eNB1 requests (block 803, transmits RRCConnectionReconfiguration) the terminal device to acquire SFN of the cell to be added by signaling an additional measurement configuration to the terminal device. In steps 804, 805, the base station receives the measurement result including the SFN offset between PCell of eNB1 and the requested cell of eNB2 from the terminal device. An eNB2 addition procedure is triggered by which eNB2 is able to get the SFN offset (block 807).

Referring to Figure 9, in response to the SFN offset associated timer of NR in NRT expiring (block 901), eNB1 requests (block 902) the terminal device to acquire the SFN offset of the cell corresponding to NR, by signaling an additional indicator when configuring the measurement for the terminal device (RRCConnectionReconfiguration). The base station receives from the terminal device the measurement result including the SFN offset between PCell of eNB1 (block 904) and the requested cell of SeNB (block 903). eNB1 updates (block 905) NR with the reported SFN offset and re-starts the associated timer. In step 906, the SeNB modification procedure is triggered to inform the updated SFN offset to SeNB.

Referring to Figure 10, after receiving (block 1001) the measurement configuration (RRCConnectionReconfiguration) from the base station, the terminal device starts (block 1002) acquiring SFN by reading MIB of the indicated cell in the measurement configuration, and responds the measurement configuration in step 1003. The order of steps 1002 and 1003 may be reversed. The terminal device reports to eNB1 the measurement result including the SFN offset between PCell of eNB1 and the requested cell of eNB2 in step 1004. In step 1005, the SeNB modification procedure is triggered to inform the updated SFN offset to SeNB.

In an embodiment, the embodiments of Figures 5 to 10 may be combined. In a modification, the processes of any of Figures 5 to 10 may be exclusive to small area cell base stations, e.g. the base station 100 may carry out the embodiments of Figure 2 to 10 but the macro base station 102 may not.

An embodiment provides an apparatus comprising at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to carry out the procedures of the above-described base station or the network node. The at least one processor, the at least one memory, and the computer program code may thus be considered as an embodiment of means for executing the above-described procedures of the base station or the network node. Figure 11 illustrates a block diagram of a structure of such an apparatus. The apparatus may be comprised in the base station or the network node, e.g. the apparatus may form a chipset or a circuitry in the base station or the network node. In some embodiments, the apparatus is the base station or the network node. The apparatus comprises a processing circuitry 10 comprising the at least one processor. The processing circuitry 10 may comprise an NRT management circuitry 16 configured to check and update NRT with the SFN offset. An X2 setup circuitry 18 may be configured to exchange dual connectivity information. A message generator 12 may be configured to generate ta RRCConnectionReconfiguration message.

The processing circuitry 10 may comprise the circuitries 12 to 18 as sub-circuitries, or they may be considered as computer program modules executed by the same physical processing circuitry. The memory 20 may store one or more computer program products 24 comprising program instructions that specify the operation of the circuitries 12 to 18. The memory 20 may further store a database comprising definitions for the selection of the link adaptation scheme, for example. The apparatus may further comprise a communication interface 22 providing the apparatus with radio communication capability with the terminal devices. The communication interface 22 may comprise a radio communication circuitry enabling wireless communications and comprise a radio frequency signal processing circuitry and a baseband signal processing circuitry. The baseband signal processing circuitry may be configured to carry out the functions of the transmitter and/or the receiver, as described above in connection with Figures 1 to 10. In some embodiments, the communication interface may be connected to a remote radio head comprising at least an antenna and, in some embodiments, radio frequency signal processing in a remote location with respect to the base station. In such embodiments, the communication interface 22 may carry out only some of radio frequency signal processing or no radio frequency signal processing at all. The connection between the communication interface 22 and the remote radio head may be an analogue connection or a digital connection.

An embodiment provides another apparatus comprising at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to carry out the procedures of the above-described terminal device. The at least one processor, the at least one memory, and the computer program code may thus be considered as an embodiment of means for executing the above-described procedures of the terminal device. Figure 12 illustrates a block diagram of a structure of such an apparatus. The apparatus may be comprised in the terminal device, e.g. it may form a chipset or a circuitry in the terminal device. In some embodiments, the apparatus is the terminal device. The apparatus comprises a processing circuitry 50 comprising the at least one processor. The processing circuitry 50 may comprise a communication controller circuitry 54 configured to extract control messages received from a serving base station, to acquire RRCConnectionControl message, and to control the terminal device to transmit or receive data between the base station in the scheduled communication resources. The apparatus may further comprise an SFN offset selector configured to read SFN offset based on based on measurement control instructions.

The processing circuitry 50 may comprise the circuitries 52, 54 as sub-circuitries, or they may be considered as computer program modules executed by the same physical processing circuitry. The memory 60 may store one or more computer program products 64 comprising program instructions that specify the operation of the circuitries 52, 54. The apparatus may further comprise a communication interface 62 providing the apparatus with radio communication capability with base stations of one or more cellular communication networks. The communication interface 62 may comprise a radio communication circuitry enabling wireless communications and comprise a radio frequency signal processing circuitry and a baseband signal processing circuitry. The baseband signal processing circuitry may be configured to carry out the functions of the transmitter and/or the receiver, as described above in connection with Figures 1 to 12.

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

This definition of ‘circuitry’ applies to all uses of this term in this application. As a further example, as used in this application, the term “circuitry” would also cover an implementation of merely a processor (or multiple processors) or portion of a processor, e.g. one core of a multi-core processor, and its (or their) accompanying software and/or firmware. The term “circuitry” would also cover, for example and if applicable to the particular element, a baseband integrated circuit, an application-specific integrated circuit (ASIC), and/or a field-programmable grid array (FPGA) circuit for the apparatus according to an embodiment of the invention.

The processes or methods described above in connection with Figures 1 to 12 may also be carried out in the form of one or more computer process defined by one or more computer programs. The computer program shall be considered to encompass also a module of a computer programs, e.g. the above-described processes may be carried out as a program module of a larger algorithm or a computer process. The computer program(s) may be in source code form, object code form, or in some intermediate form, and it may be stored in a carrier, which may be any entity or device capable of carrying the program. Such carriers include transitory and/or non-transitory computer media, e.g. a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package. Depending on the processing power needed, the computer program may be executed in a single electronic digital processing unit or it may be distributed amongst a number of processing units.

The present invention is applicable to cellular or mobile communication systems defined above but also to other suitable communication systems. The protocols used, the specifications of cellular communication systems, their network elements, and terminal devices develop rapidly. Such development may require extra changes to the described embodiments. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

List of abbreviations

ANR	automatic neighbour relation
DC	dual connectivity
DRX	discontinuous reception
eNB	evolved node-B
IE	information element
MeNB	master eNB
MIB	master information block
NR	neighbour cell relation
NRT	neighbour relation table
RRC	radio resource control
SeNB	secondary eNB
SFN	system frame number
UE	user equipment
SCG	secondary cell group
MCG	master cell group
RAN	radio access network

CLAIMS

1. A method comprising:

storing, in a first network node, dual connectivity capability information on a cell and a system frame number offset for each neighbouring dual connectivity capable cell;

wherein, if required, the method further comprises:

causing, in the first network node, transmission of a request message to a terminal device, the request message intending to request the terminal device to provide a system frame number offset for a second network node; and

acquiring, in the first network node, a report message from the terminal device, the report message comprising at least one information element indicating the system frame number offset for the second network node.

2. The method of claim 1, wherein the step of storing the system frame number further comprises in the first network node:

storing a system frame number offset timer for the cell.

3. The method of claim 1 or 2, comprising in the first network node:

establishing an additional measurement configuration indicator during an RRC procedure to request the system frame number offset of the cell.

4. The method of claim 1, 2 or 3, comprising in the first network node:

storing the dual connectivity capability information on the second network node, the system frame number offset, and optionally the system frame number offset timer, by adding them in a neighbour cell relation table NRT.

5. The method of any of claims 1 to 4, comprising in the first network node:

causing the transmission of the request message to the terminal device, the request message comprising at least one information element requesting the terminal device to provide the updated system frame number offset for the second network node

if there is no valid system frame number offset available for the second network node, if the system frame number offset for the second network node expires, or if it is for some other reason so decided in the first network node.

6. The method of any of claims 1 to 5, comprising in the first network node:

storing the dual connectivity capability information on the cell, the system frame number offset, and optionally the system frame number offset timer in a corresponding neighbour relation table NRT;

checking a neighbour cell relation in the neighbour relation table NRT, whether there is a valid system frame number offset available for the second network node, wherein if so is, the method further comprises

initiating a procedure towards the secondary base station to inform the system frame number offset to the second network node, wherein the initiated procedure comprises at least one of configuration of dual connectivity and reconfiguration of dual connectivity.

7. The method of any of claims 1 to 6, wherein the request message comprising the at least one information element requesting the terminal device to provide the updated system frame number offset for the second network node, comprises a measurement configuration message.

8. The method of any of claims 1 to 7, comprising in the first network node:

in response to the acquiring the report message from the terminal device, the report message comprising the at least one information element indicating the updated system frame number offset for the second network node, updating the neighbour cell relation with the updated system frame number offset and optionally re-starting an associated frame number offset timer.

9. The method of any of claims 1 to 8, comprising in the first network node:

updating the system frame number offset regularly to maintain synchronization accuracy.

10. The method of any of claims 1 to 9, comprising in the first network node:

if the system frame number offset is updated for the second network node and optionally if the corresponding system frame number offset timer is re-started, the method further comprises

initiating a second network node modification procedure towards the second network node to inform the updated system frame number offset to the second network node.

11. A method comprising:

acquiring, in a terminal device of a cellular communication system, a request message from a first network node, the request message comprising at least one information element requesting the terminal device to provide an updated system frame number offset for a second network node;

causing, in a terminal device, transmission of a report message to the first network node, the report message comprising at least one information element indicating the updated system frame number offset for the second network node.

12. The method of claim 11, wherein the report message comprises a measurement report of the cell.

13. The method of claim 11 or 12, comprising in the terminal device:

causing the transmission of the report message if the quality of the cell is better than a predefined threshold.

14. The method of claim 11, 12 or 13, comprising in the terminal device:

acquiring the system frame number offset by reading a master information block in a measurement configuration of the cell.

15. An apparatus comprising:

at least one processor; and

at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

store dual connectivity capability information on cell and a system frame number offset for each neighbouring dual connectivity capable cell; and

if required,

cause transmission of a request message to a terminal device, the request message intending to request the terminal device to provide a system frame number offset for a second network node; and

acquire a report message from a terminal device, the report message comprising at least one information element indicating the system frame number offset for the second network node.

16. The apparatus of claim 15, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

store a system frame number offset timer for the cell.

17. The apparatus of claim 15 or 16, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

establish an additional measurement configuration indicator during an RRC procedure to request the system frame number offset of the cell.

18. The apparatus of claim 15, 16 or 17, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

store the dual connectivity capability information on the second network node, the system frame number offset, and optinally the system frame number offset timer, by adding them in a neighbour cell relation table NRT.

19. The apparatus of any of claims 15 to 18, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

cause the transmission of the request message to the terminal device, the request message comprising at least one information element requesting the terminal device to provide the updated system frame number offset for the second network node

if there is no valid system frame number offset available for the second network node, if the system frame number offset for the second network node expires, or if it is for some other reason so decided in the first network node.

20. The apparatus of any of claims 15 to 19, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

store the dual connectivity capability information on the cell, the system frame number offset, and optionally a system frame number offset timer in a corresponding neighbour relation table NRT;

check a neighbour cell relation in the neighbour relation table NRT, whether there is a valid system frame number offset available for the second network node, and if there is

initiate a procedure towards the secondary base station to inform the system frame number offset to the second network node, wherein the initiated procedure comprises at least one of configuration of dual connectivity and reconfiguration of dual connectivity.

21. The apparatus of any of claims 15 to 20, wherein the request message comprises the at least one information element requesting the terminal device to provide the updated system frame number offset for the second network node, comprises a measurement configuration message.

22. The apparatus of any of claims 15 to 21, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

in response to the acquiring the report message from the terminal device, the report message comprising the at least one information element indicating the updated system frame number offset for the second network node, update the neighbour cell relation with the updated system frame number offset and optionally re-start an associated frame number offset timer.

23. The apparatus of any of claims 15 to 22, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

update the system frame number offset regularly to maintain synchronization accuracy.

24. The apparatus of any of claims 15 to 23, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

if the system frame number offset is updated for the second network node and optionally if the corresponding system frame number offset timer is re-started, initiate a second network node modification procedure towards the second network node to inform the updated system frame number offset to the second network node.

25. An apparatus comprising:

at least one processor; and

at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

acquire a request message from a first network node, the request message comprising at least one information element requesting a terminal device to provide an updated system frame number offset for a second network node;

cause transmission of a report message to the first network node, the report message comprising at least one information element indicating the updated system frame number offset for the second network node.

26. The apparatus of claim 25, wherein the report message comprises a measurement report of the cell.

27. The apparatus of claim 25 or 26, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

cause the transmission of the report message if the quality of the cell is better than a predefined threshold.

28. The apparatus of claim 25, 26 or 27, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to:

acquire the system frame number offset by reading a master information block in a measurement configuration of the cell.

29. A computer program product embodied on a non-transitory distribution medium readable by a computer and comprising program instructions which, when loaded into the computer, execute a computer process comprising:

the method steps of any preceding claim 1 to 14.

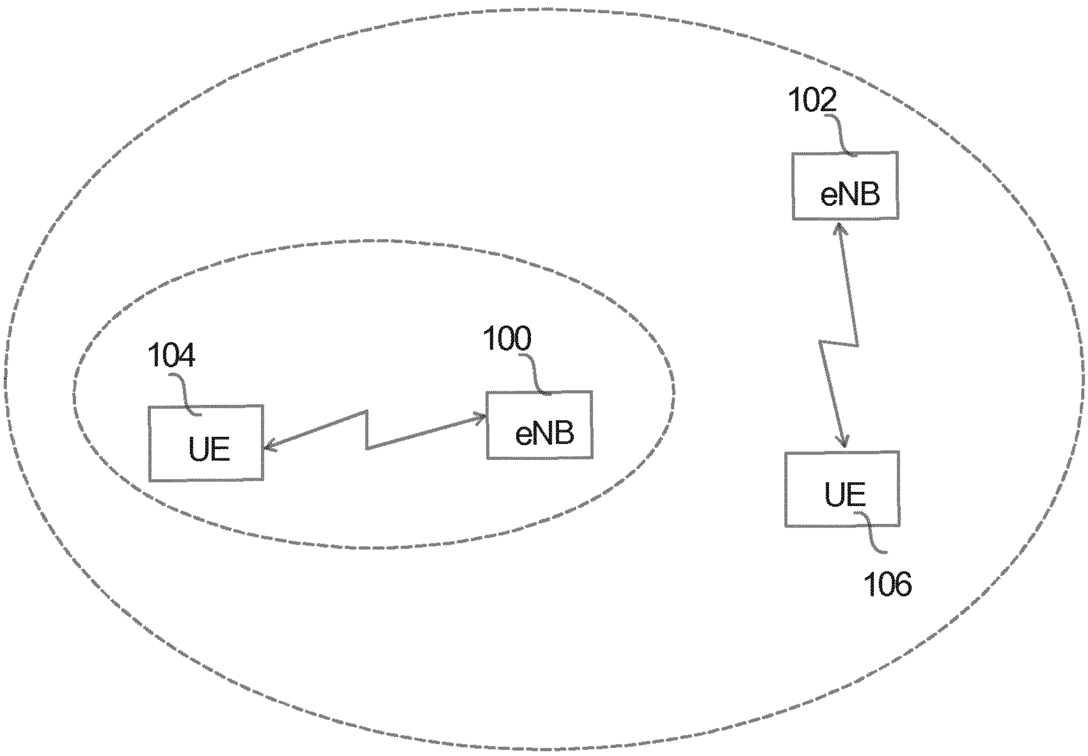

Fig. 1

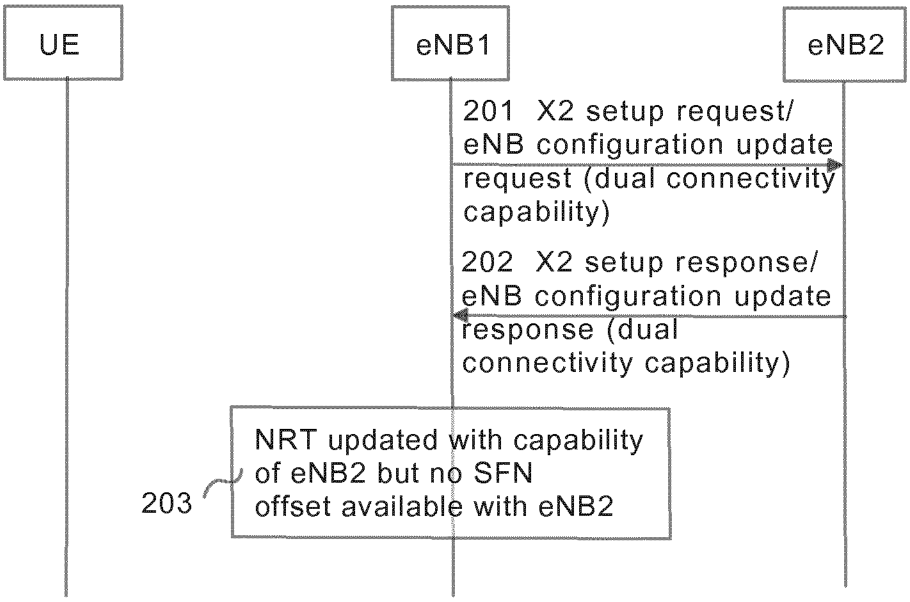
UE
eNB1
eNB2
201 X2 setup request/
eNB configuration update
request (dual connectivity
capability)
202 X2 setup response/
eNB configuration update
response (dual
connectivity capability)
NRT updated with capability
of eNB2 but no SFN
offset available with eNB2
203

Fig. 2

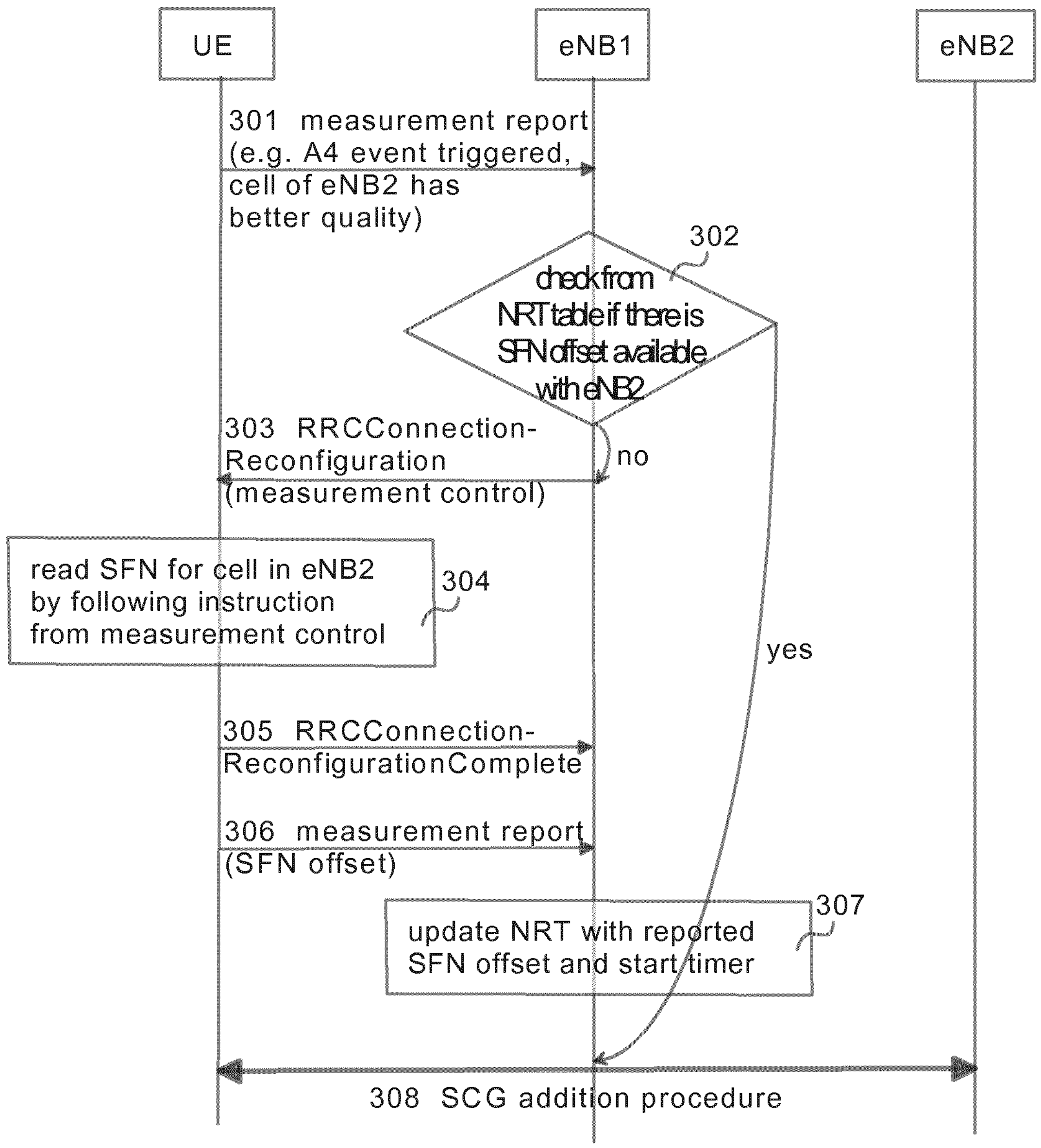
UE
eNB1
eNB2
301 measurement report (e.g. A4 event triggered, cell of eNB2 has better quality)
302
check from NRT table if there is SFN offset available with eNB2
303 RRCConnection-Reconfiguration (measurement control)
no
read SFN for cell in eNB2 by following instruction from measurement control
304
yes
305 RRCConnection-ReconfigurationComplete
306 measurement report (SFN offset)
307
update NRT with reported SFN offset and start timer
308 SCG addition procedure

Fig. 3

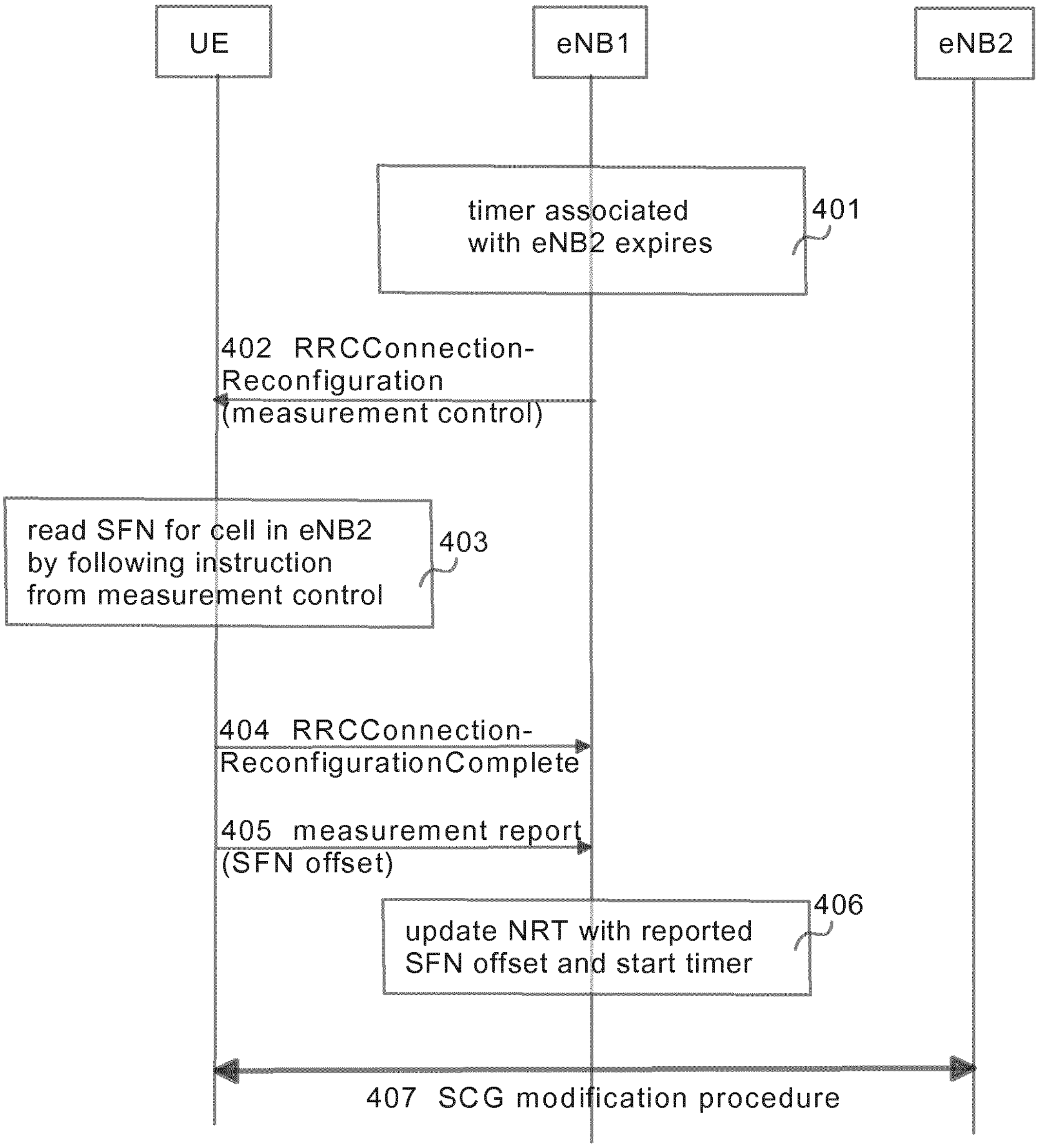
UE
eNB1
eNB2
timer associated with eNB2 expires
401
402 RRCConnection-Reconfiguration (measurement control)
read SFN for cell in eNB2 by following instruction from measurement control
403
404 RRCConnection-ReconfigurationComplete
405 measurement report (SFN offset)
406
update NRT with reported SFN offset and start timer
407 SCG modification procedure

Fig. 4

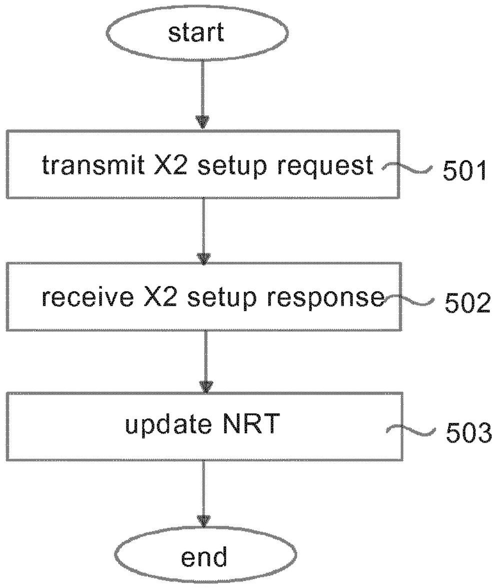
start
transmit X2 setup request
501
receive X2 setup response
502
update NRT
503
end

Fig. 5

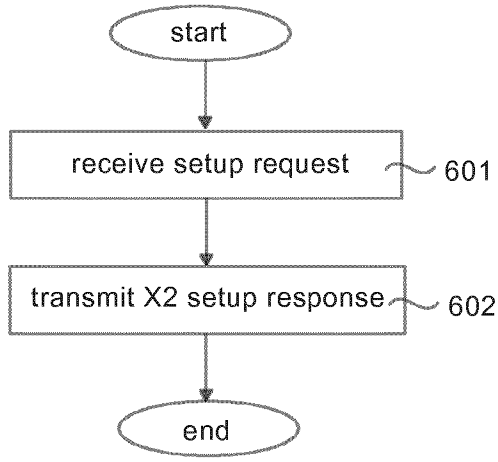
start
receive setup request
601
transmit X2 setup response
602
end

Fig. 6

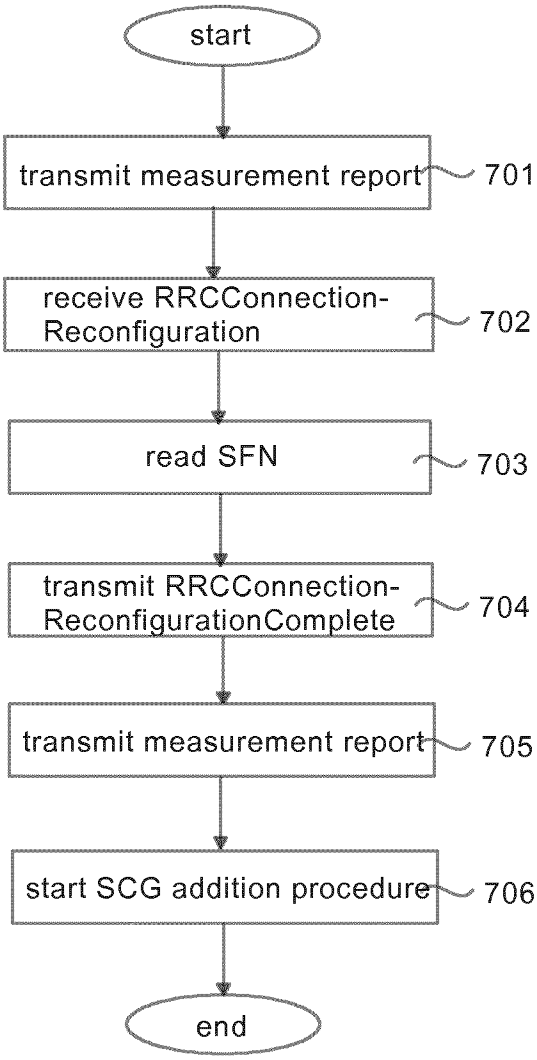
start
transmit measurement report
701
receive RRCConnection-Reconfiguration
702
read SFN
703
transmit RRCConnection-ReconfigurationComplete
704
transmit measurement report
705
start SCG addition procedure
706
end

Fig. 7

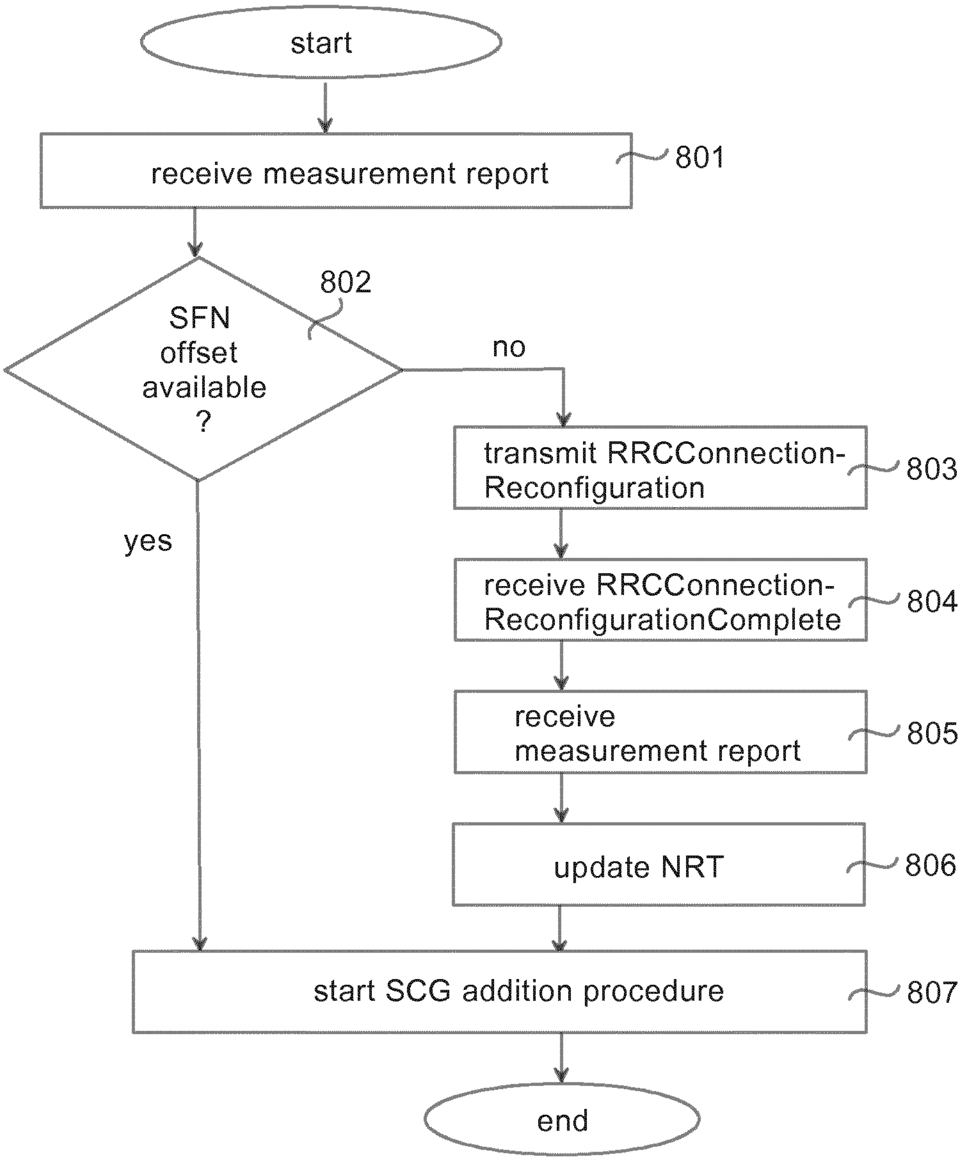
start
receive measurement report
801
SFN
offset
available
?
802
no
yes
transmit RRCConnection-
Reconfiguration
803
receive RRCConnection-
ReconfigurationComplete
804
receive
measurement report
805
update NRT
806
start SCG addition procedure
807
end

Fig. 8

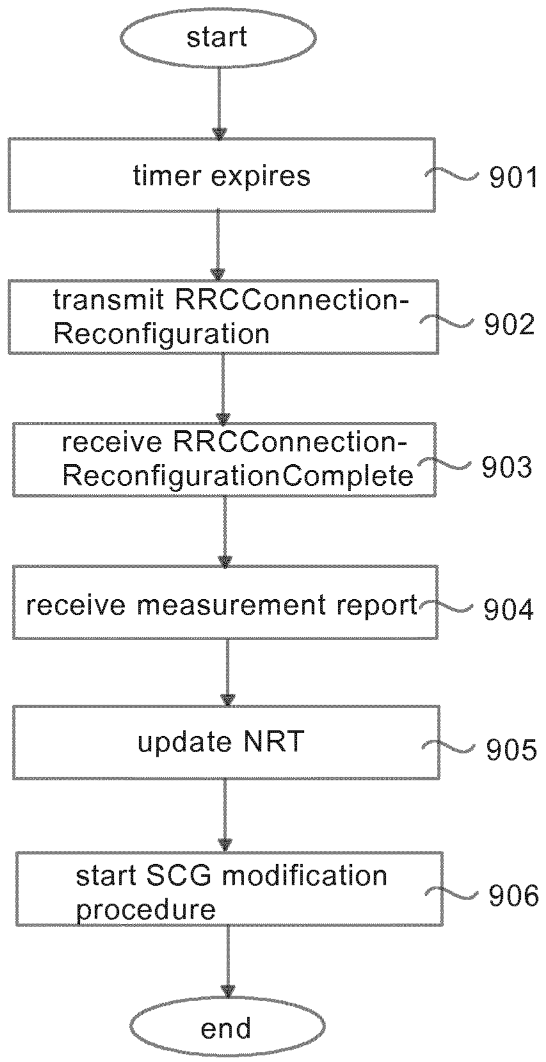
start
timer expires
901
transmit RRCConnection-Reconfiguration
902
receive RRCConnection-ReconfigurationComplete
903
receive measurement report
904
update NRT
905
start SCG modification procedure
906
end

Fig. 9

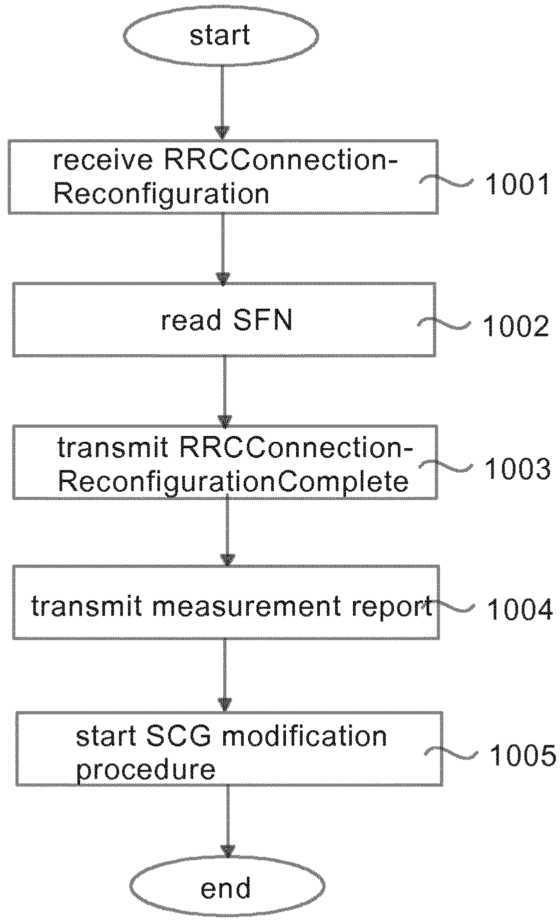
start
receive RRCConnection-Reconfiguration
1001
read SFN
1002
transmit RRCConnection-ReconfigurationComplete
1003
transmit measurement report
1004
start SCG modification procedure
1005
end

Fig. 10

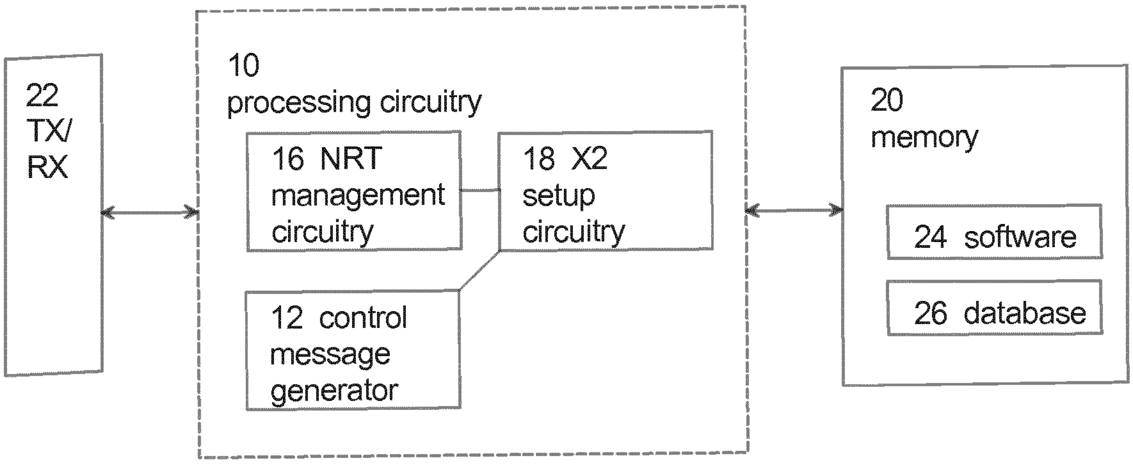
22
TX/
RX
10
processing circuitry
16 NRT
management
circuitry
18 X2
setup
circuitry
12 control
message
generator
20
memory
24 software
26 database

Fig. 11

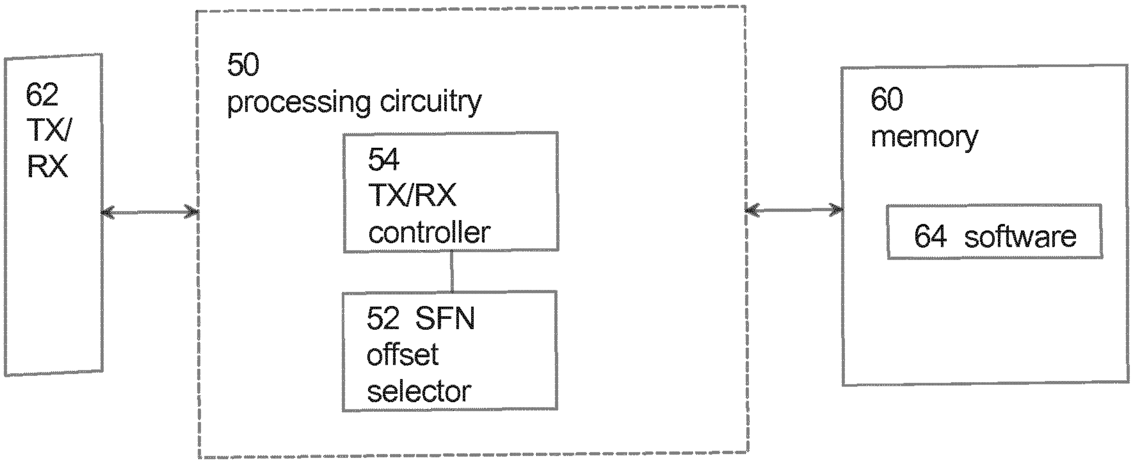
62
TX/
RX
50
processing circuitry
54
TX/RX
controller
52 SFN
offset
selector
60
memory
64 software

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2014/066966

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-10, 15-24(completely); 29(partially)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/066966

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W24/10
ADD. H04W92/20

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Huawei: "SFN Handling in Dual Connectivity", 3GPP, 3rd Generation Partnership Project 3GPP TS-RAN WG3 Meeting 84, vol. RAN WG3, no. Seoul, Korea, 19-23 May, 2014 29 March 2014 (2014-03-29), XP002730657, Mobile Competence Centre, 650, route des Lucioles, F-06921 Sophia-Antipolis Cedex, France Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_85bis/Docs/ [retrieved on 2014-10-02]	5,19
A	Title paragraph [0001] paragraph [02.2] -----	1,15,29
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 October 2014	09/12/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Costa, Elena

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/066966

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2013/041757 A1 (NOKIA SIEMENS NETWORKS OY [FI]; HOOLI KARI JUHANI [FI]; TIIROLA ESA TA) 28 March 2013 (2013-03-28) page 11, line 27 - page 12, line 1 page 13, lines 6-12 page 14, lines 16-19 page 19, lines 6-15 page 22, lines 15-17 -----	1-4,7,8, 15-18, 21,22,29 5,6,9, 10,19, 20,23,24
Y	CATT: "DRX interaction between MeNB and SeNB", 3GPP DRAFT; R2-140184 DRX INTERACTION BETWEEN MENB AND SENB, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Prague, Czech Republic; 20140210 - 20140214 29 January 2014 (2014-01-29), XP050753897, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_85/Docs/ [retrieved on 2014-01-29] paragraph [02.2] -----	6,9,10, 20,23,24
A	INTEL CORPORATION: "Scenarios and benefits of dual connectivity", 3GPP DRAFT; R2-130570, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. St. Julian; 20130128 - 20130201 19 January 2013 (2013-01-19), XP050668406, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_81/Docs/ [retrieved on 2013-01-19] paragraph [0002] -----	1,15,29
A	WO 2014/089069 A1 (INTERDIGITAL PATENT HOLDINGS [US]) 12 June 2014 (2014-06-12) paragraphs [0069] - [0070] paragraph [0081] paragraph [0136] paragraph [0223] figure 21 -----	1,15,29

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/066966

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013041757 A1	28-03-2013	EP 2759160 A1	30-07-2014
		US 2014226609 A1	14-08-2014
		WO 2013041757 A1	28-03-2013
WO 2014089069 A1	12-06-2014	NONE	

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10, 15-24(completely); 29(partially)

   Method, apparatus, and computer-program product for maintaining, at a network node, SFN offset information for the dual-connectivity capable neighbouring cells.

   ---

2. claims: 11-14, 25-28(completely); 29(partially)

   Method, apparatus, and computer-program product for providing, by a terminal device, to a first network node an update of the SFN offset for a second network node.
