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(54) Title: METHOD AND APPARATUS FOR COORDINATED MULTIPOINT TRANSMISSION

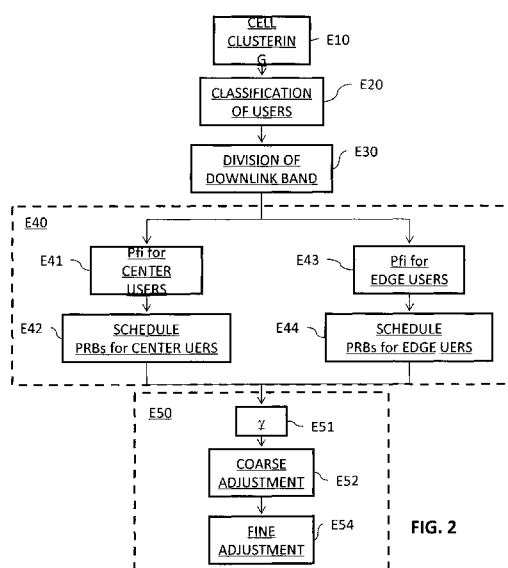


FIG. 2

(57) Abstract: This method of allocating a downlink frequency band in a coordinated multi-point system based on multi-cell joint signal processing, this method comprises: - a step (E10) of clustering said cells for determining at least a collaborative set of cells; and - a step (E20) of classifying the user equipments in said cells in a category of center user equipments (CCU) or in a category of edge user equipments (CEU); said center user equipments being served independently and said edge user equipments being jointly served by said collaborative set of cells, said method further comprising, at each transmission time interval: - a step (E30) of dynamically allocating to each category (CCU, CEU) part of the downlink frequency spectrum available for said system according to the number of user equipments in each category; - a step (E40) of scheduling the physical resource block allocated to said user equipments in their respective frequency band according to a priority (PFI) taking into account a channel state (Hi) and a traffic condition (Vi, Ri) of said user equipments.

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Method and Apparatus for Coordinated Multipoint Transmission

Background of the invention

5 The field of the invention is the field of 4G LTE (Long Term Evolution) networks, and more particularly the field of 4G LTE Coordinated Multipoint (CoMP) transmission and reception technology.

 Coordinated multipoint transmission and reception aim to improve the system performance, the end user service quality and especially to
10 achieve high data rates at the cell edges. This is achieved through a dynamic collaboration between access points at several locations to provide joint processing technology or coordinating scheduling/ coordinating beamforming technology (CS/CB).

 A user equipment UE located at the edge of a cell can thereby be
15 served by two or more access points to improve signals reception / transmission and increase throughput.

 The techniques used for coordinated multipoint are different for the uplink and downlink. This results from the fact that the base stations are connected to each others in a network, whereas the user equipment
20 are individual elements.

 The downlink LTE CoMP requires dynamic coordination amongst several geographically separated base stations eNBs transmitting to the user equipment UE. It can be classified into two categories: (a) the joint processing schemes and (b) the Coordinated scheduling and or
25 beamforming.

a) Joint processing schemes for transmitting in the downlink

 The data information transmitted to the user equipment is transmitted simultaneously from several base stations in a CoMP
30 collaboration set. These multiple information is coherently or not-coherently merged to improve the received signal quality and strength and to inhibit interference from transmissions that are intended for other user equipment.

b) Coordinated scheduling and or beamforming:

Using this concept, data to singleuser equipment is transmitted from one base station. The scheduling decisions and beams are coordinated to control the interference that may be generated.

The three possible user equipment scheduling methods are the
5 round-robin scheduling, the Max-C/I scheduling and the proportional fair scheduling.

The proportional fairness scheduling scheme is widely used. Compared with absolutely fair round-robin scheduling which does not consider the channel state and with the Max-C/I scheduling, which ignores
10 the fairness to maximize the throughput of the system, the proportional fairness scheduling chooses instantaneous user equipments in good condition or user equipments which have less weighted average throughput. It is not only able to take the spectral efficiency of the system into account but also the fairness between multi-user equipments.

15 The proportional fair algorithm considers the spectral efficiency and fairness but unfortunately, it does not take the diversities of the different types of traffic into account.

Frequency resource division and allocation

20 With respect to frequency resource division and allocation in the downlink cellular network, both fixed and flexible schemes were introduced.

In "Discussion of CoMP SU-MIMO", Samsung, 3GPP TSG RAN WG1 Meeting #56, R1-090613, Feb. 2009, a fixed resource allocation scheme
25 based on CoMP SU-MIMO was presented (coordinated multi-point transmission for single-user equipment multi-input multi-output).

This scheme divides each cell's frequency band into two parts: one is the CoMP frequency zone which is reserved for cell-edge UEs employing CoMP SU-MIMO, and the other is non-CoMP frequency zone for cell-center
30 UEs which are served by individual cell.

The central frequency and bandwidth of CoMP frequency zones are the same for each cell; this spectrum division scheme is therefore fixed and static. This scheme suffers from throughput loss due to the lack of flexibility between different cells.

35 To improve the system performance, "Further discussion of frequency plan scheme on CoMP-SU-MIMO", Potevio, 3GPP TSG RAN WG1

Meeting #56bis, R1-091415, Mar. 2009 and "Sub-carrier allocation combined with coordinated multi-point transmission in multi-cell OFDMA system" Proceedings of the 2009 IEEE International Conference on Network Infrastructure and Digital Content, IEEE Press, 6-8 Nov. 2009, pp.842-846 by XingkunXu, Tao Qiu et al. proposed so called flexible frequency allocation plan (FFAP) schemes, where each sector in one cell has an identical CoMP frequency zone that is allocated according to the proportion of cell-edge UE in its cluster.

However, once there is a frequency zone partition, some of the resources must be assigned to a fixed transmission mode. This scheme lacks flexibility and it causes a performance loss of the system.

As a summary, the existing CoMP transmission schemes, which adopt fixed spectrum division strategies for cell-edge and cell-center user equipments, suffer from uneven distribution and low utilization of resources.

Object and summary of the invention

The present invention proposes a method of allocating adownlink frequency band in a coordinated multi-point system based on multi-cell joint signal processing, this method comprising:

- a step of clustering said cells for determining at least a collaborative set; and
- a step of classifying the user equipments in said cells in a category of center user equipments or in a category of edge user equipments ; said center user equipments being served independently and said edge user equipments being jointly served by said collaborative set , said method further comprising, at each transmission time interval :
- a step of dynamically allocating to each category part of the downlink frequency spectrum available for said system according to the number of user equipments in each category ; and
- a step of scheduling the physical resource blocks allocated to said user equipments in their respective frequency band according to a priority taking into account a channel state and a traffic condition of said user equipments.

The invention correspondingly provides a base station usable in a coordinated multi-point system based on multi-cell joint signal processing, said base station comprising a MAC scheduler comprising:

- a module for clustering said cells for determining at least a collaborative set; and
- a module for classifying the user equipments in said cells in a category of center user equipments or in a category of edge user equipments; said center user equipments being served independently and said edge user equipments being jointly served by said collaborative set , said MAC scheduler further comprising:
 - a module for dynamically allocating to each category, at each transmission time interval, part of the downlink frequency spectrum available for said system according to the number of user equipments in each category ; and
 - a module for scheduling the physical resource block allocated to said user equipments in their respective frequency band according to a priority taking into account a channel state and a traffic condition of said user equipments.

The invention is applicable to the LTE downlink system with coordinated multi-point transmission with downlink QoS scheduling.

The dynamic algorithm of downlink frequency band allocation adjusts the frequency band allocation leading to the increase of the frequency band utilization.

Besides, the scheduling algorithm proposed in the invention fully accounts for both channel condition and traffic diversities.

In one particular embodiment of the invention, the method comprises a step of adjusting said spectrum allocation for minimizing the number of user equipments having an unrealized demanded downlink transmission rate superior to a threshold.

This scheme dynamically adjusts the resource block allocation and utilizes the system spectrum resources effectively according to the feedback from the dissatisfaction degree of user equipments. It improves in particular the throughput of cell-edge user equipments.

The invention hereby provides a progressive way for adaptive spectrum division maximizing a defined user equipment satisfaction indicator. The scheduler of the invention allocates appropriate frequency

bands to the user equipments according to a user equipment's priority determined by this indicator

After several rounds adjustment, near-optimal spectrum allocation for cell-edge and cell-center user equipments can be reached, and most
5 user equipments can be satisfied, whatever the traffic they bear.

In a particular embodiment of the invention, a static collaboration set division is used. A dynamic collaboration set division can also be used.

In a particular embodiment of the invention, the category of center user equipments comprises the user equipments having a channel quality
10 indicator CQI superior to a threshold, the category of edge user equipments comprising the user equipments having said channel quality indicator lower than said threshold.

In a particular embodiment of the invention, the percentage of frequency spectrum allocated dynamically to each category of user
15 equipments corresponds to the percentage of user equipments in said category.

Brief description of the drawings

Other characteristics and advantages of the present invention
20 appear from the following description made with reference to the accompanying drawings that show an embodiment without any limiting character. In the figures:

- Figure 1 shows a base station in accordance with the invention;
- Figure 2 shows, in the form of a flow chart, the main steps of a
25 method of frequency allocation in accordance with the invention;
- Figure 3 shows a distribution of user equipment;
- Figure 4 shows the result of scheduling applied to the distribution of Figure 3; and
- Figure 5a to 5c illustrate an example of a coarse and of a fine
30 adjustments steps in accordance with the invention.

Detailed description of an embodiment of the invention

35 Figure 1 shows a base station BS in accordance with the invention. This base station BS comprises a MAC entity ME, which, in this specific

embodiment, has the hardware architecture of a conventional computer. In particular, it comprises a processor 11, a read/write memory 12 of the random access memory (RAM) type, and a read-only memory 13 having recorded therein a MAC scheduler MS computer program including instructions for executing the steps of the method represented by the flow chart shown in Figure 2.

Figure 2 represents in flow chart form the main steps of a particular embodiment of a method according to the invention.

As a general overview, the method of the invention consists in clustering the cells (step E10) either statically or dynamically. The user equipments are then classified into center user equipments and edge user equipments (step E20).

At any transmission time interval TTI, the system available downlink frequency bandwidth is divided according to the percentage of user equipments in each category (step E30). Then, a center user equipments scheduling in each cell and a centralized edge user equipments scheduling at the cluster level are performed in parallel (step E40). Finally, the spectrum allocation is adjusted to maximize the number of user equipments for which the demanded downlink transmission rate is realized (step E50).

In this embodiment, the frequency allocation method of the invention comprises a step E10 of cell clustering for determining a collaboration set.

The method of the invention can use either a static clustering, where clustering is performed once, for examples based on field measurements and/or ray-launching simulations, or a dynamic clustering where measurements based on the received channel state information (CSI) are used to adapt clustering decisions over time.

Step E10 is followed by a step E20 of classifying all the user equipments UE into center user equipments (CCU) and edge user equipments (CEU), the center user equipments being the user equipments UE having a channel quality indicator (CQI) superior or equal to a predefined threshold α , and edge user equipments, the user equipments with a channel quality indicator CQI lower than said threshold, the channel quality indicator CQI being estimated using the reference signal RS.

For example, in the distribution of Figure 3, user equipment UE1-UE10 could be classified in the CCU category (center user equipments) and user equipment UE11-UE15 in the CEU category (edge user equipments).

5 The classification step E20 is done on a per cell basis. It could be performed before step E10.

Step E20 (or step E10 if performed before step E10) is followed by a step E30 of dividing the downlink frequency band according to the percentage of center user equipments CCU and edge user equipments
10 CEU.

$$B_EDGE = B * |CEU| / (|CCU| + |CEU|) ;$$

$$B_CENTER = B - B_EDGE,$$

Where:

- B means the system available frequency bandwidth;
- 15 - B_EDGE, the frequency band allocated for edge user equipments;
- B_CENTER, the frequency band allocated for center user equipments;
- |CEU|, the total number of edge user equipments; and
- 20 - |CCU|, the total number of center user equipments.

The frequency band division could be different from one collaborative cluster to another but the frequency band division must be the same for all the cells in a given collaborative cluster.

Step E30 is followed by a general step E40 of user equipment
25 scheduling, which will be described in details.

In the invention, the cell center user equipments are served independently, the edge user equipments being jointly served by the collaborative set.

Steps E41 and E42 relate to the center user equipment scheduling.

30 Step E41 is a step of calculating a priority factor PF_i for all the center user equipments in each cell. In this embodiment,

$$PF_i = \frac{|H_i|^2}{|H_i|_{MAX}^2} \cdot a + \frac{(V_i - R'_i)}{(V_i - R'_i)_{MAX}} \cdot b, \quad \text{with } a + b = 1$$

Where:

- PF_i means the priority of user equipment i

- a means the weight of the channel state;
- b means the weight of the satisfaction of the user equipment;
- $|H_i|^2$ means the norm of the channel state matrix of user equipment i;
- 5 - V_i means the demanded downlink transmission rate for user equipment i;
- R'_i means the realized downlink transmission rate for user equipment i.

10 In a particular embodiment, $|H_i| = (\sum_{k=1}^M \sum_{j=1}^N |h_{j,k}|^p)^{1/p}$ for the $N \times M$ matrix H_i .

At step E42, each cell sorts the center user equipments allocates the downlink Physical Resource Bloc PRB.

15 Table 1 below gives an example of center user equipments sorting for the three cells CELL_1, CELL2, CELL 3 of figure 3.

Cell ID	UE ID			
CELL_1	UE2	UE1	UE3	...
CELL_2	UE4	UE6	UE5	...
CELL_3	UE7	UE8	UE9	UE10

Table 1

Steps E43 and E44 relate to the edge user equipment scheduling.

20 Step E43 is a step of calculating a priority factor PFI for all the edge user equipments in each cell. In this embodiment, step E43 is similar to step E41 of calculating a priority factor for center user equipments.

$$PFI_i = \frac{|H_i|_{combine}^2}{|H_i|_{MAX}^2} \cdot a + \frac{(V_i - R'_i)_{combine}}{(V_i - R'_i)_{MAX}} \cdot b, \quad \text{with } a + b = 1$$

Where:

- 25 - H_i combine means the composite channel from the Base Station defining the cluster; and
- $(V_i - R'_i)$ combine means the data rate realized by joint transmission.

30 At step E44, the edge user equipments are sorted in a centralized manner by the collaborative cluster.

Table 2 below gives an example of edge user equipments sorting for the collaborative cluster CC_1 of figure 3.

Cluster ID	UE ID			
CC_1	UE11	UE15	UE12 UE14	...

Table 2

5

Figure 4 represents the result of the step E40 of user equipment scheduling applied to the distribution of Figure 3. It can be seen that all the three cells CELL_1, CELL2, CELL_3 allocate the same downlink frequency band and perform downlink CoMP joint transmission for each group of edge user equipments {UE11}, {UE15} and {UE12, UE14}.

10

In some configurations, there may be some vacant frequency bands may after step E40 is completed.

Step E40 is followed by a step E50 of adjusting spectrum allocation based on the dissatisfaction degree of user equipment, after a sufficient number of time transmission intervals TTI.

15

In a specific embodiment, this step E50 consists in adjusting said spectrum allocation for minimizing the number of user equipments having an unrealized demanded downlink transmission rate γ superior to a threshold γ_{th} .

20

This step E50 enables to further adjust the spectrum division based on the knowledge of frequency usage and realization of user equipments' demand for data delivery.

In this embodiment, we use an indicator γ representative of a dissatisfaction degree, defined as follows at step E51:

$$\gamma = V_i - R'_i$$

25

According to the value of the dissatisfaction degree γ , the user equipments fall into two categories, the category of satisfied user equipments if $\gamma < \gamma_{th}$ and the category of the dissatisfied user equipments if $\gamma \geq \gamma_{th}$, γ_{th} being a threshold.

30

Step E52 is a step of adjusting coarsely the frequency band; this step consisting in allocating vacant frequency bands to dissatisfied user equipments. More precisely, vacant non-CoMP bands are totally moved to CoMP band and then distributed to dissatisfied edge users (CEU) or vacant

CoMP bands are totally moved to non-CoMP band and the distributed to dissatisfied center users.

One example of coarse adjustment is described in reference to Figures 5a and 5b. The vertical line BVB of Figure 5a represents the border between the used bands and the vacant bands within the Non CoMP band after step E40 is completed, before coarse adjustment. More precisely, VB1, VB2 and VB3 represent the vacant bands in cells CELL_1, CELL_2 and CELL_3.

At step E52, the vacant band VB1, which is the smallest band among VB1, VB23 and VB3 is moved to the CoMP zone to form a bigger one. Figure 5b illustrates the result of this coarse adjustment step, CELL_2 and CELL_3 having vacant bands VB2 and VB3 in their Non CoMP band.

In the described embodiment, the whole vacant bands are allocated to either CEU or CCU in order to satisfy as many user equipments as possible.

Step E54 is a step of adjusting finely the frequency band if:

- No vacant bands are available
- All user equipments in a category are satisfied, i.e. their satisfaction degree $\gamma < \gamma_{th}$;
- User equipments in the other category need more frequency band, since at least one of them is dissatisfied, i.e. their satisfaction degree $\gamma \geq \gamma_{th}$;

The step E54 consists of several iterations, in each one of which the scheduler moves N physical resource blocks PRB from one category where all users are satisfied to the other category where at least one user is not satisfied. Figure 5c illustrates the fine adjustment step and the result thereof. The step E54 of fine adjustment stops when one user equipment in the original satisfy category becomes unsatisfied, i.e. $\gamma \geq \gamma_{th}$, after a certain iteration.

CLAIMS

1. A method of allocating a downlink frequency band in a coordinated multi-point system based on multi-cell joint signal processing, this method comprising:
- a step (E10) of clustering said cells for determining at least a collaborative set of cells; and
 - a step (E20) of classifying the user equipments in said cells in a category of center user equipments (CCU) or in a category of edge user equipments (CEU);
- said center user equipments being served independently and said edge user equipments being jointly served by said collaborative set of cells, said method further comprising, at each transmission time interval :
- a step (E30) of dynamically allocating to each category (CCU, CEU) part of the downlink frequency spectrum available for said system according to the number of user equipments in each category ;
 - a step (E40) of scheduling the physical resource block allocated to said user equipments in their respective frequency band according to a priority (PFi) taking into account a channel state (Hi) and a traffic condition (Vi, R'i) of said user equipments.
2. A method according to Claim 1 comprising a step (E50) of adjusting said spectrum allocation for minimizing the number of user equipments having an unrealized demanded downlink transmission rate (γ) superior to a threshold (γ_{th}).
3. A method according to Claim 1 or 2 characterized in that a static collaboration set division is used in said clustering step.
4. A method according to any one of Claims 1 to 3 characterized in that said category of center user equipments comprises the user equipments having a channel quality indicator (CQI) superior to a threshold (α), the category of edge user equipments comprising the user equipments having said channel quality indicator lower than said threshold (α).

5. A method according to any one of Claims 1 to 4, characterized in that the percentage of frequency spectrum allocated dynamically (E30) to each of said categories corresponds to the percentage of user equipments in each category.

5

6. A method according to any one of Claims 1 to 5 in which said priority (PF_i) is defined as follows:

$$PF_i = \frac{|H_i|^2}{|H_i|_{MAX}^2} \cdot a + \frac{(V_i - R'_i)}{(V_i - R'_i)_{MAX}} \cdot b, \quad \text{with } a + b = 1$$

Where:

- 10
- PF_i means the priority of user equipment i
 - a means the weight of the channel state;
 - b means the weight of the satisfaction of the user equipment;
 - |H_i|² means the channel state matrix of user equipment i;
 - V_i means the demanded downlink transmission rate for user
 - 15 equipment i;
 - R'_i means the realized downlink transmission rate for user equipment i.

7. A base station usable in a coordinated multi-point system based on multi-cell joint signal processing, said base station comprising a scheduler comprising:

- 20
- a module for clustering said cells for determining at least a collaborative set of cells; and
 - a module for classifying the user equipments in said cells in a category of center user equipments (CCU) or in a category of edge user equipments (CEU);
 - 25

said center user equipments being served independently and said edge user equipments being jointly served by said collaborative set of cells, said scheduler further comprising:

- 30
- a module for dynamically allocating to each category (CCU, CEU), at each transmission time interval, part of the downlink frequency spectrum available for said system according to the number of user equipments in each category ; and

- a module for scheduling the physical resource block allocated to said user equipments in their respective frequency band according to a priority (P_{Fi}) taking into account a channel state (H_i) and a traffic condition (V_i, R'_i) of said user equipments.

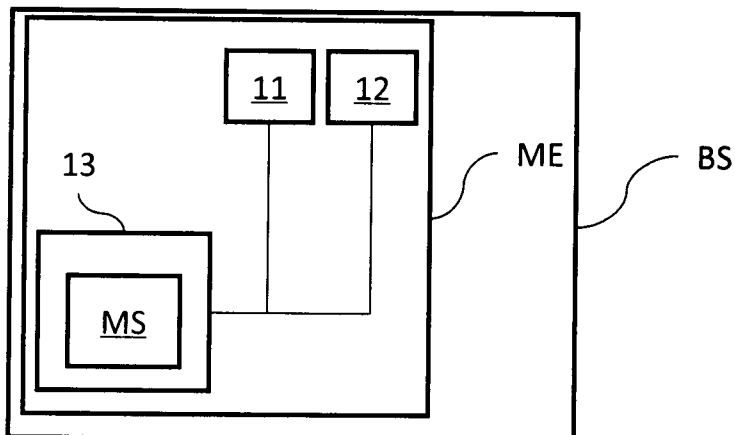


FIG. 1

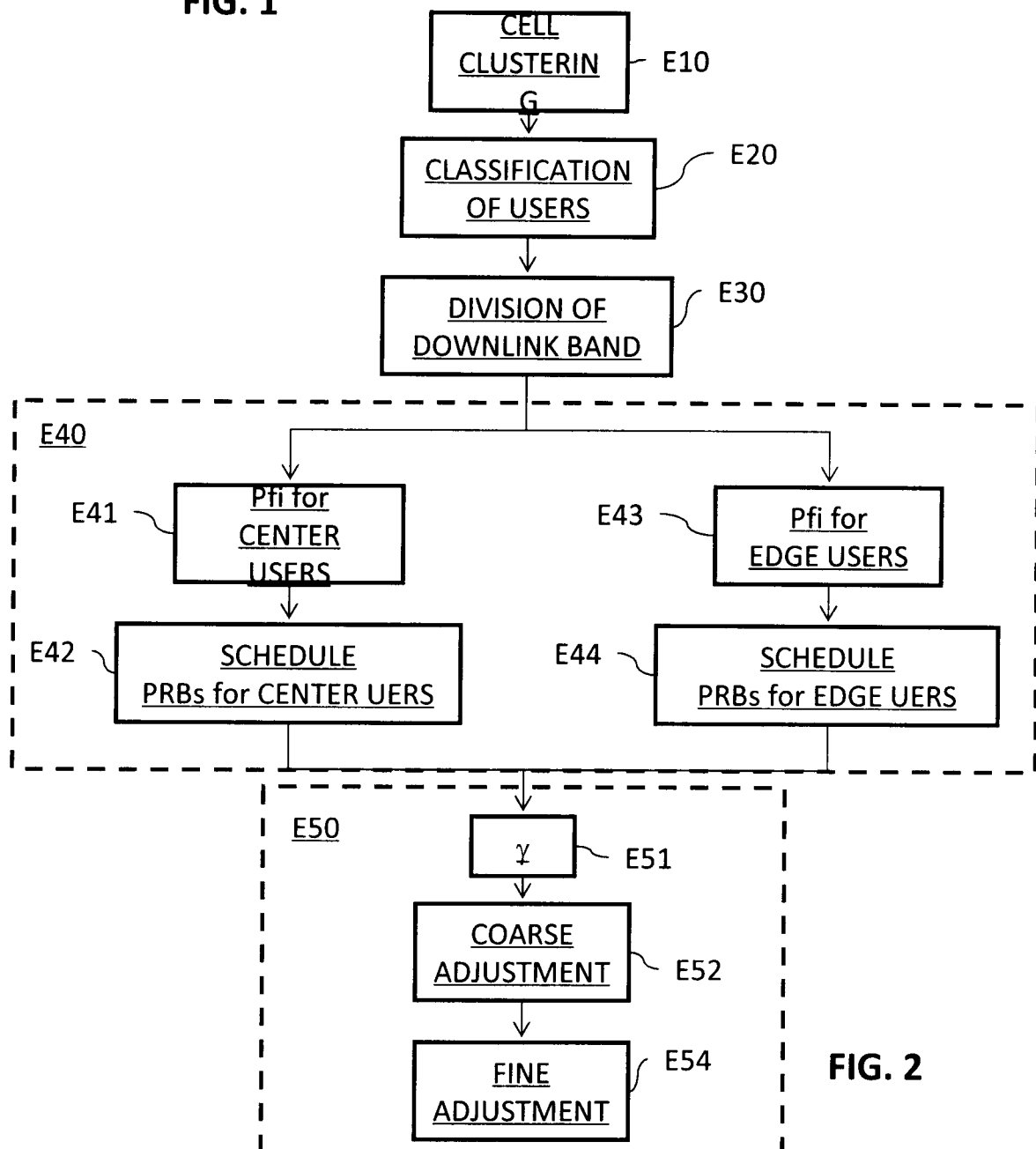
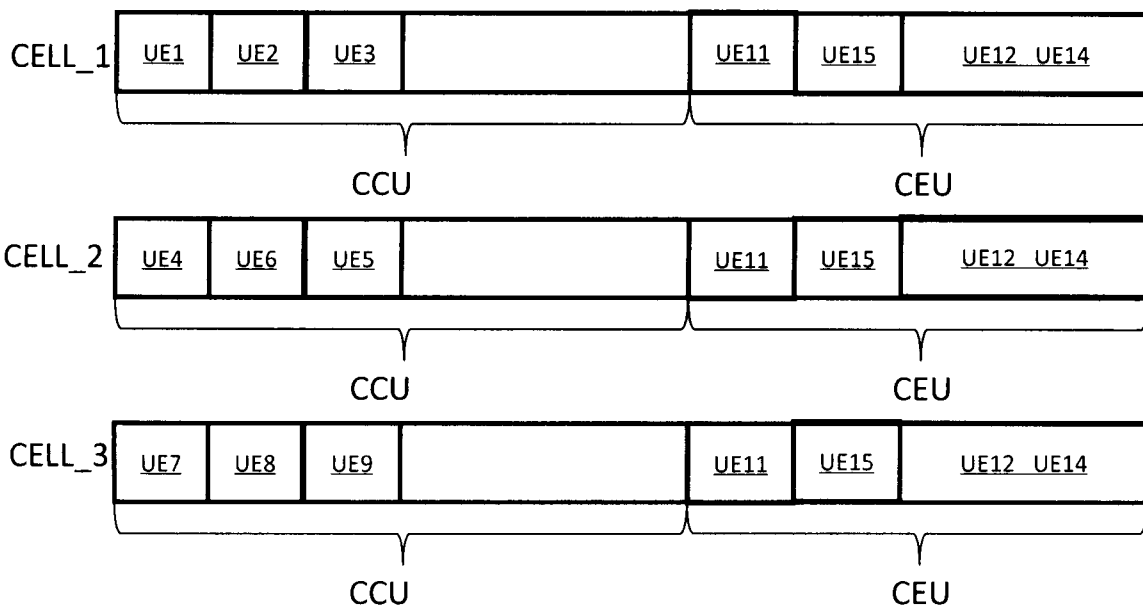
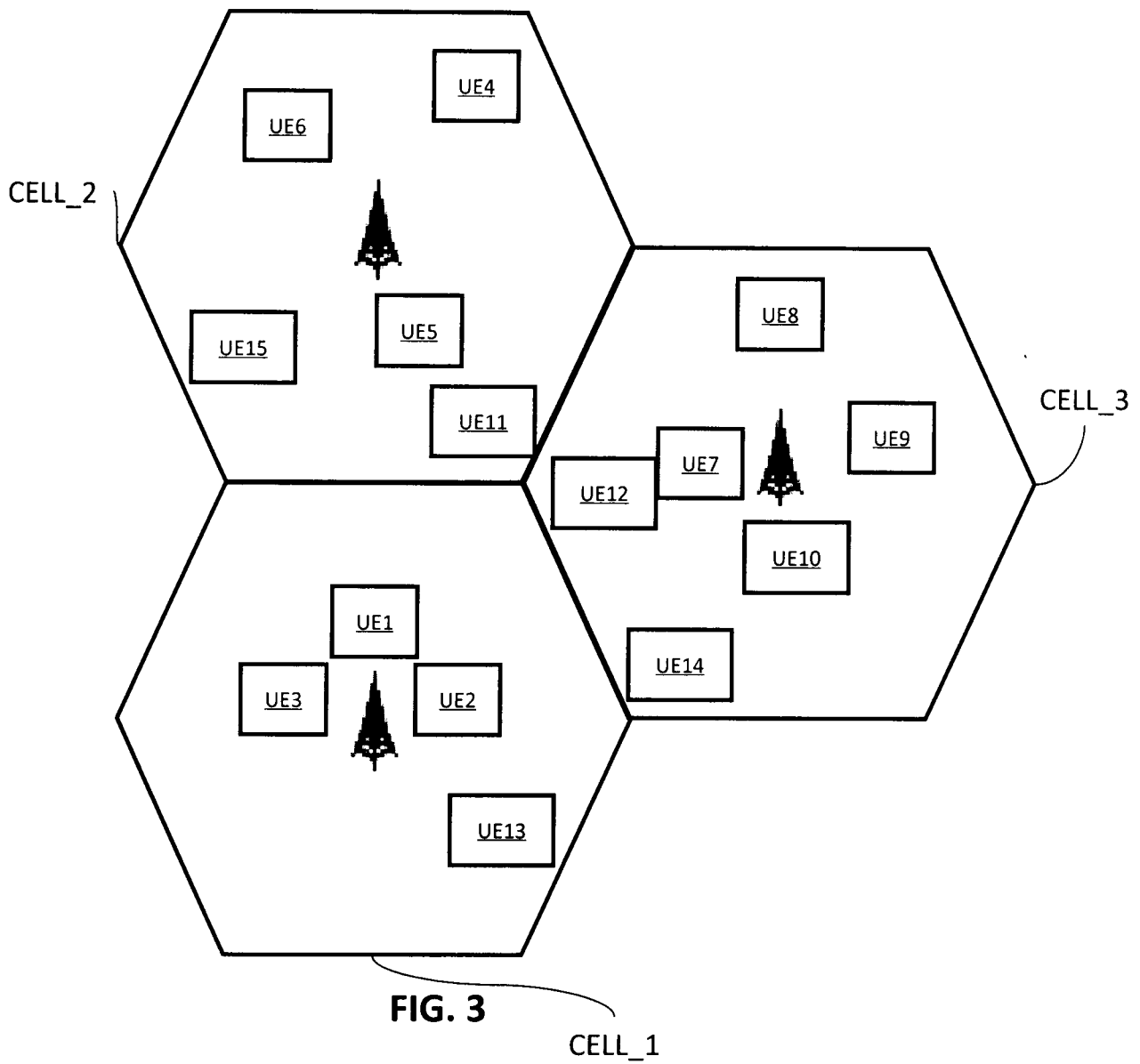
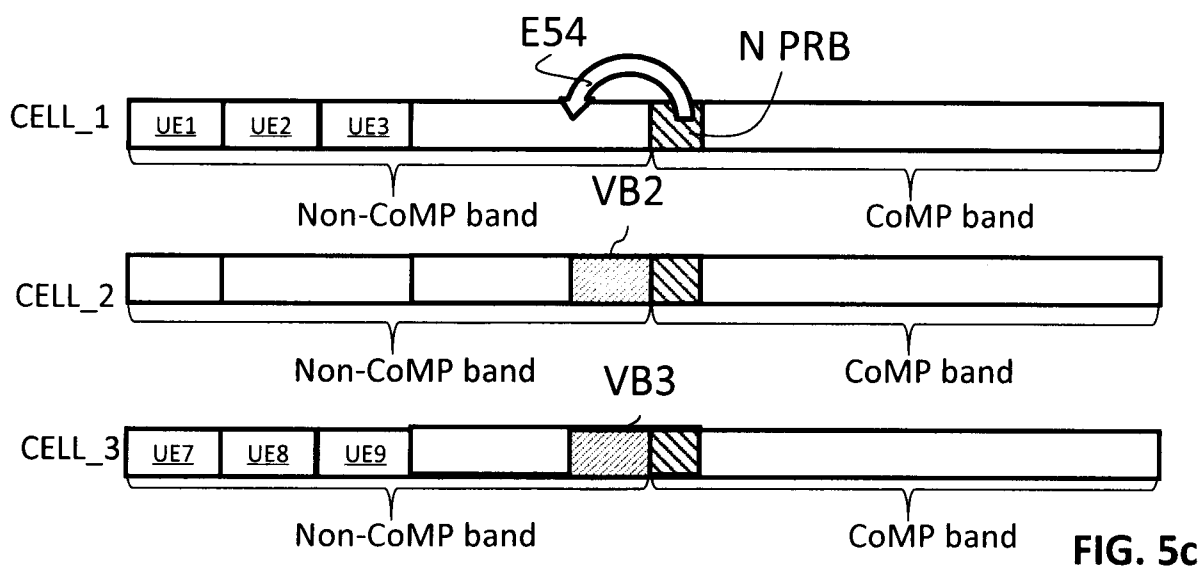
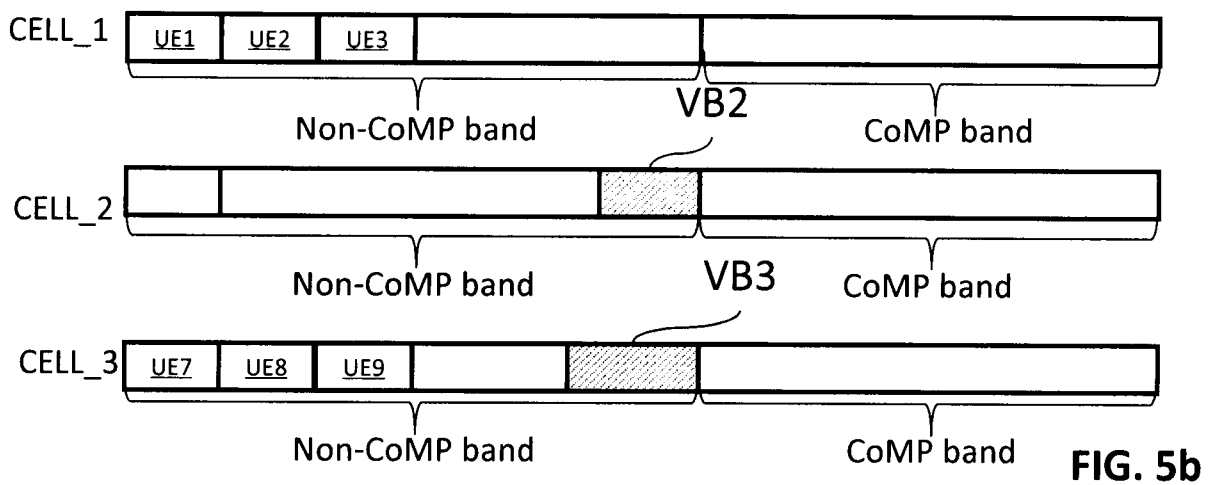
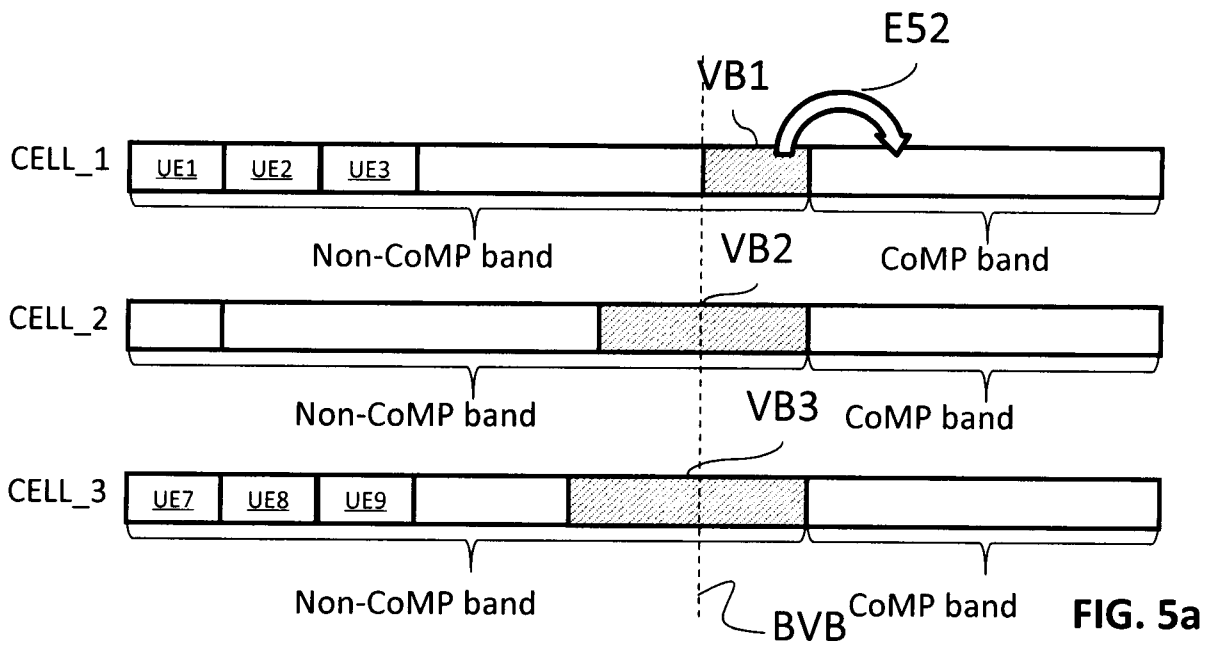


FIG. 2





INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/001716

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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;H04Q;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)

WPI, EPODOC, CNKI, IEEE, CNPAT, 3GPP: coordinated, multi point, CoMP, multi cell, joint, cluster, collaborative, cooperation, center, central, edge, user, category, physical resource, block, element, channel state, traffic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102647212 A(HTC CORP.), 22 August 2012 (22.08.2012), see description, paragraphs 0032-0034, 0038-0043	1-7
A	CN 102098737 A(ZTE CORP.), 15 June 2011 (15.06.2011), the whole document	1-7
A	WO 2012093742 A1(PANTECH CO., LTD.), 12 July 2012 (12.07.2012), the whole document	1-7
A	US 2012281556 A1(MOTOROLA MOBILITY, INC.), 08 November 2012 (08.11.2012), the whole document	1-7
A	QUALCOMM EUROPE, "Coordinated Multi-Point downlink transmission in LTE-Advanced", 3GPP TSG-RAN WG1 #55, R1-084400, 10-15 November 2008	1-7

☐ 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
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Date of the actual completion of the international search 09 September 2013(09.09.2013)	Date of mailing of the international search report 26 Sep. 2013 (26.09.2013)
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 PENG,Liang Telephone No. (86-10)62413311

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102647212 A	22.08.2012	US 2012207093 A1	16.08.2012
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INTERNATIONAL SEARCH REPORT

International application No.

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H04B 7/02 (2006.01) i