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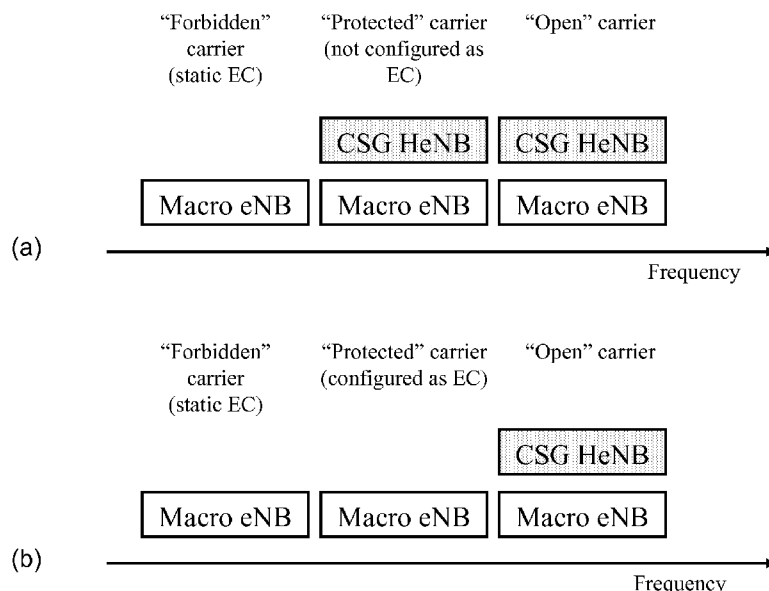


Figure 5

(57) Abstract: There are provided measures for carrier management in heterogeneous networks, said measures exemplarily comprising determining a triggering condition for carrier reconfiguration between a macrocell and at least one microcell using the same carrier frequency band according to radio conditions of a macrocell user, reconfiguring at least one carrier in terms of usability by the at least one microcell, and signaling carrier reconfiguration information from the macrocell to the at least one microcell. Said measures may exemplarily be applied for mobility procedures in LTE, LTE-Advanced, HSPA and/or UMTS radio access systems.

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Carrier management in heterogeneous network environments

5 Field of the invention

The present invention relates to carrier management in heterogeneous network environments

10 Background of the invention

In the development of radio communication systems, in particular cellular communication (like for example GSM (Global System for Mobile Communication), GPRS (General Packet Radio Service), HSPA (High Speed Packet Access), UMTS (Universal Mobile Telecommunication System) or the like), efforts are made for an evolution of the radio access part thereof. In this regard, the evolution of radio access networks (like for example the GSM EDGE radio access network (GERAN) and the Universal Terrestrial Radio Access Network (UTRAN) or the like) is currently addressed. Such improved radio access networks are sometimes denoted as evolved or advanced radio access networks (like for example the Evolved Universal Terrestrial Radio Access Network (E-UTRAN)) or as being part of a long-term evolution (LTE) or LTE-Advanced, also generally referred to as International Mobile Communications - Advanced (IMT-A). Although such denominations primarily stem from 3GPP (Third Generation Partnership Project) terminology, the usage thereof herein-
after does not limit the respective description to 3GPP technology, but generally refers to any kind of radio access evolution irrespective of the underlying system architecture.

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In the following, for the sake of intelligibility, LTE (Long-Term Evolution according to 3GPP terminology) or LTE-Advanced is taken as a non-limiting example for a radio access network of cellular type being applicable in the context of the present invention and its embodiments. However, it is to be noted that any kind of radio access network of cellular type, such as HSPA and/or UMTS, may likewise be applicable, as long as it exhibits comparable features and characteristics as described hereinafter.

In the development of cellular systems in general, and access networks in particular, heterogeneous network environments comprising a combination of macrocells and microcells (also referred to as picocells or femtocells) are proposed as one concept. Thereby, the macrocells typically provide for a large coverage, while the microcells (having low transmit power) typically provide for additional capacity in areas with a high user deployment. In the context of LTE or LTE-Advanced, the macrocells are deployed by base stations denoted as eNBs, while microcells are deployed by home base stations denoted as HeNBs. Such heterogeneous network environment may be considered to be composed of two network layers, i.e. a microcell network layer and an overlay macrocell network layer.

In a specific case, the microcells may be CSG or hybrid cells, i.e. cells of a closed subscriber group (CSG) or of a closed subscriber group (CSG) and other subscribers, which represent permitted cells for subscribers being members of the particular closed subscriber group (CSG) and non-permitted cells for subscribers being no members of the particular closed subscriber group (CSG). In this case,

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CSG/hybrid microcells are said to be operated in restricted or closed access mode.

Figure 1 shows a schematic diagram of a deployment scenario of a heterogeneous network environment comprising a combination of macrocells and microcells. In Figure 1, macrocells are illustrated by hexagonal blocks, while microcells are illustrated by rectangular blocks. In the dashed circle, an enlarged view of a microcell including a microcell base station and a user equipment is illustrated.

In the present and the near future, it is foreseen that deployment of microcells such as e.g. HeNBs within an overlay network layer of macrocells such as e.g. eNBs will be high or even very high. That is, there will be a high or even very high number of microcells as compared with the number of macrocells.

In the present and the near future, it is also foreseen that both network layers, i.e. macrocells and microcells, operate in the same carrier frequency band. That is, cells with restricted access mode (e.g. CSG HeNBs) may use the same carrier frequency/frequencies as macrocells, which may be referred to as co-channel deployment.

For the further description, a dense deployment scenario with CSG/hybrid microcells utilizing co-channel deployment is assumed as a non-limiting example for a heterogeneous network environment. Although the aspects explained below are specifically relevant in such an exemplary network environment, they are also valid and relevant in other network environments such as e.g. a deployment scenario with lower density of microcells in un-/restricted access mode utilizing co-channel deployment.

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In case of heterogeneous networks including microcells with restricted access mode (e.g. CSG HeNBs) operating on the same carrier frequency as macrocells, a desired coverage and/or quality of service cannot be guaranteed for all users in all locations. Due to issues in radio conditions, when a macrocell user (also referred to as macro user), i.e. a user equipment UE being served by a macrocell (or a macrocell base station), encounters a non-permitted CSG/hybrid HeNB, it may observe a coverage hole and/or a reduced quality of service, which may be caused by high interference between the serving macrocell and the microcell in the UE's proximity. Due to this, it may happen especially for dense HeNB deployments that a significant part of a macrocell area may be inaccessible or only accessible with unsatisfying quality of service (QoS) for macrocell users.

Figure 2 shows a graph illustrating simulation results for a dense co-channel deployment according to conventional carrier management mechanisms.

In Figure 2, a cumulative distribution function (cdf) is plotted against an effective signal to interference-plus-noise ratio (SINR) in decibel (dB) for a macrocell user in a dense co-channel deployment according to conventional carrier management mechanisms. The solid reference curve represents a case of a network environment only comprising macrocells, i.e. no HeNBs being deployed. The dashed simulation curve represents a case of a dense HeNB co-channel deployment without HeNB power control (PC). The dotted simulation curve represents a case of a dense HeNB co-channel deployment with HeNB power control (PC).

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As may be observed from Figure 2, the operation of both network layers in the same carrier frequency band may not always be possible in dense HeNB deployments, which is mainly due to outage (i.e. a coverage hole or reduced QoS) caused by (CSG/hybrid) microcells for macrocell users in the downlink.

A conceivable approach in view of the above-outlined problems may be to secure at least one carrier to be not used by microcells such as restricted access cells. Such a carrier, which may be referred to as "escape carrier" (EC), may be used as an escape for macrocell UEs suffering from lack of coverage and/or reduced quality of service due to a high interference between the serving macrocell and the microcell(s) in the UEs' proximity. The disadvantage of such a static allocation of a carrier as an escape carrier is that, for an operator having a limited number of carriers available, reserving an escape carrier in advance might be very expensive in terms of radio capacity usage, while not always being necessary.

Another conceivable approach in view of the above-outlined problems may be that an escape carrier may under certain conditions also be used by microcells (for example, when the HeNB is close to the eNB, or when there is only a low density of HeNBs). While such approach may be less restrictive in terms of radio capacity usage, the applicability thereof is restricted to only a part of HeNB locations, and it may be non-optimal in case of high density deployments, especially in dense urban areas.

Accordingly, there is a demand for mechanisms for carrier management in heterogeneous network environments, especially in heterogeneous network environments with a combi-

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nation of macrocells and a high density of microcells using the same carrier frequency band.

Summary of embodiments of the invention

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The present invention and its embodiments aim at solving the above problems.

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The present invention and its embodiments are made to provide for mechanisms for carrier management in heterogeneous network environments, especially in heterogeneous network environments with a combination of macrocells and a high density of microcells using the same carrier frequency band.

15

According to an exemplary first aspect of the present invention, there is provided a method comprising determining a triggering condition for carrier reconfiguration between a macrocell and at least one microcell using the same carrier frequency band according to radio conditions of a macrocell user, reconfiguring at least one carrier in terms of usability by the at least one microcell, and signaling carrier reconfiguration information from the macrocell to the at least one microcell.

25

According to further developments or modifications thereof, one or more of the following applies:

- the method further comprises detecting an amount of traffic in the macrocell, and/or detecting a level of interference between the macrocell and the at least one microcell, wherein the triggering condition is determined according to the detected amount of traffic and/or level of interference,

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- the triggering condition is determined to be satisfied when satisfaction of requirements on macrocell coverage and/or quality of service of the macrocell user changes instantaneously and/or for a predefined time period,

5 - the reconfiguring comprises changing a mode of at least one carrier between a protected carrier mode, in which the respective carrier is usable by the macrocell and the at least one microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only, according to the radio conditions,

10 - the reconfiguring comprises reserving and/or allocating a number of carriers for use by the macrocell by changing the mode of the number of carriers from the protected carrier mode to the escape carrier mode, and allowing a remaining number of carriers for use by the at least one microcell and/or releasing the remaining number of carriers from use by the macrocell by changing the mode of the remaining number of carriers from the escape carrier mode to the protected carrier mode,

20 - the carrier reconfiguration information comprises an indication of the mode of the at least one carrier, or an indication of the mode of the at least one carrier and a condition for usability of the at least one carrier by the at least one microcell,

25 - the condition for usability by the at least one microcell comprises a threshold of a downlink transmit power of the at least one microcell and/or a threshold of a reference signal received power of the macrocell at the at least one microcell,

30 - the signaling comprises at least one of transmitting a dedicated signaling message including the carrier reconfiguration information towards the at least one macrocell, broadcasting a macrocell broadcast message including the carrier reconfiguration information as system information

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towards the at least one macrocell, and communicating the carrier reconfiguration information directly to the at least one microcell,

- the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell,

- the at least one microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers, and the macrocell user is no member of the closed subscriber group,

- the method is operable at a macrocell base station, and/or

- the macrocell comprises a base station, eNB, and the microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or the macrocell comprises an access node and the microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

According to an exemplary second aspect of the present invention, there is provided a method comprising receiving carrier reconfiguration information for at least one carrier from a macrocell at a microcell, the macrocell and the microcell using the same carrier frequency band, and adjusting use of the at least one carrier by the microcell.

According to further developments or modifications thereof, one or more of the following applies:

- the carrier reconfiguration information comprises an indication of a mode of the at least one carrier, or an indication of a mode of the at least one carrier and a condition for usability of the at least one carrier by the microcell, wherein the indicated mode is one of a protected carrier mode, in which the respective carrier is usable by the macrocell and the microcell, and an escape carrier

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mode, in which the respective carrier is usable by the macrocell only,

- the condition for usability by the microcell comprises a threshold of a downlink transmit power of the microcell and/or a threshold of a reference signal received power of the macrocell at the microcell,

- the adjusting comprises releasing and/or inhibiting allocating the at least one carrier from use by the microcell, when the indicated mode thereof is the escape carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is not satisfied, and/or allocating and/or inhibiting releasing the at least one carrier for use by the microcell when the indicated mode thereof is the protected carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is satisfied,

- the receiving comprises at least one of receiving a dedicated signaling message including the carrier reconfiguration information, receiving a macrocell broadcast message including the carrier reconfiguration information as system information, and receiving direct communication of the carrier reconfiguration information from the macrocell,

- the method further comprises delaying a start of the adjusting after receiving the carrier reconfiguration information by a random time selected from a predefined range, and/or periodically checking receipt of further carrier reconfiguration information,

- the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell,

- the microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers,

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- the method is operable at a microcell base station,
and/or

- the macrocell comprises a base station, eNB, and the
microcell comprises a home base station, HeNB, in accor-
5 dance with an LTE or LTE-Advanced radio access system, or
the macrocell comprises an access node and the microcell
comprises a femto access node in accordance with a HSPA or
UMTS radio access system.

10

According to an exemplary third aspect of the present in-
vention, there is provided an apparatus comprising a proc-
essor configured to determine a triggering condition for
carrier reconfiguration between a macrocell and at least
15 one microcell using the same carrier frequency band accord-
ing to radio conditions of a macrocell user, and reconfig-
ure at least one carrier in terms of usability by the at
least one microcell, and a transmitter configured to signal
carrier reconfiguration information from the macrocell to
20 the at least one microcell.

According to further developments or modifications thereof,
one or more of the following applies:

- the apparatus further comprises a detector configured
25 to detect an amount of traffic in the macrocell, and/or de-
tect a level of interference between the macrocell and the
at least one microcell, wherein the processor is configured
to determine the triggering condition according to the de-
tected amount of traffic and/or level of interference,

30 - the processor is configured to determine the triggering
condition to be satisfied when satisfaction of requirements
on macrocell coverage and/or quality of service of the mac-
rocell user changes instantaneously and/or for a predefined
time period,

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- the processor, for reconfiguring, is configured to change a mode of at least one carrier between a protected carrier mode, in which the respective carrier is usable by the macrocell and the at least one microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only, according to the radio conditions,

- the processor, for reconfiguring, is configured to reserve and/or allocate a number of carriers for use by the macrocell by changing the mode of the number of carriers from the protected carrier mode to the escape carrier mode, and allow a remaining number of carriers for use by the at least one microcell and/or release the remaining number of carriers from use by the macrocell by changing the mode of the remaining number of carriers from the escape carrier mode to the protected carrier mode,

- the carrier reconfiguration information comprising an indication of the mode of the at least one carrier, or an indication of the mode of the at least one carrier and a condition for usability of the at least one carrier by the at least one microcell,

- the condition for usability by the at least one microcell comprises a threshold of a downlink transmit power of the at least one microcell and/or a threshold of a reference signal received power of the macrocell at the at least one microcell,

- the transmitter is configured to transmit a dedicated signaling message including the carrier reconfiguration information towards the at least one macrocell, and/or broadcast a macrocell broadcast message including the carrier reconfiguration information as system information towards the at least one macrocell, and/or communicate the carrier reconfiguration information directly to the at least one microcell,

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- the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell,

- the at least one microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers, and the macrocell user is no member of the closed subscriber group,

- the apparatus is operable as or at a macrocell base station, and/or

- the macrocell comprises a base station, eNB, and the microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or the macrocell comprises an access node and the microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

According to an exemplary fourth aspect of the present invention, there is provided an apparatus comprising a receiver configured to receive carrier reconfiguration information for at least one carrier from a macrocell at a microcell, the macrocell and the microcell using the same carrier frequency band, and a processor configured to adjust use of the at least one carrier by the microcell.

According to further developments or modifications thereof, one or more of the following applies:

- the carrier reconfiguration information comprises an indication of a mode of the at least one carrier, or an indication of a mode of the at least one carrier and a condition for usability of the at least one carrier by the microcell, wherein the indicated mode is one of a protected carrier mode, in which the respective carrier is usable by the macrocell and the microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only,

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- the condition for usability by the microcell comprises a threshold of a downlink transmit power of the microcell and/or a threshold of a reference signal received power of the macrocell at the microcell,

5 - the processor, for adjusting, is configured to release and/or inhibit allocation of the at least one carrier from use by the microcell, when the indicated mode thereof is the escape carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability
10 by the microcell is not satisfied, and/or allocate and/or inhibit release of the at least one carrier for use by the microcell when the indicated mode thereof is the protected carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the
15 microcell is satisfied,

 - the receiver is configured to receive a dedicated signaling message including the carrier reconfiguration information, and/or receive a macrocell broadcast message including the carrier reconfiguration information as system
20 information, and/or receive direct communication of the carrier reconfiguration information from the macrocell,

 - the processor is configured to delay a start of the adjusting after receiving the carrier reconfiguration information by a random time selected from a predefined range,
25 and/or periodically check receipt of further carrier reconfiguration information,

 - the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell,

 - the microcell is a cell of a closed subscriber group or
30 a hybrid cell of a closed subscriber group and other subscribers,

 - the apparatus is operable as or at a microcell base station, and/or

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- the macrocell comprises a base station, eNB, and the microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or the macrocell comprises an access node and the microcell
5 comprises a femto access node in accordance with a HSPA or UMTS radio access system.

According to an exemplary fifth aspect of the present invention, there is provided a computer program product including a program comprising software code portions being
10 arranged, when run on a processor of an apparatus (such as e.g. according to the above third aspect and/or developments or modifications thereof), to perform the method according to the above first aspect and/or developments or
15 modifications thereof.

According to an exemplary sixth aspect of the present invention, there is provided a computer program product including a program comprising software code portions being
20 arranged, when run on a processor of an apparatus (such as e.g. according to the above fourth aspect and/or developments or modifications thereof), to perform the method according to the above second aspect and/or developments or
modifications thereof.

25 According to further developments or modifications thereof, the computer program product according to the fifth or sixth aspect comprises a computer-readable medium on which the software code portions are stored, and/or the program
30 is directly loadable into a memory of the processor.

By way of exemplary embodiments of the present invention, there are provided mechanisms for carrier management in heterogeneous network environments, especially in heteroge-

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neous network environments with a combination of macrocells and a high density of microcells using the same carrier frequency band.

5 By way of exemplary embodiments of the present invention, there are provided mechanisms for dynamic and/or flexible frequency carrier reconfiguration for microcells in restricted or closed access mode, such as for example CSG/hybrid HeNBs.

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By way of exemplary embodiments of the present invention, the provided mechanisms are applicable to any kind of heterogeneous network environments comprising a combination of macrocells and microcells, for example in LTE/LTE-Advanced, HSPA, and/or UMTS network systems.

15

Brief description of the drawings

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In the following, the present invention will be described in greater detail by way of non-limiting examples with reference to the accompanying drawings, in which

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Figure 1 shows an exemplary illustration of a deployment scenario of a heterogeneous network environment comprising a combination of macrocells and microcells,

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Figure 2 shows a graph illustrating simulation results for a dense co-channel deployment according to conventional carrier management mechanisms,

Figure 3 shows another exemplary illustration of a deployment scenario of a heterogeneous network environment comprising a combination of macrocells and microcells,

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Figure 4 shows a flowchart of methods according to exemplary embodiments of the present invention,

5 Figure 5 shows a schematic diagram of an example of an initial carrier configuration (Figure 5(a)) and a reconfigured carrier configuration (Figure 5(b)) according to exemplary embodiments of the present invention,

10 Figure 6 shows a graph illustrating simulation results for a dense co-channel deployment according to exemplary embodiments of the present invention, and

Figure 7 shows a block diagram of apparatuses according to exemplary embodiments of the present invention.

15

Detailed description of embodiments of the present invention

20 The present invention is described herein with reference to particular non-limiting examples and to what are presently considered to be conceivable embodiments of the present invention. A person skilled in the art will appreciate that the invention is by no means limited to these examples, and may be more broadly applied.

25

In particular, the present invention and its embodiments are mainly described in relation to 3GPP specifications being used as non-limiting examples for certain exemplary network configurations and deployments. In particular, an
30 LTE/LTE-A (E-UTRAN) radio access network is used as a non-limiting example for the applicability of thus described exemplary embodiments. Further, a heterogeneous network environment comprising a combination of macrocells being represented by eNB nodes and microcells being represented by

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HeNB nodes or, particularly, by CSG/hybrid microcells is used as a non-limiting example for the applicability of thus described exemplary embodiments. As such, the description of exemplary embodiments given herein specifically refers to terminology which is directly related thereto. Such terminology is only used in the context of the presented non-limiting examples, and does naturally not limit the invention in any way. Rather, any other network configuration or system deployment comprising macrocells and microcells, etc. may also be utilized as long as compliant with the features described herein.

Embodiments of the present invention may be equally applied to any heterogeneous network environments comprising a combination of macrocells and microcells, irrespective of the underlying radio access system or technology. In LTE/LTE-Advanced, embodiments of the present invention are applicable to HeNB microcells, e.g. CGS/hybrid microcells, exemplarily employing a concept of superordinate and/or subordinate component carriers. In HSPA/UMTS, embodiments of the present invention are applicable to pico-/femtocells, e.g. CGS/hybrid pico-/femtocells, exemplarily using a multi-carrier/multi-band scheme employing a concept of superordinate and/or subordinate component carriers.

A concept of superordinate and/or subordinate component carriers, as mentioned above, may be any carrier selection scheme for carrier selection using carrier aggregation. For example, the concept of superordinate and/or subordinate component carriers may relate to primary component carriers (PCC) and secondary component carriers (SCC) as described in the ACCS (autonomous component carrier selection) scheme.

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The ACCS scheme is a concept, proposed for LTE or LTE-Advanced networks, that uses carrier aggregation and describes a way in which operating frequencies (referred to as component carriers in LTE or LTE-Advanced) are allocated to different microcell base stations HeNBs over time. This concept includes possible changes of secondary component carriers (SCC) and (less frequent) changes of a primary component carrier (PCC). When the ACCS scheme is applied to heterogeneous network environments comprising a combination of macrocells and microcells, the macrocells may still use a plain frequency reuse one, while the microcells may use ACCS in order to control interference among the macrocells and microcells.

In this regard, it is noted that superordinate component carriers, hereinafter exemplarily denoted as primary component carriers, may also be referred to as base / main / basic / essential / dependable / private component carriers or the like, and that subordinate component carriers, hereinafter exemplarily denoted as secondary component carriers, may also be referred to as supplementary / side / extra / volatile / fickle / public component carriers or the like. As a non-limiting example, superordinate component carriers may be primary or base component carriers as described in the ACCS concept, and subordinate component carriers may be secondary or supplementary component carriers as described in the ACCS concept.

Hereinafter, various embodiments and implementations of the present invention and its aspects or embodiments are described using several alternatives. It is generally noted that, according to certain needs and constraints, all of the described alternatives may be provided alone or in any

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conceivable combination (also including combinations of individual features of the various alternatives).

In the following, exemplary embodiments of the present invention are described with reference to methods, procedures and functions.

Figure 3 shows another exemplary illustration of a deployment scenario of a heterogeneous network environment comprising a combination of macrocells and microcells. It is to be noted that the illustrations of both Figures 1 and 3 are applicable for the same heterogeneous network environment (apart from the different number of macrocells and microcells in these figures).

15

In Figure 3, a deployment scenario of a heterogeneous network environment in a E-UTRAN architecture is exemplarily depicted. The eNBs of Figure 3 represent macrocell base stations and the shaded areas around them represent macrocells, while the HeNBs of Figure 3 represent microcell base stations and the shaded areas around them represent microcells. The eNBs and HeNBs are connected to a core network portion (not shown) via combined mobility management entities and serving gateways and/or HeNB gateways, respectively.

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In Figure 3, there is illustrated a situation in which a user equipment UE served by a macrocell or eNB, i.e. a macro (or macrocell) user, encounters a microcell or HeNB, which may be a non-permitted CSG/hybrid microcell or HeNB for the UE.

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Accordingly, as an assumption for the further description, the UE is assumed to approach a HeNB microcell, and a car-

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rier management between the eNB macrocell and the HeNB microcell is to be performed in view of the above-outlined problems in such situations (e.g. lack of coverage and/or reduced quality of service). In this regard, by way of example, there is particularly considered a case in which additional radio resources are to be provided for macrocell users, while the case of resuming a previous resource distribution is not explained in detail but may be handled accordingly.

10

According to exemplary embodiments of the present invention, the following structure of a carrier configuration is defined (as evident e.g. from Figures 5(a) and 5(b) below).

15 A first type of carriers (component carriers) is denoted as "open" carriers. Such "open" carriers may be used by the HeNB or HeNBs (as well as by the eNB or eNBs) at all times. That is, the HeNB or HeNBs may operate on such "open" carriers with respect to other mechanisms for carrier selection and/or aggregation (e.g. in the ACCS scheme primary/base component carriers may be allocated to such "open" carriers).

20

A second type of carriers (component carriers) is denoted as "forbidden" carriers. Such "forbidden" carriers must not be used by the HeNB or HeNBs but may only be used by the eNB or eNBs at all times. That is, the HeNB or HeNBs may not operate on such "forbidden" carriers, and may possibly not even be informed about them. Such "forbidden" carriers are static escape carriers (EC) for the macrocell.

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A third type of carriers (component carriers) is denoted as "protected" carriers. Such "protected" carriers may be used by the HeNB or HeNBs (as well as by the eNB or eNBs) de-

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pending on a specific re-/configuration thereof. That is, the HeNB or HeNBs may operate on such "protected" carriers only if allowed by the respective macrocell (e.g. in the ACCS scheme secondary/supplementary component carriers may be allocated to such "protected" carriers). Such "protected" carriers may be re-/configured by the macrocell as semi-static (dynamic/flexible) escape carriers (EC) for the macrocell.

10 Generally, carriers in the meaning of the present description may be superordinate component carriers and/or subordinate component carriers of the microcell or microcells, as explained above. Namely, for example, such superordinate component carriers may be primary or base component carriers as described in the ACCS concept (or any other carrier selection procedure for carrier selection using carrier aggregation), and such subordinate component carriers may be secondary or supplementary component carriers as described in the ACCS concept (or any other carrier selection procedure for carrier selection using carrier aggregation).

In particular, the carrier management according to exemplary embodiments of the present invention is for example applicable to LTE-Advanced (LTE-A) carrier aggregation (CA) supporting dynamic secondary carrier allocation and release. Namely, triggers for mechanisms and mechanisms of (CSG/hybrid) HeNB secondary carrier reconfiguration (allocation and release) relating to radio conditions of macrocell users are described hereinafter.

30 Figure 4 shows a flowchart of methods according to exemplary embodiments of the present invention. In Figure 4, the procedure on the left side illustrates a method executable at a macrocell or macrocell base station, and the

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procedure on the right side illustrates a method executable at a microcell or microcell base station. The macrocell base station of Figure 4 may e.g. be represented by the eNB of Figure 3, in the area of which the UE is located, and
5 the microcell base station of Figure 4 may e.g. be represented by the (CSG/hybrid) HeNB of Figure 3, to which the UE approaches.

During an initial startup configuration phase, the macro-
10 cell eNB and the microcell HeNB(s) are informed about an initial carrier configuration, such as for example that depicted in Figure 5(a). The HeNB(s) may e.g. be informed by a home enhanced NodeB management system (HMS) or an operation and maintenance entity. According to this exemplary
15 initial carrier configuration, the "protected" carriers are not configured in EC mode and may, thus, be used by the microcell HeNB(s) of the respective CSG as well as by the respective macrocell eNB.

20 According to exemplary embodiments of the present invention, a method at the macrocell eNB may be as follows.

In a first operation according to Figure 4, the macrocell eNB (or, in particular, a processor thereof) determines a
25 triggering condition for carrier reconfiguration between the macrocell eNB and one or more microcell HeNBs in the proximity of which a relevant macrocell user (UE) is located. A corresponding carrier reconfiguration may be triggered on the basis of (radio) measurements performed by the
30 macrocell eNB and macrocell users in the macrocell. In this regard, an amount of traffic in the macrocell and/or a level of interference between the macrocell and the at least one microcell (i.e. a level of activity of the respective microcell) may be detected. Depending on the thus

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detected amount of traffic and/or level of interference, it may be determined by the macrocell eNB whether or not a predefined triggering condition is satisfied, which would e.g. be the case when (radio) requirements of a macrocell user (e.g. on macrocell coverage and/or quality of service) are no longer satisfied, either instantaneously and/or for a predefined time period. According to exemplary embodiments of the present invention, the triggering condition is such that time restrictions for avoiding too frequent re-configurations are taken into consideration.

In a second operation according to Figure 4, the macrocell eNB (or, in particular, a processor thereof) reconfigures at least one carrier of the initial carrier configuration by executing a carrier reconfiguration (in particular, a reconfiguration of one or more "protected" carriers). A corresponding carrier reconfiguration may include changing a mode of at least one carrier between the protected carrier mode and the escape carrier mode according to the radio conditions. A triggering condition for reconfiguring a "protected" carrier into the EC mode may include high downlink load in the macrocell and/or common low signal quality measured by macrocell users. That is, when the triggering condition is satisfied because the macrocell user experiences degraded radio services, the macrocell eNB changes one or more "protected" carriers into the escape carrier (EC) mode, in which an operation on such carriers by the microcell HeNB is not allowed. Such a reconfigured carrier configuration is exemplarily depicted in Figure 5(b), according to which the "protected" carriers are configured in EC mode and may, thus, not be used by the microcell HeNB(s) of the respective CSG.

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In a carrier reconfiguration of the second operation according to Figure 4, the macrocell eNB may reserve a number of carriers for use by the macrocell by changing the mode of corresponding carriers into EC mode, and may accordingly allocate such carriers in the EC mode for use by macrocell users. Also, the macrocell eNB may allow a remaining number of carriers for use by the at least one microcell by changing the mode of corresponding carriers from EC mode to the non-EC mode, and may accordingly release such carriers in non-EC mode from use by macrocell users. The number of carriers to be reserved may depend on detected radio conditions, and may vary from 0 to N escape carriers, where $N < K$ and K is the number of all "protected" carriers available for the operator. Accordingly, macrocell users may operate on "protected" carriers correspondingly reconfigured into EC mode in addition to "forbidden" carriers and "open" carriers.

In a third operation according to Figure 4, the macrocell eNB (or, in particular, a transmitter thereof) signals carrier reconfiguration information to the at least one microcell, i.e. each relevant (CSG/hybrid) HeNB. According to exemplary embodiments of the present invention, the signaling could be done by means of at least one of transmitting a dedicated signaling message including the carrier reconfiguration information towards the at least one macrocell, broadcasting a macrocell broadcast message including the carrier reconfiguration information as system information towards the at least one macrocell, and communicating the carrier reconfiguration information directly to the at least one microcell.

In the first option, a dedicated signaling message is sent from the macrocell eNB towards the MME (mobility management

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entity) which would then forward the dedicated signaling message to the HMS, which then would order the relevant HeNBs to adjust their use of carriers accordingly, e.g. to abandon use of the carrier or carriers indicated as being
5 changed into the EC mode.

In detail, the macrocell eNB may send a signaling message to the MME over an S1-MME interface, said signaling message containing a command to change an operation mode of a carrier or carriers indicated in this particular message (i.e. one/several of the N carriers reserved by the eNB). Additionally, this command may be accompanied by an identifier of the macrocell eNB (e.g. physical cell identifier (PCI) and/or cell global identity (CGI)) and/or a tracking area
10 code (TAC). This signaling message may then be forwarded towards the HMS which stores measurements done by HeNBs in the initial startup phase, i.e. macrocells that it is able to "see" by means of PCI/CGI or TAC. Based on this information, i.e. the PCI, CGI and TAC of a macrocell eNB, the HMS
15 shall be able to derive microcell HeNBs operating in the vicinity of this macrocell eNB, since the combination of PCI/CGI/TAC is unique and as such enables unambiguous eNB cell identification. Once the relevant HeNBs may be identified, the signaling message sent from the source microcell
20 eNB may be forwarded to the target microcell HeNBs via a S1 interface (that is, the signaling message could be sent from the MME, HMS or OAM system). After successful reception, the microcell HeNBs may change their operational mode to adjust to the reconfigured carrier or carriers indicated
25 in the message.
30

In the second option, a macrocell broadcast message is broadcast with a new field containing a flag visible to HeNBs, the flag indicating the reconfigured carrier con-

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figuration, e.g. carrier or carriers indicated as being changed into the EC mode as "escape carrier(s)". That is, the macrocell eNB may set a flag within system information blocks (SIBs) for indicating to the target microcell HeNBs the reconfigured configuration of the specific carrier or carriers. Upon receipt thereof, the microcell HeNBs may acquire and read the SIBs periodically in idle periods and/or in time intervals indicated e.g. by the HMS or OAM system.

10 In the third option, any other signaling methods may be employed, such as e.g. direct radio communication between the macrocell eNB and its neighboring microcells HeNBs (also known as Over the Air Communication (OTAC)).

15 According to exemplary embodiments of the present invention, the thus signaled carrier reconfiguration information may - instead of the previously assumed option of comprising (only) an indication of the mode of the at least one carrier being reconfigured - also comprise an indication of the mode of the at least one carrier and a condition for usability of the at least one carrier by the at least one microcell. In this regard, an EC indication flag may be defined as a set of bits relating to some predefined condition or conditions. Accordingly, only those microcell HeNBs meeting those conditions would be allowed to operate at the considered carrier or carriers. This way the macrocell eNB may gradually decrease the density of (active) microcell HeNBs at a given carrier up to the point when it would be a full macrocell deployment only (see reference curves in
20 Figures 2 and 6). Conceivable conditions in this regard may include e.g. a threshold of a downlink transmit power of the at least one microcell and/or a threshold of a reference signal received power of the macrocell at the at least one microcell.

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For example, in case of a condition relating to HeNB
downlink transmit power, a (CSG/hybrid) HeNB is allowed to
operate on the "protected" carrier(s) only if its transmit
5 power is below X dBm (X being selected from predefined val-
ues by the bits in the EC indication flag). For example, in
case of a condition relating to eNB power measured by a
HeNB, a (CSG/hybrid) HeNB is allowed to operate on the
"protected" carrier(s) only if the reference signal re-
10 ceived power (RSRP) of the macrocell eNB at the HeNB loca-
tion is above X dBm (X being selected from predefined val-
ues by the bits in the EC indication flag).

According to exemplary embodiments of the present inven-
15 tion, a method at a microcell (CSG/hybrid) HeNB may be as
follows.

In a first operation according to Figure 4, the microcell
HeNB or HeNBs (or, in particular, a receiver thereof) re-
20 ceive/s the carrier reconfiguration information for at
least one carrier, as signaled from the macrocell eNB. The
thus received carrier reconfiguration information is as de-
scribed above. Accordingly, it may comprise an indication
of a mode of the at least one carrier, or an indication of
25 a mode of the at least one carrier and a condition for us-
ability of the at least one carrier by the microcell,
wherein the indicated mode is one of the protected carrier
mode and the escape carrier (EC) mode.

30 The carrier reconfiguration information may be received in
the same way as being signaled, i.e. by at least one of re-
ceiving a dedicated signaling message including the carrier
reconfiguration information, receiving a macrocell broad-
cast message including the carrier reconfiguration informa-

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tion as system information, and receiving direct communication of the carrier reconfiguration information from the macrocell. For details in this regard, reference is made to the above.

5

In a second operation according to Figure 4, the microcell HeNB or HeNBs (or, in particular, a processor thereof) adjust/s use of the at least one carrier by the microcell according to the received carrier reconfiguration information.

10

In a carrier adjustment, i.e. an adjustment of its operation mode, the microcell HeNB may release the corresponding carrier or carriers from use by the microcell and/or may inhibit allocation thereof for use by the microcell, when the indicated mode is the EC mode, or when the indicated mode thereof is the EC mode and the condition for usability by the microcell is not satisfied. Also, the microcell HeNB may allocate the corresponding carrier or carriers for use by the microcell and/or may inhibit a releasing thereof, when the indicated mode thereof is the protected carrier mode (non-EC mode), or when the indicated mode thereof is the EC mode and the condition for usability by the microcell is satisfied.

25

Stated in other terms, after having received the carrier reconfiguration information by means of one of the three described ways, any active HeNB operating on the indicated carrier or carriers has to take actions aiming to adjusting its operation accordingly, for example by abandoning carriers being changed into EC mode. This includes e.g. reconfiguration of radio settings of the HeNB, rescheduling (microcell) UEs being active on that carrier(s) to other available carrier(s) (e.g. to the HeNB's primary carrier)

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etc. Accordingly, microcell users may not operate on "protected" carriers correspondingly reconfigured into EC mode, but only on "protected" carriers configured in non-EC mode, in addition to "open" carriers.

5

To avoid collisions during reconfigurations or operational adjustments of HeNBs (in particular, of many HeNBs at the same time), each HeNB may start the reconfiguration or adjustment procedure after a random time is passed, which may
10 be selected from a predefined range. Thereby, a potential drawback may be avoided, namely that a change in the "protected" carrier configuration might lead to a mass reconfiguration of many microcell HeNBs.

15 In the meantime, a HeNB is allowed to use the "protected" carrier in EC mode until it completes radio parameter reconfigurations or operational adjustments (while the time, in which this is allowed, depends on the predefined maximum reconfiguration start delay mentioned above). In addition,
20 no new HeNBs are allowed to take advantage of the "protected" carrier in EC mode. That is, an initial configuration of a HeNB newly participating in communications (due to being switched on or becoming active) would look like the one depicted in Figure 5(b).

25

After radio reconfiguration or operational adjustment in view of recently received carrier reconfiguration information, a microcell HeNBs shall resume its normal mode of operation. However, any HeNB may periodically check (using
30 the same method which was used to convey the carrier reconfiguration information to change the operating carrier, i.e. periodic reading of broadcast information from the overlaying macrocell, listening to OTAC messages and/or network signaling) for any new messages which could make

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the "protected" carriers in EC mode accessible again (i.e. EC mode being disabled). If such an indication is observed, the microcell HeNBs may again allocate such carriers for their use (if needed).

5

In view of the above, exemplary embodiments of the present invention are based on carriers (component carriers) for which usability or accessibility by a microcell (e.g. (CSG/hybrid) HeNB) may be reconfigured during network operation, which are denoted as "protected carriers" herein. For such "protected carriers", exemplary embodiments of the present invention provide for a semi-static (dynamic/flexible) allocation as "escape carrier" (EC), i.e. a re-/configuration in EC mode or not, which may be executed upon a specific triggering condition indicating that basic requirements of a macrocell user are not satisfied due to current radio conditions.

Figure 6 shows a graph illustrating simulation results for a dense co-channel deployment according to exemplary embodiments of the present invention.

In Figure 6, a cumulative distribution function (cdf) is plotted against an effective signal to interference-plus-noise ratio (SINR) in decibel (dB) for a macrocell user in a dense co-channel deployment according to exemplary embodiments of the present invention. The underlying simulation is based on the same scenarios and assumptions as that underlying the simulation of Figure 2. The solid reference curve represents a case of a network environment only comprising macrocells, i.e. no HeNBs being deployed.

The dashed simulation curves represent cases of a dense HeNB co-channel deployment without HeNB power control (PC)

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, wherein the bandwidth of carriers/amount of resources being reserved for macrocell users (i.e. the sum of "forbidden" carriers and "protected" carriers in EC mode) is 10%, 30% and 50% of the total, respectively. The dotted simulation curves represent cases of a dense HeNB co-channel deployment with HeNB power control (PC), wherein the bandwidth of carriers/amount of resources being reserved for macrocell users (i.e. the sum of "forbidden" carriers and "protected" carriers in EC mode) is 10%, 30% and 50% of the total, respectively.

As may be observed from Figure 6, carrier management according to exemplary embodiments of the present invention may improve performance of macrocell user communications in heterogeneous network environments, partly even in a significant way. Further, it may be observed that a different performance may be achieved with different bandwidths of carriers/amount of resources being reserved for macrocell users. The number of escape carriers may beneficially be changed to reflect an increase in macrocell user outages (due to interference between the serving macrocell and one or more microcells in the proximity of the relevant macrocell user).

As evident from the above, at least the following advantages may be achieved by exemplary embodiments of the present invention.

Generally, exemplary embodiments of the present invention provide for a flexible carrier allocation or selection for microcells (e.g. (CSG/hybrid) HeNBs) in heterogeneous network environments with co-channel deployment.

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In particular, the thus proposed mechanisms are more flexible in time domain than those according to previously conceived approaches, i.e. carriers for macrocell traffic are reserved only if needed, and the network configuration is autonomously adapting to varying radio conditions (i.e. changing activity of (CSG/hybrid) HeNBs) and amount of traffic in the macrocell (e.g. high load in rush hours, low load during nights).

Further, the thus proposed mechanisms are capable of limiting radio disturbances in all locations of a heterogeneous network environment. Accordingly, an improved coverage and quality of service may be ensured for macrocell users served by the overlay macrocell network layer even when encountering one or more (non-permitted CSG/hybrid) microcells.

Still further, the thus proposed mechanisms may improve carrier aggregation and carrier/resource utilization in advanced radio access networks comprising a combination of macrocells and microcells.

Also, each of the described methods to convey the carrier reconfiguration information from the macrocell eNB towards the microcell HeNB(s) has its specific advantages.

Network signaling is a very accurate technique, and does not involve any changes to the radio interface. It also enables good (or even perfect) timing of the carrier reconfiguration or operational adjustments at the microcell HeNBs, since the HMS/MME is able to send the carrier reconfiguration information in the signaling message to the relevant HeNBs only once when this is really needed and with different time intervals avoiding a carrier re-

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reconfiguration or operational adjustment of all (or a large number of) microcells HeNBs within a given area at the same time, which might have detrimental effects on network and UE behavior.

5

Information distributed on macrocell broadcast does not involve other network entities (e.g. HMS, MME) to convey the carrier reconfiguration information towards the microcell HeNBs. The proposed (EC indication) flag in one of the SIBs shall be only of importance to relevant microcell HeNBs, so there are no issues with backwards compatibility concerning e.g. UEs.

Regarding OTAC, once this technique would be implemented for the usage of the ACCS scheme, it would be fairly easy to add an additional marker/flag for escape carrier (EC) indication. This additionally has the advantage that no changes to the SIBs or network signaling would be needed.

The above-described procedures and functions may be implemented by respective functional elements, processors, or the like, as described below.

While in the foregoing exemplary embodiments of the present invention are described mainly with reference to methods, procedures and functions, corresponding exemplary embodiments of the present invention also cover respective apparatuses, network nodes and systems, including both software and/or hardware thereof.

30

Respective exemplary embodiments of the present invention are described below referring to Figure 7, while for the sake of brevity reference is made to the detailed description of respective corresponding methods and operations ac-

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according to Figures 4 and 5 on the basis of Figures 1 and 3, respectively.

In Figure 7 below, the solid line blocks are basically configured to perform respective operations as described above. The entirety of solid line blocks are basically configured to perform the methods and operations as described above, respectively. With respect to Figure 7, it is to be noted that the individual blocks are meant to illustrate respective functional blocks implementing a respective function, process or procedure, respectively. Such functional blocks are implementation-independent, i.e. may be implemented by means of any kind of hardware or software, respectively. The arrows interconnecting individual blocks are meant to illustrate an operational coupling therebetween, which may be a physical and/or logical coupling, which on the one hand is implementation-independent (e.g. wired or wireless) and on the other hand may also comprise an arbitrary number of intermediary functional entities not shown. The direction of arrow is meant to illustrate the direction in which certain operations are performed and/or the direction in which certain data is transferred.

Further, in Figure 7, only those functional blocks are illustrated, which relate to any one of the above-described methods, procedures and functions. A skilled person will acknowledge the presence of any other conventional functional blocks required for an operation of respective structural arrangements, such as e.g. a power supply, a central processing unit, respective memories or the like. Among others, memories are provided for storing programs or program instructions for controlling the individual functional entities to operate as described herein.

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Figure 7 shows a block diagram of apparatuses according to exemplary embodiments of the present invention. In view of the above, the thus described apparatus on the left side may represent a (part of a) macrocell base station such as a eNB, as described above, and the thus described apparatus on the right side may represent a (part of a) microcell base station such as a (CSG/hybrid) HeNB, as described above.

10 According to Figure 7, the left-handed apparatus according to exemplary embodiments of the present invention is configured to perform a procedure as described in conjunction with the left side of Figure 4, and the right-handed apparatus according to exemplary embodiments of the present invention is configured to perform a procedure as described in conjunction with the left side of Figure 4. Therefore, while basic operations are described hereinafter, reference is made to the above description for details thereof.

20 According to an exemplary embodiment depicted in Figure 7, a thus depicted apparatus related to the macrocell comprises a processor and a transmitter, as well as, optionally, a detector. The processor may be specifically configured to determine a triggering condition for carrier reconfiguration between the macrocell and at least one microcell according to radio conditions of a macrocell user, thus representing means for determining a triggering condition (or trigger) or comprising a determining functionality. The processor may further be specifically configured to reconfigure at least one carrier in terms of usability by the at least one microcell, i.e. to perform reconfiguration of a carrier configuration, thus representing means for reconfiguring carriers or comprising a reconfiguring functionality. The transmitter may be specifically configured to sig-

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nal carrier reconfiguration information from the macrocell to or at least towards the at least one microcell, thus representing means for signaling carrier reconfiguration information.

5

The optional detector may be specifically configured to detect an amount of traffic in the macrocell, and/or a level of interference between the macrocell and the at least one microcell, thus representing means for detecting radio conditions of the macrocell. To this end, the detector may
10 comprise a measuring unit for performing measurements on the radio level and/or to coordinate measurements on the radio level with one or more macrocell users (UEs). The processor may further be specifically configured to deter-
15 mine the triggering condition according to the amount of traffic and/or level of interference detected by the detector.

The processor may further be specifically configured to
20 change a mode of at least one carrier, especially to change the mode of a "protected" carrier to EC mode and vice versa, thus representing means for changing carrier modes (which could be included in the reconfiguring functionality).

25

The processor may further be specifically configured to reserve and/or allocate a number of carriers (i.e. a certain bandwidth of carriers/amount of radio resources) for use by the macrocell, and allow a remaining number of carriers for
30 use by the at least one microcell and/or to release the remaining number of carriers from use by the macrocell, thus representing means for carrier allocation and/or release for macrocell and/or microcell (which could be included in the reconfiguring functionality). Accordingly, the proces-

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5 sor may further be specifically configured to command macrocell users (UEs) to use correspondingly allocated macrocell carriers, thus representing means for commanding macrocell carrier usage (which could be included in the reconfiguring functionality).

According to an exemplary embodiment depicted in Figure 7, a thus depicted apparatus related to the microcell comprises a receiver and a processor. The receiver may be specifically configured to receive carrier reconfiguration information for at least one carrier from a macrocell or at least from the direction of a macrocell, thus representing means for receiving carrier reconfiguration information. The processor may be specifically configured to adjust use of the at least one carrier by the microcell, thus representing means for performing operational adjustments and/or (radio/parameter) reconfigurations or comprising an adjusting functionality.

20 The processor may further be specifically configured to release and/or inhibit allocation of the at least one carrier from use by the microcell, and/or allocate and/or inhibit release of the at least one carrier for use by the microcell, thus representing means for carrier allocation and/or release for the microcell (which could be included in the adjusting functionality). Accordingly, the processor may further be specifically configured to command microcell users (UEs) to use correspondingly allocated microcell carriers, thus representing means for commanding microcell carrier usage (which could be included in the adjusting functionality).

The processor may further be specifically configured to delay a start of said adjustment/reconfiguration after re-

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receipt of said carrier reconfiguration information by a random time selected from a predefined range, thus representing means for delaying operation or comprising a delaying functionality, and/or to periodically check receipt of further carrier reconfiguration information, thus representing means for checking receipt of carrier reconfiguration information or comprising a checking functionality.

The above-mentioned carrier reconfiguration information may comprise either an indication of the mode of the at least one carrier, or an indication of the mode of the at least one carrier and a condition for usability of the at least one carrier by the at least one microcell. The above-mentioned carrier reconfiguration information may be transferred from the macrocell to the microcell in an arbitrary manner, specifically for example by one of the three ways described above, wherein the transmitter of the macrocell base station and the receiver of the microcell base station are specifically configured accordingly.

20

The above-mentioned carrier re-/configuration may be applied to superordinate and/or subordinate component carriers (in particular, subordinate component carriers) of the microcell or microcells, as explained above. Namely, for example, such superordinate component carriers may be primary or base component carriers as described in the ACCS concept (or any other carrier selection procedure for carrier selection using carrier aggregation), and such subordinate component carriers may be secondary or supplementary component carriers as described in the ACCS concept (or any other carrier selection procedure for carrier selection using carrier aggregation).

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According to exemplarily embodiments of the present invention, a system may comprise any conceivable combination of the thus depicted apparatuses (such as an eNB and one or more HeNBs) and other network elements (such as MME, HeNB
5 GW, HMS/OAM entities), which are configured to cooperate as described above. Additionally and/or alternatively, a system may comprise any conceivable number of macrocell users (UEs) linked with a macrocell base station and/or any conceivable number of microcell users (UEs) linked with a microcell base station, wherein a user equipment (UE) may
10 change its status between being a macrocell UE and a microcell UE by way of corresponding handovers between respective macrocell/microcell base station.

15 In general, it is to be noted that respective functional blocks or elements according to above-described aspects can be implemented by any known means, either in hardware and/or software, respectively, if it is only adapted to perform the described functions of the respective parts.

20 The mentioned method steps can be realized in individual functional blocks or by individual devices, or one or more of the method steps can be realized in a single functional block or by a single device.

25 Generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the present invention. Devices and means can be implemented as individual devices, but this does not exclude that they are implemented in a distributed fashion throughout the system,
30 as long as the functionality of the device is preserved. Such and similar principles are to be considered as known to a skilled person.

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Software in the sense of the present description comprises software code as such comprising code means or portions or a computer program or a computer program product for performing the respective functions, as well as software (or a computer program or a computer program product) embodied on a tangible medium such as a computer-readable (storage) medium having stored thereon a respective data structure or code means/portions or embodied in a signal or in a chip, potentially during processing thereof.

Generally, for the purpose of the present invention as described herein above, it should be noted that

- method steps and functions likely to be implemented as software code portions and being run using a processor at one of the entities, a network element, or a terminal (as examples of devices, apparatuses and/or modules thereof, or as examples of entities including apparatuses and/or modules therefor), are software code independent and can be specified using any known or future developed programming language, such as e.g. Java, C++, C, and Assembler, as long as the functionality defined by the method steps is preserved;

- generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the invention in terms of the functionality implemented;

- method steps, functions, and/or devices, apparatuses, units or means likely to be implemented as hardware components at a terminal or network element, or any module(s) thereof, are hardware independent and can be implemented using any known or future developed hardware technology or any hybrids of these, such as MOS (Metal Oxide Semiconductor), CMOS (Complementary MOS), BiMOS (Bipolar MOS), BiCMOS (Bipolar CMOS), ECL (Emitter Coupled Logic), TTL (Transistor-Transistor Logic), etc., using for example ASIC (Appli-

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cation Specific IC (Integrated Circuit)) components, FPGA (Field-programmable Gate Arrays) components, CPLD (Complex Programmable Logic Device) components or DSP (Digital Signal Processor) components; in addition, any method steps
5 and/or devices, units or means likely to be implemented as software components may for example be based on any security architecture capable e.g. of authentication, authorization, keying and/or traffic protection;

- devices, apparatuses, units or means can be implemented
10 as individual devices, apparatuses, units or means, but this does not exclude that they are implemented in a distributed fashion throughout the system, as long as the functionality of the device, apparatus, unit or means is preserved,

- an apparatus may be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of an apparatus or module, instead of being hardware implemented, be implemented as software in a
15 (software) module such as a computer program or a computer program product comprising executable software code portions for execution/being run on a processor;

- a device may be regarded as an apparatus or as an assembly of more than one apparatus, whether functionally in co-
20 operation with each other or functionally independently of each other but in a same device housing, for example.

The present invention also covers any conceivable combination of method steps and operations described above, and
30 any conceivable combination of nodes, apparatuses, modules or elements described above, as long as the above-described concepts of methodology and structural arrangement are applicable.

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There are provided measures for carrier management in heterogeneous networks, said measures exemplarily comprising determining a triggering condition for carrier reconfiguration between a macrocell and at least one microcell using
5 the same carrier frequency band according to radio conditions of a macrocell user, reconfiguring at least one carrier in terms of usability by the at least one microcell, and signaling carrier reconfiguration information from the macrocell to the at least one microcell. Said measures may
10 exemplarily be applied for mobility procedures in LTE, LTE-Advanced, HSPA and/or UMTS radio access systems.

Even though the invention is described above with reference to the examples according to the accompanying drawings, it
15 is to be understood that the invention is not restricted thereto. Rather, it is apparent to those skilled in the art that the present invention can be modified in many ways without departing from the scope of the inventive idea as disclosed herein.

Claims

- 5 1. A method comprising
determining a triggering condition for carrier reconfiguration between a macrocell and at least one microcell using the same carrier frequency band according to radio conditions of a macrocell user,
10 reconfiguring at least one carrier in terms of usability by the at least one microcell, and
signaling carrier reconfiguration information from the macrocell to the at least one microcell.
- 15 2. The method according to claim 1, further comprising
detecting an amount of traffic in the macrocell, and/or
detecting a level of interference between the macrocell and the at least one microcell, wherein
the triggering condition is determined according to the
20 detected amount of traffic and/or level of interference.
3. The method according to claim 1 or 2, wherein the triggering condition is determined to be satisfied when satisfaction of requirements on macrocell coverage and/or quality of service of the macrocell user changes instantaneously and/or for
25 a predefined time period.
4. The method according to any one of claims 1 to 3, said reconfiguring comprising
30 changing a mode of at least one carrier between a protected carrier mode, in which the respective carrier is usable by the macrocell and the at least one microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only, according to the radio conditions.
35

5. The method according to claim 4, said reconfiguring comprising

reserving and/or allocating a number of carriers for use by the macrocell by changing the mode of the number of carriers from the protected carrier mode to the escape carrier mode, and

allowing a remaining number of carriers for use by the at least one microcell and/or releasing the remaining number of carriers from use by the macrocell by changing the mode of the remaining number of carriers from the escape carrier mode to the protected carrier mode.

6. The method according to claim 4 or 5, the carrier reconfiguration information comprising

an indication of the mode of the at least one carrier, or

an indication of the mode of the at least one carrier and a condition for usability of the at least one carrier by the at least one microcell.

7. The method according to claim 6, wherein the condition for usability by the at least one microcell comprises a threshold of a downlink transmit power of the at least one microcell and/or a threshold of a reference signal received power of the macrocell at the at least one microcell.

8. The method according to any one of claims 1 to 7, said signaling comprising at least one of

transmitting a dedicated signaling message including the carrier reconfiguration information towards the at least one macrocell,

broadcasting a macrocell broadcast message including the carrier reconfiguration information as system information towards the at least one macrocell, and

communicating the carrier reconfiguration information directly to the at least one microcell.

9. The method according to any one of claims 1 to 8, wherein the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell.

5

10. The method according to any one of claims 1 to 9, wherein the at least one microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers, and said macrocell user is no member of said closed subscriber group.

10

11. The method according to any one of claims 1 to 10, wherein

the method is operable at a macrocell base station, and/or

15

said macrocell comprises a base station, eNB, and said microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or said macrocell comprises an access node and said microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

20

12. A method comprising

receiving carrier reconfiguration information for at least one carrier from a macrocell at a microcell, said macrocell and said microcell using the same carrier frequency band, and

25

adjusting use of the at least one carrier by the microcell.

30

13. The method according to claim 12, the carrier reconfiguration information comprising

an indication of a mode of the at least one carrier, or an indication of a mode of the at least one carrier and a condition for usability of the at least one carrier by the microcell, wherein

35

the indicated mode is one of a protected carrier mode, in which the respective carrier is usable by the macrocell and the microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only.

5

14. The method according to claim 13, wherein the condition for usability by the microcell comprises a threshold of a downlink transmit power of the microcell and/or a threshold of a reference signal received power of the macrocell at the
10 microcell.

15. The method according to claim 13 or 14, said adjusting comprising

releasing and/or inhibiting allocating the at least one
15 carrier from use by the microcell, when the indicated mode thereof is the escape carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is not satisfied, and/or

allocating and/or inhibiting releasing the at least one
20 carrier for use by the microcell when the indicated mode thereof is the protected carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is satisfied.

25 16. The method according to any one of claims 12 to 15, said receiving comprising at least one of

receiving a dedicated signaling message including the carrier reconfiguration information,

receiving a macrocell broadcast message including the
30 carrier reconfiguration information as system information, and

receiving direct communication of the carrier reconfiguration information from the macrocell.

35 17. The method according to any one of claims 12 to 16, further comprising

delaying a start of said adjusting after receiving said carrier reconfiguration information by a random time selected from a predefined range, and/or

periodically checking receipt of further carrier reconfiguration information.

18. The method according to any one of claims 12 to 17, wherein the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell.

19. The method according to any one of claims 12 to 18, wherein the microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers.

20. The method according to any one of claims 12 to 19, wherein

the method is operable at a microcell base station, and/or

said macrocell comprises a base station, eNB, and said microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or said macrocell comprises an access node and said microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

21. An apparatus comprising

a processor configured to

determine a triggering condition for carrier reconfiguration between a macrocell and at least one microcell using the same carrier frequency band according to radio conditions of a macrocell user, and

reconfigure at least one carrier in terms of usability by the at least one microcell, and

a transmitter configured to

signal carrier reconfiguration information from the macrocell to the at least one microcell.

22. The apparatus according to claim 21, further comprising

5 a detector configured to

detect an amount of traffic in the macrocell, and/or

detect a level of interference between the macrocell and the at least one microcell, wherein

the processor is configured to determine the triggering

10 condition according to the detected amount of traffic and/or level of interference.

23. The apparatus according to claim 21 or 22, wherein the

processor is configured to determine the triggering condition

15 to be satisfied when satisfaction of requirements on macro-

cell coverage and/or quality of service of the macrocell user

changes instantaneously and/or for a predefined time period.

24. The apparatus according to any one of claims 21 to 23,

20 wherein the processor, for reconfiguring, is configured to

change a mode of at least one carrier between a pro-

TECTED carrier mode, in which the respective carrier is us-

able by the macrocell and the at least one microcell, and an

escape carrier mode, in which the respective carrier is us-

25 able by the macrocell only, according to the radio condi-

tions.

25. The apparatus according to claim 24, wherein the proces-

sor, for reconfiguring, is configured to

30 reserve and/or allocate a number of carriers for use by

the macrocell by changing the mode of the number of carriers

from the protected carrier mode to the escape carrier mode,

and

allow a remaining number of carriers for use by the at

35 least one microcell and/or release the remaining number of

carriers from use by the macrocell by changing the mode of

the remaining number of carriers from the escape carrier mode to the protected carrier mode.

26. The apparatus according to claim 24 or 25, the carrier reconfiguration information comprising

an indication of the mode of the at least one carrier,
or

an indication of the mode of the at least one carrier
and a condition for usability of the at least one carrier by
the at least one microcell.

27. The apparatus according to claim 26, wherein the condition for usability by the at least one microcell comprises a threshold of a downlink transmit power of the at least one microcell and/or a threshold of a reference signal received power of the macrocell at the at least one microcell.

28. The apparatus according to any one of claims 21 to 27, the transmitter is configured to

transmit a dedicated signaling message including the carrier reconfiguration information towards the at least one macrocell, and/or

broadcast a macrocell broadcast message including the carrier reconfiguration information as system information towards the at least one macrocell, and/or

communicate the carrier reconfiguration information directly to the at least one microcell.

29. The apparatus according to any one of claims 21 to 28, wherein the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell.

30. The apparatus according to any one of claims 21 to 29, wherein the at least one microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group

and other subscribers, and said macrocell user is no member of said closed subscriber group.

31. The apparatus according to any one of claims 21 to 30,
5 wherein

the apparatus is operable as or at a macrocell base station, and/or

said macrocell comprises a base station, eNB, and said microcell comprises a home base station, HeNB, in accordance
10 with an LTE or LTE-Advanced radio access system, or said macrocell comprises an access node and said microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

15 32. An apparatus comprising

a receiver configured to receive carrier reconfiguration information for at least one carrier from a macrocell at a microcell, said macrocell and said microcell using the same carrier frequency band, and

20 a processor configured to adjust use of the at least one carrier by the microcell.

33. The apparatus according to claim 32, the carrier reconfiguration information comprising

25 an indication of a mode of the at least one carrier, or an indication of a mode of the at least one carrier and a condition for usability of the at least one carrier by the microcell, wherein

30 the indicated mode is one of a protected carrier mode, in which the respective carrier is usable by the macrocell and the microcell, and an escape carrier mode, in which the respective carrier is usable by the macrocell only.

34. The apparatus according to claim 33, wherein the condition for usability by the microcell comprises a threshold of
35 a downlink transmit power of the microcell and/or a threshold

of a reference signal received power of the macrocell at the microcell.

35. The apparatus according to claim 33 or 34, wherein the processor, for adjusting, is configured to

release and/or inhibit allocation of the at least one carrier from use by the microcell, when the indicated mode thereof is the escape carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is not satisfied, and/or

allocate and/or inhibit release of the at least one carrier for use by the microcell when the indicated mode thereof is the protected carrier mode, or when the indicated mode thereof is the escape carrier mode and the condition for usability by the microcell is satisfied.

36. The apparatus according to any one of claims 32 to 35, wherein the receiver is configured to

receive a dedicated signaling message including the carrier reconfiguration information, and/or

receive a macrocell broadcast message including the carrier reconfiguration information as system information, and/or

receive direct communication of the carrier reconfiguration information from the macrocell.

37. The apparatus according to any one of claims 32 to 36, wherein the processor is configured to

delay a start of said adjusting after receiving said carrier reconfiguration information by a random time selected from a predefined range, and/or

periodically check receipt of further carrier reconfiguration information.

38. The apparatus according to any one of claims 32 to 37, wherein the at least one carrier comprises superordinate and/or subordinate component carriers of the microcell.

5 39. The apparatus according to any one of claims 32 to 38, wherein the microcell is a cell of a closed subscriber group or a hybrid cell of a closed subscriber group and other subscribers.

10 40. The apparatus according to any one of claims 32 to 39, wherein
the apparatus is operable as or at a microcell base station, and/or
said macrocell comprises a base station, eNB, and said
15 microcell comprises a home base station, HeNB, in accordance with an LTE or LTE-Advanced radio access system, or said macrocell comprises an access node and said microcell comprises a femto access node in accordance with a HSPA or UMTS radio access system.

20 41. A computer program product including a program comprising software code portions being arranged, when run on a processor of an apparatus, to perform the method according to any one of claims 1 to 11.

25 42. A computer program product including a program comprising software code portions being arranged, when run on a processor of an apparatus, to perform the method according to any one of claims 12 to 20.

30 43. The computer program product according to claim 41 or 42, wherein the computer program product comprises a computer-readable medium on which the software code portions are stored, and/or wherein the program is directly loadable into
35 a memory of the processor.

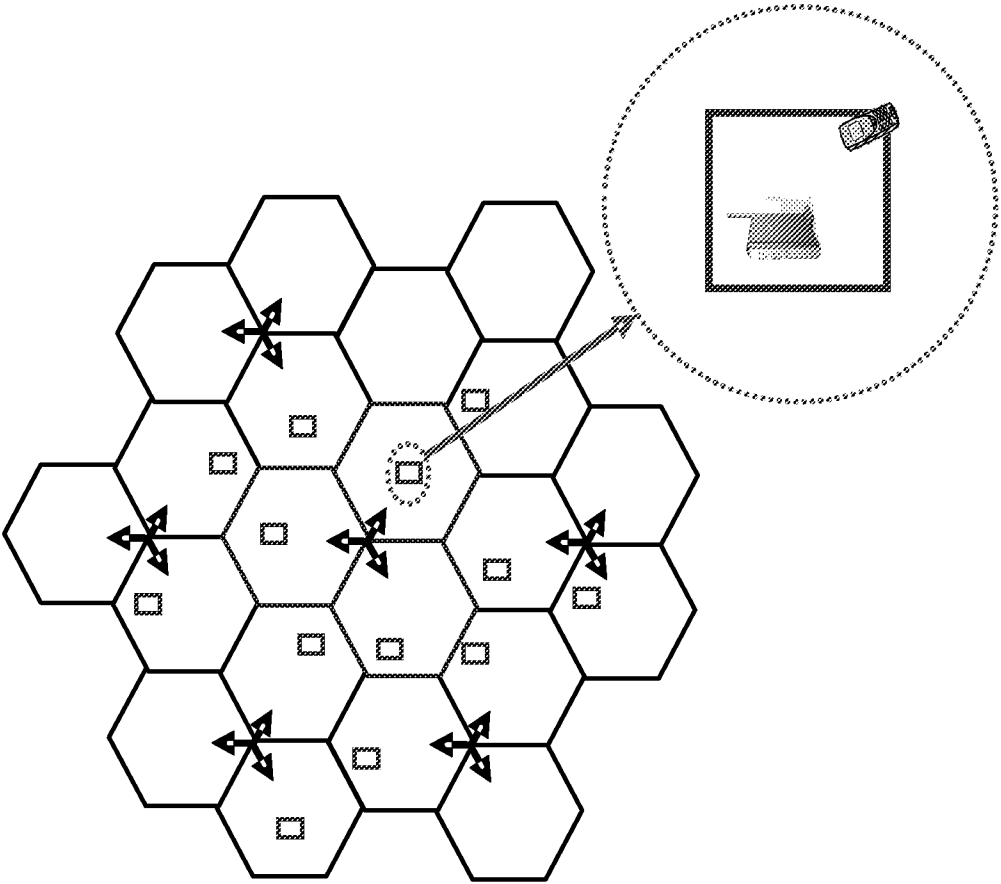


Figure 1

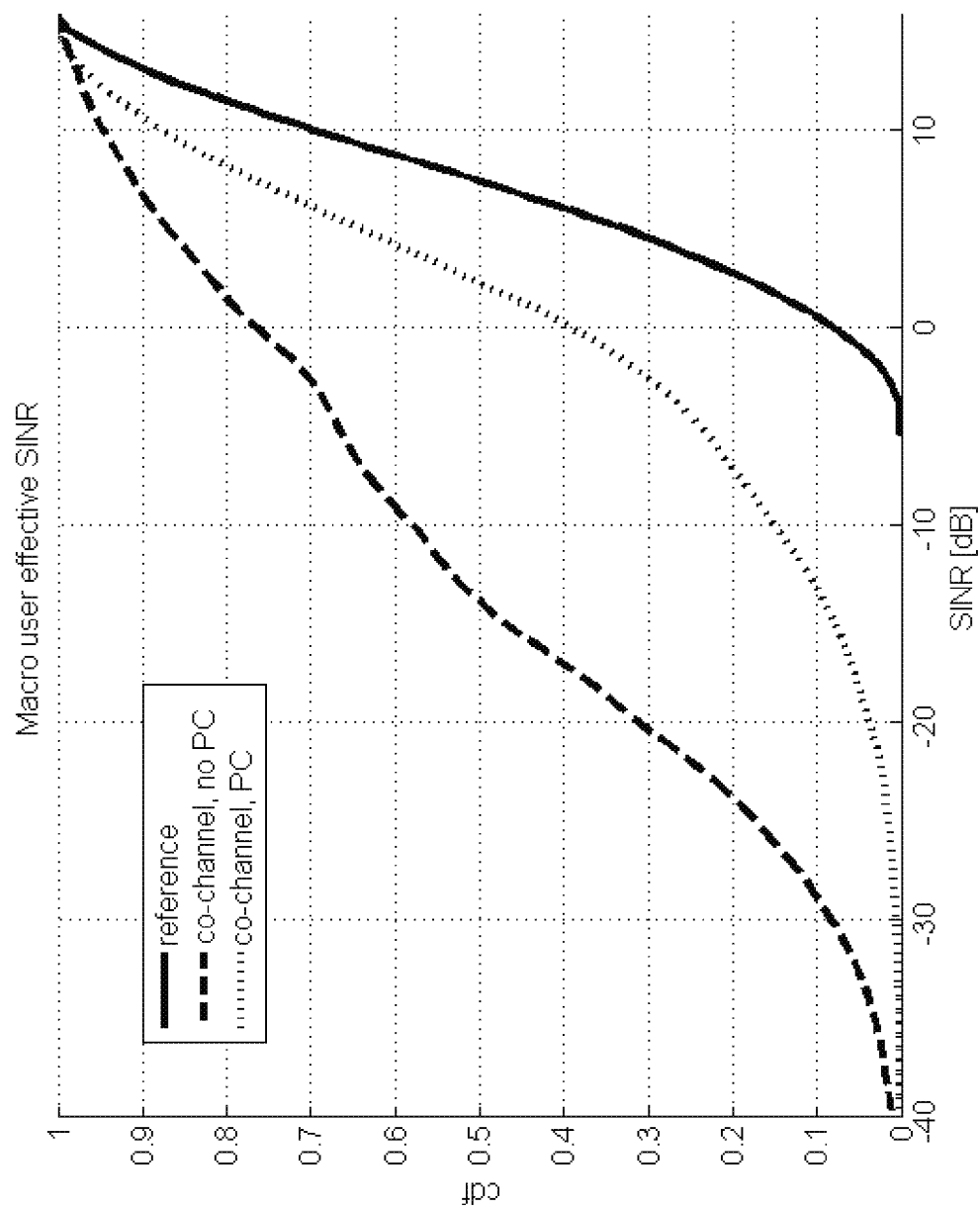


Figure 2

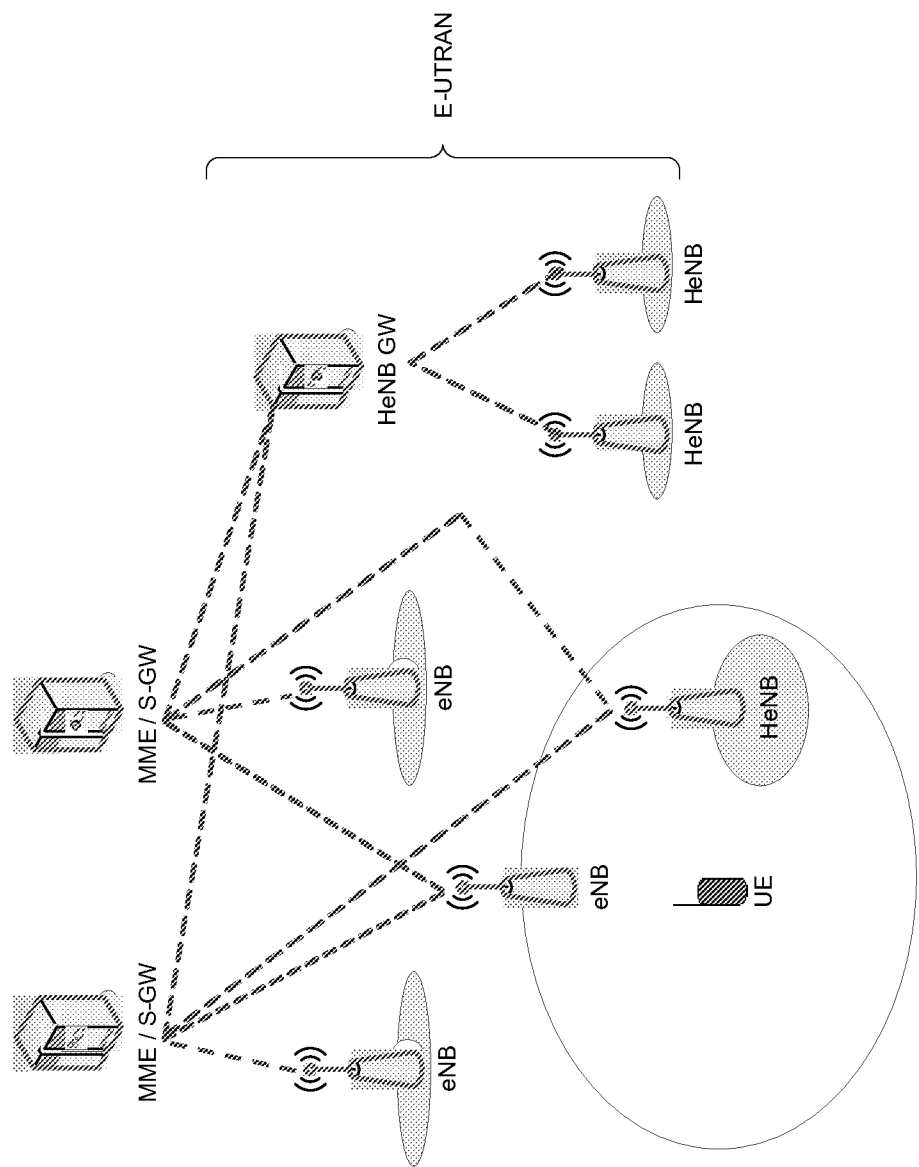


Figure 3

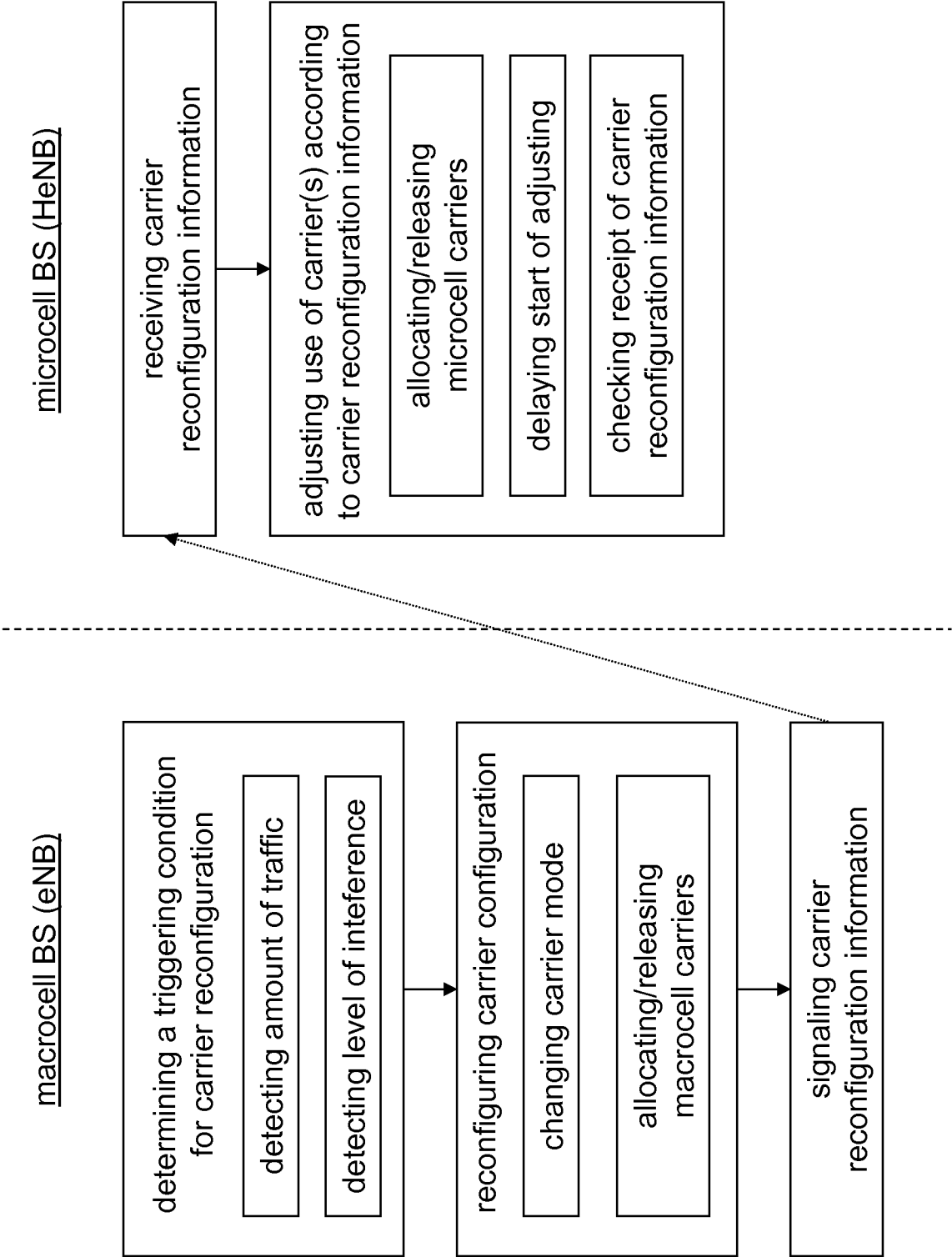


Figure 4

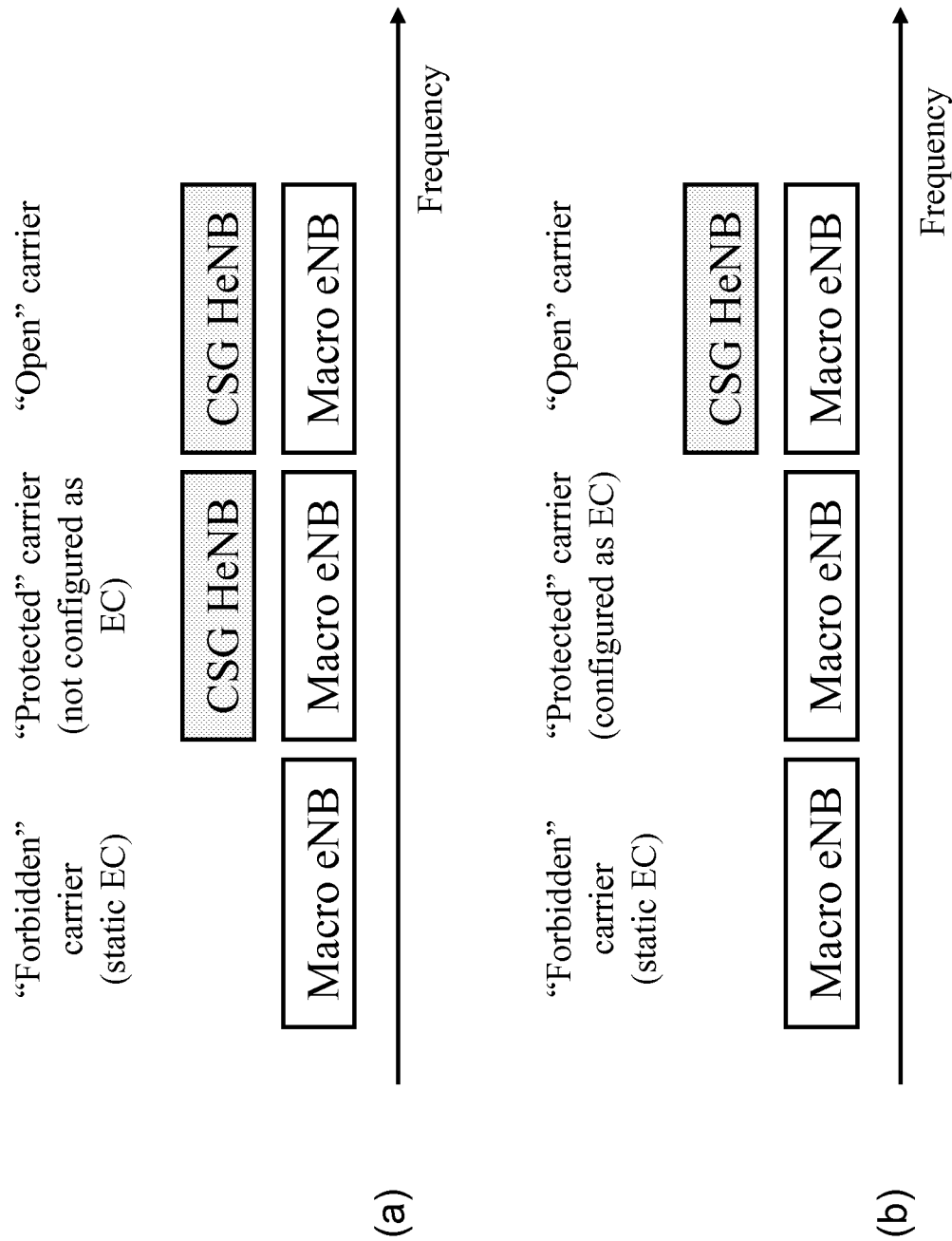


Figure 5

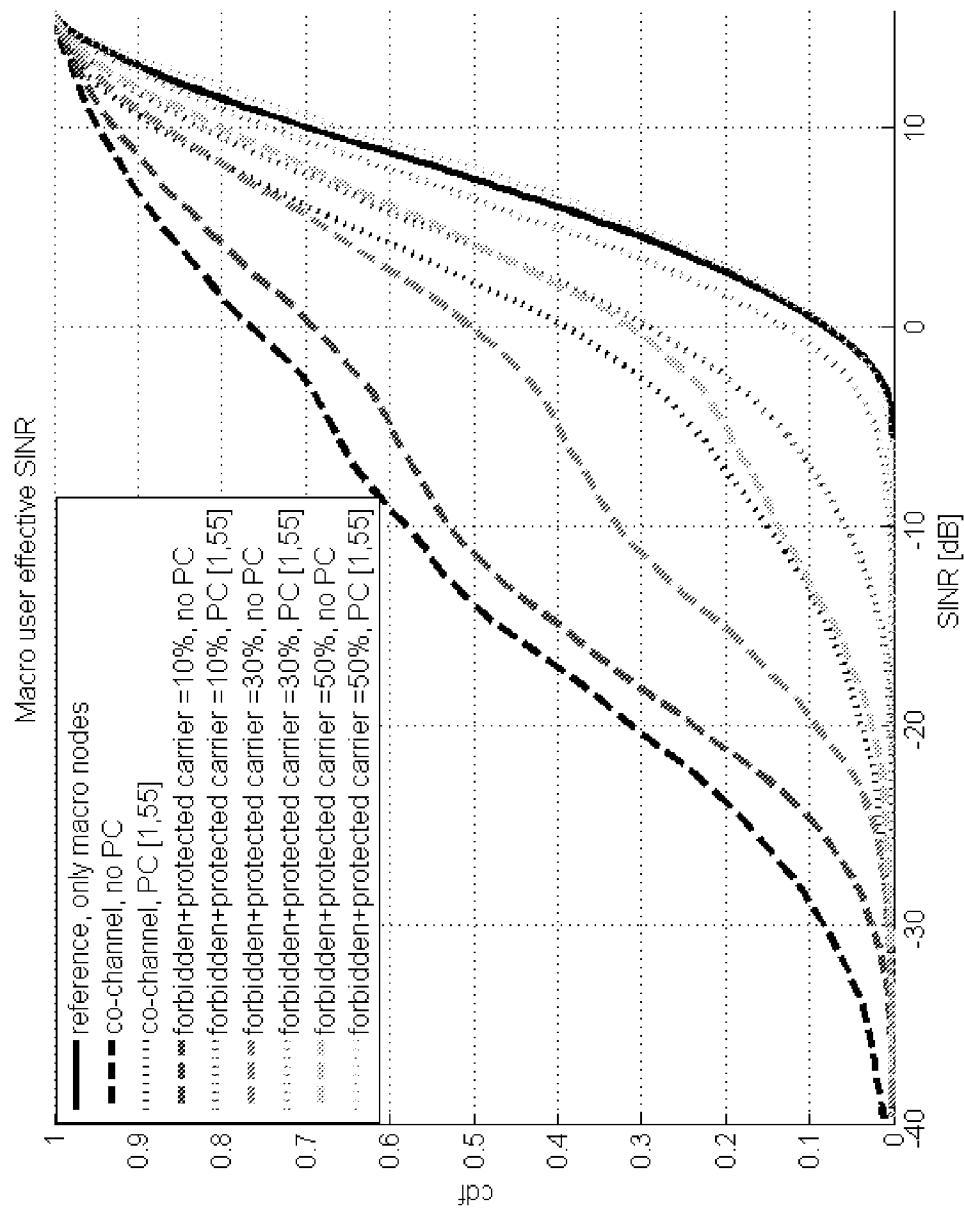


Figure 6

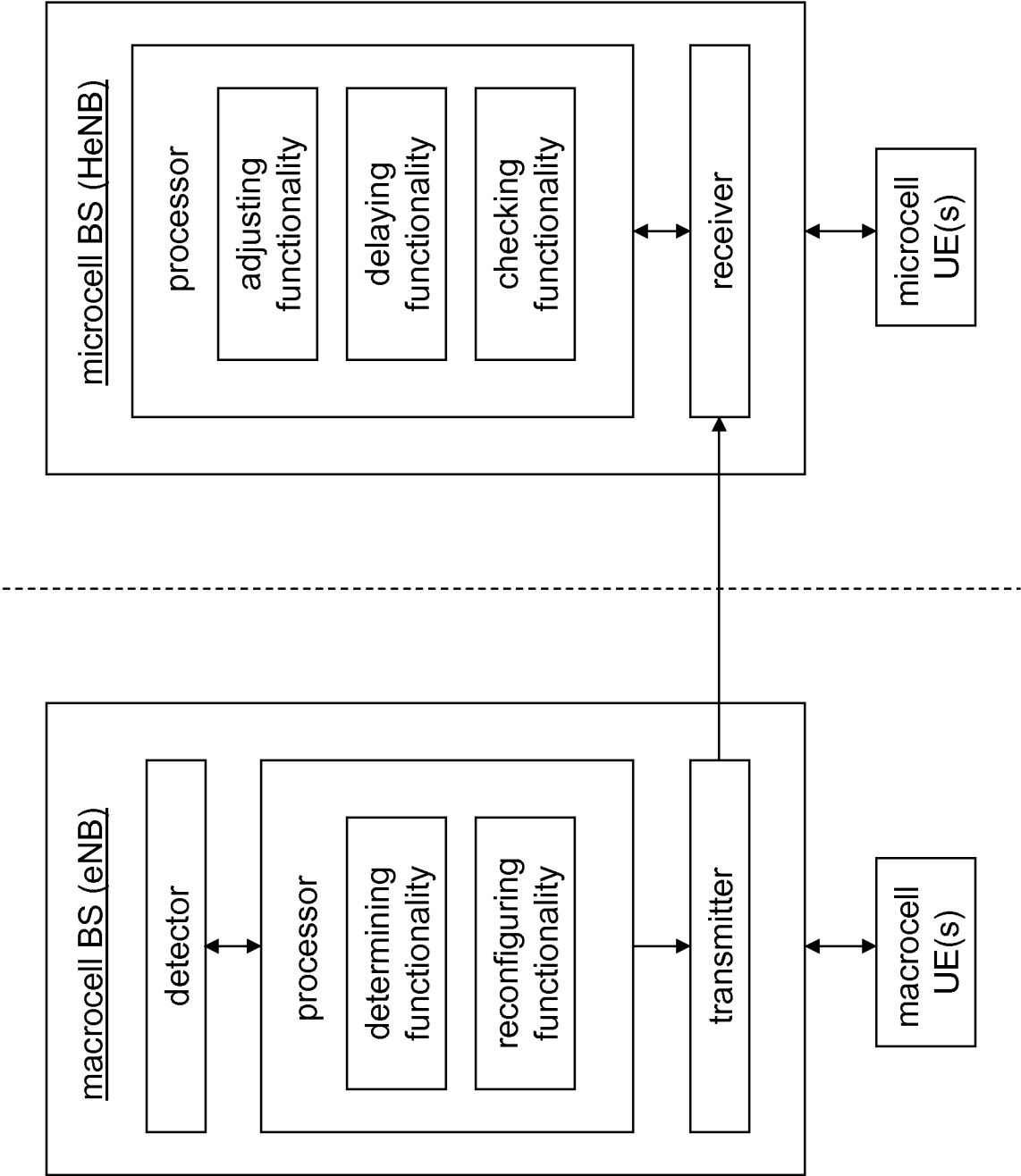


Figure 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/055922

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W16/10

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 practical, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/029282 A1 (STAMOULIS ANASTASIOS [US] ET AL) 4 February 2010 (2010-02-04)	1-3,8, 10-12, 16,17, 19-23, 28, 30-32, 36,37, 39-43 4-7,9, 13-15, 18, 24-27, 29, 33-35,38
Y	paragraph [0003] paragraph [0012] paragraph [0049] - paragraph [0052] paragraph [0054] - paragraph [0056] paragraph [0058] paragraph [0061] paragraph [0065] - paragraph [0068] paragraph [0075] paragraph [0081] paragraph [0089] - paragraph [0092] paragraph [0125] -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

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"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

13 January 2011

Date of mailing of the international search report

28/01/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/055922

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	figure 6 ----- NOKIA SIEMENS NETWORKS ET AL: "Macro+HeNB performance with escape carrier or dynamic carrier selection", 3GPP DRAFT; R1-101924, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Beijing, china; 20100412, 6 April 2010 (2010-04-06), XP050419269, [retrieved on 2010-04-06] the whole document	4-7,9, 13-15, 18, 24-27, 29, 33-35,38
A	----- QUALCOMM EUROPE: "Carrier Aggregation in Heterogeneous Networks", 3GPP DRAFT; R1-090357, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Ljubljana; 20090108, 8 January 2009 (2009-01-08), XP050318263, [retrieved on 2009-01-08] the whole document -----	1-43

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/055922

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010029282 A1	04-02-2010	W0 2010014961 A2	04-02-2010
