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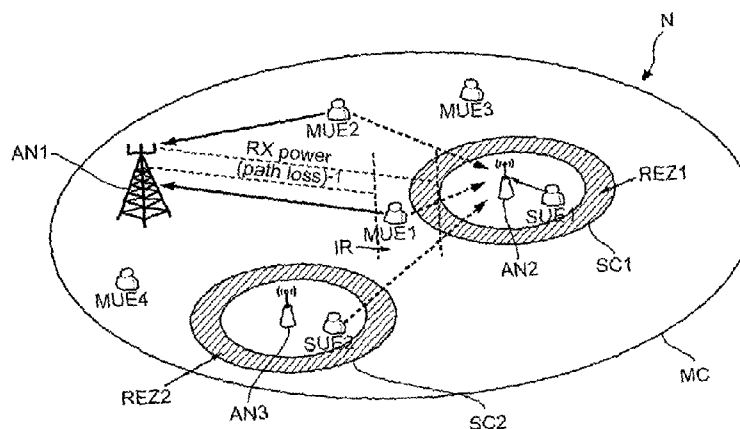
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(54) **Title:** METHOD FOR SCHEDULING USER EQUIPMENT IN A HETEROGENEOUS NETWORK

FIG 1



(57) **Abstract:** The invention relates to a method for scheduling user terminals in a heterogeneous network comprising a plurality of cooperating cells constituted by at least one macro cell and at least one small cell having at least partially overlapping coverage, each cooperating cell having corresponding radio resource blocks assigned to their respective user terminals, wherein for a centralized controller to assign a radio resource block of the macro cell, a utility metric associated with said radio resource block of the macro cell is determined for each combination of user terminal of the macro cell and of a user terminal of the small cell assigned to the corresponding radio resource block, and the radio resource block of the macro cell is assigned to the user terminal of the macro cell that maximizes said second utility metric.

METHOD FOR SCHEDULING USER EQUIPMENT IN A HETEROGENEOUS NETWORK

CONTEXT AND BACKGROUND OF THE INVENTION

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The invention generally relates to scheduling in a cellular network, more particularly for the uplink transmission in a heterogeneous cellular network.

Wireless networks have witnessed the proliferation of smart communication terminals and drastic growth in the network traffic from data services. To effectively
10 cope with the rapidly growing demands on network capacity, heterogeneous networks have been proposed, where small cells are introduced, as a complement to macro cells. Such small cells allow to significantly offload the traffic from macro cells, and to extend the network coverage. In addition, access nodes (or hotspots) of such small cells may use the short transmission range for exchanging data with user equipment, thus
15 increasing local capacities at hotspots.

However, such small cells have a coverage overlapping that of the macro cells. Their presence in the heterogeneous network (HetNet) thus creates severe interference scenarios in both the uplink and the downlink to the overlaid macro cells, and vice versa. Small cells also receive significant interference from co-channel macro cells.
20 These high interference levels may compromise the benefits obtained through the use of additive small cells in cellular networks operating with universal frequency reuse, such as the 3GPP UTRAN Long Term Evolution (LTE).

Actually, when a macro-associated user is in the vicinity of a small cell, it is far away from the serving node of the macro cell: hence, it has to increase its emitting
25 power to compensate for the large propagation loss. However, the short distance between this user and the small cell access node, combined with a high transmission power, may generate severe interference in the small cell uplink.

The uplink interference may substantially jeopardize the received signal quality of small cells and, in turn, the transmission performance. If closed-loop power control is
30 adopted in the small cell uplink, users will reactively increase the transmission power to maintain the signal-to-interference-plus-noise ratio (SINR). Nevertheless, this may add to the co-channel interference in the uplink of macro cells and may aggravate the already weak macro cell uplink channels.

A solution could consist of allocating some sub-bands for the exclusive use of macro cells to avoid cross-tier interference. This may significantly enhance the received signal quality of both macro cells and small cells, but at the cost of limiting the spectrum access in small cells.

5 In order to improve the performance and quality of experience of mobile users in a cellular network such as a LTE (Long Term Evolution) network defined in E-UTRAN standard,, several approaches have been proposed to control the uplink inter-cell interference. Among these, P. Frank et al. suggest, in an article called “Cooperative Interference-Aware Joint Scheduling for the 3GPP LTE Uplink”, IEEE PIMRC, 2010,
10 to perform coordinated scheduling between different base stations (BS): thus, different BSs cooperate with each other via a fast backhaul network, in order to jointly allocate frequency resources to the various UEs (User Equipment), taking the inter-cell interference from and to nearby BSs into account.

 According to this method, the resource allocation is performed in a cooperative
15 fashion by a central scheduling unit for a set of cooperating BSs. Multi-cell Channel State Information (CSI) of all UEs associated with the set of cooperating BSs can be periodically exchanged in order to predict the experienced inter-cell interference level if a certain UE would be scheduled on certain physical resource blocks. This information is then considered in the scheduling decisions for minimizing the inter-cell
20 interference, leading to an interference-aware scheduling.

 Though very interesting for conventional LTE Release 8 cellular networks, such a multi-cell scheduling method was solely designed for homogeneous networks, and does not take into account the characteristics of interference scenarios encountered in the uplink of heterogeneous networks. In other words, such a method is not optimized in
25 terms of performance or complexity for HetNet, notably as it requires the use of a central scheduler, which is needed to make scheduling decisions based on global user channel information.

 PCT application WO2015/081570 describes a method for scheduling user equipment in a heterogeneous network, or HetNet, comprising at least one macro cell
30 and at least one small cell having at least partially overlapping coverage, the method being run by a scheduling unit for said at least one macro cell and comprising the steps of:

- scheduling user equipment served by said macro cell and allocating radio resources to said scheduled user equipment,
- determining a set of at least one of said scheduled user equipment prone to cause interference in the uplink on at least one of said small cell(s), called a victim small cell,
- sending, through a backhaul link between said scheduling unit for said macro cell and a scheduling unit for said victim small cell, a coordination message comprising information on said at least one scheduled user equipment prone to cause interference on said victim small cell and on radio resources allocated to it.

The heterogeneous network coordinated scheduler in WO2015/081570 presents a method of utilizing macro scheduling information in small cell resource allocation to find the best user combination on resource blocks. Nevertheless, it is confined to single-point reception hence the small cell scheduler attempts to find the user that is spatially orthogonal to the aggressor macro-associated user. This imposes constraint on small cell reception as some spatial degree of freedom is used in nulling macro user interference. Moreover, macro user does not benefit from the coordinated scheduler even though it is subject to the weak communication link to the serving cell.

SUMMARY OF THE INVENTION

The invention aims at proposing a method for interference-aware scheduling in a heterogeneous network that can improve the existing situation. There is proposed an innovative centralized scheduler for the HetNet system.

In this respect, the invention relates to a method for scheduling user terminals in a heterogeneous network comprising a plurality of cooperating cells constituted by at least one macro cell and at least one small cell having at least partially overlapping coverage, each cooperating cell having corresponding radio resource blocks assigned to their respective user terminals, the method being run by a centralized controller that performs radio resource block assignment for said cooperating cells, wherein radio resource block assignment comprises:

a first step in which radio resource blocks of the small cell are allocated to user terminals that maximize a first utility metric associated with said radio resource blocks of the small cell, and

a second step in which for assigning a radio resource block of the macro cell, a second
5 utility metric associated with said radio resource block of the macro cell is determined for each combination of user terminal of the macro cell and of a user terminal of the small cell assigned to the corresponding radio resource block, and the radio resource block of the macro cell is assigned to the user terminal of the macro cell that maximizes said second utility metric.

10

Hence, the invention relies on a novel and inventive approach of the scheduling in a heterogeneous network. The centralized controller performs a centralized scheduling and is responsible for user-channel assignment for a cluster of macro cells and overlaid macro cells. The centralized controller attempts to find the best user terminal combination for
15 assigned radio resource blocks, managing interference and boosting performance for user terminals both in small cells and in macro cells. Global visibility of user channel conditions and joint decisions for both transmit and receive ends allow the proposed centralized controller to effectively mitigate the cross-tier interference in the HetNet uplink and to optimize the user performance of both small cell user terminals and macro cell user
20 terminals.

An interfering user terminal associated with a macro cell is typically on a weak link towards its serving cell, and thus the performance of said user terminal should be enhanced maybe as equally as its small cell user terminal counterpart that is subject to the uplink
25 interference. One solution is to implement successive interference cancellation (SIC) receiver at the small cell access point. In order to cancel the interference introduced by macro-associated users, macro user signals need to be decoded by small cells. The decoded information can be sent to macro cell whereby decoding switching can be performed between serving node and small cell node to enhance macro user performance.

30

As illustrated above, SIC performance is subject to the received power of small cell signals (traditionally considered as desired signals) relative to the macro cell user signals (used to

be considered as interfering signals). The method allows determining the best user combination in conjunction with SIC receivers and multi-node decoding switching.

According to an embodiment, each macro cell receives channel state information from each user terminal served by said macro cell, and on the basis of said channel state information, each macro cell partitions the user terminals served by said macro cell into two user sets defined by their reception mode:

- a single-node reception user set for the user terminals which are not prone to cause interference in the uplink on at least one small cell, and
- 10 - a coordinated multi-point reception user set for the user terminals which are prone to cause interference in the uplink on at least one small cell;

and the second step comprises

- determining among the single-node reception user set the user terminal that maximizes a combined utility metric associated with said radio resource block in combination with the user terminal of the small cell to which the corresponding radio resource is assigned;
- 15 • determining among the coordinated multi-point reception user set the user terminal that maximizes a combined utility metric associated with said radio resource block in combination with the user terminal of the small cell to which the radio resource is assigned;
- 20 • assigning the radio resource block of the macro cell on the basis of a comparison of the combined utility metric of said determined user terminal from the single-node reception user set and of the combined utility metric of said determined user terminal from the coordinated multi-point reception user set.

25

As a means to enhance user signal quality, multi-point joint reception mode is considered. Therefore, the central controller takes into account the multi-point reception in user terminal pairing such that the best user terminal pairs are not necessarily to be mutually orthogonal but rather maximize the utility metric with multi-point reception technologies.

30 It is favorable to partition user terminals served by a macro cell into two user sets, i.e. a single-node reception (SNR) user set and a coordinated multi-point (CoMP) reception user set, and apply different scheduling strategies accordingly.

For the sake of simplicity, and since the combined utility metric for a user terminal of the single-node reception user set may be approximated by a utility metric of said user terminal, without consideration for any user terminal of the small cell.

5 The method may also comprises steps in which:

- a small cell receives signals from user terminals of the coordinated multi-point reception user set, decode said signals, and send said decoded signals to a macro cell,
- said macro receives signals from user terminals of the coordinated multi-point reception user set, and decode said signals,

10 - wherein the signals decoded by the small cell and the signals decoded by the macro cell are compared to each other, and for each user terminal, a decoded signal of said user terminal is selected on the basis of this comparison, said selected decoded signal being used for determining the combined utility metric for said user terminal of the coordinated multi-point reception user set.

15

This allows maximizing the performance of a user terminal of the CoMP user set, by exploiting the signals received by a small cell from said user terminal of the CoMP user set, not only for successive interference cancellation, but also for maximizing the efficiency of the radio resource block assignment.

20

Preferably, the combined utility metric for said user terminal of the coordinated multi-point reception user set is determined from an average throughput R_i of user terminal i of the macro cell, an average throughput R_{j_l} of user terminal j_l of the small cell, an estimated data rate r_i of user terminal i of the macro cell, an estimated data rate r_{j_l} of user terminal j_l of the small cell:

25

$$PF(i, j_l) = \frac{1}{R_i} r_i + \frac{1}{R_{j_l}} r_{j_l},$$

BRIEF DESCRIPTION OF THE DRAWINGS

30

Other aspects, objects and advantages of the present invention will become better apparent upon reading the following detailed description of preferred embodiments thereof,

given as non-limiting examples, and made with reference to the appended drawings wherein:

- FIG. 1 represents an exemplary heterogeneous network N in which the method of the invention can be run;
- 5 - FIG. 2 illustrates interactions between an exemplary configuration of two macro cells, a small cell and a centralized controller;
- FIG. 3 illustrates the partitioning of the user terminals according to their respective location with respect to a macro cell and a small cell;
- FIG. 4 is a diagram illustrating steps of the scheduling method according to a
10 possible embodiment.

DETAILED DESCRIPTION OF THE INVENTION

It must be noted that, throughout this document, the terms “small cell” designate any cell,
15 which is smaller than a conventional macro cell served by a macro base station, as described in the LTE standard: for example, such a small cell may be a pico cell for in-building coverage, or a femto cell served by an access point, which is called a Home Node B (HeNB). More precisely, an heterogeneous network as described in this document usually comprises macro eNodes B (eNBs), which are deployed for initial coverage of the
20 network by macro cells, and pico access nodes or HeNBs, which serve small cells, and are added to the network for capacity growth and better user experience.

Figure 1 represents a network N in which the methods of the invention are run. The network N is for example a heterogeneous LTE network, comprising several macro cells and several small cells showing overlapping coverage. For the sake of clarity, the
25 network N on figure 1 shows only one macro cell MC, covered by an access node AN1. The network N also comprises two small cells SC1 and SC2, which coverage is included in the coverage of the macro cell MC. Each small cell SC1, SC2 is covered by an access node, respectively AN2, AN3. Each access node AN1, AN2, AN3, comprises at least one antenna for radio signal transmission. Several mobile devices, such as
30 mobile phones, laptops or tablets for example, are attached to the access nodes of network N. As shown in **figure 1**, mobiles devices SUE1 and SUE2 are respectively attached to access nodes AN2 and AN3 of small cells SC1 and SC2. Hence, a transmission channel is established between the mobile device SUE1 and the access

node AN2, as well as between the mobile device SUE2 and the access node AN3. Small cells SC1 and SC2 thus serve respectively mobile devices SUE1 and SUE2.

While traffic is served by macro base stations in homogeneous networks, deploying small cells SC1, SC2 in heterogeneous network N offers capacity gains by traffic offloading, which means that UEs are preferably served by the small cells SC1, SC2, rather than the macro cell MC. Better load balancing between macro and small layer improves the network capacity and the user experience. To this end, as shown in figure 1, the coverage area of the small cell SC1, SC2 is artificially enlarged, in such a way that the UE should connect to the small cell even if the macro cell downlink coverage is stronger. Such an artificial enlargement is called a Range Extension Zone, shown as REZ1 for small cell SC1 and REZ2 for small cell SC2.

Other mobile devices MUE1 to MUE4 are also located in the coverage area of the macro cell MC.

User association is classically determined following some well-known criteria: for example, a mobile device is attached to the cell from which it receives the maximum Reference Signal Receive Power (RSRP). Actually, RSRP is a key parameter in LTE network measurement, which provides cell-specific signal strength metric. This measurement can be used to rank different LTE cells according to their signal strength, and hence serves as an input for handover and cell reselection. RSRP is defined for a specific cell as the linear average over the power contributions (in Watts) of the Resource Elements (REs), which carry cell-specific reference signal within the considered measurement frequency bandwidth.

According to this RSRP criterion, adjusted with RE bias, it is decided that mobile devices MUE1 to MUE4 are all camping on the macro cell MC. As can be seen on **figure 1**, mobile device MUE1 is located in a so-called imbalance region IR, at the boundary between the macro cell MC and the small cell SC1. Therefore, MUE1 transmission power has to be tuned high to compensate for the weak channel link between itself and the access node AN1 of the serving macro cell MC. This may create strong interference in the uplink of small cell SC1 and compromise the user performance, for example for the mobile device SUE1. Such a strong interference is illustrated in figure 1 by a dashed arrow going from user equipment MUE1 to access node AN2 of small cell SC1. Other mobile devices MUE2 and SUE2 may also generate

some interference on small cell SC1, also illustrated by dashed arrows between mobile devices SUE2, MUE2 and access node AN2. However, such interference is typically weaker than that generated by mobile device MUE1.

One possible approach to mitigate the uplink interference is to employ advanced
5 successive interference cancellation (SIC) techniques at small cell receive ends. By decoding MUE 1 signal and then subtracting the macro-generated interference, small cell signals can be better recovered. Nevertheless, the performance of the SIC method is sensitive to the received power of small cell signals with respect to the macro user interference. The benefit is manifest when the interference introduced by the macro user is
10 significantly higher to allow successful decoding of interfering signals. With this macro interference can be accurately generated and then eliminated from signals at the small cell receiver. In cases that the received power of desired signals and interfering signals are similar, the performance gains may diminish. It thus adds to the complexity of small cell access nodes AN2 and AN3, and the performance is sensitive to the interference levels of
15 cross-tier signals.

An alternative method is presented in WO2015/081570 that utilizes macro-cell scheduler decision to find small cell users that best match to macro cell interferers. Those small cell users are nearly orthogonal to the macro-associated users in the spatial domain such that their signals can be separated from the interfering signals.

20 **Figure 2** shows a generic framework of an exemplary simplified embodiment of the present invention. The system comprises a centralized controller CC that jointly determines user terminal reception mode and schedules user terminal data packet transmission for a number of cooperating cells. The cooperating cells comprises two macro cells MC and one small cell SC. Since multi-point reception best works with tight coupling between macro
25 cells and small cells, the cooperating cells are preferably linked by low-latency, high-bandwidth inter-BBU connections. Thus it is conveniently applied to baseband unit (BBU) centralization architectures, e.g., Cloud RAN.

In a first stage S1, each cooperating cells MC, SC receive channel state information (CSI) from their respective user terminals and from the user terminals prone to cause
30 interference. User terminal thus report to their respective serving cells the CSI of their links to the serving cells as well as those that are the most susceptible to the uplink interference caused by the user terminals.

In a second stage S2, each macro cell MC partitions the user terminals MUE served by said macro cell MC into:

- a single-node reception (SNR) user set for the user terminals MUE which are not prone to cause interference in the uplink on at least one small cell SC, and
- a coordinated multi-point reception user set (CoMP) for the user terminals MUE which are prone to cause interference in the uplink on at least one small cell SC.

Figure 3 illustrates the partitioning of the user terminals according to their respective location with respect to a macro cell and a small cell. Multi-node decoded user terminals users are distinguished from user terminals received by one serving cell only. In **figure 3**, there are three user terminals UE1, UE2, UE3 at different radio positions with respect to two serving nodes. The serving node on the left is a high power macro base station defining a macro cell and the serving node on the right is a low power access point defining a small cell. The macro cell and the small cell have overlapping coverage. User partitioning is typically determined by user terminal measurement of RSRP power in the downlink. The resulted cell coverage, marked by the right-most vertical dashed line, is quite limited for small cell for which the radio resource is under-utilized.

To offload more users to the small cell, cell range extension (CRE) is introduced to offset the RSRP associated with small cell whereby small cell boundary is extended (denoted by the vertical dashed line in the middle) and more users can camp on small cells. Typically the CRE boundary is not as far as the point where user pathloss to the low power node equals that to the high power base station (denoted by the left-most vertical dashed line in the figure), otherwise the downlink coverage of small cell will becomes too weak compared to the macro interference.

According to CRE criterion, UE1 and UE2 camp on the macro cell while UE3 is associated with the small cell. For user terminals $i \in \{1,2,3\}$, P_t^i is the respective transmit powers from user terminal i, $P_{r,m}^i$ is the received power at macro base station from user terminal i, and $P_{r,s}^i$ the received power at small cell from user terminal i, respectively. Located at the inner region of macro cell MC, UE1 is received by the serving macro MC

cell at $P_{r,m}^1$ that is significantly higher than interfering signals. Thus the desired signals can be reliably decoded. On the other hand, UE1 signal power received by the small cell node SC, i.e., $P_{r,s}^1$, is quite weak compared to that of small cell users. Therefore, attempts to decode UE1 signal at small cell node SC may lead to unreliable results and it is not recommended to apply multi-point reception to UE1.

UE 2 is located at the outer region of macro cell MC and it is equally distant from small cell node SC as from the macro cell base station MC or even closer to the former geographically. As a result, it is received at a high power level $P_{r,m}^i$ by small cell node SC. Multi-path diversity can be exploited to achieve significant gains in user throughput by applying multi-point reception to this user. Moreover, decoded UE2 signals can be used to re-construct the introduced interference and help decoding small cell user signals via successive interference cancellation SIC.

The user terminal partitioning, or user terminal classification can follow a variety of sensible rules and only some exemplary ways are given for separating CoMP user terminals from SNR user terminals are given below.

A first way is pathloss-determined user terminal classification. Under this rule, macro user terminals that are closer to small cells SC are considered for CoMP decoding, i.e. as belonging to a coordinated multi-point reception user set. Hence said coordinated multi-point reception user set can be determined as

$$U_m^{\text{CoMP}} = \{i \mid i \in U_m, \alpha_{i,m} - \alpha_{i,s} \geq \Delta\alpha\} \quad (1)$$

$$U_m^{\text{SNR}} = \{i \mid i \in U_m, \alpha_{i,m} - \alpha_{i,s} < \Delta\alpha\}, \quad (2)$$

where U_m denotes user terminals camping on macro cell m, $\alpha_{i,m}$ denotes the pathloss between user i and macro cell base station m, $\alpha_{i,s}$ denotes the pathloss between user i and small cell node and $\Delta\alpha$ denotes the system-defined parameter for user terminal portioning which can be optimized via numerical experiments.

Another way is received power-determined user terminal classification. From user terminal received power perspective, macro cell served user terminals that are received by

small cell node at strong power levels are suitable for multi-point reception. It can be formulated as

$$P_{r,s}^i = P_t^i - \alpha_{i,s} \geq P_{s,0} + \Delta P, \quad (3)$$

where $P_{s,0}$ is the target received power of small cell and ΔP denotes the system-defined parameter for user separation which can be determined via numerical optimization. Applying fractional pathloss compensation (FPC), such as explained in 3GPP TR36.942, “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) Systems Scenarios”, macro user transmit power is given as

$$P_t^i = \min \{ P_{\max}, P_{m,0} + \gamma_m \alpha_{i,m} \}, \quad (4)$$

where $\gamma_m \leq 1$ is the FPC power control parameter. It is then derived that the CoMP user terminals should satisfy

$$\gamma_m \alpha_{i,m} - \alpha_{i,s} \geq P_{s,0} - P_{m,0} + \Delta P. \quad (5)$$

Therefore, CoMP user sets are determined as

$$\{ U_m^{\text{CoMP}}, S_m^{\text{CoMP}} \} = \{ i, s \mid i \in U_m, \gamma_m \alpha_{i,m} - \alpha_{i,s} \geq P_{s,0} - P_{m,0} + \Delta P \}, \quad (6)$$

where S^{CoMP} denotes the small cells participating in CoMP with user terminals in macro cell m . Correspondingly, the SNR user set of cell m is given by

$$U_m^{\text{SNR}} = \{ i \mid i \in U_m, \gamma_m \alpha_{i,m} - \alpha_{i,s} < P_{s,0} - P_{m,0} + \Delta P \}. \quad (7)$$

Once the user terminals classified, in a third stage S3 each cooperating cell MC, SC reports to the centralized controller CC said channel state information and each macro cell MC reports user set information about the portioning of the user terminals served by said macro cell. The cooperating cells report messages facilitating joint scheduling and multi-node reception over an enhanced backhaul. There are two types of messages to be sent to the central controller

- Instant user CSI (for serving and interfering links) that is sent every a few milliseconds or up to every millisecond; and
- SNR and CoMP user set information from the macro cells. Since user terminal reception mode is heavily dependent on the user terminal location,

it needs not be updated frequently, because user terminal location does not change very fast.

In a fourth stage S4, the centralized controller CC performs radio resource block assignment for said cooperating cells. The centralized controller CC performs multi-cell user terminal assignment to find the best user terminal pairs for the assigned resource blocks by taking into account inter-cell interference and user terminal reception mode.

It is proposed an optimal way of determining best user combination for radio resource blocks that can maximize sum user terminal throughput. Following the arguments of user classification for macro cell, it can be realized that only user terminals in CoMP user set may generate significant interference to small cell in the uplink. In other words, user terminals of the macro cells in the single node reception user set are virtually decoupled from user terminal of small cell in user assignment. This can greatly simplify the procedures.

On the other hand, performance of user terminals of the macro cells in the CoMP user set is heavily coupled on that of co-channel small cell user terminals and it is also true vice versa. To find the user pair maximizing the overall performance, one way could be to check all possible user pairs across cooperating cells, which incurs tremendous complexity even for a moderate-sized CoMP cluster (i.e., assembly of cells that participate in joint reception and coordinated scheduling).

Table 1 below illustrates the complexity of user terminals pairing for different cooperation cluster sizes.

Number of macro cells in the CoMP cluster M_{macro}		9	3	1
Number of users per macro cell N_{macro}		10	10	10
Number of small cells in the macro coverage M_{small}		2	2	2
Number of users per small cell N_{small}		3	3	3
Number of user	Exhaustive search	3.87e+17	7.29e+5	90

pairs to be checked	$N_{\text{macro}}^{M_{\text{macro}}} (N_{\text{small}})^{M_{\text{macro}} M_{\text{small}}}$			
	Greedy search $(N_{\text{macro}} + N_{\text{small}} \cdot M_{\text{small}}) \cdot M_{\text{macro}}$	144	48	16

Table 1

Table 1 shows the number of user terminal pairs to be checked for CoMP clusters of different size. It can be seen that exhaustive search incurs an exponential complexity which becomes infeasible as the CoMP cluster size increases. Greedy search, an algorithm that determines the user terminals successively and maximizes the combined performance in each incremental step, can be used in practice to approach the optimal performance. The resulting complexity is linear with respect to the number of cooperating cells. Nevertheless, the cluster size should also be restricted to a small number (e.g., a handful of cooperating macro and small cells) to minimize the complexity of the proposed centralized scheduler.

A first way for performing such an assignment would be single cell user terminal assignment regardless of the user terminal of the CoMP user set. This is a low-complexity scheme where user assignment for each cell is determined independently without considering the interference caused to neighbour cells. In computing the user scheduling priority, user signal quality is determined by the link between the terminal and the serving cell, i.e., CoMP reception is not taken into account in user assignment. Obviously this is only a baseline user assignment method.

Another way is coordinated scheduling without considering CoMP classification. A coordinated scheduler such as in WO 2015/081570 can also be used for allocating resource blocks to user terminals. The interference that macro-associated user terminals introduce to the proximate small cells is taken into account in selecting small cell users to maximize the overall performance of cooperating cells. It is realized that macro users in the SNR user set would not severely interfere small cells hence the user pairing only tackles the interference caused by macro cell user terminals in the CoMP user set.

First, all macro cells assign resource blocks to users with the maximum utility metric, e.g., proportional fair (PF) metric, without considering the interference caused to small cells.

Then, small cell scheduler transverses S43 over all resource block l , and

- 5 – If a macro-associated user terminal belongs to the SNR user set, i.e. $i_l \in U_{\text{SNR}}^m$, said user terminal does not introduce significant interference to small cells. As a result small cell user terminal assignment is nearly decoupled from macro cell scheduling, and the resource block is allocated to the user associated with the maximum utility metric $j_l = \arg \max_{j \in U_s} PF_l(j)$,

10 where U_s denotes the small cell user set and $PF_l(j)$ denotes the PF metric of user j .

- If a macro-associated user terminal belongs to the CoMP user set, i.e. $i_l \in U_{\text{CoMP}}^m$, small cells assign the resource block to the user that are best matched with macro cell users to achieve the maximum sum performance.

15
$$j_l = \arg \max_{j \in U_s} PF_l(i_l, j) = \arg \max_{j \in U_s} (PF_l(i_l) + PF_l(j))$$

The preferred way to assign radio resource block to user terminals associated to macro cells is CoMP-aware coordinated user assignment. The CoMP-aware coordinated user assignment scheme optimizing the overall performance of cooperating cells. It determines the best user pair between macro cells and small cells following the greedy
20 approach. On the other hand it distinguishes itself as it takes into account the multi-point reception mode and is closely coupled with the CoMP technologies applied at the receiver end.

Figure 4 is a diagram illustrating steps of an exemplary CoMP-aware coordinated user terminal assignment.

- 25 Radio resource block assignment comprises a first step S40 of small cell user terminal assignment, in which radio resource block of the small cell SC are allocated to user terminals SUE that maximize a first utility metric associated with said radio resource blocks of the small cell.

The centralized controller CC then performs a second step S42 of a CoMP-aware user assignment in which for assigning a radio resource block l of the macro cell MC, a second utility metric $PF_l(i, j_l)$ associated with said radio resource block l of the macro cell MC is determined for each combination (i, j_l) of user terminal of the macro cell MC and of a user terminal of the small cell SC assigned to the corresponding radio resource block l , and the radio resource block l of the macro cell is assigned to the user terminal of the macro cell that maximizes said second utility metric $PF_l(i, j_l)$.

In a first step, radio resource blocks l of the small cell are allocated to user terminals that maximize a first utility metric $PF_l(j)$ associated with said radio resource blocks l of the small cell. All small cells assign resource blocks to the user associated with the maximum utility metric $j_l = \arg \max_{j \in U_s} PF_l(j)$.

The second step of the radio resource block l assignment comprises CoMP-aware user assignment S42 of macro cell resource block to the user terminal with the maximum sum utility metric as

$$\begin{aligned} i_l &= \arg \max_{i \in U_m} PF_l(i, j_l) = \arg \max_{i \in U_m} (PF_l(i) + PF_l(j_l)) \\ &= \arg \max \left\{ \max_{i \in U_m^{\text{SNR}}} (PF_l(i) + PF_l(j_l)), \max_{i \in U_m^{\text{CoMP}}} (PF_l(i) + PF_l(j_l)) \right\}, \end{aligned} \quad (8)$$

User assignment in (8) can also be re-formulated as

$$\tilde{i}_l = \arg \max_{i \in U_m^{\text{SNR}}} (PF_l(i) + PF_l(j_l)) \quad (9)$$

$$\hat{i}_l = \arg \max_{i \in U_m^{\text{CoMP}}} (PF_l(i) + PF_l(j_l)) \quad (10)$$

The second step of the radio resource block assignment thus comprises:

- determining (S44) among the single-node reception SNR user set the user terminal $\tilde{i}_l$ that maximizes a combined utility metric $PF_l(i, j_l)$ associated with said radio resource block in combination with the user terminal of the small cell to which the corresponding radio resource is assigned;
- determining (S45) among the coordinated multi-point reception CoMP user set the user terminal $\hat{i}_l$ that maximizes a combined utility metric associated with said

radio resource block in combination with the user terminal of the small cell to which the radio resource is assigned.

The utility metric $PF(\tilde{\mathbf{i}}_l)$ of said determined user terminal $\tilde{\mathbf{i}}_l$ from the single-node reception user set is then compared (S46) with the utility metric $PF(\hat{\mathbf{i}}_l)$ of said determined user terminal $\hat{\mathbf{i}}_l$ from the coordinated multi-point reception user set, and the radio resource block of the macro cell is assigned on the basis of this comparison:

$$i_l = \begin{cases} \tilde{i}_l & \text{if } PF_l(\tilde{i}_l) + PF_l(j_l) > PF_l(\hat{i}_l) + PF_l(j_l) \\ \hat{i}_l & \text{otherwise} \end{cases} \quad (11)$$

The radio resource block is assigned to the user terminal associated with the higher utility metric.

Regarding the joint user terminal assignment involving SNR user terminals S44, macro cell associated user terminal data rate is determined by the link between the user terminal and the serving macro cell. Macro cell associated user terminal that is best matched with small cell user terminal j_l shown in (9) can be re-written as

$$\tilde{i}_l = \arg \max_{i \in U_m^{\text{SNR}}} \left[\frac{1}{R_i} \log_2 \left(1 + \frac{S_i}{I_{j_l \rightarrow m} + \tilde{I}_m + N_0} \right) + \frac{1}{R_{j_l}} \log_2 \left(1 + \frac{S_{j_l}}{I_{i \rightarrow s} + \tilde{I}_s + N_0} \right) \right] \quad (12)$$

with:

R_i : average throughput of user terminal i

R_{j_l} : average throughput of user terminal j_l

$S_i = \|\mathbf{w}_{i,m}^H \mathbf{h}_{i,m}\|^2 P_i$: received power of macro cell associated user terminal i

$S_{j_l} = \|\mathbf{w}_{j_l,s}^H \mathbf{h}_{j_l,s}\|^2 P_{j_l}$: received power of small cell associated user terminal j_l

$I_{i \rightarrow s} = \|\mathbf{w}_{j_l,s}^H \mathbf{h}_{i,s}\|^2 P_i$: macro-introduced interference received with filter $\mathbf{w}_{j_l,s}$

$\tilde{I}_s$: small cell interference excluding $I_{i \rightarrow s}$

$I_{j_l \rightarrow m} = \|\mathbf{w}_{i,m}^H \mathbf{h}_{j_l,m}\|^2 P_{j_l}$: small cell-introduced interference received with filter $\mathbf{w}_{i,m}$

$\tilde{I}_m$: small cell interference excluding $I_{j_l \rightarrow m}$

Since small cell user terminals are normally closer to serving node, the assigned transmit power is much lower than that of their macro cell counterparts. As a result the interference introduced to macro cell is typically marginal, that is, $I_{j_l \rightarrow m} \rightarrow 0$. It is also realized that for users in SNR user set, they are unlikely to cause significant interference to small cell user terminals either, i.e., $I_{i \rightarrow s} \rightarrow 0$. In light of this, user terminals selected from SNR user set can be decoupled from macro-cell-associated user terminal j_l and equation (12) can be simplified to

$$\tilde{i}_l = \arg \max_{i \in U_m^{\text{SNR}}} \frac{1}{R_i} \log_2 \left(1 + \frac{S_i}{\tilde{I}_m + N_0} \right) \quad (13)$$

The combined utility metric for a user terminal of the single-node reception user set can thus be approximated by a utility metric of said user terminal, and not by a combined utility metric of said terminal of the single-node reception user set and of the small-cell-associated user terminal j_l .

Regarding joint user assignment involving CoMP user terminals, with CoMP user signal decoding can be noticeably improved resulting in enhanced user performance. This alters user priority in resource assignment and should be taken into account properly by the scheduler.

Accordingly,

- a small cell receives signals from user terminals of the coordinated multi-point reception user set, decode said signals, and send said decoded signals to a macro cell,
- said macro receives signals from user terminals of the coordinated multi-point reception user set, and decode said signals,
- wherein the signals decoded by the small cell and the signals decoded by the macro cell are compared to each other, and for each user terminal, a decoded signal of said user terminal is selected on the basis of this comparison, said selected decoded signal being used for determining the combined utility metric for said user terminal of the coordinated multi-point reception user set.

Virtual Soft Handoff (VHSO) enabled dominant interference cancellation is set as an example. In VSHO, small cell receiver performs successive interference cancellation (SIC) to sequentially decode signals of small cell and interfering macro cells. Small cell-decoded macro cell data is then sent to macro cells for selective combination, i.e.,

5 small-cell decoded signals is compared with those received by macro cells and the better of the two would be retained. The combined utility metric for the user terminal of the coordinated multi-point reception user set is determined from an average throughput R_i of user terminal i of the macro cell, an average throughput R_{j_l} of user terminal j_l of the small cell, an estimated data rate r_i of user terminal i of the macro cell, an estimated data

10 rate r_{j_l} of user terminal j_l of the small cell:

$$PF(i, j_l) = \frac{1}{R_i} r_i + \frac{1}{R_{j_l}} r_{j_l},$$

Taking the case that joint scheduling is happened within macro cell and only one small cell for example, pending on the decoding order of VSHO and the selective

15 combination results, there can be three different scenarios corresponding to different sum utility metric for the VSHO-equipped small cell and the interfering macro cell, under the case that only one small cell users collaborate with CoMP macro user.

In the first scenario, small cell decodes macro cell signals first; macro cell (such as eNB) chooses small cell-decoded data. In this case, the estimated instantaneous data rates of

20 macro and small cell user terminals can be obtained as

$$r_i^{\text{SIC-a}} = \log_2 \left(1 + \frac{S_{i \rightarrow s}}{I_{j_l} + \tilde{I}_s + N_0} \right) \quad (14)$$

$$r_{j_l}^{\text{SIC-a}} = \log_2 \left(1 + \frac{S_{j_l}}{\tilde{I}_s + N_0} \right), \quad (15)$$

and the sum PF utility metric is given by

$$PF_a(i, j_l) = \frac{1}{R_i} r_i^{\text{SIC-a}} + \frac{1}{R_{j_l}} r_{j_l}^{\text{SIC-a}}. \quad (16)$$

In the second scenario, small cell decodes small cell signals first; macro cell (such as eNB) choose small cell-decoded data. The corresponding user data rate and the sum PF utility metric is given by

$$r_i^{\text{SIC-b}} = \log_2 \left(1 + \frac{S_{i \rightarrow s}}{\tilde{I}_s + N_0} \right) \quad (17)$$

$$5 \quad r_{j_l}^{\text{SIC-b}} = \log_2 \left(1 + \frac{S_{j_l}}{I_{i \rightarrow s} + \tilde{I}_s + N_0} \right) \quad (18)$$

$$PF_b(i, j_l) = \frac{1}{R_i} r_i^{\text{SIC-b}} + \frac{1}{R_{j_l}} r_{j_l}^{\text{SIC-b}}. \quad (19)$$

In the third scenario, both the macro cell and the small cell performs single node reception, resulting in

$$r_i^{\text{SNR}} = \log_2 \left(1 + \frac{S_i}{\tilde{I}_m + N_0} \right) \quad (20)$$

$$10 \quad r_{j_l}^{\text{SNR}} = \log_2 \left(1 + \frac{S_{j_l}}{I_{i \rightarrow s} + \tilde{I}_s + N_0} \right) = r_{j_l}^{\text{SIC-b}} \quad (21)$$

$$PF_c(i, j_l) = \frac{1}{R_i} r_i^{\text{SNR}} + \frac{1}{R_{j_l}} r_{j_l}^{\text{SNR}} \quad (22)$$

In equations (14)-(22), $S_{i \rightarrow s} = \|\mathbf{w}_{i,s}^H \mathbf{h}_{i,s}\|^2 P_i$ denotes the received signal power of macro cell user terminal with filter $\mathbf{w}_{i,s}$ and $I_{j_l} = \|\mathbf{w}_{i,s}^H \mathbf{h}_{j_l,s}\|^2 P_{j_l}$ denotes the signal power of small cell user terminal j_l (posed as interference when decoding macro cell associated user terminal i). The combined utility metric $PF_l(i, j_l)$ for the user terminal pair $\{i, j_l\} \in U_m^{\text{CoMP}} \times U_s$ can then be obtained as

$$PF_l(i, j_l) = \max(PF_a(i, j_l), PF_b(i, j_l), PF_c(i, j_l)). \quad (23)$$

The joint scheduler transverse the set union $U_m^{\text{CoMP}} \times U_s$ to compute the combined utility metric for all user terminal pair $\{i, j_l\} \in U_m^{\text{CoMP}} \times U_s$ and to find the user terminal pair associated with the maximum combined utility metric value according to expression (10).

It should be noted that the method of radio resource assignment for CoMP-aware user terminals can also be extended to the macro layers for macro cells to determine the scheduled user terminals in coordination.

After the centralized controller has performed radio resource block assignment for the cooperating cells, in a fifth stage, the centralized controller adjusts modulation coding scheme (MCS). Centralized controller accounts for accurate user signal signal-to-interference-plus-noise ratios (SNRs) in a large CoMP cluster and adjust modulation coding scheme (MCS) to closely couple with user terminal signal quality. Along the process of determining user terminals' SINR and MCS, user signal reception mode is also determined.

Following user-resource assignment, the MCS employed by user terminal should be decided. Nevertheless the SINR values derived at the user assignment stage cannot be used in all scenarios. Macro cell in the CoMP cell set can be denoted as $M = \{1, 2, \dots, M\}$, for any resource block l , the co-channel user terminals can be denoted as $i_l^1, i_l^2, \dots, i_l^M, j_l$ where i_l^m denotes the selected user terminal by macro cell m and j_l denotes the user terminal selected by the small cell of interest. From the perspective of small cell user terminal j_l , there can be three different cases regarding the co-channel macro user terminals.

In the first case, all macro-cell-assigned user terminals are either from the SNR user set or from the CoMP user set nevertheless the cooperating cell is not the small cell s of consideration. In this case, small cell should perform single-node reception on user terminal signals and the signal SINR can be estimated as

$$SINR_{j_l} = \frac{S_{j_l}}{\sum_m I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0}, \quad (24)$$

where $I_{i_l^m \rightarrow s}$ denotes the interference that macro user terminal i_l^m causes to the small cell.

In the second case, there is only macro cell user terminal in CoMP reception with small cell user terminal j_l , all other macro user terminals are either received with single-node reception or in CoMP reception mode with other small cells. Without losing generality we assume the macro cell user terminal i_l^1 in in the CoMP with small cell associated user

terminal j_l . Following the derivation in the user assignment stage, the signal qualities of i_l^1 and j_l can be obtained as:

$$SINR_{i_l^1} = \begin{cases} \frac{S_{i_l^1 \rightarrow s}}{I_{j_l} + \sum_{m \neq 1} I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0} & \text{SIC decodes macro user } i_l^1 \text{ first} \\ \frac{S_{i_l^1 \rightarrow s}}{\sum_{m \neq 1} I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0} & \text{SIC decodes macro user } j_l \text{ first} \\ \frac{S_{i_l^1}}{\sum_{m \neq 1} I_{i_l^m \rightarrow 1} + N_0} & \text{Macro and small cell perform SNR} \end{cases} \quad (25)$$

$$SINR_{j_l} = \begin{cases} \frac{S_{j_l}}{\sum_{m \neq 1} I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0} & \text{SIC decodes macro user } i_l^1 \text{ first} \\ \frac{S_{j_l}}{\sum_m I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0} & \text{SIC decodes macro user } j_l \text{ first} \\ \frac{S_{j_l}}{\sum_m I_{i_l^m \rightarrow s} + \tilde{I}_s + N_0} & \text{Macro and small cell perform SNR} \end{cases} \quad (26)$$

5

In the third case, there are more than one macro cell user terminal in CoMP reception mode with small cell user terminal j_l . Without losing generality, we assume the macro cell user terminals $\{i_l^n\}_{n=1}^N$ are jointly decoded with the small cell user terminal j_l where $2 \leq N \leq M$. As a result, there are $N+1$ cells, i.e, N macro cells and small cell s , in the CoMP cluster. The SIC decoding order is determined before computing the accurate user SINRs. However, the steps of estimating user priorities (and associated SINRs) in user assignment only applies to 2-point CoMP scenario, while there is no straightforward way to extend it to a general $(N+1)$ -point CoMP case.

10

An example of a 3-point CoMP ($N = 2$) is given to show the complexity of determining the SIC order of $(N+1)$ -point CoMP where $N \geq 2$. In summary, there can be 11 different hypotheses regarding the multi-point reception of user terminals i_l^1 , i_l^2 and j_l , where i_l^1 and i_l^2 denote two macro-associated user terminals and j_l denote the co-channel small cell user terminal:

15

- User terminals i_l^1 , i_l^2 and j_l are decoded by small cell SIC in sequence;

- User terminals i_l^1 , j_l and i_l^2 are decoded by small cell SIC in sequence;
 - User terminals i_l^2 , i_l^1 and j_l are decoded by small cell SIC in sequence;
 - User terminals i_l^2 , j_l and i_l^1 are decoded by small cell SIC in sequence;
 - User terminals j_l , i_l^1 and i_l^2 are decoded by small cell SIC in sequence;
 - 5 • User terminals j_l , i_l^2 and i_l^1 are decoded by small cell SIC in sequence;
 - User terminals i_l^1 and j_l are decoded by small cell SIC in sequence, user terminal i_l^2 is decoded by the serving cell;
 - User terminals j_l and i_l^1 are decoded by small cell SIC in sequence, user terminal i_l^2 is decoded by the serving cell;
 - 10 • User terminals i_l^2 and j_l are decoded by small cell SIC in sequence, user terminal i_l^1 is decoded by the serving cell;
 - User terminals j_l and i_l^2 are decoded by small cell SIC in sequence, user terminal i_l^1 is decoded by the serving cell;
 - User terminals i_l^1 , i_l^2 and j_l are decoded by their own serving cells, respectively.
- 15 The module of the centralized controller responsible for MCS mapping needs to compute the sum utility metrics corresponding to all the above-mentioned hypotheses and selects the CoMP reception mode associated with optimum sum utility. The number of CoMP hypotheses for the $(N+1)$ -point CoMP can be shown to be $\sum_{n=0}^N C_N^n (n+1)!$, which increases quickly with respect to N .
- 20 Alternatively, a reduced-complexity algorithm is proposed to determine the SIC decoding order and corresponding SINRs for user terminals participating in SIC. For illustrative purpose, we define the notations as follows:

$\text{SIC}(N, \{x_1, x_2, \dots, x_N\})$: N -point CoMP where the small cell employs SIC to sequentially decode user terminal signals x_1 through x_N in the increasing order of n .

$\text{SNR}(\{y_1, y_2, \dots, y_Q\})$: Single-node reception where user terminal signals $y_1, y_2, \dots, y_Q$ are separately decoded by their own serving cells. It is clear that $\text{SIC}(1, x_1)$ is equivalent to $\text{SNR}(x_1)$.

5 $\gamma(\text{SIC}(N, \Phi^{\text{SIC}}), \text{SNR}(\Phi^{\text{SNR}}))$: sum utility metric of CoMP users in Φ^{SIC} and SNR users in Φ^{SNR} . When proportional fair criterion is used for network utility then the utility function γ would be PF metric.

Without losing generality we assume the CoMP user set $\Phi_0^{\text{SIC}} = \{i_l^1, i_l^2, \dots, i_l^k, j_l, \dots, i_l^N\}$ are arranged in the decreasing order of received power at small cell such that
 10 $P_{r,s}^{i_l^n} > P_{r,s}^{i_l^m} \forall n < m$ and $P_{r,s}^{i_l^k} > P_{r,s}^{j_l} > P_{r,s}^{i_l^{k+1}}$. The single-node reception user set is initialized to be empty, that is, $\Phi_0^{\text{SNR}} = \emptyset$. The proposed algorithm is given as below.

DEC_ORDER($\Phi_0^{\text{SIC}}, \Phi_0^{\text{SNR}}, k$)

Initialize $\Phi^{\text{SIC}} = \Phi_0^{\text{SIC}}, \Phi^{\text{SNR}} = \Phi_0^{\text{SNR}}, N = |\Phi_0^{\text{SIC}}| - 1, n = 1$

Compute sum utility metric $\gamma_0 = \gamma(\text{SIC}(N+1, \Phi^{\text{SIC}}), \text{SNR}(\Phi^{\text{SNR}}))$

15 $\{x_1, x_2, \dots, x_N\} \leftarrow \Phi^{\text{SIC}} / \{j_l\},$

WHILE $n \leq N$ DO

$\tilde{\Phi}^{\text{SNR}} = \Phi^{\text{SNR}} \cup \{x_n\}$

IF $n \leq k$

$\tilde{\Phi}^{\text{SIC}} = \{x_1, \dots, x_{n-1}, x_{n+1}, \dots, x_k, j_l, \dots, x_N\}, \tilde{k} = k - 1$

20 ELSE

$\tilde{\Phi}^{\text{SIC}} = \{x_1, \dots, x_k, j_l, \dots, x_{n-1}, x_{n+1}, \dots, x_N\}, \tilde{k} = k$

END IF

Compute sum utility metric $\tilde{\gamma} = \gamma(\text{SIC}(N, \tilde{\Phi}^{\text{SIC}}), \text{SNR}(\tilde{\Phi}^{\text{SNR}}))$

IF $\tilde{\gamma} > \gamma$

DEC_ORDER($\tilde{\Phi}^{\text{SIC}}, \tilde{\Phi}^{\text{SNR}}, \tilde{k}$)

END IF

5 END WHILE

OUTPUT Φ^{SIC} and Φ^{SNR}

EXIT

The user terminal signal SINR can be determined for CoMP user set $\Phi^{\text{SIC}} = \{x_1, x_k, j_l, \dots, x_N\}$ and SNR user set $\Phi^{\text{SNR}} = \{y_1, y_2, \dots, y_Q\}$ as

$$10 \quad \text{SINR}_{x_n} = \begin{cases} \frac{S_{x_n \rightarrow s}}{I_{j_l} + \sum_{m=n+1}^N I_{x_m \rightarrow s} + \tilde{I}_s + N_0} & \text{if } n \leq k \\ \frac{S_{x_n \rightarrow s}}{\sum_{m=n+1}^N I_{x_m \rightarrow s} + \tilde{I}_s + N_0} & \text{Otherwise} \end{cases} \quad (27)$$

$$\text{SINR}_{j_l} = \frac{S_{j_l}}{\sum_{m=k+1}^N I_{x_m \rightarrow s} + \tilde{I}_s + N_0} \quad (28)$$

$$\text{SINR}_{y_q} = \frac{S_{y_q}}{\sum_n I_{x_n \rightarrow q} + \sum_{k \neq q} I_{y_k \rightarrow q} + N_0} \quad (29)$$

These SINR values are then be used in MCS allocation.

15 After this fifth stage in which the centralized controller adjusts modulation coding scheme, in a sixth stage, the centralized controller notifies all cooperating cells the results of the blocks resources assignment, and the reception mode of the user terminals.

Finally, in a seventh stage, each small cell decodes signals from user terminals of the coordinated multi-point reception user set and sends said decoded signals to each macro cell serving said user terminals. Successive interference cancellation can be performed.

- 5 While the present invention has been described with respect to certain preferred embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the scope of the invention as defined in the appended claims.

Claims

1. A method for scheduling user terminals in a heterogeneous network comprising a plurality of cooperating cells constituted by at least one macro cell and at least one
5 small cell having at least partially overlapping coverage, each cooperating cell having corresponding radio resource blocks assigned to their respective user terminals, wherein radio resource block assignment comprises a first step in which radio resource blocks of the small cell are allocated to user terminals that maximize a first utility metric associated with said radio resource blocks of the small cell,
10 and a second step run by a centralized controller in which for assigning a radio resource block of the macro cell, a second utility metric associated with said radio resource block of the macro cell is determined for each combination of user terminal of the macro cell and of a user terminal of the small cell assigned to the corresponding radio resource block, and the radio resource block of the macro cell is assigned to the user terminal of the macro cell that
15 maximizes said second utility metric.
2. The method of claim 1, wherein each macro cell receive channel state information from each user terminal served by said macro cell, and on the basis of said channel state information, each macro cell partitions the user terminals served by said macro cell into
20 two user sets defined by their reception mode :
- a single-node reception user set for the user terminals which are not prone to cause interference in the uplink on at least one small cell, and
 - a coordinated multi-point reception user set for the user terminals which are prone to cause interference in the uplink on at least one small cell;
- 25 and the second step comprises
- determining among the single-node reception user set the user terminal that maximizes a combined utility metric) associated with said radio resource block in combination with the user terminal of the small cell to which the corresponding radio resource is assigned;
 - 30 • determining among the coordinated multi-point reception user set the user terminal that maximizes a combined utility metric associated with said radio resource block in combination with the user terminal of the small cell to which the radio resource is assigned;

- assigning the radio resource block of the macro cell on the basis of a comparison of the combined utility metric of said determined user terminal from the single-node reception user set and of the combined utility metric of said determined user terminal from the coordinated multi-point reception user set.

5

3. The method of claim 2, wherein the combined utility metric for a user terminal of the single-node reception user set is approximated by a utility metric of said user terminal.

4. The method of claim 2 or 3, wherein

10 - a small cell receives signals from user terminals of the coordinated multi-point reception user set, decode said signals, and send said decoded signals to a macro cell,

- said macro receives signals from user terminals of the coordinated multi-point reception user set, and decode said signals,

15 - wherein the signals decoded by the small cell and the signals decoded by the macro cell are compared to each other, and for each user terminal, a decoded signal of said user terminal is selected on the basis of this comparison, said selected decoded signal being used for determining the combined utility metric for said user terminal of the coordinated multi-point reception user set.

20 5. The method of claim 4, wherein the combined utility metric for said user terminal of the coordinated multi-point reception user set is determined from an average throughput R_i of user terminal i of the macro cell, an average throughput R_{j_l} of user terminal j_l of the small cell, an estimated data rate r_i of user terminal i of the macro cell, an estimated data rate r_{j_l} of user terminal j_l of the small cell:

$$PF(i, j_l) = \frac{1}{R_i} r_i + \frac{1}{R_{j_l}} r_{j_l},$$

6. The method according to any one of claim 2 to 5, wherein the centralized controller notifies to the cooperating cells the reception mode of user terminals.

7. The method according to any one of claim 2 to 6, wherein the centralized controller adjusts modulation coding scheme by discriminating user terminals served by a macro cell on the basis of their respective reception mode.

5 8. The method of any one of claim 1 to 7, comprising the following step:

(1) each cooperating cells receive channel state information from their respective user terminals and from the user terminal prone to cause interference,

(2) each macro cell partitions the user terminals served by said macro cell into:

- 10 - a single-node reception user set for the user terminals which are not prone to cause interference in the uplink on at least one small cell, and
- a coordinated multi-point reception user set for the user terminals which are prone to cause interference in the uplink on at least one small cell;

(3) each cooperating cell reports to the centralized controller said channel state information and each macro cell reports user set information about the portioning of the user terminals served by said macro cell,

(4) the centralized controller performs radio resource block assignment for said cooperating cells,

(5) the centralized controller adjusts modulation coding scheme,

(6) the centralized controller notifies all cooperating cells the results of the blocks resources assignment, the reception mode of the user terminals,

20 (7) each small cell decodes signals from user terminals of the coordinated multi-point reception user set and sends said decoded signals to each macro cell serving said user terminals.

FIG 1

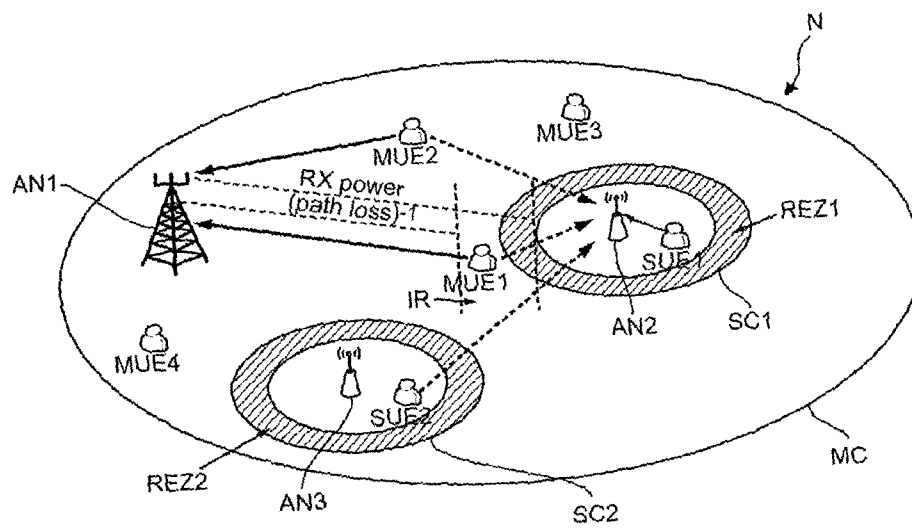


FIG 2

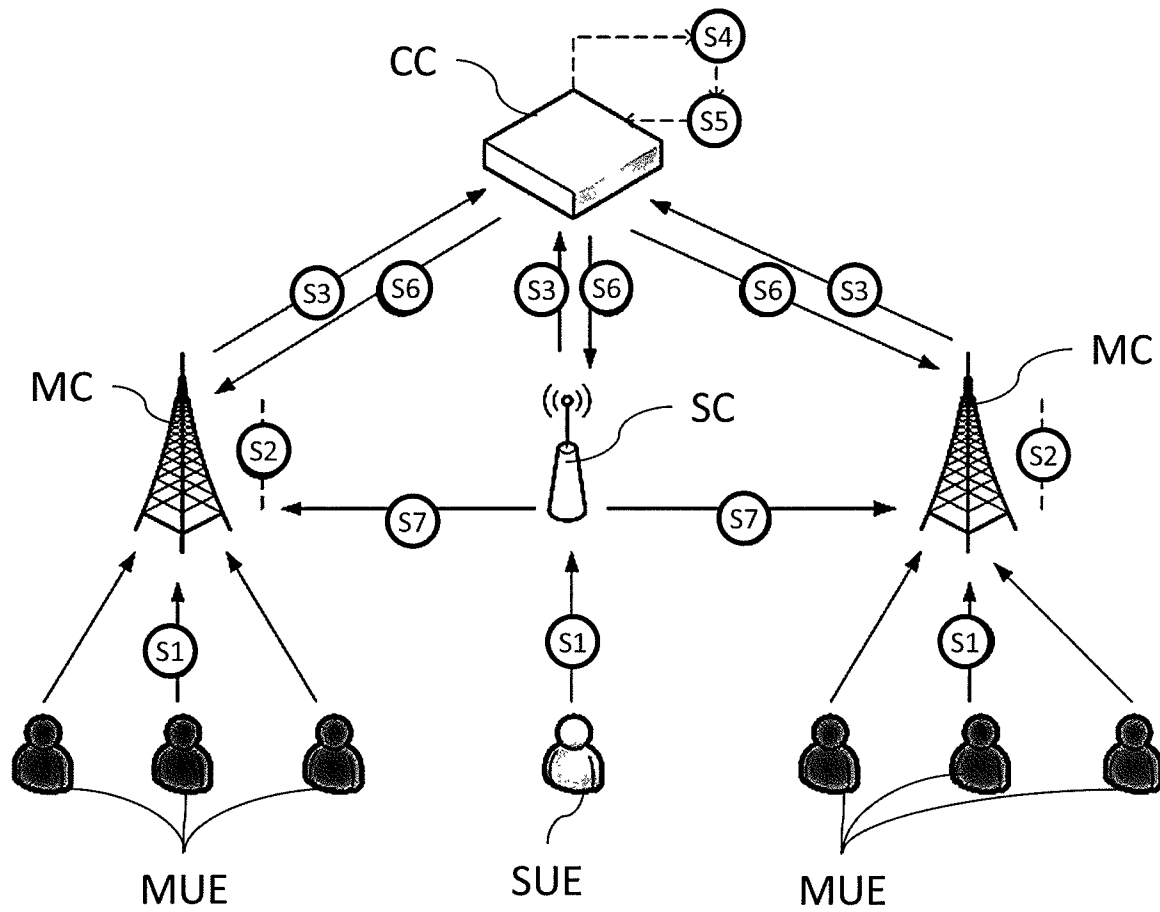


FIG 3

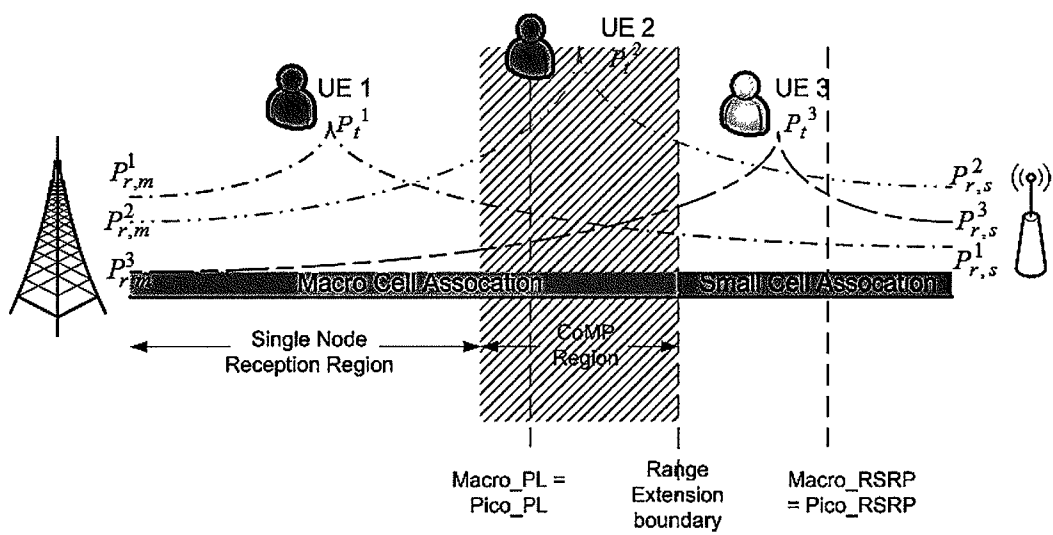
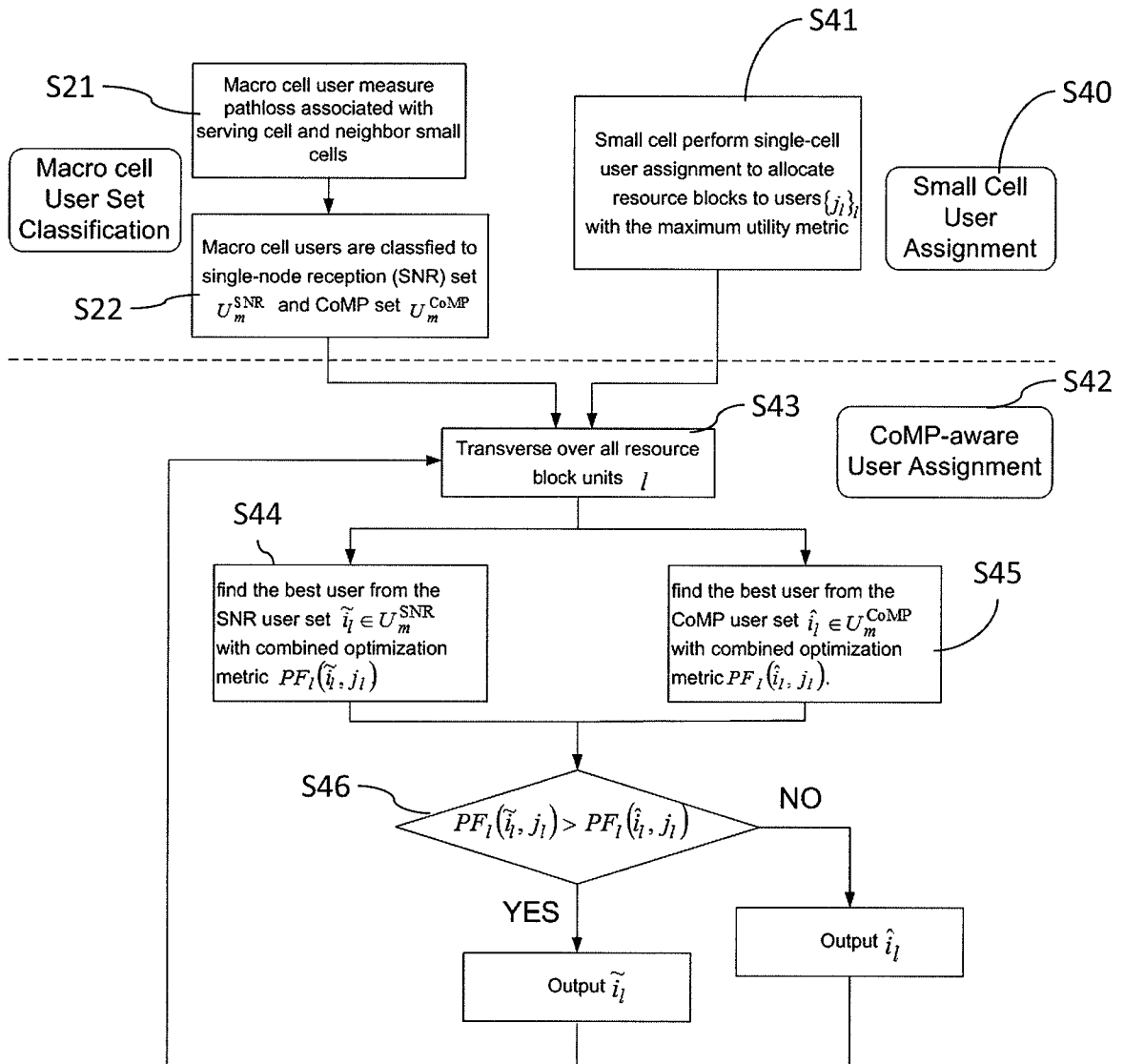


FIG 4



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/12 H04B7/02
ADD. H04W16/32

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GREGORY MOROZOV ET AL: "Performance evaluation of dynamic point selection CoMP scheme in heterogeneous networks with FTP traffic model", ULTRA MODERN TELECOMMUNICATIONS AND CONTROL SYSTEMS AND WORKSHOPS (ICUMT), 2012 4TH INTERNATIONAL CONGRESS ON, IEEE, 3 October 2012 (2012-10-03), pages 922-926, XP032330609, DOI: 10.1109/ICUMT.2012.6459792 ISBN: 978-1-4673-2016-0 INTRODUCTION; page 922, paragraph I - page 923 DYNAMIC POINT SELECTION COMP SCHEME; page 923, paragraph II - page 924 ----- -/-	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

4 October 2016

Date of mailing of the international search report

13/10/2016

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/001081

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2015/030522 A1 (LG ELECTRONICS INC [KR]) 5 March 2015 (2015-03-05) page 30, paragraph 148 - page 34, paragraph 182 -----	1-8
A	TIAN SHUANG ET AL: "Sharpe ratio for user association design in downlink heterogeneous cellular networks", 2014 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS WORKSHOPS (ICC), IEEE, 10 June 2014 (2014-06-10), pages 61-66, XP032630877, DOI: 10.1109/ICCW.2014.6881173 [retrieved on 2014-08-20] SYSTEM MODEL; page 62, paragraph II - page 63 -----	1-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2016/001081

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015030522 A1	05-03-2015	US 2016204838 A1 WO 2015030522 A1	14-07-2016 05-03-2015
