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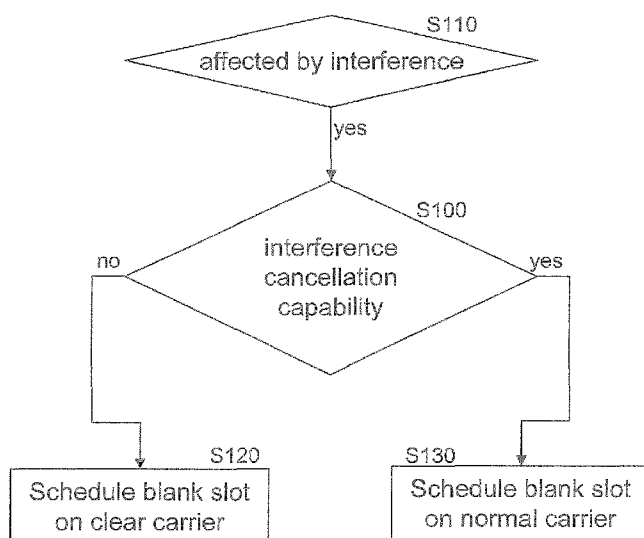


Fig. 2

(57) **Abstract:** It is provided a method, comprising classifying a first terminal having at least a downlink communication with an apparatus performing the method into one of a cancellation category and a non-cancellation category, wherein the cancellation category indicates that the first terminal is capable of reference signal interference cancellation; assessing whether the first terminal is affected by interference caused by an aggressor device by more than a first interference level; if it is assessed that the first terminal is affected by more than the first interference level and the terminal is classified into the non-cancellation category, scheduling a first blank slot of a clear carrier for the downlink communication, and if it is assessed that the first terminal is affected by more than the first interference level and the first terminal is classified into the cancellation category, scheduling a second blank slot of a normal carrier for the downlink communication, wherein the scheduling is based on a carrier information received from the aggressor device according to which the clear carrier is comprised by one or more extension carriers of the aggressor device and based on a slot information received from the aggressor device according to which each of the first and second blank slots is of one of an almost blank slot type and a blank slot with reduced power type.

IMPROVEMENTS IN HETNETS

Field of the invention

5 The present invention relates to an apparatus, a method, and a computer program product for heterogeneous networks. More particularly, the present invention relates to an apparatus, a method, and a computer program product for assigning carriers and/or slots.

10 Background of the invention

Abbreviations

	DL	Downlink
	UL	Uplink
15	eNB	Enhanced NodeB
	UE	User Equipment
	Tx	Transmit
	Rx	Receive
	LTE™	Long Term Evolution
20	PDCCH	Physical Downlink Control Channel
	PDSCH	Physical Downlink Shared Channel
	ICIC	Inter-Cell Interference Coordination
	eICIC	Enhanced Inter-Cell Interference Coordination
	CRE	Cell Range Expansion
25	ABS	Almost Blank Subframe
	LP-ABS	Low Power Almost Blank Subframe
	ZP-ABS	Zero Power Almost Blank Subframe
	PRB	Physical Resource Block
	CCE	Control Channel Element
30	RRH	Remote Radio Head
	CRS	Cell-specific Reference Signal
	E-UTRA	Evolved Universal Terrestrial Radio Access
	CA	Carrier Aggregation
	LA	Local Area

	IE	Information Element
	CC	Component Carrier
	RSRP	Reference Signal Received Power
	RSRQ	Reference Signal Received Quality
5	RSSI	Received Signal Strength Indicator
	PCI	Physical Cell Identifier
	3GPP	3rd Generation Partnership Project
	TS	Technical Specification
	Rel	Release
10	PCC	Primary Component Carrier
	PSS	Primary Synchronization Signal
	SSS	Secondary Synchronization Signal
	OAM	Operation And Management
	EARFCN	E-UTRA Absolute Radio Frequency Channel Number

15

Mobile communication is constantly making progress. Under one aspect of such progress, heterogeneous networks (HetNets) are being investigated to improve coverage and, in general, performance.

20

General technical details of such HetNet scenarios, e.g. under LTE™ and adopted communication protocols are publicly available. A repeated detailed description of each such property/functionality of the known LTE™ system is considered dispensable as those skilled in the pertinent art of technology will readily understand the description as given herein. Examples of the present invention exploit those basic properties and at least in aspects modify the functionality so as to obtain the advantages of at least some embodiments of the present invention.

25

30 Those HetNets comprise network transceiver devices or, more general, network entities providing different, and at least partially overlapping coverage for communication, and those are simultaneously in operation. A typical example, when applying LTE™ terminology, of such networks

entities reside in general in evolved NodeBs (eNB's), such as a macro eNB (of "large" coverage) and pico or femto eNBs or even remote radio heads (RRH) (of "small" coverage when compared to the macro eNB's coverage).

5 Terminals such as user equipments UE are present within the coverage of both entities and may experience interference due to the network entities operating on neighboring or even identical bandwidth partitions or (physical) channels. In this regard, a macro cell or macro eNB which typically transmits using higher transmission power can be regarded as a
10 source of interference, and is thus referred to herein also as "aggressor cell". On the other hand, a pico cell or pico eNB, more particularly the terminals camping in its coverage, experience the interference and are thus "victims". Hence not only those UEs but also those pico/femto eNBs / cells are also referred to herein as "victim cell". Note that a physical
15 channel carries plural logical channels such as one or more payload channels and one or more control channels, in uplink and/or downlink, which are distributed within a channel's physical resources.

A channel's physical resources are defined in time and frequency domain.
20 As an example, it is referred to LTE™, where a smallest unit is named a resource element RE. A RE carries in time domain one (QPSK modulated) symbol and has a corresponding duration, while in frequency domain it covers a bandwidth of one subcarrier. A plurality of 7 symbols in time domain constitute 1 slot of 0.5 ms duration, 2 slots constitute 1 subframe
25 of 1 ms duration, and 20 slots (10 subframes) constitute one radioframe of 10 ms duration. A group of resource elements covering one slot in time domain and 12 subcarriers in frequency/bandwidth domain is referred to as physical resource block PRB. A physical channel in general comprises one or more PRBs in bandwidth, but may also be definable as comprising
30 a fraction (non-integer multiple) of one or more PRBs, in an extreme also as being represented by a single subcarrier only.

Further, in e.g. the case of LTE™, a group of 4 symbols is referred to as resource element group, REG. 9 REGs and thus 36 resource elements RE in turn constitute for example a control channel element CCE to which a PDCCH message is mapped. Note that resource elements of REGs and REG's of a CCE do not need to be adjacent to each other in time/frequency domain but can be distributed at distinct physical locations within a time/frequency resource grid of REs; they are thus at least logically linked to each other.

In heterogeneous network deployment, a combined usage of enhanced inter-cell interference coordination (eICIC) and cell range expansion (CRE) is effective for improving the system and cell-edge throughput. With eICIC, a macro cell (or macro eNB) utilizes so-called almost blank subframes (ABS) with zero transmission power mainly in physical downlink control channel or physical downlink shared channel (PDCCH/PDSCH) to mitigate the interference to the pico user equipments (UEs) (those UEs camping in the coverage of the pico eNB) with CRE.

Furthermore, the Resource Status mechanism enables a pico eNB to provide information in order to *"aid the macro eNB designating ABS to evaluate the need for modification of the ABS pattern"*, as for example described in [1] to [3]. It means that the macro eNB determines the ABS pattern adjustment based on the *DL ABS status* information.

Moreover, in the recent discussion of 3GPP (3rd Generation Partnership Project), low power ABS (LP-ABS) (also known as reduced power ABS or non-zero power ABS) is suggested to tradeoff the performance loss of an aggressor cell that is incurred when pure ABS (i.e. zero power ABS (ZP-ABS)) is employed. By using LP-ABS, some subframes in the previous ABS pattern are allowed to transmit data with a low transmission power in

PDCCH/PDSCH etc., to serve the aggressor cell center UE with the acceptable performance while less interference to victim cell UEs.

On the other hand, a new carrier type of an "extension carrier" is discussed for carrier aggregation (CA) deployment scenarios. One of the main target scenarios for further enhancement of CA in Rel-11 could be a HetNet deployment scenario with macro cell plus local area (LA) small (such as pico, femto, relay or RRH) cells. One use case of the additional carrier type, i.e. the extension carrier, will be to deploy it in such small cell areas to facilitate inter-cell interference coordination (ICIC) between the macro-cell and small cells by applying "complete" blank subframes even without transmitting a cell-specific reference signal (CRS) and the PDCCH. Such a blank subframe or radio resource features without CRS and PDCCH transmissions is also beneficial in reducing inter-cell interference in dense local area deployments with fractional traffic loads and in achieving energy efficient operation in small cells.

However, it is not agreed on how to judge whether such extension carrier should be activated/deactivated, and what is the appropriate number of the extension carriers is also still not explored, for example.

When the extension carrier is employed to combat the inter-cell interference, perfect ICIC capability may potentially be achieved by applying "complete" blank subframes without transmitting a cell-specific reference signal (CRS) and the PDCCH. However, allowing more number of extension carriers will lead to more severe under-utilization of control channel resource at the aggressor cell. Henceforth, under the limited available carrier resource, it is a critical issue how to set up the optimum carrier configuration to minimize the number of the required extension carriers at aggressor cell while ensuring the system performance.

- In the time domain based eICIC, it was agreed e.g. in [3] that a new information element IE called "*DL ABS Status IE*" shall be included in the resource status update message, to reflect a resource usage indication allocated to the UEs protected by ABSs. Based thereon, the macro eNB
- 5 can determine whether the protected resources are effectively utilized or not, and do the corresponding measurement. However, it is targeted for the time domain ICIC, but not for the frequency domain in regard of a usage of CA and/or extension carriers.
- 10 In fact, when the extension carrier is employed to combat the inter-cell interference, there are the following example cases on the carrier allocation and adjustment.
- a) Given that any component carrier can be configured as extension
- 15 carrier. When a carrier is added/reduced, what kind of carrier (extension carrier or ordinary carrier) should it be activated/deactivated as?
- b) Given that there are two component carrier sets, which is respectively extension carrier set and the ordinary carrier set. When a carrier is
- 20 needed to be activated or deactivated, which carrier set should it be selected from or returned to?
- c) If all the carrier resource has been fully utilized and the available protected carrier resources at the aggressor cell and victim cell are heavily
- 25 loaded, how can the aggressor cell make an appropriate decision for the optimum allocation between extension carrier and ordinary carrier to maximize the performance overall the system?

References:

[1] R3-110516, CR to TS 36.423, "Enabling reporting of ABS resource status for eICIC purposes", Nokia Siemens Networks, Qualcomm Incorporated, Samsung, Interdigital Communications.

5 [2] R3-110498, CR to TS 36.423, "Introduction of X2 signalling support for eICIC", Ericsson, Qualcomm Incorporated, Nokia Siemens Networks, Alcatel-Lucent, Alcatel-Lucent Shanghai Bell, Samsung, InterDigital, NTT DoCoMo, Inc., KDDI.

[3] 3GPP TS 36.423-a20.

10 [4] R3-103776, "Enabling reporting of ABS resource status for eICIC purposes", Nokia Siemens Networks, Qualcomm Incorporated, Samsung, Interdigital Communications.

[5] R1-113206, Intel Corporation, On New Carrier Types: Extension Carriers and Carrier Segments

15 Summary of the invention

It is an object of the present invention to improve the prior art.

20 In particular, it is an object to get an optimum or nearly optimal resource allocation to cater for the system needs. In detail, it is an object to minimize the required number of extension carriers and to improve the spectral utilization from the point of view of overall carrier utilization efficiency.

25 Furthermore, it is an object to configure the UE measurements appropriately, taking into account the configuration of carriers of the PDCCH protected carrier type. PDCCH protected carrier means a carrier that mutes PDCCH part in aggressor cell. It may be a normal carrier in victim cell. An extension carrier is an example of a PDCCH protected carrier. In contrast, in LP-ABS, some subframes are allowed to transmit data with a low transmission power in
30 PDCCH/PDSCH.

According to a first aspect of the invention, there is provided an apparatus, comprising classifying means adapted to classify a first terminal having at least a downlink communication with the apparatus into one of a cancellation category and a non-cancellation category, wherein the cancellation category indicates that the first terminal is capable of reference signal interference cancellation; assessing means adapted to assess whether the first terminal is affected by interference caused by an aggressor device by more than a first interference level; scheduling means adapted to schedule, if it is assessed that the first terminal is affected by more than the first interference level and the terminal is classified into the non-cancellation category, a first blank slot of a clear carrier for the downlink communication, and to schedule, if it is assessed that the first terminal is affected by more than the first interference level and the first terminal is classified into the cancellation category, a second blank slot of a normal carrier for the downlink communication, wherein the scheduling is based on a carrier information received from the aggressor device according to which the clear carrier is comprised by one or more extension carriers of the aggressor device and based on a slot information received from the aggressor device according to which each of the first and second blank slots is of one of an almost blank slot type and a blank slot with reduced power type.

The apparatus may be comprised by a base station or a cell of a base station.

According to a second aspect of the invention, there is provided an apparatus, comprising suppressing means adapted to suppress transmitting a reference signal on a carrier of an extension carrier type; first configuring means adapted to configure a first carrier to be of the extension carrier type; deploying means adapted to deploy one or more blank slots on the first carrier, wherein each of the blank slots is of an almost blank slot type or of a blank slot with reduced power type; checking means adapted to check if an indication received from a victim device indicates that a total ratio of a number of physical resource blocks in blank slots on the first carrier scheduled for downlink communication of terminals of a non-cancellation category by the victim device to a total number of physical resource blocks in blank slots on the first carrier exceeds a predetermined first threshold, wherein the terminals are indicated to be affected by an interference caused by the apparatus at more than a first interference level;

and second configuring means adapted to configure a second carrier different from the first carrier to be of the extension carrier type if the first threshold is exceeded.

- 5 The apparatus may be comprised by a base station or a cell of a base station.

According to a third aspect of the invention, there is provided a method, comprising classifying a first terminal having at least a downlink communication with an apparatus performing the method into one of a cancellation category and
10 a non-cancellation category, wherein the cancellation category indicates that the first terminal is capable of reference signal interference cancellation; assessing whether the first terminal is affected by interference caused by an aggressor device by more than a first interference level; if it is assessed that the first terminal is affected by more than the first interference level and the terminal is
15 classified into the non-cancellation category, scheduling a first blank slot of a clear carrier for the downlink communication, and if it is assessed that the first terminal is affected by more than the first interference level and the first terminal is classified into the cancellation category, scheduling a second blank slot of a normal carrier for the downlink communication, wherein the scheduling
20 is based on a carrier information received from the aggressor device according to which the clear carrier is comprised by one or more extension carriers of the aggressor device and based on a slot information received from the aggressor device according to which each of the first and second blank slots is of one of an almost blank slot type and a blank slot with reduced power type.

25

According to a fourth aspect of the invention, there is provided a method, comprising suppressing transmitting a reference signal on a carrier of an extension carrier type; configuring a first carrier to be of the extension carrier
30 type; deploying one or more blank slots on the first carrier, wherein each of the blank slots is of an almost blank slot type or of a blank slot with reduced power type; checking if an indication received from a victim device indicates that a total ratio of a number of physical resource blocks in blank slots on the first carrier scheduled for downlink communication of terminals of a non-cancellation
35 category by the victim device to a total number of physical resource blocks in

blank slots on the first carrier exceeds a predetermined first threshold, wherein the terminals are indicated to be affected by an interference caused by an apparatus performing the method at more than a first interference level; and configuring a second carrier different from the first carrier to be of the extension carrier type if the first threshold is exceeded.

According to a fifth aspect of the invention, there is provided an apparatus, comprising first receiving means adapted to receive, from a first aggressor device, a first indication of one or more first carriers of a plurality of carriers to be first candidates of an PDCCH protected carrier type of the first aggressor device; second receiving means adapted to receive, from a second aggressor device different from the first aggressor device, a second indication of one or more second carriers of the plurality of carriers to be second candidates of the PDCCH protected carrier type of the second aggressor device; negotiating means adapted to negotiate with the first aggressor device and the second aggressor device on a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the first aggressor device and the second aggressor device; selecting means adapted to select the common available carrier; indicating means adapted to indicate the common available carrier to the first aggressor device and the second aggressor device to cause them to configure the common available carrier to be of the PDCCH protected carrier type.

According to a sixth aspect of the invention, there is provided an apparatus, comprising monitoring means adapted to monitor if one or more carriers are common available carriers, wherein a common available carrier is indicated to be a candidate for a PDCCH protected carrier type by a first aggressor device and a candidate for a PDCCH protected carrier type by a second aggressor device different from the first aggressor device; informing means adapted to inform at least one of the first and second aggressor devices about the one or more common available carriers; and scheduling means adapted to schedule a terminal on the common available carrier.

According to a seventh aspect of the invention, there is provided an apparatus, comprising selecting means adapted to select one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type of the apparatus; informing means adapted to inform an aggressor device about the

candidate carriers; agreeing means adapted to agree with the aggressor device on an common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the apparatus and of the aggressor device; configuring means adapted to configure the common available carrier to be of the PDCCH protected carrier type; suppressing means adapted to suppress transmitting a control signal on the configured common available carrier.

According to an eighth aspect of the invention, there is provided an apparatus, comprising selecting means adapted to select one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type; informing means adapted to inform a victim device about the candidate carriers; configuring means adapted to configure, based on an indication received from the victim device, a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type; suppressing means adapted to suppress transmitting a control signal on the common available carrier.

According to a ninth aspect of the invention, there is provided an apparatus, comprising informing means adapted to inform a victim device about one or more common available carriers, wherein the common available carriers are indicated in a message received from an operation and management system to be suitable as PDCCH protected carriers; and suppressing means adapted to suppress transmitting a control signal on the one or more common available carriers.

According to a tenth aspect of the invention, there is provided an apparatus, comprising deciding means adapted to decide to configure a measurement of a terminal operatively connected to the apparatus, wherein an information received from a victim device about one or more common available carriers is taken into account in the deciding, wherein a common available carrier is indicated to be both a candidate for a PDCCH protected carrier type of the apparatus and a candidate for a PDCCH protected carrier type of an aggressor device different from the apparatus; configuring means adapted to configure the measurement of the terminal.

According to an eleventh aspect of the invention, there is provided an apparatus, comprising checking means adapted to check if both one or more first carriers of

a plurality of carriers and one or more second carriers of the plurality of carriers comprise a common available carrier, wherein the first carriers are potential candidates to be of an PDCCH protected carrier type of a first aggressor device, and the second carriers are potential candidates to be of the PDCCH protected carrier type of a second aggressor device different from the first aggressor device; selecting means adapted to select, if the first and second carriers comprise the common available carrier, the common available carrier to be a candidate of the PDCCH protected carrier type of the first aggressor device and the second aggressor device; and informing means adapted to inform the first aggressor device and the second aggressor device about the common available carrier.

According to an twelfth aspect of the invention, there is provided a method, comprising receiving, from a first aggressor device, a first indication of one or more first carriers of a plurality of carriers to be first candidates of an PDCCH protected carrier type of the first aggressor device; receiving, from a second aggressor device different from the first aggressor device, a second indication of one or more second carriers of the plurality of carriers to be second candidates of the PDCCH protected carrier type of the second aggressor device; negotiating with the first aggressor device and the second aggressor device on a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the first aggressor device and the second aggressor device; selecting the common available carrier; indicating the common available carrier to the first aggressor device and the second aggressor device to cause them to configure the common available carrier to be of the PDCCH protected carrier type.

According to an thirteenth aspect of the invention, there is provided a method, comprising monitoring if one or more carriers are common available carriers, wherein a common available carrier is indicated to be a candidate for a PDCCH protected carrier type by a first aggressor device and a candidate for a PDCCH protected carrier type by a second aggressor device different from the first aggressor device; informing at least one of the first and second aggressor devices about the one or more common available carriers; and scheduling a terminal on the common available carrier.

According to an fourteenth aspect of the invention, there is provided a method, comprising selecting one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type of an apparatus performing the method; informing an aggressor device about the candidate carriers; agreeing
5 with the aggressor device on an common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the apparatus and of the aggressor device; configuring the common available carrier to be of the PDCCH protected carrier type; suppressing transmitting a control signal on the configured common available carrier.

According to an fifteenth aspect of the invention, there is provided a method, comprising selecting one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type; informing a victim device about the candidate carriers; configuring, based on an indication received from the
15 victim device, a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type; suppressing transmitting a control signal on the common available carrier.

According to an sixteenth aspect of the invention, there is provided a method, comprising informing a victim device about one or more common available
20 carriers, wherein the common available carriers are indicated in a message received from an operation and management system to be suitable as PDCCH protected carriers; and suppressing transmitting a control signal on the one or more common available carriers.

According to an seventeenth aspect of the invention, there is provided a method, comprising deciding to configure a measurement of a terminal operatively connected to an apparatus performing the method, wherein an information received from a victim device about one or more common available carriers is
30 taken into account in the deciding, wherein a common available carrier is indicated to be both a candidate for a PDCCH protected carrier type of the apparatus and a candidate for a PDCCH protected carrier type of an aggressor device different from the apparatus; configuring the measurement of the terminal.

According to an eighteenth aspect of the invention, there is provided a method, comprising checking if both one or more first carriers of a plurality of carriers and one or more second carriers of the plurality of carriers comprise a common available carrier, wherein the first carriers are potential candidates to be of an
5 PDCCH protected carrier type of a first aggressor device, and the second carriers are potential candidates to be of the PDCCH protected carrier type of a second aggressor device different from the first aggressor device; selecting, if the first and second carriers comprise the common available carrier, the common available carrier to be a candidate of the PDCCH protected carrier type of the first
10 aggressor device and the second aggressor device; and informing the first aggressor device and the second aggressor device about the common available carrier.

According to a nineteenth aspect of the invention, there is provided an apparatus
15 comprising at least one processor, and at least one memory including computer program code, the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform at least one of the methods according to any of the third, fourth, and twelfth to eighteenth aspects.

20 According to a twentieth aspect of the invention, there is provided a computer program product comprising a set of instructions which, when executed on an apparatus, is configured to cause the apparatus to carry out the method according to any one of the third, fourth, and twelfth to eighteenth aspects. The
25 computer program product may be embodied on a computer-readable medium.

Each of the apparatuses according to the first, second, and fifth to tenth aspects may be comprised by a base station or a cell of a base station.

30 The apparatus according to the eleventh aspect may be comprised by an operation and maintenance system.

Each of the methods according to any of the third, fourth, and twelfth to eighteenth aspects may be a method of cell range extension.

35

According to some embodiments of the invention, at least the following advantages are achieved:

5 An effective resource utilization at victim cell is achieved. The required number of extension carriers at the aggressor cell is minimized and, hence, spectral utilization is improved. The solution is backwards compatible.

10 It is to be understood that any of the above modifications can be applied singly or in combination to the respective aspects to which they refer, unless they are explicitly stated as excluding alternatives.

15 According to embodiments of the invention, it is ensured that there exists a common subset of PDCCH protected carrier configuration from multiple interfering macro cells, so that the UEs in the CRE area of a pico cell have one or more appropriate PDCCH protected carriers to do data transmission. Furthermore, carrier switching is avoided to a large extent.

20 The feedback of the adopted PDCCH protected carrier (from the aggressor cell) by the victim cell may be used to properly configure the aggressor cell's measurement object.

Brief description of the drawings

25 Further details, features, objects, and advantages are apparent from the following detailed description of the preferred embodiments of the present invention which is to be taken in conjunction with the appended drawings, wherein

30 Fig. 1 shows an apparatus according to an embodiment of the invention;

Fig. 2 shows a method according to an embodiment of the invention;

Fig. 3 shows an apparatus according to an embodiment of the invention; and

Fig. 4 shows a method according to an embodiment of the invention.

Fig. 5 shows a basic usage exemplification;

5 Fig. 6 shows a scenario exemplification;

Fig. 7 shows an apparatus according to an embodiment of the invention;

Fig. 8 shows a method according to an embodiment of the invention;

10

Fig. 9 shows an apparatus according to an embodiment of the invention;

Fig. 10 shows a method according to an embodiment of the invention;

15 Fig. 11 shows an apparatus according to an embodiment of the invention;

Fig. 12 shows a method according to an embodiment of the invention;

Fig. 13 shows an apparatus according to an embodiment of the invention;

20

Fig. 14 shows a method according to an embodiment of the invention;

Fig. 15 shows an apparatus according to an embodiment of the invention;

25 Fig. 16 shows a method according to an embodiment of the invention;

Fig. 17 shows an apparatus according to an embodiment of the invention;

Fig. 18 shows a method according to an embodiment of the invention;

30

Fig. 19 shows an apparatus according to an embodiment of the invention; and

Fig. 20 shows a method according to an embodiment of the invention.

Detailed description of certain embodiments

Herein below, certain embodiments of the present invention are described in detail with reference to the accompanying drawings, wherein the features of the
5 embodiments can be freely combined with each other unless otherwise described. However, it is to be expressly understood that the description of certain embodiments is given for by way of example only, and that it is by no way intended to be understood as limiting the invention to the disclosed details.

10 Moreover, it is to be understood that the apparatus is configured to perform the corresponding method, although in some cases only the apparatus or only the method are described.

DL ABS Status IE according to [3] is only targeted for the time domain ICIC but
15 does not consider the impact of different UE capabilities. According to embodiments of the invention, a presence or non-presence of a capability of the UE for CRS interference cancellation is taken into account for scheduling a downlink from the victim cell to the UE. In addition, an extended PRB ratio may be used to determine the configuration of extension carrier and ABS/LP-ABS in
20 normal carrier of aggressor cell in order to maximize the spectral utilization. Details of the extended PRB ratio are explained further below.

Different UE may have or not have a capability of CRS interference cancellation. For example, the capability may depend on the release of the UE:

25

- Typically, release 11 UEs are capable to do CRS interference cancellation, e.g. by an advanced receiver, hence they may be scheduled in ABS subframe of normal carrier with acceptable performance; as an example, if the interference cancellation capable UE
30 is aware of the PCI and antenna port information of the aggressor cell(s), then its receiver can effectively remove the CRS interference to the data RE in the victim cell.
- On the other hand, typically, release 8/9/10 UEs do not have this capability, hence they are preferred to be scheduled in an extension

carrier to ensure its performance; note that the extension carrier is defined as a carrier where no CRS is transmitted, thus it is free from the CRS interference.

- 5 The extended PRB ratio may be semi-statically (e.g. periodically, potentially with a relatively long period) reported by the victim cell to the aggressor cell, and/or the extended PRB ratio may be evaluated by the victim cell and reporting may be triggered if a certain value of the extended PRB ratio is reached.
- 10 In the following, clear channel designates a carrier that is configured as normal carrier at the victim cell but as an extension carrier at the aggressor cell. eNB#1 denote the aggressor cell eNB, and eNB#2 denote the victim cell eNB;

According to some embodiments, eNB #2 differentiates its served UEs according to the level of interference they are affected by. For example, it may differentiate between weakly affected UEs and more than weakly effect UEs. In another example, eNB#2 differentiates its served UE as the strongly interfered UE and moderately interfered UE as well as the weakly interfered UE. The differentiation may be based on the RSRP that is signaled to eNB #2 by the respective UE.

20 According to embodiments of the invention, the following principle is applied:

- For the weakly interfered UEs:
 - both PDCCH and PDSCH of all UEs are preferred be sent in non-ABS of normal carrier;
- For the medium interfered UEs:
 - both PDCCH and PDSCH of $\leq R_{10}$ UEs are preferred be sent in LP-ABS of clear carrier;
 - PDCCH of R_{11} UE is preferred be sent in clear channel while PDSCH of R_{11} UE is preferred be sent in LP-ABS of normal channel;
- For the strongly interfered UEs:
 - Both PDCCH and PDSCH of $\leq R_{10}$ UEs are preferred be sent in ABS of clear carrier;

- PDCCH of R11 UE is preferred be sent in clear channel while PDSCH of R11 UE is preferred be sent in ABS of normal channel.

5 Here and in the following, R11 UE designate release 11 UEs, and $\leq R10$ UEs designate UEs of release 10 and before (releases 9, 8, ...). Note that the releases are indicated in order to easily designate the presence (R11 UE) or non-presence ($\leq R10$ UE) capability of CRS interference cancellation. However, the principle of these embodiments may be applied to UEs of other releases, too, as long as they
10 are distinguished according to their capability of CRS interference cancellation.

In order to allow the aggressor cell to configure the carriers (nearly) optimally, in some embodiments the following metrics of an extended PRB ratio (PRB occupation) is applied and reported from the victim cell to the aggressor cell:

15

PRB occupation indicates the percentage of data channel resource blocks of clear channel, wherein

- *PRB occupation 1* is equal to

20

(number of PRBs scheduled for strongly interfered $\leq R10$ UE in ABS subframe of a clear channel) /
(number of all the available PRBs in ABS subframe of clear carrier).

- *PRB occupation 2* is equal to

25

(number of PRBs scheduled for medium interfered $\leq R10$ UE in LP-ABS subframe of clear channel) /
(number of all the available PRBs in LP-ABS subframe of clear carrier).

30 When there are multiple clear carriers, the defined metric may be an average percentage value of all the clear carriers, or a separate indication for each clear channel may be given.

If the aggressor cell is aware of the respective denominators (number of all the available PRBs ...), it is sufficient if the victim cell reports at least one of the enumerators (number of PRBs scheduled ...) to the aggressor cell. Thus, it may report the respective enumerators or ratios or both.

5

According to some embodiments of the invention, the following procedure may be applied:

10 The victim (eNB#2) reports the extended PRB ratio (PRB occupation) of the UEs classified not to be capable of CRS interference cancellation. The reporting can be triggered by the eNB#2 periodically or aperiodically based on some predefined events, e.g. upon the *PRB occupation1 and/or 2* is higher or lower than some predetermined thresholds.

15 Then, based on the reported PRB occupation, the aggressor (eNB #1) determines whether the currently allocated extension carrier and/or ABS/LP-ABS resource is appropriate. That is, eNB#1 makes a decision on whether to reconfigure extension carrier and/or ABS/LP-ABS subframe in its normal carrier to maximize the spectral utilization, by taking into account the extended PRB ratio.

20

For example, the decision process in eNB #1 may be as follows:

- 25
 - When a sum of *PRB occupation 1* and *PRB occupation 2* is higher than a threshold μ_1 , eNB#1 shall consider to add more extension carriers to lead to more clear channels at eNB#2; Instead of a sum, another appropriately defined combined value such as a product of the ratios may be checked. Vice versa, if the combined value (e.g. sum) is less than a threshold μ_1' , a clear channel may be removed. μ_1 may be the same as μ_1' . Though, in order to avoid rapid fluctuation of the configuration, it is preferable that $\mu_1' < \mu_1$ (hysteresis).
- 30
 - If the sum is not higher than the threshold μ_1 , the following is performed:
 - When *PRB occupation 1* exceeds a predefined threshold μ_2 , eNB#1 shall consider to add more ABS in the clear carrier, and vice versa (potentially with hysteresis);

- When *PRB occupation 2* exceeds a predefined threshold μ_3 , eNB#1 shall consider to add more LP-ABS in the clear carrier, and vice versa (potentially with hysteresis);
- Otherwise, if there is still a need for capacity in eNB #2, eNB#1 shall consider adding more ABSs in its normal carrier, rather than increasing the number of extension carrier, and vice versa. For example, the number of ABSs and LP-ABSs in the normal carrier may be determined based on the feedback of PRB utilization of R11 UE that are respectively strongly interfered and medium interfered.

That is, with the extension of PRB ratio integrated, one may distribute the additional control channel burden into the normal carrier with ABS and meanwhile with a higher aggregation level allowed/configured in the corresponding protected resource, instead of configuring more number of extension carriers to alleviate the control channel burden.

According to some embodiments, the above mentioned procedure may be modified in that eNB#2 first evaluates the extended PRB ratio, formulates the corresponding request (e.g. add an extension carrier) and then reports to eNB#1 requesting its final decision along with the local information of eNB#1.

When the new carrier configuration and ABS/LP-ABS configuration are signaled by eNB#1 over the interface, the eNB#2 shall do the scheduling of its served UE according to the above mentioned principles.

In summary, by integrating extended PRB ratio (PRB occupation 1 and PRB occupation 2), the configuration of the extension carrier as well as the allocation of ABS/LP-ABS subframe in the normal carrier may be determined. By taking into account the extended PRB ratio, one can configure the minimal number of required extension carriers when the carrier resource is limited, while ensuring that the system performance is satisfied.

If, in some embodiments, medium interfered UEs are not distinguished from strongly interfered UEs, ABS and LP-ABS may be jointly considered as blank subframes, and, hence, PRB occupation 1 may coincide with PRB occupation 2.

- 5 In the following, three exemplary ways to implement the extended PRB ratio are outlined. Modifications over the present standards are underlined.

Since according to 3GPP TS 36.423, the ABS Status IE is used to aid the eNB designating ABS to evaluate the need for modification of the ABS pattern, a new

- 10 IE may be included in the ABS status.

IE/Group Name	Presence	Range	IE type and reference	Semantics description
DL ABS status	M		INTEGER (0..100)	Percentage of ABS resource allocated for UEs protected by ABS from strong inter-cell interference. The denominator of the percentage calculation is indicated in the Usable ABS Information.
<u>Clear channel ABS status (i.e., PRB occupation 1)</u>	<u>O</u>		<u>INTEGER (0..100)</u>	<u>Percentage of PRB resource utilized by <=R10 strongly interfered UEs in the ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available PRB number in ABS subframe(s) of the clear channel(s).</u>
<u>Clear channel LP-ABS status (i.e., PRB occupation 2)</u>	<u>O</u>		<u>INTEGER (0..100)</u>	<u>Percentage of PRB resource utilized by <=R10 medium interfered UEs in the LP-ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available PRB number in LP-ABS subframe(s) of the clear channel(s).</u>

Table 1: Implementation option 1

- 15 Implementation option 2 is to add new IE in the load information:

	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.13		YES	ignore
Cell Information	M				YES	ignore
>Cell Information Item		1 to maxCellInfoNB			EACH	ignore
>>Cell ID	M		ECGI 9.2.14	Id of the source cell	—	—
>>UL Interference Overload Indication	O		9.2.17		—	—
>>UL High Interference Information		0 to maxCellInfoNB			—	—
>>>Target Cell ID	M		ECGI 9.2.14	Id of the cell for which the HII is meant	—	—
>>>UL High Interference Indication	M		9.2.18		—	—
>>Relative Narrowband Tx Power (RNTP)	O		9.2.19		—	—
>>Clear channel status	O		9.2.x		YES	ignore
>>>Clear channel ABS status (i.e., PRB occupation 1)	O		INTEGER (0..100)	Percentage of PRB resource utilized by <=R10 strongly interfered UEs in the ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available PRB number in ABS subframe(s) of the clear channel(s).	YES	ignore
>>>Clear channel LP-ABS status (i.e., PRB occupation 2)	O		INTEGER (0..100)	Percentage of PRB resource utilized by <=R10 medium interfered UEs in the LP-ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available	YES	ignore

				PRB number in LP-ABS subframe(s) of the clear channel(s).		
>>Invoke Indication	O		9.2.y		YES	ignore

Table 2: Implementation option 2

Implementation option 3 is to add new message:

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.13		YES	ignore
Carrier configuration reference	M				YES	ignore
>Cell ID	M		ECGI 9.2.14	Id of the source cell	–	–
>>>Clear channel ABS status (i.e., PRB occupation 1)	O		INTEGER (0..100)	Percentage of PRB resource utilized by <=R10 strongly interfered UEs in the ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available PRB number in ABS subframe(s) of the clear channel(s).	YES	ignore
>>>Clear channel LP-ABS status (i.e., PRB occupation 2)	O		INTEGER (0..100)	Percentage of PRB resource utilized by <=R10 medium interfered UEs in the LP-ABS subframe(s) of clear channel(s). The denominator of the percentage calculation may be all the available PRB number in LP-ABS subframe(s) of the clear channel(s).	YES	ignore

Table 3: Implementation option 3

Fig. 1 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof.

- 5 The apparatus comprises at least one processor 10, and at least one memory 20 including computer program code, wherein the at least one processor 10, with

the at least one memory 20 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 2.

Fig. 2 shows a method according to an embodiment of the invention. The apparatus according to Fig. 1 may perform the method of Fig. 2 but is not limited to this method. The method of Fig. 2 may be performed by the apparatus of Fig. 1 but is not limited to being performed by this apparatus.

According to step S100, a terminal having at least a downlink communication is classified according to its capability for reference signal interference cancellation, e.g. by an advanced receiver. More in detail, it is classified into one of a cancellation category and a non-cancellation category, wherein the cancellation category indicates that the terminal is capable of reference signal interference cancellation, and the non-cancellation category indicates that the terminal is not capable thereto.

In step S110, it is assessed whether the terminal is affected by interference caused by an aggressor device by more than a first interference level. Steps S100 and S110 may be interchanged or performed simultaneously.

If it is assessed in step S110 that the first terminal is affected by more than the first interference level and in step S100 that the terminal is classified into the non-cancellation category, a blank slot of a clear carrier is scheduled for the downlink communication of the terminal (S120).

If it is assessed in step S110 that the first terminal is affected by more than the first interference level and in step 100 that the first terminal is classified into the cancellation category, a blank slot of a normal carrier is scheduled for the downlink communication (S130).

The scheduling in steps S120 and S130 is based on a carrier information received from the aggressor device. According to the carrier information, the clear carrier is comprised by one or more extension carriers of the aggressor device. In addition, the scheduling in steps S120 and S130 is based on a slot information received from the aggressor device. According to the slot information, the blank

slots are of one of an almost blank slot type (corresponding to ABS on a subframe level instead of a slot level) and a blank slot with reduced power type (corresponding to LP-ABS on a subframe level instead of a slot level).

5 Fig. 3 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 50, and at least one memory 60 including computer program code, wherein the at least one processor 50, with the at least one memory 60 and the computer program code, being configured to
10 cause the apparatus to at least perform one of the methods shown in Fig. 4.

Fig. 4 shows a method according to an embodiment of the invention. The apparatus according to Fig. 3 may perform the method of Fig. 4 but is not limited to this method. The method of Fig. 4 may be performed by the apparatus of Fig.
15 3 but is not limited to being performed by this apparatus.

According to step S210, transmitting a reference signal such as a CRS on a carrier of an extension carrier type is suppressed. That is, if the apparatus performing the method configures a carrier as one of an extension carrier type, a
20 reference signal is not transmitted on this carrier.

According to step S220, a first carrier is configured to be of the extension carrier type.

25 According to step S230, one or more blank slots are deployed on the first carrier. The blank slots are of one of an almost blank slot type (corresponding to ABS on a subframe level instead of a slot level) and a blank slot with reduced power type (corresponding to LP-ABS on a subframe level instead of a slot level).

30 Then, according to step S240, it is checked if an indication from a victim device is received that indicates that a total ratio exceeds a predetermined threshold. The total ratio is a ratio of a number of physical resource blocks in blank slots on the first carrier scheduled for downlink communication of terminals by the victim device to a total number of physical resource blocks in blank slots on the first
35 carrier, wherein only terminals of a non-cancellation category are considered.

If the threshold is exceeded, a second carrier different from the first carrier is configured to be of the extension carrier type (S250).

- 5 According to the prior art, it is not clear, how to handle PDCCH protected carrier patterns from multiple macro cells (aggressors) to a pico cell (victim). In addition, the prior art does not describe how to adopt carrier information feedback of the victim cell toward the aggressor cell(s) in order to ensure correct measurements, in particular in the case of multiple aggressors.

10

One of the basic usage illustrations [5] of PDCCH protected carriers in a HetNet scenario is shown in Fig.5. In top part of Fig. 5, it is shown that a terminal UE1 is connected to a macro cell, and a terminal UE2 is connected to a pico-cell within the coverage area of the macro cell.

15

In the bottom part of Fig. 5, the subframes received by UE1 and UE2, respectively, are schematically shown. In the macro cell, CC1 is configured as normal carrier carrying the PDCCH and PDSCH 1, and CC2 is configured as PDCCH protected carrier, not carrying the PDCCH but PDSCH2. In the pico cell, the configuration is just opposite: CC2 is configured as normal carrier carrying the PDCCH and PDSCH2, and CC1 is configured as PDCCH protected carrier not carrying the PDCCH but PDSCH1.

20

From Fig. 5, one may derive the following:

25

1. Different eNBs may configure different CCs as PDCCH protected carrier.
2. By cross layer scheduling, the PDCCH protected carrier can be associated to a backward compatible carrier for utilization.
3. Highly interfered UEs in victim cell are preferred to be scheduled in the normal carrier of victim cell (I.e. which is the PDCCH muted carrier for the aggressor cell). In this way, the interfered UE in victim cell can be
 - i. free from interference from PDCCH transmissions from aggressor cell
 - ii. of less interference from CRS/PSS/SSS transmissions from aggressor cell

30

Fig. 6 shows a scenario with multiple macro cells (in Fig. 6 exemplarily: two macro cells, Macro cell 1 and Macro cell 2) interfering with one pico cell (Pico cell 1). In addition, Pico cell 2 is shown which is affected by interference from Macro cell 2 only.

In the following, a *PDCCH protected carrier* is defined as a carrier that is configured as ordinary carrier at victim cell and as PDCCH muted carrier at aggressor cell. Pico cell 1 will receive multiple PDCCH protected carrier patterns from the associated macro cells. An PDCCH protected carrier pattern means an indication which of the carriers are configured as PDCCH protected carriers and which are not. Since conventionally Macro cells 1 and 2 do not coordinate their PDCCH protected carrier patterns, it is possible that there is no common subset among those PDCCH protected carrier patterns. Consequently, there is no appropriate PDCCH protected carrier for the pico UEs in the CRE area of this specific pico cell to do data transmission.

In addition, if the PDCCH protected carriers are configured differently for pico UEs (here: UEs attached to Pico cell 1) that are located in the overlapping area with macro cell 1 and 2 respectively, pico UEs that migrate from the CRE area of macro cell 1 to the CRE area of macro cell 2 have to change its PDCCH protected carrier. In some cases the PDCCH protected carrier at macro cell 1 may even potentially be configured as PCC. Such a change of the PDCCH protected carrier would therefore be at least unreasonable.

In the exemplary scenario of Fig. 2, the pico cell 1 is located between macro cells 1 and 2. If carrier 2 is PDCCH protected carrier configuration in macro cell 1, while carrier 2, 3 are PDCCH protected carriers in macro cell 2, a common set of PDCCH protected carriers comprising carrier 2 is available. However if in another exemplary scenario, carrier 2 (only) is PDCCH protected carrier of macro cell 1, while carriers 1 and 3 (only) are PDCCH protected carriers in macro cell 2, there is no joint PDCCH protected carrier, i.e. no carrier is suitable for the pico UE in CRE zone to use. In this case, there will be interference from one macro cell for

the corresponding PDCCH protected carrier pattern of the other one, and both the data transmission and the measurement will be greatly impacted.

Moreover, even in the absence of joint interference from multiple macro eNBs for the pico UE in pico cell 1, it is not preferred for a pico UE to switch its carrier when it migrates from one side of the pico cell (interfered by macro cell 1) to the other side of the pico cell (interfered by macro cell 2) in the CRE zone of pico cell 1.

According to embodiments of the invention, it is ensured that a common subset of PDCCH protected carriers of the multiple interfering macro cells exists. In some embodiments, the usable PDCCH protected carriers of the pico cell are sent to the macro cell in order to facilitate a proper configuration of the macro's measurement subset.

According to some embodiments of the invention, one or more of the following solutions is employed in order to ensure the existence of a common subset of PDCCH protected carriers of the multiple macro cells interfering simultaneously with a pico cell. The multiple macro cells interfering with the pico cell are also named neighboring macro cells.

➤ **Solution #1:** Neighbouring macro eNBs negotiate with each other directly. They may inform the pico cell (victim) about their agreed common available carrier, that is the carrier that is agreed to be a PDCCH protected carrier of all the neighbouring macro eNBs.

➤ **Solution #2:** Neighbouring macros negotiate via the affected pico cell. For example,

- The macros cells may send a set of candidate PDCCH protected carrier patterns to the affected pico cell.
- Pico may propose an acceptable common set for all neighbouring macros; For example, it may check if there is a set of carriers being configured as PDCCH protected carriers in all macro cells and select these carriers. If this is not the case, it may select some carriers to

be an PDCCH protected carrier of all the affecting macro cells, e.g. based on some radio parameters of the carriers such as RSRQ, RSRP etc..

- The pico cell informs the affecting macro cells of the selection.

5

According to this solution, a common set of PDCCH protected carriers could be obtained by the pico cell in any case. However, in a worst case scenario, it might lead to disabling of a macro cell, if all its carriers are configured as extension carries (potentially by different pico cells).

10

- **Solution #3:** OAM configuration ensures that a 'common subset' exists between the PDCCH protected carrier patterns of those interfering cells.

- In this case, OAM may provide the exact PDCCH protected carrier or a common PDCCH protected carrier pattern for macro eNBs,

15

- The macro eNBs may determine the PDCCH protected carrier pattern for pico based on the guidance from OAM.
- The macro eNBs may inform the pico cell (victim) about the configured PDCCH protected carrier(s).

20

In order to achieve this solution, a consistency check may be implemented in the OAM to ensure that there is a common PDCCH protected carrier pattern for the adjacent macro cells.

25

According to some embodiments of the invention, pico eNB gives a feedback about its actually used (usable) PDCCH protected carriers, i.e., adopted PDCCH protected carriers from macro cells. It may give a feedback on the measurement subset to the macro eNB, too.

30

In such embodiments, a PDCCH protected carrier *Information* IE is included in the LOAD INFORMATION message, wherein a *PDCCH protected carrier Pattern Info* IE indicates the carriers designated as PDCCH protected carriers by or protected from strong inter-cell interference for the sending eNB for the purpose of interference coordination. The receiving eNB may take such information into consideration when scheduling UEs or making a proper decision for its own

PDCCH protected carrier pattern. Furthermore, the LOAN INFORMATION message may comprise *Measurement Subset* IE, which the receiving eNB may use for the configuration of specific measurements towards the UE.

- 5 According to some embodiments, the receiving eNB considers the received information as immediately applicable. The receiving eNB shall consider the value of the *PDCCH protected carrier Information* IE valid until reception of a new LOAD INFORMATION message carrying an update. However, in some
10 active/inactive.

The pico cell may provide this information periodically or triggered by some events. In particular, the information may be requested from one of the macro cells. For example, an *Invoke Indication* IE may be included in the LOAD
15 INFORMATION message, which indicates which type of information the sending eNB would like the receiving eNB to send back. The receiving eNB may take such request into account. As a detailed example, if the *Invoke Indication* IE is set to "PDCCH protected carrier Information", it indicates that the sending eNB would like the receiving eNB to initiate the Load Indication procedure, with the LOAD
20 INFORMATION message containing the *PDCCH protected carrier Information* IE indicating PDCCH protected carrier patterns in the relevant aggressor/victim cells. Exemplarily, the format of notification may be the carrier bitmap or the actual carrier identification, e.g., EARFCN and bandwidth indication.

- 25 According to some embodiments, one or both of the macro and the pico UE may be informed about their neighbour pico cells' PDCCH protected carrier pattern. In the exemplary scenario of Fig. 6, pico cell 2 is a neighbour pico cell for pico cell 1 and macro cell 2. This information may be used to configure and perform the measurement to its neighbour pico cells. The information may be conveyed by
30 dedicated signaling, e.g. using measurement object.

In the following, some exemplary implementations for the IE *PDCCH protected carrier information* are given. This IE may provide information about the carrier(s) the sending eNB has configuring as PDCCH protected carriers, and/or which

subset of PDCCH protected carriers are recommended for configuring measurements towards the UE. The new parts over the present standard definitions are underlined.

IE/Group Name	Presence	Range	IE type and reference	Semantics description
<u>PDCCH protected carrier Information</u>	<u>O</u>		=	=
> <u>PDCCH protected carrier Pattern Info</u>	<u>O</u>		<u>BIT STRING (SIZE(40))</u>	<u>Each position in the bitmap represents a carrier, for which value "1" indicates 'configured as PDCCH protected carrier in DL' and value "0" indicates 'not configured as PDCCH protected carrier in DL'.</u> Note that OAM configures the mapping between the <u>actual carrier identification</u> and the <u>corresponding bit in the carrier bitmap</u> .
> <u>Measurement Subset</u>	<u>O</u>		<u>BIT STRING (SIZE(40))</u>	Indicates a subset of the <u>PDCCH protected carrier Pattern Info</u> above, and is used to configure specific <u>measurements towards the UE</u> .
> <u>PDCCH protected carrier Inactive</u>	<u>O</u>		<u>NULL</u>	Indicates that interference coordination by means of <u>PDCCH protected carrier is not active</u>

5 Table 1: implementation example 1 of PDCCH protected carrier information

According to implementation example 2, the new IE may be comprised in the load information:

Table 2 Exemplified case 2IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.13		YES	ignore
Cell Information	M				YES	ignore
>Cell Information Item		1 to maxCellInfoNB			EACH	ignore
>>Cell ID	M		ECGI 9.2.14	Id of the source cell	—	—
>>UL Interference Overload Indication	O		9.2.17		—	—
>>UL High Interference Information		0 to maxCellInfoNB			—	—
>>>Target Cell ID	M		ECGI 9.2.14	Id of the cell for which the HII is meant	—	—
>>>UL High Interference Indication	M		9.2.18		—	—
>>Relative Narrowband Tx Power (RNTP)	O		9.2.19		—	—
>> PDCCH protected carrier Information	O		=	=	YES	ignore
>>>PDCCH protected carrier Pattern Info	O		BIT STRING (SIZE(40))	Each position in the bitmap represents a carrier, for which value "1" indicates 'configured as PDCCH protected carrier in DL' and value "0" indicates 'not configured as PDCCH protected carrier in DL'. Note that OAM configures the mapping between the actual carrier identification and the corresponding bit in the carrier bitmap.	YES	ignore
>>>Measurement Subset	O		BIT STRING (SIZE(40))	Indicates a subset of the PDCCH protected carrier Pattern Info above, and is used to configure specific measurements towards the UE.	YES	ignore
>>>PDCCH protected carrier Inactive	O		NULL	Indicates that interference coordination by means of PDCCH protected carrier is not active	YES	ignore
>>Invoke Indication	O		9.2.y		YES	ignore

Table 2: implementation example 2 of PDCCH protected carrier information

According to a third implementation example, PDCCH protected carrier information may be implemented as a new message compared to the present standard:

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.13		YES	ignore
<u>PDCCH protected carrier Information</u>	<u>O</u>		=	=	YES	ignore
>Cell ID	M		ECGI 9.2.14	Id of the source cell	-	-
>PDCCH protected carrier Pattern Info	<u>O</u>		BIT STRING (SIZE(40))	Each position in the bitmap represents a carrier, for which value "1" indicates 'configured as PDCCH protected carrier in DL' and value "0" indicates 'not configured as PDCCH protected carrier in DL'. Note that OAM configures the mapping between the actual carrier identification and the corresponding bit in the carrier bitmap.	YES	ignore
>Measurement Subset	<u>O</u>		BIT STRING (SIZE(40))	Indicates a subset of the PDCCH protected carrier Pattern Info above, and is used to configure specific measurements towards the UE.	YES	ignore
>PDCCH protected carrier Inactive	<u>O</u>		NULL	Indicates that interference coordination by means of PDCCH protected carrier is not active	YES	ignore

Table 3: implementation example 3 of PDCCH protected carrier information

Fig. 7 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof.

The apparatus comprises at least one processor 300, and at least one memory 305 including computer program code, wherein the at least one processor 300, with the at least one memory 305 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 8.

Fig. 8 shows a method according to an embodiment of the invention. The apparatus according to Fig. 7 may perform the method of Fig. 8 but is not limited to this method. The method of Fig. 8 may be performed by the apparatus of Fig. 7 but is not limited to being performed by this apparatus.

According to step S310, an indication of one or more carriers of a plurality of carriers to be candidates of an PDCCH protected carrier type of a first aggressor device is received from the first aggressor device. According to step S320, an indication of one or more carriers of the plurality of carriers to be candidates of the PDCCH protected carrier type of a second aggressor device is received from the second aggressor device. The first aggressor device may be different from the second aggressor device. The indications may comprise an PDCCH protected carrier pattern. Steps S310 and S320 may be interchanged or performed simultaneously.

According to step S330, the apparatus negotiates with the first aggressor device and the second aggressor device on a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of both the first aggressor device and the second aggressor device. At the end of the negotiations, the apparatus selects the common available carrier (S340). For example, it may select a carrier that is comprised in the candidate sets of both aggressor devices. Alternatively, e.g. if there is no carrier in both candidate sets, it may select one based on some radio measurements.

Then, in step S350, the selected common available carrier is indicated to the first aggressor device and the second aggressor device in order to instruct them to configure the common available joint carrier to be of the PDCCH protected carrier type.

Fig. 9 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 400, and at least one memory 405 including computer program code, wherein the at least one processor 400, with the at least one memory 405 and the computer program code, being

configured to cause the apparatus to at least perform one of the methods shown in Fig. 10.

Fig. 10 shows a method according to an embodiment of the invention. The apparatus according to Fig. 9 may perform the method of Fig. 10 but is not limited to this method. The method of Fig. 10 may be performed by the apparatus of Fig. 9 but is not limited to being performed by this apparatus.

According to step S410, the apparatus monitors if there is a common available carrier indicated by a first aggressor device and a second aggressor device different from the first aggressor device. Then, according to step S420, it selects and informs at least one of the aggressor devices about the common available carrier such that they are caused to configure the common available carrier as a PDCCH protected carrier. According to step S430, a terminal is scheduled on the selected common available carrier.

Fig. 11 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 500, and at least one memory 505 including computer program code, wherein the at least one processor 500, with the at least one memory 505 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 12.

Fig. 12 shows a method according to an embodiment of the invention. The apparatus according to Fig. 11 may perform the method of Fig. 12 but is not limited to this method. The method of Fig. 12 may be performed by the apparatus of Fig. 11 but is not limited to being performed by this apparatus.

According to step 510, one or more candidate carriers of a plurality of carriers are selected as candidates for a PDCCH protected carrier type of the apparatus. A victim device is informed about the candidate carriers (S520).

In step S530, an indicated carrier of the plurality of carriers is configured to be of the PDCCH protected carrier type based on an indication received from the victim

device, which means at least that transmitting control signal on the configured PDCCH protected carrier is suppressed (S540).

Fig. 13 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 600, and at least one memory 605 including computer program code, wherein the at least one processor 600, with the at least one memory 605 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 14.

Fig. 14 shows a method according to an embodiment of the invention. The apparatus according to Fig. 13 may perform the method of Fig. 14 but is not limited to this method. The method of Fig. 13 may be performed by the apparatus of Fig. 14 but is not limited to being performed by this apparatus.

According to step 610, one or more candidate carriers of a plurality of carriers are selected as candidates for a PDCCH protected carrier type of the apparatus. An aggressor device is informed about the candidate carriers (S620).

Then, according to step S630, the apparatus agrees with the aggressor device on a common available carrier of the plurality of carriers which is to be of the PDCCH protected carrier type of both the apparatus and the aggressor device. Accordingly, in step S640, the common available carrier is configured to be of the PDCCH protected carrier type, which means at least that transmitting control signal on the common available carrier is suppressed (S650).

Fig. 15 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 700, and at least one memory 705 including computer program code, wherein the at least one processor 700, with the at least one memory 705 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 16.

Fig. 16 shows a method according to an embodiment of the invention. The apparatus according to Fig. 15 may perform the method of Fig. 16 but is not limited to this method. The method of Fig. 15 may be performed by the apparatus of Fig. 16 but is not limited to being performed by this apparatus.

5

According to step S710, a victim device is informed about common available carrier(s). The common available carriers are indicated in a message received from an OAM system and are indicated as suitable to be PDCCH protected carriers.

10 Then, according to step S720, the common available carrier is configured to be of the PDCCH protected carrier type, which means at least that transmitting control signal on the common available carrier is suppressed (S730).

Fig. 17 shows an apparatus according to an embodiment of the invention. The apparatus may be a base station such as a NodeB or eNodeB, or a part thereof. The apparatus comprises at least one processor 800, and at least one memory 805 including computer program code, wherein the at least one processor 800, with the at least one memory 805 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 18.

20

Fig. 18 shows a method according to an embodiment of the invention. The apparatus according to Fig. 17 may perform the method of Fig. 18 but is not limited to this method. The method of Fig. 17 may be performed by the apparatus of Fig. 18 but is not limited to being performed by this apparatus.

25

In step S810, it is decided to configure a measurement of a terminal operatively connected to the apparatus. In the deciding, an information received from a victim device about one or more common available carriers that may be a subset of the usable carriers is taken into account. Accordingly, in step S820, the measurement of the terminal is configured.

30

Fig. 19 shows an apparatus according to an embodiment of the invention. The apparatus may be a OAM such as an OAM processor or OAM center, or a part thereof. The apparatus comprises at least one processor 900, and at least one

35

memory 905 including computer program code, wherein the at least one processor 900, with the at least one memory 905 and the computer program code, being configured to cause the apparatus to at least perform one of the methods shown in Fig. 20.

5

Fig. 20 shows a method according to an embodiment of the invention. The apparatus according to Fig. 19 may perform the method of Fig. 20 but is not limited to this method. The method of Fig. 19 may be performed by the apparatus of Fig. 20 but is not limited to being performed by this apparatus.

10

According to step S910, it is checked if both one or more first carriers of a plurality of carriers and one or more second carriers of the plurality of carriers comprise a common available carrier. The first carriers are potential candidates to be of an PDCCH protected carrier type of a first aggressor device, and the second carriers are potential candidates to be of the PDCCH protected carrier type of a second aggressor device different from the first aggressor device.

15

If this is the case, i.e. if the first and second carriers comprise the common available carrier, in step S920 the common available carrier is selected to be a candidate of the PDCCH protected carrier type of both the first aggressor device and the second aggressor device.

20

Then, according to step S930, at least one of the first and second aggressor devices is informed about the common available carrier, in order to cause the aggressor device to configure the common available carrier to be a PDCCH protected type.

25

In some embodiments, it is checked if the aggressors and victims are neighbored. This may be performed by interference measurements, but it may also be known from the network configuration.

30

The control signal in the embodiments of Figs. 7 to 20 may be a PDCCH signal.

Some embodiments of the invention are described with respect to subframes and some with respect to slots, wherein a subframe comprises one or more slots.

35

Since the embodiments of the invention are not sensitive whether they are applied to a slot or a subframe, a reference to a subframe may be replaced by one to a slot (including a single slot) and vice versa. That is, each embodiment described for a subframe may be applied to a slot and each embodiment
5 described for a slot may be applied to a subframe.

Embodiments of the invention are described based on an LTE-A system but embodiments of the invention may be applied to other radio access technologies such as LTE, WiFi, WLAN, UMTS, HSPA, if extension carriers and blank frames
10 are foreseen.

A device may be a user equipment, a terminal, a mobile phone, a laptop, a smartphone, a tablet PC, or any other device that may attach to the mobile network. A base station may be for example a NodeB, an eNodeB or any other
15 base station of a radio network.

If not otherwise stated or otherwise made clear from the context, the statement that two entities are different means that they are differently addressed in their respective network. It does not necessarily mean that they are based on
20 different hardware. That is, each of the entities described in the present description may be based on a different hardware, or some or all of the entities may be based on the same hardware.

According to the above description, it should thus be apparent that exemplary
25 embodiments of the present invention provide, for example a victim apparatus such as a base station or a cell of a base station or a component thereof, an apparatus embodying the same, a method for controlling and/or operating the same, and computer program(s) controlling and/or operating the same as well as mediums carrying such computer program(s) and forming computer program
30 product(s). Furthermore, it should thus be apparent that exemplary embodiments of the present invention provide, for example an aggressor apparatus such as a base station or a cell of a base station or a component thereof, an apparatus embodying the same, a method for controlling and/or operating the same, and computer program(s) controlling and/or operating the

same as well as mediums carrying such computer program(s) and forming computer program product(s). Furthermore, it should thus be apparent that exemplary embodiments of the present invention provide, for example an operation apparatus such as a OAM center or a component thereof, an apparatus
5 embodying the same, a method for controlling and/or operating the same, and computer program(s) controlling and/or operating the same as well as mediums carrying such computer program(s) and forming computer program product(s).

According to exemplarily embodiments of the present invention, a system may
10 comprise any conceivable combination of the thus depicted devices/apparatuses and other network elements, which are configured to cooperate with any one of them.

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

Generally, any structural means such as a processor or other circuitry may refer to one or more of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) combinations
25 of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) circuits, such as a microprocessor(s) or a portion of a
30 microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. Also, it may also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware, any integrated circuit, or the like.

Generally, any procedural step or functionality is suitable to be implemented as software/firmware or by hardware without changing the idea of the present invention. Such software may be 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. Such hardware may be hardware type 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 (Application Specific IC (Integrated Circuit)) components, FPGA (Field-programmable Gate Arrays) components, CPLD (Complex Programmable Logic Device) components or DSP (Digital Signal Processor) components. A device/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 a device/apparatus or module, instead of being hardware implemented, be implemented as software in a (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 a device/apparatus or as an assembly of more than one device/apparatus, whether functionally in cooperation with each other or functionally independently of each other but in a same device housing, for example.

Apparatuses and/or means or parts thereof can be implemented as individual devices, but this does not exclude that they may be implemented in a distributed fashion throughout the system, as long as the functionality of the device is preserved. Such and similar principles are to be considered as known to a skilled person.

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.

5 The present invention also covers any conceivable combination of method steps and operations described above, and 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.

10 It is to be understood that what is described above is what is presently considered the preferred embodiments of the present invention. However, it should be noted that the description of the preferred embodiments is given by way of example only and that various modifications may be made without departing from the scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform:

classifying a first terminal having at least a downlink communication with the apparatus into one of a cancellation category and a non-cancellation category, wherein the cancellation category indicates that the first terminal is capable of reference signal interference cancellation;

assessing whether the first terminal is affected by interference caused by an aggressor device by more than a first interference level;

if it is assessed that the first terminal is affected by more than the first interference level and the terminal is classified into the non-cancellation category, scheduling a first blank slot of a clear carrier for the downlink communication, and

if it is assessed that the first terminal is affected by more than the first interference level and the first terminal is classified into the cancellation category, scheduling a second blank slot of a normal carrier for the downlink communication, wherein

the scheduling is based on a carrier information received from the aggressor device according to which the clear carrier is comprised by one or more extension carriers of the aggressor device and based on a slot information received from the aggressor device according to which each of the first and second blank slots is of one of an almost blank slot type and a blank slot with reduced power type.

2. The apparatus according to claim 1, wherein the processor is further configured to perform

scheduling of the second blank slot of the normal carrier only if the carrier information indicates that the normal carrier is not an extension carrier.

3. The apparatus according to any of claims 1 to 2, wherein the processor is further configured to perform

schedule the first blank slot if the first terminal is affected by the interference by more than the first interference level; and to

schedule a third blank slot if the first terminal is affected by the interference by more than a second interference level higher than the first interference level if the slot information comprises an indication that the first blank slot is of the blank slot with reduced power type and that the third blank slot of the clear carrier is of the almost blank slot type.

4. The apparatus according to any of claims 1 to 3, wherein the processor is further configured to perform

scheduling a slot of a normal type which is different from the almost blank slot type and the blank slot with reduced power type in the normal carrier if the first terminal is affected by the interference by not more than the first interference level.

5. The apparatus according to any of claims 1 to 4, wherein the processor is further configured to perform

the classifying, the assessing, and the scheduling correspondingly for one or more terminals including the first terminal, wherein respective blank slots different from each other are scheduled for each of the terminals;

reporting, to the aggressor device, an indication of a number of physical resource blocks in the blank slots of the clear carrier scheduled for downlink communications of the one or more terminals that are classified into the non-cancellation category.

6. The apparatus according to claim 5, wherein the processor is further configured to perform

obtaining a total number of physical resource blocks in the blank slots of the clear carrier from the slot information; and wherein

the indication comprises a total ratio of the number of the physical resource blocks scheduled for downlink communications and the total number.

7. The apparatus according to claim 6, wherein the processor is further configured to perform

checking if the total ratio exceeds a predetermined threshold; and

requesting, from the aggressor device, a configuration of a further clear carrier if the ratio exceeds the predetermined threshold.

8. The apparatus according to any of claims 5 to 7, wherein the processor is further configured to perform

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the almost blank slot type scheduled for downlink communications of the one or more terminals that are classified into the non-cancellation category; and

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the blank slot with reduced power type scheduled for downlink communications of the one or more terminals that are classified into the non-cancellation category.

9. The apparatus according to any of claims 5 to 8, wherein the processor is further configured to perform

reporting, to the aggressor device, an indication of a number of physical resource blocks in the blank slots of the clear carrier scheduled for downlink communications of the one or more terminals that are classified into the cancellation category.

10. The apparatus according to any of claims 8 and 9, wherein the processor is further configured to perform

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the almost blank slot type scheduled for downlink communications of the one or more terminals that are classified into the cancellation category; and

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the blank slot with reduced power type scheduled for downlink communications of the one or more terminals that are classified into the cancellation category.

11. The apparatus according to any of claims 5 to 10, wherein the processor is further configured to perform

triggering the reporting periodically and/or when a predefined event occurs.

12. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer

5 program code, being configured to cause the apparatus to at least perform:

suppressing transmitting a reference signal on a carrier of an extension
carrier type;

configuring a first carrier to be of the extension carrier type;

10 deploying one or more blank slots on the first carrier, wherein each of the
blank slots is of an almost blank slot type or of a blank slot with reduced power
type;

checking if an indication received from a victim device indicates that a
total ratio of a number of physical resource blocks in blank slots on the first
carrier scheduled for downlink communication of terminals of a non-cancellation
15 category by the victim device to a total number of physical resource blocks in
blank slots on the first carrier exceeds a predetermined first threshold, wherein
the terminals are indicated to be affected by an interference caused by the
apparatus at more than a first interference level; and

20 configuring a second carrier different from the first carrier to be of the
extension carrier type if the first threshold is exceeded.

13. The apparatus according to claim 12, wherein the processor is further
configured to perform

25 checking if an indication received from the victim device indicates that a
first ratio of a number of the physical resource blocks in the blank slots of the
almost blank slot type on the first carrier scheduled for downlink communication
of terminals of the non-cancellation category by the victim device to a total
number of the blank slots of the almost blank slot on the first carrier exceeds a
predetermined second threshold and the total ratio does not exceed the first
30 threshold, wherein the strongly interfered terminals are indicated to be affected
by the interference at more than a second interference level higher than the first
interference level;

35 deploying at least one additional blank slot of the almost blank slot type on
the first carrier if the first ratio exceeds a predetermined second threshold and
the total ratio does not exceed the first threshold.

14. The apparatus according to any of claims 12 to 13, wherein the processor is further configured to perform

checking if an indication received from the victim device indicates that a second ratio of a number of physical resource blocks of the blank slots of the blank slot of reduced power type on the first carrier scheduled for downlink communication of medium interfered terminals of the non-cancellation category by the victim device to a total number of the blank slots of the blank slot with reduced power type on the first carrier exceeds a predetermined third threshold and the total ratio does not exceed the first threshold, wherein the medium interfered terminals are indicated to be affected by the interference at more than the first interference level and less than the second interference level;

deploying at least one additional blank slot of the blank slot with reduced power type on the first carrier if the second ratio exceeds a predetermined third threshold and the total ratio does not exceed the first threshold.

15. The apparatus according to any of claims 12 to 14, wherein the processor is further configured to perform

suppressing the configuring of the second carrier to be of the extension type if the total ratio does not exceed the first threshold, and

deploying a blank slot of a normal carrier which is not of an extension carrier type based on a report of one or more terminals that are not classified into the non-cancellation category.

16. The apparatus according to claim 15, wherein the processor is further configured to perform

checking, if an indication received from the victim device indicates that a third ratio of a number of physical resource blocks in blank slots of the almost blank slot type on the normal carrier scheduled for downlink communication of strongly interfered terminals of the cancellation category by the victim device to a total number of physical resource blocks in blank slots of the almost blank slot type on the normal carrier exceeds a predetermined fourth threshold, wherein the strongly interfered terminals are indicated to be affected by the interference at more than a second interference level higher than the first interference level; wherein

the additional blank slot is of the almost blank slot type if the third ratio exceeds the fourth threshold.

17. The apparatus according to claim 16, wherein the processor is further configured to perform

checking, if an indication received from the victim device indicates that a
5 fourth ratio of a number of physical resource blocks in blank slots of the blank slot of reduced power type on the normal carrier scheduled for downlink communication of medium interfered terminals of the cancellation category by the victim device to a total number of physical resource blocks in blank slots of the blank slot of reduced power type on the normal carrier exceeds a
10 predetermined fifth threshold, wherein the medium interfered terminals are indicated to be affected by the interference at less than the second interference level and more than the first interference level; wherein

the additional blank slot is of the blank slot of reduced power type if the
15 fourth ratio exceeds the fifth threshold.

18. Method, comprising

classifying a first terminal having at least a downlink communication with an apparatus performing the method into one of a cancellation category and a non-cancellation category, wherein the cancellation category indicates that the
20 first terminal is capable of reference signal interference cancellation;

assessing whether the first terminal is affected by interference caused by an aggressor device by more than a first interference level;

if it is assessed that the first terminal is affected by more than the first interference level and the terminal is classified into the non-cancellation category,
25 scheduling a first blank slot of a clear carrier for the downlink communication, and

if it is assessed that the first terminal is affected by more than the first interference level and the first terminal is classified into the cancellation category, scheduling a second blank slot of a normal carrier for the downlink
30 communication, wherein

the scheduling is based on a carrier information received from the aggressor device according to which the clear carrier is comprised by one or more extension carriers of the aggressor device and based on a slot information received from the aggressor device according to which each of the first and
35 second blank slots is of one of an almost blank slot type and a blank slot with reduced power type.

19. The method according to claim 18, further comprising
scheduling of the second blank slot of the normal carrier only if the carrier
information indicates that the normal carrier is not an extension carrier.

5

20. The method according to any of claims 18 to 19, further comprising
schedule the first blank slot if the first terminal is affected by the
interference by more than the first interference level; and to

10 schedule a third blank slot if the first terminal is affected by the
interference by more than a second interference level higher than the first
interference level if the slot information comprises an indication that the first
blank slot is of the blank slot with reduced power type and that the third blank
slot of the clear carrier is of the almost blank slot type.

15 21. The method according to any of claims 18 to 20, further comprising
scheduling a slot of a normal type which is different from the almost blank
slot type and the blank slot with reduced power type in the normal carrier if the
first terminal is affected by the interference by not more than the first
interference level.

20

22. The method according to any of claims 18 to 21, further comprising the
classifying, the assessing, and the scheduling correspondingly for one or more
terminals including the first terminal, wherein respective blank slots different
from each other are scheduled for each of the terminals;

25 reporting, to the aggressor device, an indication of a number of physical
resource blocks in the blank slots of the clear carrier scheduled for downlink
communications of the one or more terminals that are classified into the non-
cancellation category.

30 23. The method according to claim 22, further comprising obtaining a total
number of physical resource blocks in the blank slots of the clear carrier from the
slot information; and wherein

the indication comprises a total ratio of the number of the physical
resource blocks scheduled for downlink communications and the total number.

35

24. The method according to claim 23, further comprising checking if the total ratio exceeds a predetermined threshold; and

requesting, from the aggressor device, a configuration of a further clear carrier if the ratio exceeds the predetermined threshold.

5

25. The method according to any of claims 22 to 24, further comprising reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the almost blank slot type scheduled for downlink communications of the one or more terminals that are classified into the non-cancellation category; and

10

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the blank slot with reduced power type scheduled for downlink communications of the one or more terminals that are classified into the non-cancellation category.

15

26. The method according to any of claims 22 to 25, further comprising

reporting, to the aggressor device, an indication of a number of physical resource blocks in the blank slots of the clear carrier scheduled for downlink communications of the one or more terminals that are classified into the cancellation category.

20

27. The method according to any of claims 25 and 26, further comprising reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the almost blank slot type scheduled for downlink communications of the one or more terminals that are classified into the cancellation category; and

25

reporting, to the aggressor device, an indication of a number of the physical resource blocks in the blank slots of the blank slot with reduced power type scheduled for downlink communications of the one or more terminals that are classified into the cancellation category.

30

28. The method according to any of claims 22 to 27, further comprising triggering the reporting periodically and/or when a predefined event occurs.

35 29. Method, comprising

suppressing transmitting a reference signal on a carrier of an extension carrier type;

configuring a first carrier to be of the extension carrier type;

5 deploying one or more blank slots on the first carrier, wherein each of the blank slots is of an almost blank slot type or of a blank slot with reduced power type;

10 checking if an indication received from a victim device indicates that a total ratio of a number of physical resource blocks in blank slots on the first carrier scheduled for downlink communication of terminals of a non-cancellation category by the victim device to a total number of physical resource blocks in blank slots on the first carrier exceeds a predetermined first threshold, wherein the terminals are indicated to be affected by an interference caused by an apparatus performing the method at more than a first interference level; and

15 configuring a second carrier different from the first carrier to be of the extension carrier type if the first threshold is exceeded.

30. The method according to claim 29, wherein the processor is further configured to perform

20 checking if an indication received from the victim device indicates that a first ratio of a number of the physical resource blocks in the blank slots of the almost blank slot type on the first carrier scheduled for downlink communication of terminals of the non-cancellation category by the victim device to a total number of the blank slots of the almost blank slot on the first carrier exceeds a predetermined second threshold and the total ratio does not exceed the first threshold, wherein the strongly interfered terminals are indicated to be affected by the interference at more than a second interference level higher than the first interference level;

25 deploying at least one additional blank slot of the almost blank slot type on the first carrier if the first ratio exceeds a predetermined second threshold and the total ratio does not exceed the first threshold.

31. The method according to any of claims 29 to 30, wherein the processor is further configured to perform

35 checking if an indication received from the victim device indicates that a second ratio of a number of physical resource blocks of the blank slots of the blank slot of reduced power type on the first carrier scheduled for downlink

communication of medium interfered terminals of the non-cancellation category by the victim device to a total number of the blank slots of the blank slot with reduced power type on the first carrier exceeds a predetermined third threshold and the total ratio does not exceed the first threshold, wherein the medium
5 interfered terminals are indicated to be affected by the interference at more than the first interference level and less than the second interference level;

deploying at least one additional blank slot of the blank slot with reduced power type on the first carrier if the second ratio exceeds a predetermined third threshold and the total ratio does not exceed the first threshold.

10

32. The method according to any of claims 29 to 31, wherein the processor is further configured to perform

suppressing the configuring of the second carrier to be of the extension type if the total ratio does not exceed the first threshold, and

15

deploying a blank slot of a normal carrier which is not of an extension carrier type based on a report of one or more terminals that are not classified into the non-cancellation category.

20

33. The method according to claim 32, wherein the processor is further configured to perform

checking, if an indication received from the victim device indicates that a third ratio of a number of physical resource blocks in blank slots of the almost blank slot type on the normal carrier scheduled for downlink communication of strongly interfered terminals of the cancellation category by the victim device to
25 a total number of physical resource blocks in blank slots of the almost blank slot type on the normal carrier exceeds a predetermined fourth threshold, wherein the strongly interfered terminals are indicated to be affected by the interference at more than a second interference level higher than the first interference level; wherein

30

the additional blank slot is of the almost blank slot type if the third ratio exceeds the fourth threshold.

34. The method according to claim 33, wherein the processor is further configured to perform

35

checking, if an indication received from the victim device indicates that a fourth ratio of a number of physical resource blocks in blank slots of the blank

slot of reduced power type on the normal carrier scheduled for downlink communication of medium interfered terminals of the cancellation category by the victim device to a total number of physical resource blocks in blank slots of the blank slot of reduced power type on the normal carrier exceeds a
5 predetermined fifth threshold, wherein the medium interfered terminals are indicated to be affected by the interference at less than the second interference level and more than the first interference level; wherein

the additional blank slot is of the blank slot of reduced power type if the fourth ratio exceeds the fifth threshold.

10

35. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer

15 program code, being configured to cause the apparatus to at least perform:

receiving, from a first aggressor device, a first indication of one or more first carriers of a plurality of carriers to be first candidates of an PDCCH protected carrier type of the first aggressor device;

20 receiving, from a second aggressor device different from the first aggressor device, a second indication of one or more second carriers of the plurality of carriers to be second candidates of the PDCCH protected carrier type of the second aggressor device;

negotiating with the first aggressor device and the second aggressor device on a common available carrier of the plurality of carriers to be of the
25 PDCCH protected carrier type of the first aggressor device and the second aggressor device;

selecting the common available carrier;

30 indicating the common available carrier to the first aggressor device and the second aggressor device to cause them to configure the common available carrier to be of the PDCCH protected carrier type.

36. The apparatus according to claim 35, wherein the processor is configured to cause the apparatus to perform the negotiating such that it comprises

35 checking if the one or more first carriers and the one or more second carriers comprise the common available carrier.

37. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer

5 program code, being configured to cause the apparatus to at least perform:

monitoring if one or more carriers are common available carriers, wherein
a common available carrier is indicated to be a candidate for a PDCCH protected
carrier type by a first aggressor device and a candidate for a PDCCH protected
carrier type by a second aggressor device different from the first aggressor
10 device;

informing at least one of the first and second aggressor devices about the
one or more common available carriers; and

scheduling a terminal on the common available carrier.

15 38. The apparatus according to claim 37, wherein the processor is further
configured to perform

informing at least one of the first and second aggressor devices about a
measurement subset corresponding to the one or more common available
carriers.

20

39. The apparatus according to any of claims 37 and 38, wherein the processor is
configured to cause the apparatus to perform additionally

informing a victim device about the one or more common available carriers,
wherein the victim device is neighbored to the apparatus.

25

40. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer

30 program code, being configured to cause the apparatus to at least perform:

selecting one or more candidate carriers of a plurality of carriers as
candidates for an PDCCH protected carrier type of the apparatus;

informing an aggressor device about the candidate carriers;

agreeing with the aggressor device on an common available carrier of the

35 plurality of carriers to be of the PDCCH protected carrier type of the apparatus
and of the aggressor device;

configuring the common available carrier to be of the PDCCH protected carrier type;

suppressing transmitting a control signal on the configured common available carrier.

5

41. The apparatus according to claim 40, wherein the processor is configured to cause the apparatus to perform additionally

supervising if the aggressor device and the apparatus interfere with a victim device; wherein

10 the agreeing, configuring, and suppressing is performed only if the aggressor device and the apparatus interfere with the victim device.

42. Apparatus, comprising

at least one processor, and

15 at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform:

selecting one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type;

20 informing a victim device about the candidate carriers;

configuring, based on an indication received from the victim device, a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type;

suppressing transmitting a control signal on the common available carrier.

25

43. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

30 the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform:

informing a victim device about one or more common available carriers, wherein the common available carriers are indicated in a message received from an operation and management system to be suitable as PDCCH protected carriers; and

35 suppressing transmitting a control signal on the one or more common available carriers.

44. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform:

deciding to configure a measurement of a terminal operatively connected to the apparatus, wherein an information received from a victim device about one or more common available carriers is taken into account in the deciding, wherein a common available carrier is indicated to be both a candidate for a PDCCH protected carrier type of the apparatus and a candidate for a PDCCH protected carrier type of an aggressor device different from the apparatus; configuring the measurement of the terminal.

45. The apparatus according to claim 44, wherein the apparatus is further configured to take into account an information received from the victim device about a measurement subset related to the one or more common available carriers.

46. Apparatus, comprising

at least one processor, and

at least one memory including computer program code,

the at least one processor, with the at least one memory and the computer program code, being configured to cause the apparatus to at least perform:

checking if both one or more first carriers of a plurality of carriers and one or more second carriers of the plurality of carriers comprise a common available carrier, wherein the first carriers are potential candidates to be of an PDCCH protected carrier type of a first aggressor device, and the second carriers are potential candidates to be of the PDCCH protected carrier type of a second aggressor device different from the first aggressor device;

selecting, if the first and second carriers comprise the common available carrier, the common available carrier to be a candidate of the PDCCH protected carrier type of the first aggressor device and the second aggressor device; and

informing the first aggressor device and the second aggressor device about the common available carrier.

47. The apparatus according to claim 46, wherein the processor is configured to cause the apparatus to perform additionally

supervising if the first aggressor device and the second aggressor device interfere with a victim device; wherein

5 the checking is performed only if the first aggressor device and the second aggressor device interfere with the victim device.

Victim cell – negotiation of PDCCH protected carrier

10 48. Method, comprising

receiving, from a first aggressor device, a first indication of one or more first carriers of a plurality of carriers to be first candidates of an PDCCH protected carrier type of the first aggressor device;

15 receiving, from a second aggressor device different from the first aggressor device, a second indication of one or more second carriers of the plurality of carriers to be second candidates of the PDCCH protected carrier type of the second aggressor device;

20 negotiating with the first aggressor device and the second aggressor device on a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the first aggressor device and the second aggressor device;

selecting the common available carrier;

25 indicating the common available carrier to the first aggressor device and the second aggressor device to cause them to configure the common available carrier to be of the PDCCH protected carrier type.

49. The method according to claim 48, wherein the negotiating is performed such that it comprises

30 checking if the one or more first carriers and the one or more second carriers comprise the common available carrier.

50. Method, comprising

35 monitoring if one or more carriers are common available carriers, wherein a common available carrier is indicated to be a candidate for a PDCCH protected carrier type by a first aggressor device and a candidate for a PDCCH protected

carrier type by a second aggressor device different from the first aggressor device;

informing at least one of the first and second aggressor devices about the one or more common available carriers; and

5 scheduling a terminal on the common available carrier.

51. The method according to claim 50, further comprising

informing at least one of the first and second aggressor devices about a measurement subset corresponding to the one or more common available
10 carriers.

52. The method according to any of claims 50 and 51, further comprising

informing a victim device about the one or more common available carriers, wherein the victim device is neighbored to an apparatus performing the method.

15

53. Method, comprising

selecting one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type of an apparatus performing the method;

20

informing an aggressor device about the candidate carriers;

agreeing with the aggressor device on an common available carrier of the plurality of carriers to be of the PDCCH protected carrier type of the apparatus and of the aggressor device;

25

configuring the common available carrier to be of the PDCCH protected carrier type;

suppressing transmitting a control signal on the configured common available carrier.

54. The method according to claim 53, further comprising

30

supervising if the aggressor device and the apparatus interfere with a victim device; wherein

the agreeing, configuring, and suppressing is performed only if the aggressor device and the apparatus interfere with the victim device.

35

55. Method, comprising

selecting one or more candidate carriers of a plurality of carriers as candidates for an PDCCH protected carrier type;

informing a victim device about the candidate carriers;

5 configuring, based on an indication received from the victim device, a common available carrier of the plurality of carriers to be of the PDCCH protected carrier type;

suppressing transmitting a control signal on the common available carrier.

56. Method, comprising

10 informing a victim device about one or more common available carriers, wherein the common available carriers are indicated in a message received from an operation and management system to be suitable as PDCCH protected carriers; and

15 suppressing transmitting a control signal on the one or more common available carriers.

57. Method, comprising

20 deciding to configure a measurement of a terminal operatively connected to an apparatus performing the method, wherein an information received from a victim device about one or more common available carriers is taken into account in the deciding, wherein a common available carrier is indicated to be both a candidate for a PDCCH protected carrier type of the apparatus and a candidate for a PDCCH protected carrier type of an aggressor device different from the apparatus;

25 configuring the measurement of the terminal.

58. The method according to claim 57, wherein the deciding takes into account an information received from the victim device about a measurement subset related to the one or more common available carriers.

30

59. Method, comprising

35 checking if both one or more first carriers of a plurality of carriers and one or more second carriers of the plurality of carriers comprise a common available carrier, wherein the first carriers are potential candidates to be of an PDCCH protected carrier type of a first aggressor device, and the second carriers are

potential candidates to be of the PDCCH protected carrier type of a second aggressor device different from the first aggressor device;

selecting, if the first and second carriers comprise the common available carrier, the common available carrier to be a candidate of the PDCCH protected carrier type of the first aggressor device and the second aggressor device; and

informing the first aggressor device and the second aggressor device about the common available carrier.

60. The method according to claim 59, further comprising

supervising if the first aggressor device and the second aggressor device interfere with a victim device; wherein

the checking is performed only if the first aggressor device and the second aggressor device interfere with the victim device.

61. A computer program product comprising a set of instructions which, when executed on an apparatus, is configured to cause the apparatus to carry out the method according to any one of claims 18 to 34 and 48 to 60.

62. The computer program product according to claim 61, embodied as a computer-readable medium.

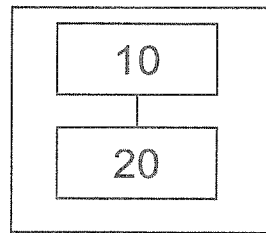


Fig. 1

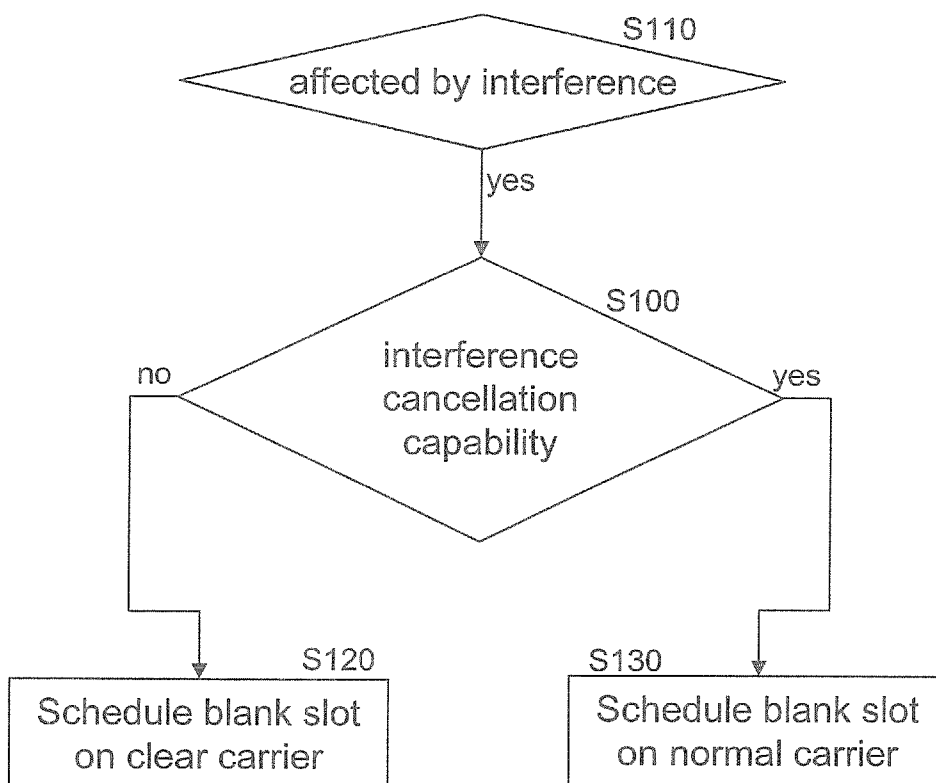


Fig. 2

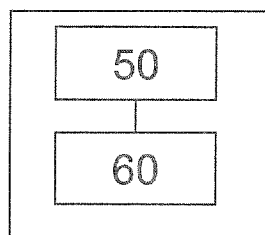


Fig. 3

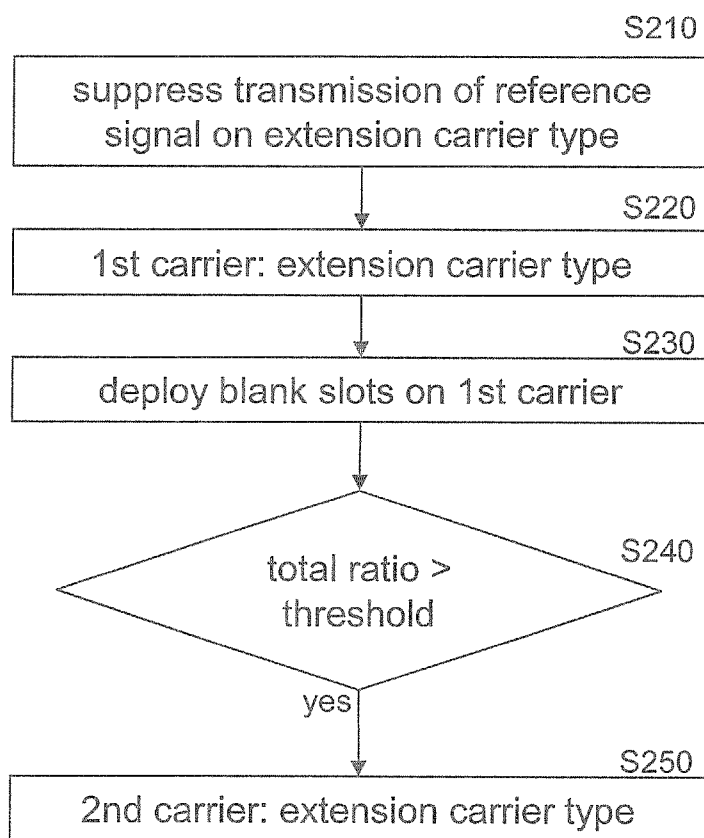


Fig. 4

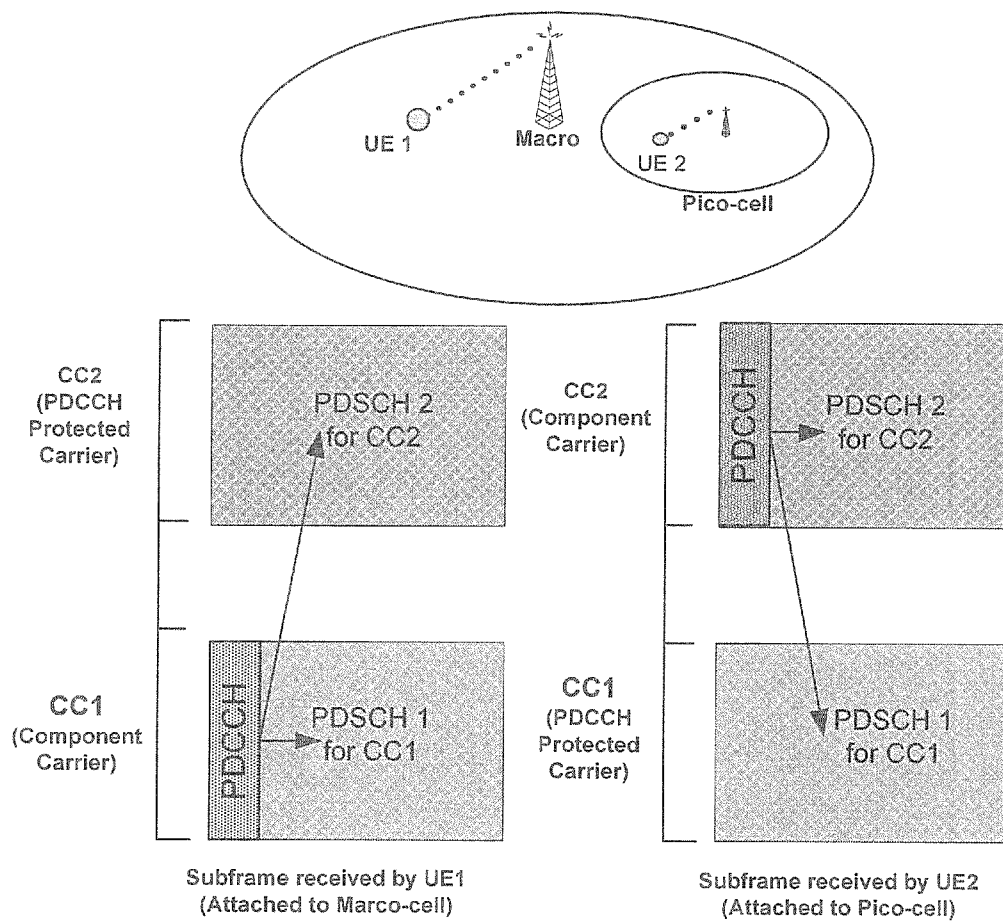


Fig. 5

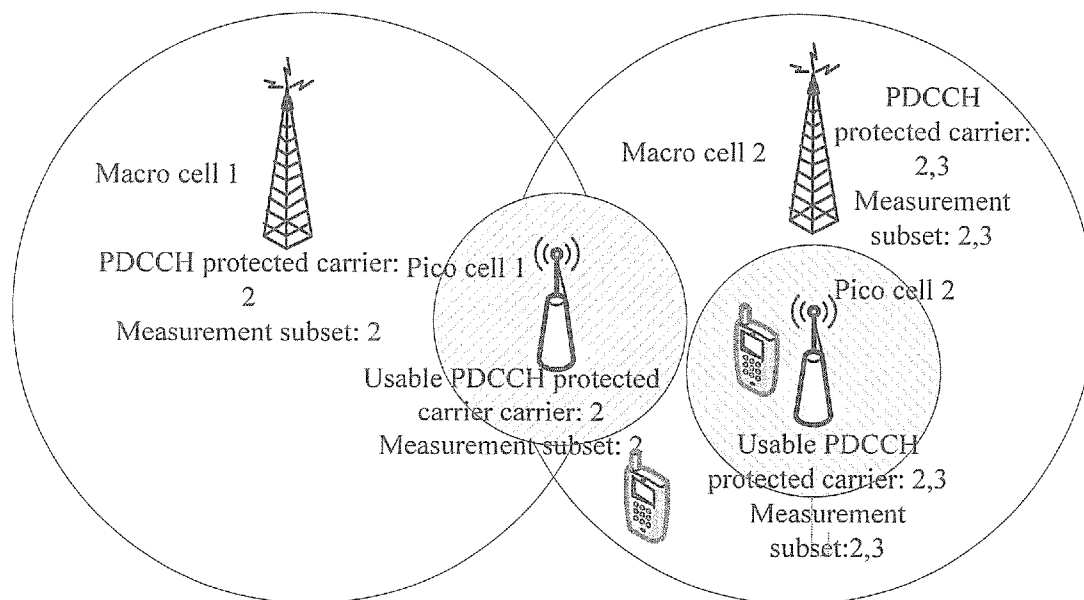


Fig. 6

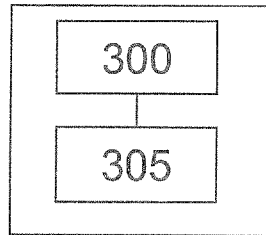


Fig. 7

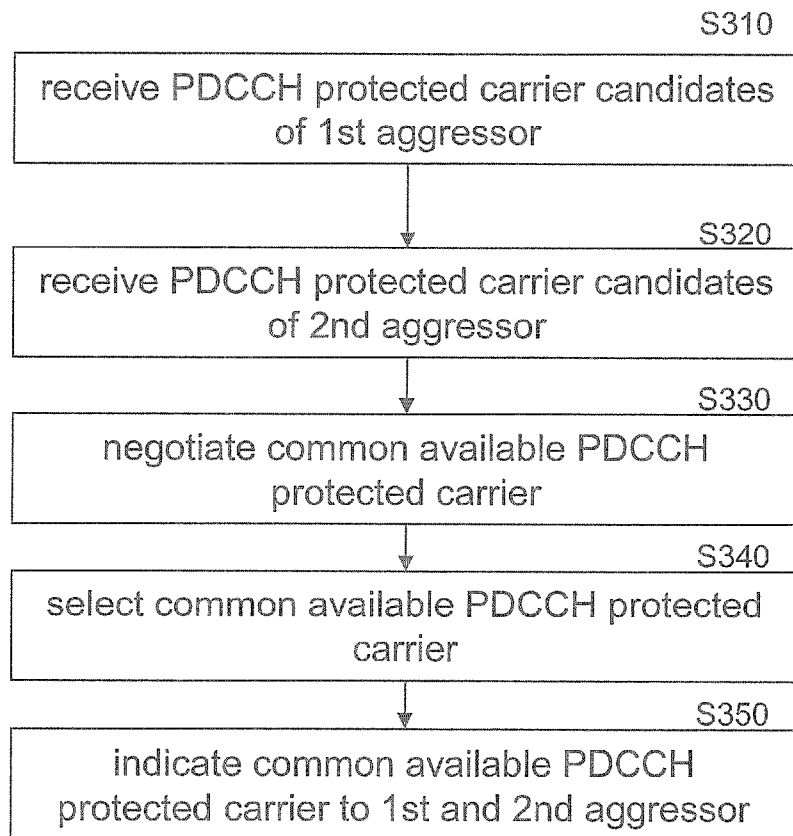


Fig. 8

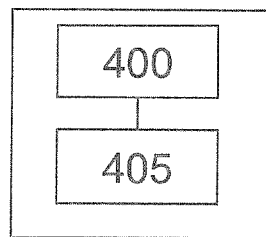


Fig. 9

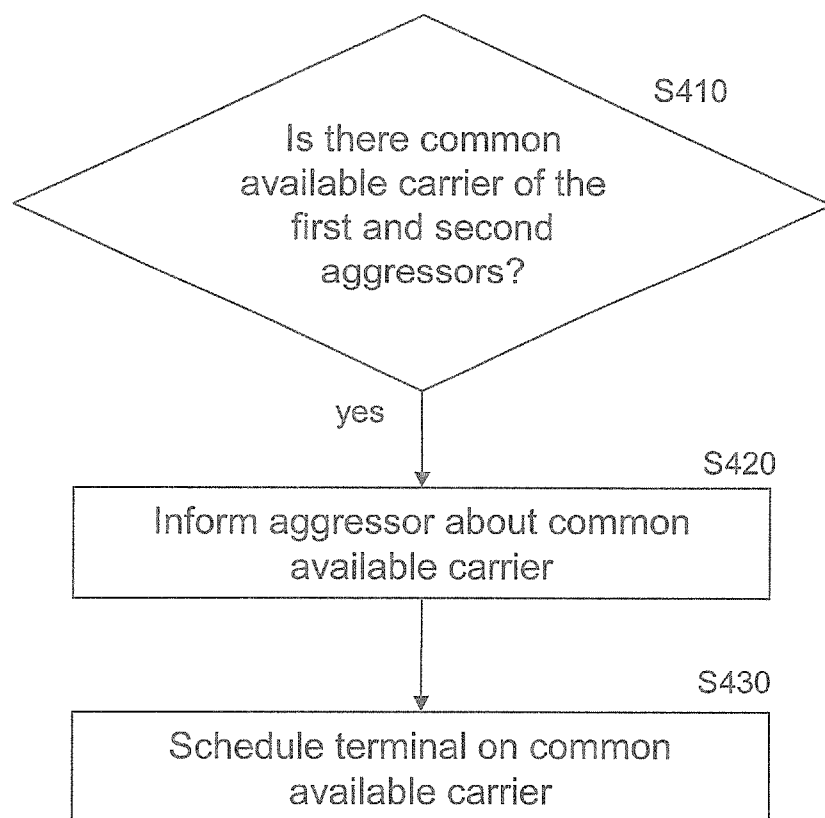


Fig. 10

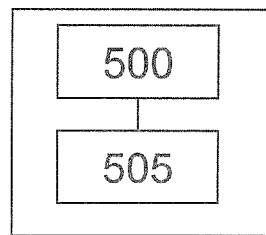


Fig. 11

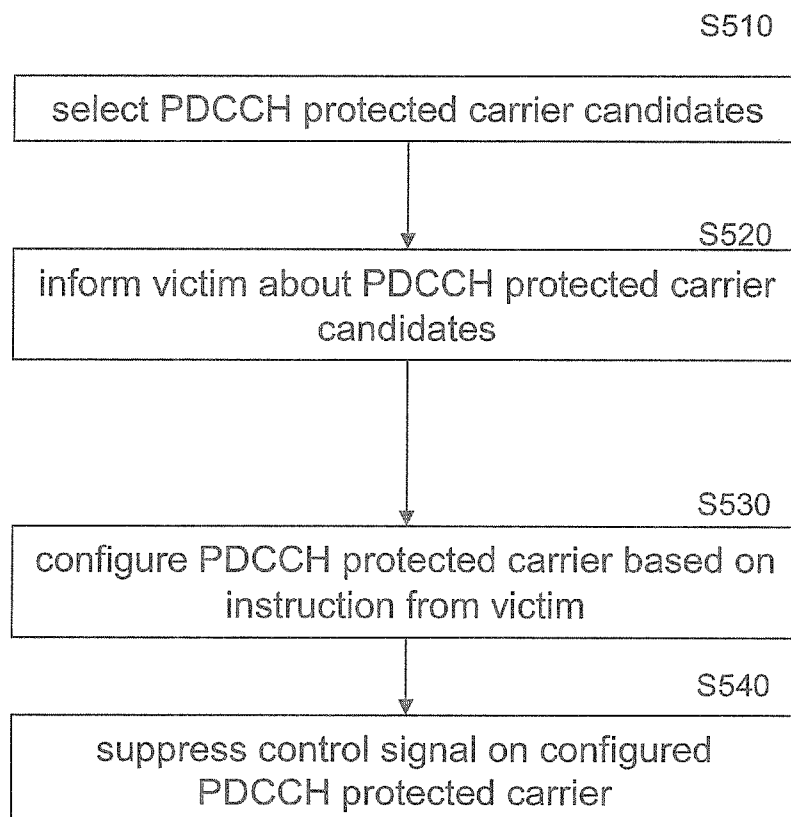


Fig. 12

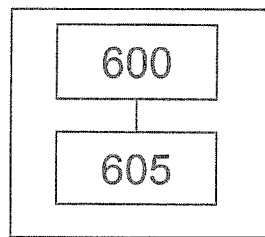


Fig. 13

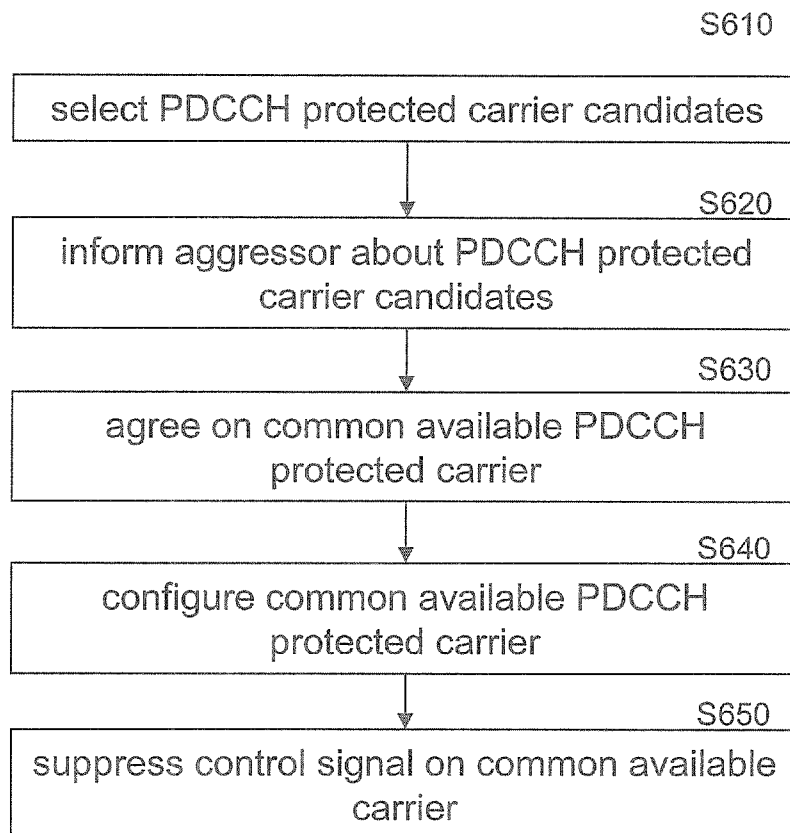


Fig. 14

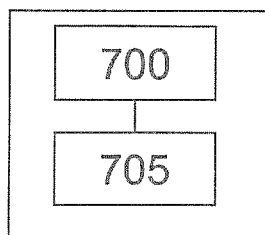


Fig. 15

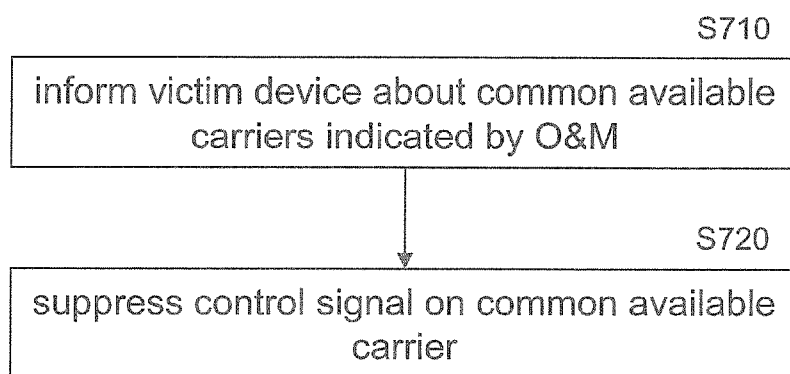


Fig. 16

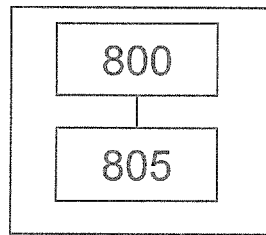


Fig. 17

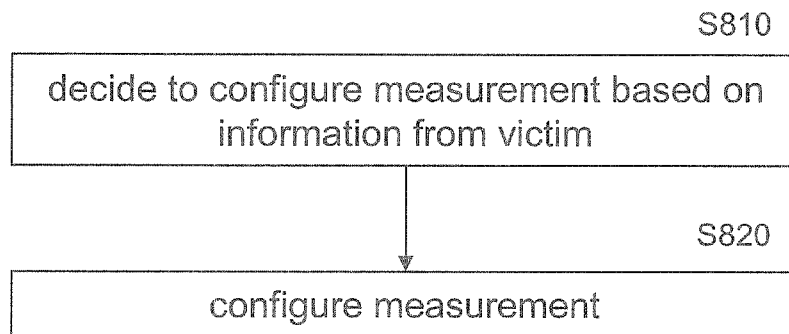


Fig. 18

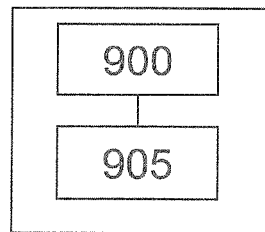


Fig. 19

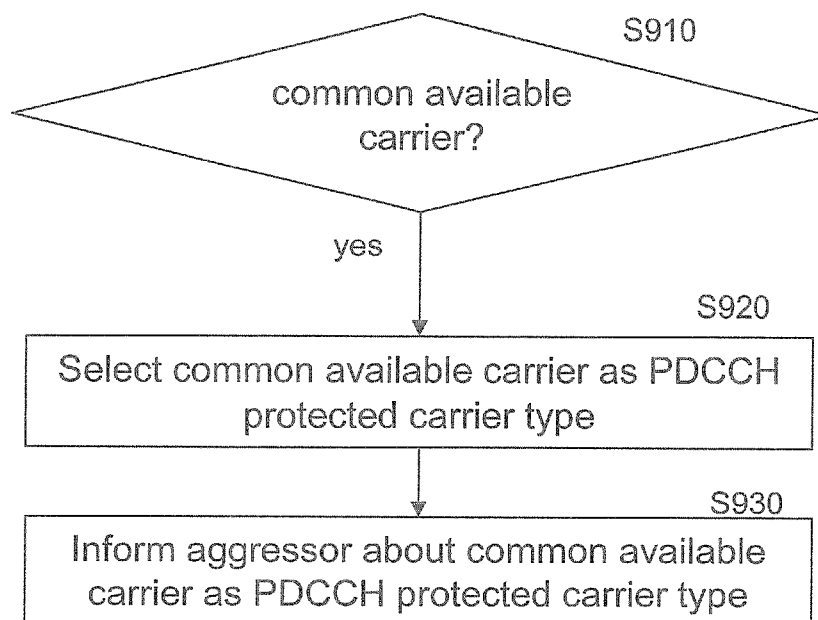


Fig. 20

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/078739

A. CLASSIFICATION OF SUBJECT MATTER

H04W 16/14(2009.01) i

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)

IPC: H04W ; H04L

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

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

CNABS, VEN, CNKI: interference, carrier, reference, signal, power, slot, blank, downlink, control, PDCCH, transmit, ABS, hetnet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN102368759A(ZTE CORPORATION)07 Mar.2012(07.03.2012)claims 1, 7, 11, description paragraphs[0002]-[0009],[0027]-[0028], [0039]-[0071],[0182]	40-47,53-62
A		1-39,48-52
A	CN102186247A(NEW POST COMMUNICATION EQUIP CO.,LTD.) 14 Sep.2011(14.09.2011)the whole document	1-62
A	CN102333338A(TD TECH COMMUNICATION TECHNOLOGIES LTD.) 25 Jan.2012(25.01.2012)the whole document	1-62

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“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
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&”document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 05 Apr.2013(05.04.2013)	Date of mailing of the international search report 25 Apr. 2013 (25.04.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer TANG Xiaoming Telephone No. (86-10)62411518

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/078739

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

This International Searching Authority found multiple inventions in this international application, as follows: The first group of claims (1,12,18,29) and the second group of claims(35,37,40,42,43,44,46,48,50,53,55,56,57,59) are covered by the claims. The same or corresponding technical features between the first group of independent claims and the second group of independent claims are as follows: at least one processor, and at least one memory including computer program code, but the features are the common knowledge in the art. Therefore there is no the same or corresponding special technical features between the two groups of claims. Thus, the application covers two inventions, hence does not meet the requirements of unity of invention as defined in Rule 13.1 PCT.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

International application No.
PCT/CN2012/078739

Form PCT/ISA /210 (patent family annex) (July 2009)