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(54) Title: METHOD AND APPARATUS FOR CONTROLLING THE INTERFERENCE BETWEEN A MICROCELL AND A MACROCELL

(57) Abstract: A method and an apparatus for controlling interference between a microcell and a macrocell in a home base station within the microcell are provided in the present invention. In particular, in the case that the existence of at least one victim macro user equipment is detected, the home base station according to the present invention controls its transmit power within an interval determined by an upper limit and a lower limit, such that it can be guaranteed that the performance requirement of a communication with the home user equipment is satisfied while interference toward the victim macro user equipment is reduced. Additionally, the home base station according to the present invention detects whether there is at least one indoor victim macro user equipment, and conducts corresponding interference control according to the detection result.



Method and Apparatus for Controlling the Interference between a Microcell and a Macrocell

5 **Field of the Invention**

The present invention is related to interference control in a communication system, in particular, to a method and an apparatus for controlling interference between a microcell and a macrocell.

10 **Background of the Invention**

As compared with a conventional macrocell base station (Macro enhanced Node B, MeNB), a microcell (Microcell or Femtocell) base station is a base station with low power and low cost, and is also referred to as a home base station (Home enhanced Node B, HeNB). The home base station is
15 mainly used in the indoor site such as home and office, etc., and is generally configured by the user himself or herself. A user equipment (UE) accessing to the macro base station and a user equipment accessing to the home base station are referred to be as a macro user equipment (Macro UE, MUE) and a home user equipment (Home UE, HUE), respectively. Under a co-channel
20 deployment of the macro base station and the home base station, a signal is transmitted and received in the same frequency band by the macro base station and the home base station, and thus the a macro user equipment located around the home base station may be interfered by the home base station. The interfered user equipment is generally referred to be as a victim
25 user equipment (victim UE). It is proposed in 3GPP TR 36.921 that the interference to the victim macro user equipment may be reduced by power control, i.e., limiting the transmit power of the home base station. Specifically, two schemes for controlling the interference through power control are proposed in 3GPP TR 36.921.

In the first scheme, the home base station determines its transmit power P_{tx} based on the formula of

$$\begin{aligned} P_{tx} &= \max(\min(\alpha \cdot (P_{MeNB-HeNB} + \beta), P_{max}), P_{min}) \\ &= \text{median}(\alpha \cdot P_{MeNB-HeNB} + \beta, P_{max}, P_{min}) \end{aligned} \quad (1)$$

where $P_{MeNB-HeNB}$ indicates the interference intensity of the macro base station to the home base station, for example, a Reference Signal Receiving Power (RSRP) received by the home base station from the macro base station, P_{max} and P_{min} indicate the maximum and minimum transmit power of the home base station, respectively, α can be used to alter the slope of the power control mapping curve, and β can be used to alter the dynamic range of the power control. For the sake of simplicity, parameters for power, propagation loss and target signal to interference ratio are in unit of dB or dBm, and any parameter related to pathloss indicate the absolute values of the corresponding pathloss.

In the second scheme, the home base station determines its transmit power P_{tx} based on the formula of

$$P_{tx} = \text{median}(P_{MeNB-HeNB} + P_{offset}, P_{max}, P_{min}) \quad (2)$$

where each of $P_{MeNB-HeNB}$, P_{max} , and P_{min} has the same meaning as that in formula (1), and P_{offset} is dependent on the pathloss (PL) $PL_{HeNB-MUE}$ between the home base station and the interfered macro user equipment. Accordingly, two autonomous methods for estimating the pathloss $PL_{HeNB-MUE}$ by the home base station are proposed in 3GPP TR 36.921:

(1) $PL_{HeNB-MUE}$ is estimated by the home base station as follows:

$$PL_{HeNB-MUE} = PL_0 + k \cdot \delta \quad (3)$$

where δ indicates a predetermined wall penetration loss whose typical value ranges over 10~30dB; PL_0 indicates a predetermined pathloss of the home base station to the edge of the home cell which is only associated with distance, and is also referred to be as indoor pathloss; k is an adjustable non-negative linear scalar which can be determined by the priority of the home base station's operation.

(2) $PL_{HeNB-MUE}$ is estimated by the home base station based on the

difference between the estimated transmit power P_{MUE} of a signal from the victim macro user equipment and the received power $P_{\text{MUE-HeNB}}$ of the signal. Specifically, $PL_{\text{HeNB-MUE}}$ may be calculated as follows:

$$\begin{aligned} PL_{\text{HeNB-MUE}} &= \Psi(PL_{\text{MeNB-MUE}}) - P_{\text{MUE-HeNB}} \\ &\approx \Psi(PL_{\text{MeNB-HeNB}}) - P_{\text{MUE-HeNB}} \end{aligned} \quad (4)$$

where $PL_{\text{MeNB-MUE}}$ indicates the pathloss between the macro base station and the macro user equipment, which may be approximated to the pathloss $PL_{\text{MeNB-HeNB}}$ between the macro base station and the home base station, and $PL_{\text{MeNB-HeNB}}$ may be estimated by the home base station by utilizing a measurement value $P_{\text{MeNB-HeNB}}$ of RSRP; $\Psi(\bullet)$ indicates the uplink power control function of the macro base station.

Summary of the Invention

There are the following disadvantages in the existing technologies.

Firstly, it is only considered, in the two schemes above for reducing the interference, that the interference to the victim macro user equipment is reduced by limiting the transmit power of the home base station, and thus a problem that may occur is that the transmit power used by the home base station is too low, thereby impacting the communication quality between the home base station and the home user equipments which it serves is, even causing an interruption of the communication.

Secondly, it is impossible to effectively reduce the interference to the macro user equipment while still ensuring the communication quality of the home user equipment by power control in the home base station in some cases, for example, when the distance between the macro user equipment and the home base station is less than the distance between the home user equipment and the home base station. In such case, it is necessary to additionally or alternatively use other interference control means such as time domain resource division, etc. to achieve effective interference control. However, when there is no cooperation between the macro base station and the home base station, the home base station can not decide when it is only

necessary to use power control as main interference control means and when it is necessary to activate additional interference control means.

In addition, when the home base station is located in an indoor site, the victim macro user equipment may be located within the indoor site (referred to as an indoor macro user equipment), and also may be located outside the indoor site (referred to as an outdoor macro user equipment). For example, when a home base station is in an access mode of a closed subscriber group (CSG), only the subscribers in the closed subscriber group corresponding to the home base station may access to the home base station, and therefore, the indoor subscribers who are not in the closed subscriber group will access to the macro base station instead of the home base station, namely being the indoor macro user equipments. The interference to the indoor victim macro user equipment is significantly different from that to the outdoor victim macro user equipment. However, the existing technologies above never differentiate them.

For the disadvantages of the existing technologies, an object of the present invention is to provide an interference control scheme in a home base station, which ensures that the performance requirement for the communication with the home user equipment can be satisfied while reducing the interference to the victim macro user equipment.

Another object of the present invention is to improve the interference control scheme in the home base station such that the two cases where the victim macro user equipment is located in the indoor and outdoor areas can be handled accordingly.

According to an aspect of the present invention, it is provided a method for controlling the interference to a victim user equipment in a first base station within a microcell, comprising the steps of A. obtaining the parameters of a first received power $P_{\text{MeNB-HUE}}$ of a signal received by a first user equipment served by the microcell from a second base station in the macrocell, and a first pathloss $PL_{\text{HeNB-HUE}}$ between the first base station and the first user equipment; B. determining a lower limit $P_{\text{tx_low}}$ of a transmit

power of the first base station according to the obtained first received power $P_{\text{MeNB-HUE}}$, the obtained first pathloss $PL_{\text{HeNB-HUE}}$, and a target signal quality of the first user equipment; and C. controlling the interference according to the determined lower limit $P_{\text{tx_low}}$.

5 Furthermore, the method above further comprises the steps as follows: determining whether there is a second user equipment served by the macrocell and interfered by the first base station; if there is at least one second user equipment served by the macrocell and interfered by the first base station, then step A further comprises obtaining the parameter of a
 10 second received power $P_{\text{MeNB-MUE}}$ of a signal received by the second user equipment from the second base station, and a second pathloss $PL_{\text{HeNB-MUE}}$ between the first base station and the second user equipment; step B further comprises determining an upper limit $P_{\text{tx_upp}}$ of the transmit power according to the obtained second received power $P_{\text{MeNB-MUE}}$, the obtained second
 15 pathloss $PL_{\text{HeNB-MUE}}$, and a target signal quality of the second user equipment; and step C controls the interference according to the lower limit $P_{\text{tx_low}}$ and the upper limit $P_{\text{tx_upp}}$.

In this way, the first base station guarantees that the performance requirement for the communication with the user equipments which it serves
 20 can be always satisfied through the lower limit of the transmit power. Moreover, the home base station can decide whether it is required to use other interference control methods by comparing the determined lower limit $P_{\text{tx_low}}$ with the upper limit $P_{\text{tx_upp}}$. Specifically, if the determined lower limit $P_{\text{tx_low}}$ is greater than the upper limit $P_{\text{tx_upp}}$, it is indicated that it is impossible to
 25 effectively reduce the interference to the macro user equipment while ensuring the communication quality of the home user equipment only by means of the power control, and accordingly, the home base station will employ other interference control methods, including handing over the home user equipment to the macro base station, or using time domain resource
 30 division, frequency domain resource division, or a combination thereof.

Furthermore, the second received power $P_{\text{MeNB-MUE}}$ and the second

pathloss $PL_{\text{HeNB-MUE}}$ may be obtained in different manners. The first base station may obtain those two parameters by signaling exchange with the second base station if there is cooperation between the first base station and the second base station. Specifically, the first base station receives a first message from the second base station with the first message including information indicating the second received power $P_{\text{MeNB-MUE}}$ and information indicating the second pathloss $PL_{\text{HeNB-MUE}}$; and determines the second received power ($P_{\text{MeNB-MUE}}$) and the second pathloss ($PL_{\text{HeNB-MUE}}$) according to the first message. The first base station may perform autonomous estimation for those two parameters if there is no cooperation between the first base station and the second base station, or if the first base station does not desire to obtain those two parameters by means of cooperation.

According to another aspect of the present invention, it is provided an apparatus for controlling interference between a microcell and a macrocell in a first base station within the microcell, comprising: a first obtaining module for obtaining the parameters of a first received power $P_{\text{MeNB-HUE}}$ of a signal received by a first user equipment of the microcell from a second base station in the macrocell, and a first pathloss $PL_{\text{HeNB-HUE}}$ between the first base station and the first user equipment; a first determining module for determining a lower limit $P_{\text{tx_low}}$ of a transmit power of the first base station according to the obtained first received power $P_{\text{MeNB-HUE}}$, the obtained first pathloss $PL_{\text{HeNB-HUE}}$, and a target signal quality of the first user equipment; and a first controlling module for controlling the interference according to the determined lower limit $P_{\text{tx_low}}$.

According to another aspect of the present invention, it is provided a method for controlling interference between a microcell and a macrocell in a first base station within the microcell, wherein the first base station is located in an indoor area, a second base station within the macrocell is located in an outdoor area, and the method comprises the steps of detecting whether there is a second user equipment served by the macrocell and interfered by the first base station; detecting whether at least one second user equipment devices is

located in the indoor area if there is the second user equipment device, and controlling the interference according to the detection result.

In this way, in the interference control, the two cases where the victim macro user equipment is located in indoor and outdoor areas are differentiated.

According to another aspect of the present invention, it is provided an apparatus for controlling interference between a microcell and a macrocell in a first base station within the microcell, wherein the first base station is located in an indoor area, a second base station within the macrocell is located in the outdoor area, and the apparatus comprises: a first detecting module for detecting whether there is a second user equipment served by the macrocell and interfered by the first base station; a second detecting module for detecting whether at least one second user equipment is located in the indoor area when there is the second user equipment device; and a second controlling module for controlling the interference according to the detection result.

Brief Description of Drawings

Other features, objects and advantages of the invention will be more apparent by reading the detailed description made for the unconstraint embodiments with reference to the accompanying drawings.

Fig. 1 shows a typical application scenario of the present invention;

Fig. 2 shows a flowchart of a method for controlling the interference between a microcell and a macrocell in a base station of the microcell according to a specific embodiment of the present invention;

Fig. 3 shows a flowchart of a method for detecting whether there is at least one indoor victim macro user equipment in the base station of the microcell according to a specific embodiment of the present invention.

In the drawings, the like or similar numbers indicate the like or similar steps or apparatuses.

Detailed Description of Embodiments

Fig. 1 shows a typical application scenario according to the present invention. An indoor site 1 may be a room, an apartment, a storey, or a house. A home base station 10 is located in the indoor site 1, directed to serve user equipments in the indoor site 1, i.e., indoor user equipments. A macro base station 20 is located outside the indoor site 1. The coverage ranges of the home base station 10 and the macro base station 20 are overlapped partly or entirely. Herein, the cells covered and served by the home base station 10 and the macro base station 20 are referred to as a microcell 11 and a macrocell 21, respectively. It is to be noted that Fig. 1 is not drawn in scale. The distance between the macro base station 20 and the indoor site 1 is generally much greater than the radius of the microcell 11, because the range of the macrocell 21 is generally much greater than that of the microcell 11. A user equipment 31 and a user equipment 41 are located in the indoor area, a user equipment 42 is located in the outdoor area and close to the indoor site 1, a user equipment 43 is located in the outdoor area and far away from the indoor site 1. As depicted in the solid line in Fig. 1, the user equipment 31 accesses to the home base station 10 and is referred to as home user equipment accordingly, and the user equipments 41, 42, and 43 access to the macro base station 20 and are referred to as macro user equipments accordingly. Herein, the user equipment 41 may not access to the home base station 10 but access to the macro base station 20 because it is not authorized, for example, although it is located in the indoor area.

With reference to Fig. 1, various interferences occur between the microcell 11 and the macrocell 21 when signals are transmitted and received at the same time in the same frequency band by the home base station 10 and the macro base station 20. As depicted in the dotted line in Fig. 1, in downlink, if the home base station 10 transmits the signal to the home user equipment while the macro base station 20 transmits the signal to the macro user equipment simultaneously, the home user equipment 31 will be interfered by the signal transmitted by the macro base station 20, and

correspondingly, the macro user equipments 41 and 42 will also be interfered by the signal transmitted by the home base station 10, but the macro user equipment 43 is not interfered by the signal because it is far away from the home base station 10. Likewise, in uplink, the interference will also occur
 5 between the microcell 11 and the macrocell 21, which is not elaborated here for brevity.

Fig. 2 shows the flowchart of the method for controlling the interference between the microcell and the macrocell in the home base station of the microcell according to a specific embodiment of the present invention.

10 With reference to Fig. 1, the transmit power of the signal transmitted by the home base station 10 to the home user equipment 31 must be high enough to satisfy certain requirement for Quality of Service (QoS), considering that the home user equipment 31 will be interfered by the macro base station 20. Therefore, the home base station 10 determines a lower limit
 15 for its transmit power so as to guarantee that the QoS of the home user equipment 31 satisfies the predetermined requirement, which will be described in detail below.

With reference to Fig. 2, firstly, in step S201, the home base station 10 obtains the two parameters of (1) the received power $P_{\text{MeNB-HUE}}$ of a signal
 20 received by the home user equipment 31 from the macro base station 20, i.e. the power of the interference caused by the macro base station 20 to the home user equipment 31; (2) the pathloss $PL_{\text{HeNB-HUE}}$ between the home base station 10 and the home user equipment 31. Next, in step S202, the lower limit $P_{\text{tx_low}}$ of the transmit power of the home base station 10 is determined according to
 25 such obtained two parameters and the QoS requirement of the home user equipment 31. For example, when the indicant of the QoS requirement of the home user equipment 31 is the target signal quality, such as target Signal to Interference Ratio (SIR) $\text{SIR}_{\text{target HUE}}$, the lower limit $P_{\text{tx_low}}$ may be determined based on the formula of

$$P_{\text{tx_low}} = P_{\text{MeNB-HUE}} + PL_{\text{HeNB-HUE}} + \text{SIR}_{\text{target HUE}} \quad (5)$$

30 It will be appreciated by the skilled in the art that the QoS requirement may

be indicated by other indicants, such as target Signal to Interference and Noise Ratio (SINR), and so on.

Furthermore, in step S203, the home base station 10 detects whether there is a macro user equipment interfered by itself, i.e., whether there is a victim macro user equipment. Preferably, step S203 may be achieved as follows. Firstly, the home base station 10 measures the received power of a signal transmitted by the macro user equipment, which is also referred to as an Uplink Received Power (ULRP) or a Received Interference Power from the macro user equipment. Next, the received power measured is compared with a predetermined first threshold, and it is decided that there is no victim macro user equipment if the received power measured is less than the first threshold; otherwise, it is decided that there is at least one victim macro user equipment. It will be appreciated by the skilled in the art that the order of steps S201 and S203 is not necessarily the same as that is shown in Fig. 2, and for example, step S203 may be performed prior to step S201.

Further referring to Fig. 2, the home base station 10 sets its transmit power P_{tx} according to the determined lower limit P_{tx_low} in step S204, if there is no victim macro user equipment. It is not necessary for the home base station 10 to consider interference caused to the macro user equipment, because there is no victim macro user equipment, and therefore, the transmit power P_{tx} may be set to be any value greater than or equal to the lower limit P_{tx_low} . Preferably, the transmit power P_{tx} is set to be equal to P_{tx_low} by the home base station 10 in order to reduce any other potential interference. In practice, the transmit power P_{tx} of the home base station 10 is also constrained by the maximum and minimum transmit power values P_{max} and P_{min} . In this case, the transmit power P_{tx} may be set to be equal to a median value among the lower limit P_{tx_low} , the minimum transmit power P_{min} , and the maximum transmit power P_{max} by the home base station 10, i.e.,

$$P_{tx} = \text{median}(P_{tx_low}, P_{min}, P_{max}) \quad (6)$$

If there is at least one victim macro user equipment, the home base station 10 determines an upper limit P_{tx_upp} for its transmit power by the

subsequent steps S205 to S209, and controls the interference to the victim macro user equipment based on the determined lower limit P_{tx_low} and upper limit P_{tx_upp} .

Firstly, in step S205, the home base station 10 obtains two parameters
 5 of (1) the received power $P_{MeNB-MUE}$ of a signal received by the macro user equipment from the macro base station 20; and (2) the pathloss $PL_{HeNB-MUE}$ between the home base station 10 and the macro user equipment. Next, in step S206, the upper limit P_{tx_upp} of the transmit power of the home base station 10 is determined according to the obtained two parameters and the
 10 QoS requirement of the macro user equipment. For example, when the indicant of the QoS requirement of the macro user equipment is target signal quality, such as target Signal to Interference Ratio $SIR_{target\ MUE}$, the lower limit P_{tx_upp} may be determined based on the formula of

$$P_{tx_upp} = P_{MeNB-MUE} + PL_{HeNB-MUE} - SIR_{target\ MUE} \quad (7)$$

Next, in step S207, the home base station 10 compares the determined
 15 lower limit P_{tx_low} with the determined upper limit P_{tx_upp} .

If the determined lower limit P_{tx_low} is greater than the determined upper limit P_{tx_upp} , then it implies that it is impossible to find a transmit power P_{tx} which not only satisfies the QoS requirement of the served home user equipment but also not cause too much interference to satisfy the QoS
 20 requirement of the victim macro user equipment. In other words, the control for the interference can not be achieved by only controlling the transmit power. Then, in step S208, the home base station 10 controls the interference by means of other specific interference control methods. For example, the specific interference control methods may comprise handing over the home
 25 user equipment 31 from the home base station 10 to the macro base station 20, or using the time domain resource division, the frequency domain resource division, or the combination thereof, namely that the home user equipment 31 and the victim macro user equipment receive useful signals on different radio resources.

30 If the determined lower limit P_{tx_low} is less than the determined upper

limit P_{tx_upp} , the home base station 10 sets the transmit power P_{tx} according to the determined lower limit P_{tx_low} and the determined upper limit P_{tx_upp} in step S209. Specifically, the transmit power P_{tx} is set to be any value in the interval of $[P_{tx_low}, P_{tx_upp}]$, which may be expressed as $P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$, where α is a value in the range of $[0, 1]$. The parameter α may be fixed or varies, and it can be generated randomly or be set according to an actual system requirement. As mentioned above, in practice, the transmit power P_{tx} of the home base station 10 is further constrained by the maximum and minimum transmit power values P_{max} and P_{min} . The maximum and minimum transmit power values P_{max} and P_{min} may be constrained by the physical equipment itself and/or specified by the related international specifications. In this case, the transmit power P_{tx} may be set to be a median value among $P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$, P_{min} , and P_{max} by the home base station 10, i.e.,

$$P_{tx} = \text{median}(P_{tx_upp} - \alpha(P_{tx_upp} - P_{tx_low}), P_{min}, P_{max}) \quad (8)$$

Considering that there may be such a case where $P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$ is out of the interval $[P_{min}, P_{max}]$, although at least one value in the interval $[P_{tx_low}, P_{tx_upp}]$ satisfies the constraints defined by the maximum and minimum transmit power values P_{max} and P_{min} , namely falling into the interval $[P_{min}, P_{max}]$. Accordingly, step S209 may be implemented by an alternative manner described by the pseudo-code below.

- if $P_{tx_upp} \leq P_{max}$ and $P_{tx_low} \geq P_{min}$, P_{tx} is set to be $P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$;
- if $P_{min} < P_{tx_upp} \leq P_{max}$ and $P_{tx_low} < P_{min}$, P_{tx_low} is set to be equal to P_{min} , then $P_{tx} = P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$ is set;
- if $P_{tx_upp} \leq P_{min}$, P_{tx} is set to be P_{min} ;
- if $P_{tx_upp} > P_{max}$ and $P_{tx_low} < P_{min}$, P_{tx_low} is set to be equal to P_{min} and P_{tx_upp} is set to be equal to P_{max} , then $P_{tx} = P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$ is set;
- if $P_{tx_upp} > P_{max}$ and $P_{min} \leq P_{tx_low} < P_{max}$, P_{tx_upp} is set to be equal to P_{min} , then $P_{tx} = P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$ is set;

- if $P_{tx_low} \geq P_{max}$, P_{tx} is set to be P_{max} .

It will be noted that the implementation of the alternative manner is not limited to the given pseudo-code. For example, the order among the respective steps may be exchanged arbitrarily, and the other equivalent
 5 implementation would be readily derivable by the skilled in the art.

Several parameters are obtained by the home base station 10 in step S201 and step S205 respectively. How to obtain those parameters will be discussed in detail as follows.

The power $P_{MeNB-HUE}$ of the interference caused by the macro base
 10 station 20 to the home user equipment 31 and the pathloss $PL_{HeNB-HUE}$ between the home base station 10 and the home user equipment 31 are obtained by the home base station 10 in step S201. Preferably, those two parameters can be measured and delivered to the home base station 10 via signaling such as a measurement report by the home user equipment 31.

15 The received power $P_{MeNB-MUE}$ of the signal received by the macro user equipment from the macro base station 20 and the pathloss $PL_{HeNB-MUE}$ between the home base station 10 and the macro user equipment are obtained by the home base station 10 in step S205.

When there is cooperation between the home base station 10 and the
 20 macro base station 20, firstly, the macro user equipment can measure those two parameters and transmits the measured values to the macro base station 20, and then the macro base station 20 transmits the measured values to the home base station 10. For example, the values of the parameters $P_{MeNB-MUE}$ and $PL_{HeNB-MUE}$ can be obtained by the home base station 10 through
 25 signaling from the macro base station 20 via an X2 or S1 interface, if there is an X2/S1 type of real-time connection between the home base station 10 and the macro base station 20. Preferably, the measured values received may be processed accordingly by the macro base station 20 before being transmitted to the home base station 10.

30 Alternatively, those two parameters may be estimated by the home base station 10 directly, which will be depicted in detail below.

As described in Background, the parameter $PL_{\text{HeNB-MUE}}$ may be estimated by means one of the two autonomous evaluation methods shown in formulas (3) and (4).

Similar to formula (3), the parameter $P_{\text{MeNB-MUE}}$ may be estimated on the basis of the formula of

$$P_{\text{MeNB-MUE}} = P_{\text{MeNB-HeNB}} + g \cdot \delta \quad (9)$$

where δ indicates a wall penetration loss whose typical value ranges over 10~30dB; $P_{\text{MeNB-HeNB}}$ indicates the received power of a signal received by the home base station 10 from the macro base station 20; and g is an adjustable non-negative linear scalar.

As shown in Fig. 1, the victim macro user equipment may be located in an indoor area (e.g., macro user equipment 41), and may also be located in an outdoor area (e.g., macro user equipment 42), and in both cases, the corresponding interference scenarios are different from each other. For example, the values of the parameters $PL_{\text{HeNB-MUE}}$ and $P_{\text{MeNB-MUE}}$ are obviously different from each other. However, both cases are not differentiated by the method hereinabove. Thus, it is proposed, in the present invention, a method for improving the control interference, which differentiates the two cases, as shown in Fig. 3.

With reference to Fig. 3, firstly, in step S301, the home base station 10 detects whether there is a macro user equipment interfered by itself, i.e., whether there is a victim macro user equipment; if there is not a victim macro user equipment, in step S303, the interference between the microcell and the macrocell is controlled in accordance with the detection result in step S301; if there is at least one victim macro user equipment, in step S302, it is detected whether at least one victim macro user equipment is located in the indoor area; next, in step S303, the interference between the microcell and the macrocell is controlled in accordance with the detection results in step S301 and step 302. Step S301 is the same as step S203 in Fig. 2, which is not elaborated here for brevity. Step S302 can be implemented as follows.

Firstly, the home base station 10 measures the interference from the macro user equipment, namely the received power $P_{\text{MUE-HeNB}}$ which is also referred to as an uplink received power or the received interference power of the macro user equipment. Next, the difference between the received power $P_{\text{MUE-HeNB}}$ and a predetermined parameter $\text{ULRP}_{\text{outdoor max}}$ is calculated by the home base station 10. Preferably, the parameter $\text{ULRP}_{\text{outdoor max}}$ indicates a maximum possible value of the interference received by the home base station 10 from the macro user equipment located in the outdoor area. Then, the home base station 10 compares the calculated difference with a predetermined second threshold and it is decided that there is no indoor victim macro user equipment, if the calculated received power is less than the second threshold; otherwise, it is decided that there is at least one indoor victim macro user equipment.

Alternatively, since both the parameter $\text{ULRP}_{\text{outdoor max}}$ and the second threshold are predetermined values, the sum of the parameter $\text{ULRP}_{\text{outdoor max}}$ and the second threshold may be regarded as the second threshold, and accordingly, the received power $P_{\text{MUE-HeNB}}$ is compared with such second threshold directly by the home base station 10, such that it is not necessary to calculate the difference between the received power $P_{\text{MUE-HeNB}}$ and the parameter $\text{ULRP}_{\text{outdoor max}}$.

Preferably, the parameter $\text{ULRP}_{\text{outdoor max}}$ and the second threshold can be respectively set as

$$\text{ULRP}_{\text{outdoor, max}} = \Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta) - \delta - \text{PL}_0 \quad (10)$$

and

$$\text{Th} = \Psi(\text{PL}_{\text{MeNB-HeNB}}) - \Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta) + \delta \quad (11)$$

where $\text{PL}_{\text{MeNB-HeNB}}$ indicates the pathloss between the macro base station 20 and the home base station 10; and δ indicates the predetermined wall penetration loss. PL_0 indicates a predetermined pathloss only associated with the distance from the home base station 10 to the edge of the home cell, which, for example, may be estimated to be $38.64 + 20\log(r)$, where r is a

predetermined radius of the indoor site. $\Psi(x)$ is the uplink power control function of the macro base station, indicating that the transmit power is $\Psi(x)$ when the pathloss between the macro base station and the macro user equipment is x .

5 The above method for detecting whether there is at least one indoor victim macro user equipment is based on the consideration that the uplink received power $P_{\text{MUE-HeNB}}$ from an outdoor macro user equipment is much less than that from an indoor victim macro user equipment.

Specifically, based on the uplink power control function $\Psi(x)$ of the
 10 macro base station, the transmit power of the macro user equipment is equal to $\Psi(\text{PL}_{\text{MeNB-MUE}})$ where $\text{PL}_{\text{MeNB-MUE}}$ is the pathloss between the macro base station and the macro user equipment. As mentioned above, the distance between the macro base station 20 and the indoor site 1 is generally much greater than the radius of the microcell covered by the home base station 10, and the victim macro user equipment is generally located within or around the
 15 microcell, and therefore, the distance $D_{\text{MeNB-indoor MUE}}$ or $D_{\text{MeNB-outdoor MUE}}$ between the macro base station to the indoor or outdoor victim macro user equipment may be approximated to be the distance $D_{\text{MeNB-HeNB}}$ between the macro base station to the home base station. In the case where the wall
 20 penetration loss δ is taken into account, the pathloss $\text{PL}_{\text{MeNB-indoor MUE}}$ between the macro base station and the indoor victim macro user equipment is approximated to be the pathloss $\text{PL}_{\text{MeNB-HeNB}}$ between the macro base station and the home base station, while the pathloss $\text{PL}_{\text{MeNB-outdoor MUE}}$ between the macro base station and the outdoor victim macro user equipment is
 25 approximated to be $\text{PL}_{\text{MeNB-HeNB}} - \delta$. Therefore, the transmit power $P_{\text{indoor MUE}}$ of the indoor victim macro user equipment can be approximated to be $\Psi(\text{PL}_{\text{MeNB-HeNB}})$, whilst the transmit power $P_{\text{outdoor MUE}}$ of the outdoor victim macro user equipment can be approximated to be $\Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta)$.

Furthermore, a minimum possible value $\text{ULRP}_{\text{indoor,min}}$ of the uplink
 30 received power $P_{\text{indoor MUE-HeNB}}$ from the indoor victim macro user equipment should be that from the indoor macro user equipment just adjacent to the wall,

and thus it can be estimated as:

$$\text{ULRP}_{\text{indoor, min}} = \Psi(\text{PL}_{\text{MeNB-HeNB}}) - \text{PL}_0 \quad (12)$$

Likewise, a maximum possible value $\text{ULRP}_{\text{outdoor, max}}$ of the uplink received power $P_{\text{outdoor MUE-HeNB}}$ from the outdoor victim macro user equipment should be that from the outdoor macro user equipment just adjacent to the wall, and thus it can be estimated as:

$$\text{ULRP}_{\text{outdoor, max}} = \Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta) - \delta - \text{PL}_0 \quad (13)$$

Thereby, if there is an indoor victim macro user equipment, the uplink received power $P_{\text{MUE-HeNB}}$ from victim macro user equipment(s) should be greater than $\text{ULRP}_{\text{outdoor, max}}$ by at least $\text{ULRP}_{\text{indoor, min}} - \text{ULRP}_{\text{outdoor, max}}$, where $\text{ULRP}_{\text{indoor, min}} - \text{ULRP}_{\text{outdoor, max}} = \Psi(\text{PL}_{\text{MeNB-HeNB}}) - \Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta) + \delta$ (14)

In other words, it can be decided that there is at least one indoor victim macro user equipment, when a difference between the uplink received power $P_{\text{MUE-HeNB}}$ from the victim macro user equipment and the $\text{ULRP}_{\text{outdoor, max}}$ is greater than or equal to $\text{ULRP}_{\text{indoor, min}} - \text{ULRP}_{\text{outdoor, max}}$.

In practice, the uplink transmit power function $\Psi(x)$ may be, for example, defined as:

$$\Psi(x) = P_0 + \varepsilon \cdot x \quad (15)$$

where the parameter P_0 and the linear scalar ε are predetermined parameters which are identical for all user equipments, and ε is generally in the interval of $[0, 1]$, preferably, in the interval of $[0.4, 0.9]$. Accordingly, the second threshold Th may be expressed as:

$$\begin{aligned} \text{Th} &= \Psi(\text{PL}_{\text{MeNB-HeNB}}) - \Psi(\text{PL}_{\text{MeNB-HeNB}} - \delta) + \delta \\ &= (1 + \varepsilon) \cdot \delta \end{aligned} \quad (16)$$

It is noted that the uplink received power $P_{\text{MUE-HeNB}}$ from the macro user equipment measured by the home base station may also be an accumulation of the uplink received power from a plurality of macro user equipments. Therefore, when there is no indoor victim macro user equipment but there is a large number of outdoor victim macro user equipments, the difference between $P_{\text{MUE-HeNB}}$ and $\text{ULRP}_{\text{outdoor, max}}$ may possibly exceed the second threshold, thereby resulting in a misjudgment. However, it is rare in

practice that there is such large number of outdoor macro user equipments, and the possibility of the misjudgment is thus very low.

Step S303 is explained in detail below. In step S303, the interference between the microcell and the macrocell is controlled by the home base station 10 according to the detection result in step S302. For example, the interference may be controlled by the home base station 10 by utilizing the method as shown in Fig. 2. In particular, the estimation for the parameters $PL_{\text{HeNB-MUE}}$ and $P_{\text{MeNB-MUE}}$ in step S205 of Fig. 2 can be improved by utilizing the detection result in step S302. Improvements for the estimation method for the parameters $PL_{\text{HeNB-MUE}}$ and $P_{\text{MeNB-MUE}}$ will be depicted one by one hereinafter.

An improvement for the first autonomous method of estimating $PL_{\text{HeNB-MUE}}$

As introduced in Background, it is proposed in 3GPP TR 36.921 that the parameter $PL_{\text{HeNB-MUE}}$ may be estimated on the basis of the formula of

$$PL_{\text{HeNB-MUE}} = PL_0 + k \cdot \delta \quad (17)$$

It is indicated, in 3GPP TR 36.921, that k is an adjustable non-negative linear scalar which can be determined by the priority of the home base station's operation, but how to determine is not specified. As mentioned above, as compared to the outdoor victim macro user equipment the pathloss between the home base station and the indoor macro user equipment is low. Therefore, k is set to be k1 when the detection result in step S302 is that there is at least one indoor victim macro user equipment, and k is set to be k2 when the detection result is that there is no indoor victim macro user equipment, where k1 and k2 are predetermined values and k1 is less than k2. For example, k1 and k2 may be set to be 0 and 1, respectively.

An improvement for the second autonomous method of estimating $PL_{\text{HeNB-MUE}}$

As introduced in Background, it is proposed, in 3GPP TR 36.921, that the parameter $PL_{\text{HeNB-MUE}}$ may also be estimated on the basis of the formula of

$$\begin{aligned} \text{PL}_{\text{HeNB-MUE}} &= \Psi(\text{PL}_{\text{MeNB-MUE}}) - P_{\text{MUE-HeNB}} \\ &\approx \Psi(\text{PL}_{\text{MeNB-HeNB}}) - P_{\text{MUE-HeNB}} \end{aligned} \quad (18)$$

However, it is not optimal that the pathloss $\text{PL}_{\text{MeNB-MUE}}$ between the macro base station and the victim macro user equipment is approximated to be the pathloss $\text{PL}_{\text{MeNB-HeNB}}$ between the macro base station and the home base station without any differentiation. Therefore, it is proposed in the present invention that the parameter $\text{PL}_{\text{HeNB-MUE}}$ is estimated on the basis of the formula of

$$\text{PL}_{\text{HeNB-MUE}} = \Psi(\text{PL}_{\text{MeNB-HeNB}} - h \cdot \delta) - P_{\text{MUE-HeNB}} \quad (19)$$

where h is a value within a range of $[0, 1]$ and is dependent on the detection result in step S302. Compared with the outdoor victim macro user equipment, the pathloss between the macro base station and the indoor macro user equipment is great. Therefore, h is set to be h_1 when the detection result is that there is at least one indoor victim macro user equipment, and h is set to be h_2 when the detection result is that there is no indoor victim macro user equipment, where h_1 and h_2 are predetermined values and h_1 is greater than h_2 . For example, h_1 and h_2 may be set to be 1 and 0, respectively.

An improvement for the autonomous method of estimating $P_{\text{MeNB-MUE}}$

As mentioned above, the parameter $P_{\text{HeNB-MUE}}$ may be estimated on the basis of the formula of

$$P_{\text{MeNB-MUE}} = P_{\text{MeNB-HeNB}} + g \cdot \delta \quad (20)$$

where g is an adjustable non-negative linear scalar. No specific criteria for determining the parameter g is given hereinabove. Considering that compared with the outdoor victim macro user equipment, the received power received by the indoor macro user equipment from the macro base station is low, the method is improved as: g is set to be g_1 when the detection result in step S302 is that there is at least one indoor victim macro user equipment, and g is set to be g_2 when the detection result is that there is no indoor victim macro user equipment, where g_1 and g_2 are the predetermined values, and g_1 is less than g_2 . For example, g_1 and g_2 may be set to be 0 and 1, respectively.

It is necessary to state that it is appreciated by the skilled in the art

that the solution for controlling the interference between the microcell and the macrocell proposed in the present invention is also suitable for other similar communication network systems, although only 3GPP system is taken as an example for illustration hereinabove.

5 For the skilled in the art, it is apparent that the present invention is not limited to the details of the above illustration embodiment, and the present invention can be implemented by other specific implementations without departing from the spirit or elementary feature of the present invention. Therefore, the embodiments should be regarded as the illustration instead of
10 the limitation regardless any aspects, and the range of the present invention is defined by the appended claims instead of the description hereinabove, thus it is directed that all variants falling into (or falling on the basis of the equal principle into) the range of the claims are inclusive of the present invention. Any indices of the drawings in the claims should not be construed to limit the
15 involved claims. In addition, significantly, the words "comprising" and "comprises" are not exclusive of other units and steps, and the singulars are not exclusive of the plurals. A plurality of units or apparatuses cited in the system claims may also be implemented by a unit or an apparatus through the software or the hardware. The words "first" and "second" and so on are used
20 to indicate the names, and not to indicate any specific order.

CLAIMS

1. A method for controlling interference between a microcell and a macrocell in a first base station (HeNB) within the microcell, comprising the steps of:

A. obtaining the parameters of

- a first received power ($P_{\text{MeNB-HUE}}$) of a signal received by a first user equipment (HUE) served by the microcell from a second base station (MeNB) within the macrocell,

- a first pathloss ($PL_{\text{HeNB-HUE}}$) between the first base station and the first user equipment,

B. determining a lower limit ($P_{\text{tx_low}}$) of a transmit power (P_{tx}) of the first base station according to the obtained first received power ($P_{\text{MeNB-HUE}}$), the obtained first pathloss ($PL_{\text{HeNB-HUE}}$), and a target signal quality of the first user equipment ($SIR_{\text{target HUE}}$); and

C. controlling the interference according to the determined lower limit ($P_{\text{tx_low}}$).

2. The method according to claim 1, wherein the method further comprises the steps of

- detecting whether there is a second user equipment (MUE) served by the macrocell and interfered by the first base station; and

- the transmit power (P_{tx}) is set to be equal to a median value among the lower limit ($P_{\text{tx_low}}$), a predetermined minimum transmit power (P_{min}) of the first base station, and a predetermined maximum transmit power (P_{max}) of the first base station in the step C, if there is no second user equipment served by the macrocell and interfered by the first base station.

3. The method according to claim 1, wherein the method further comprises the steps of

- determining whether there is a second user equipment served by the

macrocell and interfered by the first base station;

- if there is at least one second user equipment (MUE) served by the macrocell and interfered by the first base station, then

the step A further comprises obtaining the parameters of

5 - a second received power ($P_{\text{MeNB-MUE}}$) of a signal received by the second user equipment from the second base station, and

- a second pathloss ($PL_{\text{HeNB-MUE}}$) between the first base station and the second user equipment; and

the step B further comprises:

10 - determining an upper limit ($P_{\text{tx_upp}}$) of the transmit power (P_{tx}) according to the obtained second received power ($P_{\text{MeNB-MUE}}$), the obtained second pathloss ($PL_{\text{HeNB-MUE}}$), and a target signal quality ($\text{SIR}_{\text{target MUE}}$) of the second user equipment; and

controlling the interference according to the lower limit ($P_{\text{tx_low}}$) and the
15 upper limit ($P_{\text{tx_upp}}$) in the step C.

4. The method according to claim 3, wherein the step C further comprises:

- comparing the lower limit ($P_{\text{tx_low}}$) with the upper limit ($P_{\text{tx_upp}}$);

20 - controlling the interference by means of a specific interference control method if the lower limit ($P_{\text{tx_low}}$) is greater than the upper limit ($P_{\text{tx_upp}}$), wherein the specific interference control method comprises at least one of

- handing over the first user equipment to the second base station; and

- utilizing a time domain resource division, a frequency domain resource division, or a combination thereof.

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5. The method according to claim 3, wherein the step C further comprises:

- determining the transmit power (P_{tx}) to be a median value among $P_{\text{tx_upp}}$
- $\alpha (P_{\text{tx_upp}} - P_{\text{tx_low}})$, a predetermined minimum transmit power (P_{min}) of the first base station, and a predetermined maximum transmit power (P_{max}) of the
30 first base station, if the lower limit ($P_{\text{tx_low}}$) is less than or equal to the upper limit ($P_{\text{tx_upp}}$), where $P_{\text{tx_upp}}$ indicates the upper limit, $P_{\text{tx_low}}$ indicates the

lower limit, α is a predetermined value within a range of $[0, 1]$.

6. The method according to claim 3, wherein the step C further comprises:

- if the lower limit (P_{tx_low}) is less than or equal to the upper limit (P_{tx_upp}),

5 determining the transmit power (P_{tx}) as follows:

- if the lower limit (P_{tx_low}) is greater than or equal to a predetermined maximum transmit power (P_{max}) of the first base station, setting the transmit power (P_{tx}) to be equal to the maximum transmit power (P_{max});;

10 - if the upper limit (P_{tx_upp}) is less than or equal to a predetermined minimum transmit power (P_{min}) of the first base station, setting the transmit power (P_{tx}) to be equal to the minimum transmit power (P_{min}); and

15 - if the lower limit (P_{tx_low}) is less than the maximum transmit power (P_{max}), and the upper limit (P_{tx_upp}) is greater than a minimum transmit power (P_{min}), performing the steps of

i. setting the lower limit (P_{tx_low}) to be the minimum transmit power (P_{min}), if the lower limit (P_{tx_low}) is less than the minimum transmit power (P_{min});

20 ii. setting the upper limit (P_{tx_upp}) to be the maximum transmit power (P_{max}), if the upper limit (P_{tx_upp}) is greater than the maximum transmit power (P_{max}); and

25 iii. setting the transmit power (P_{tx}) to be equal to $P_{tx_upp} - \alpha (P_{tx_upp} - P_{tx_low})$, where P_{tx_upp} indicates the upper limit, P_{tx_low} indicates the lower limit, and α is a predetermined value within a range of $[0, 1]$.

7. The method according to claim 3, wherein the step A further comprises:

30 - receiving, by the first base station, a first message from the second base station, the first message including information indicating the second received power ($P_{MeNB-MUE}$) and information indicating the second pathloss

($PL_{\text{HeNB-MUE}}$); and

- determining the second received power ($P_{\text{MeNB-MUE}}$) and the second pathloss ($PL_{\text{HeNB-MUE}}$) according to the first message.

5 8. The method according to claim 3, wherein the step A further comprises:

I. determining the second received power ($P_{\text{MeNB-MUE}}$) according a third received power ($P_{\text{MeNB-HeNB}}$) of a signal received by the first base station from the second base station and a wall penetration loss (δ); and

10 II. determining the second pathloss ($PL_{\text{HeNB-MUE}}$) by means of one of two methods as follows:

(1) according to a pathloss (PL_0) in an indoor area and the wall penetration loss (δ), or

(2) according to a transmit power (P_{MUE}) of a signal from the second user equipment which is estimated on the basis of a third pathloss ($PL_{\text{MeNB-HeNB}}$)
15 between the second base station and the first base station and the wall penetration loss (δ), and according to a fourth received power ($P_{\text{MUE-HeNB}}$) of the signal from the second user equipment received by the first base station.

9. The method according to claim 8, wherein:

20 the step A further comprises:

- detecting whether at least one second user equipment is located in the indoor area;

the step I further comprises:

- determining the second received power ($P_{\text{MeNB-MUE}}$) according to the
25 detection result, the third received power ($P_{\text{MeNB-HeNB}}$), and the wall penetration loss (δ), and

the step II further comprises:

- determining the second pathloss ($PL_{\text{HeNB-MUE}}$) by means of one of two methods as follows:

30 (1) according to the detection result, the pathloss (PL_0) in the indoor area, and the wall penetration loss (δ), or

(2) according to the detection result, the estimated transmit power (P_{MUE}) of the signal from the second user equipment, and the fourth received power ($P_{\text{MUE-HeNB}}$).

10. The method according to claim 9, wherein:

the step I further comprises:

- determining the second received power ($P_{\text{MeNB-MUE}}$) based on the formula of

$$P_{\text{MeNB-MUE}} = P_{\text{MeNB-HeNB}} + g \cdot \delta ,$$

where $P_{\text{MeNB-MUE}}$ indicates the second received power, $P_{\text{MeNB-HeNB}}$ indicates the third received power, δ indicates the wall penetration loss, and g is a value within a range of [0, 1] and is dependent on the detection result; and

the step II further comprises:

- determining the second pathloss ($PL_{\text{HeNB-MUE}}$) by means of one of two methods as follows:

(1) based on the formula of

$$PL_{\text{HeNB-MUE}} = PL_0 + k \cdot \delta ,$$

where $PL_{\text{HeNB-MUE}}$ indicates the second pathloss, PL_0 indicates the pathloss in the indoor area, δ indicates the wall penetration loss, and k is a value within a range of [0, 1] and is dependent on the detection result; or

(2) based on the formula of

$$PL_{\text{HeNB-MUE}} = P_{\text{MUE}} - P_{\text{MUE-HeNB}} , \text{ where } P_{\text{MUE}} = \Psi(PL_{\text{MeNB-HeNB}} - h \cdot \delta)$$

where $PL_{\text{HeNB-MUE}}$ indicates the second pathloss, P_{MUE} indicates the estimated transmit power of the signal from the second user equipment, $P_{\text{MUE-HeNB}}$ indicates the fourth received power, $PL_{\text{MeNB-HeNB}}$ indicates the third pathloss, δ indicates the wall penetration loss, h is a value within a range of [0, 1] and is dependent of the detection result, and $\Psi(x)$ indicates an uplink power control function of the second base station, which indicates a transmit power of the second user equipment when a pathloss between the second base station and the second user equipment is x .

11. The method according to claim 9, wherein detecting whether at least one second user equipment is located in the indoor area comprising:

- comparing the fourth received power ($P_{\text{MUE-HeNB}}$) or a derived quantity thereof with a predetermined second threshold; and

- the detection result is that at least one second user equipment is located in the indoor area, if the fourth received power ($P_{\text{MUE-HeNB}}$) or the derived quantity thereof is greater than or equal to the second threshold, otherwise the detection result is that no such second user equipment is located in the indoor area.

12. The method according to claim 11, wherein the second threshold is dependent on the uplink power control function ($\Psi(x)$) of the second base station, the third pathloss ($PL_{\text{MeNB-HeNB}}$), and the wall penetration loss (δ).

13. An apparatus for controlling interference between a microcell and a macrocell in a first base station within the microcell, comprising:

- a first obtaining module for obtaining the parameters of a first received power ($P_{\text{MeNB-HUE}}$) of a signal received by a first user equipment served by the microcell from a second base station within the macrocell,

- a first pathloss ($PL_{\text{HeNB-HUE}}$) between the first base station and the first user equipment,

- a first determining module for determining a lower limit ($P_{\text{tx_low}}$) of a transmit power of the first base station according to the obtained first received power ($P_{\text{MeNB-HUE}}$), the obtained first pathloss ($PL_{\text{HeNB-HUE}}$), and a target signal quality of the first user equipment ($SIR_{\text{target HUE}}$); and

- a first controlling module for controlling the interference according to the determined lower limit ($P_{\text{tx_low}}$).

14. A method for controlling interference between a microcell and a

macrocell in a first base station within the microcell, wherein the first base station is located in an indoor area, a second base station within the macrocell is located in an outdoor area, and the method comprising the steps of

- a. detecting whether there is a second user equipment served by the macrocell and interfered by the first base station;
- b. detecting whether at least one second user equipment is located in the indoor area if there is the second user equipment; and
- c. controlling the interference according to the detection result.

15. The method according to claim 14, wherein the step b further comprises:

- comparing a fourth received power ($P_{\text{MUE-HeNB}}$) of a signal received by the first base station from the second user equipment or a derived quantity thereof with a predetermined second threshold; and

- the detection result is that at least one second user equipment is located in the indoor area, if the fourth received power ($P_{\text{MUE-HeNB}}$) or the derived quantity thereof is greater than or equal to the second threshold, otherwise the detection result is that no such second user equipment is located in the indoor area.

16. The method according to claim 14, wherein the step c further comprises: determining a transmit power of the first base station according to a second pathloss ($PL_{\text{HeNB-MUE}}$) between the first base station and the second user equipment of the second base station, and a third received power ($P_{\text{MeNB-HeNB}}$) of a signal from the second base station to the second user equipment of the first base station received by the first base station so as to controlling the interference by controlling the transmit power, wherein the second pathloss ($PL_{\text{HeNB-MUE}}$) is determined by means of one of two methods as follows:

(1) based on the formula of

$$PL_{\text{HeNB-MUE}} = PL_0 + k \cdot \delta ,$$

where $PL_{\text{HeNB-MUE}}$ indicates the second pathloss, PL_0 indicates a pathloss in the indoor area, δ indicates a wall penetration loss, and k is a value within a range of $[0, 1]$ and is dependent on the detection result; or

(2) based on the formula of

$$5 \quad PL_{\text{HeNB-MUE}} = \Psi(PL_{\text{MeNB-HeNB}} - h \cdot \delta) - P_{\text{MUE-HeNB}},$$

where $PL_{\text{HeNB-MUE}}$ indicates the second pathloss, $PL_{\text{MeNB-HeNB}}$ indicates the third pathloss, δ indicates the wall penetration loss, h is a value within a range of $[0, 1]$ and is dependent on the detection result, $\Psi(x)$ indicates an uplink power control function of the second base station, which indicates a transmit power of the second user equipment when a pathloss between the second base station and the second user equipment is x , and $P_{\text{MUE-HeNB}}$ indicates the fourth received power.

17. An apparatus for controlling interference between a microcell and a macrocell in a first base station within the microcell, wherein the first base station is located in an indoor area, a second base station within the macrocell is located in the outdoor area, and the apparatus comprising

- a first detecting module for detecting whether there is a second user equipment served by the macrocell and interfered by the first base station;
- 20 - a second detecting module for detecting whether at least one second user equipment is located in the indoor area when there is the second user equipment; and
- a second controlling module for controlling the interference according to the detection result.

25

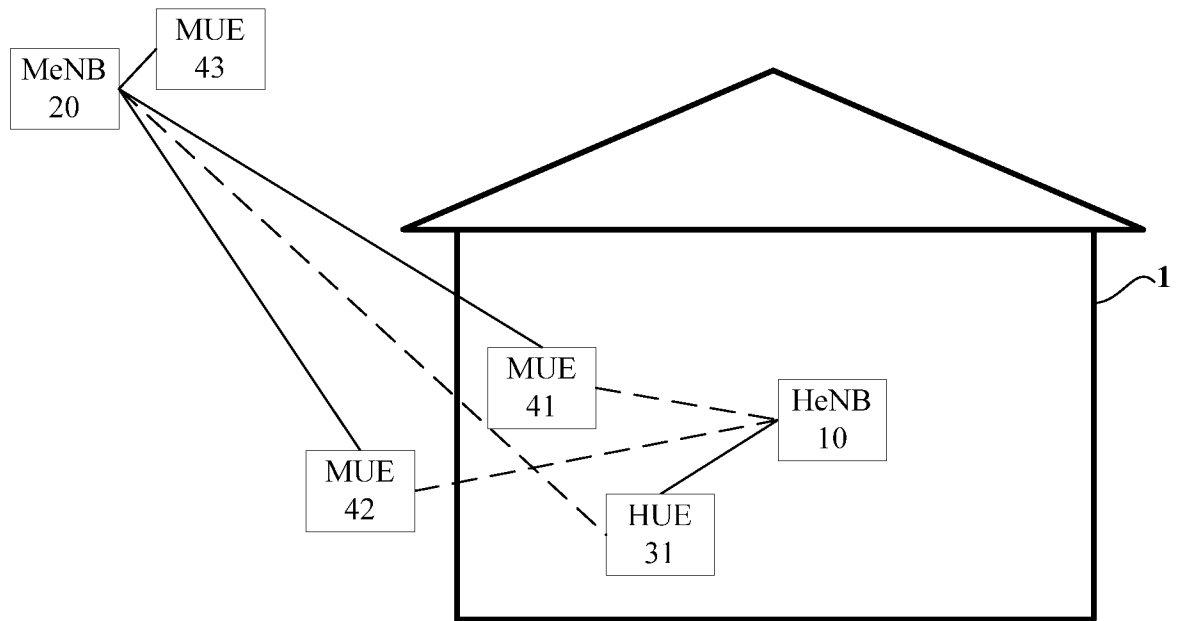


Fig.1

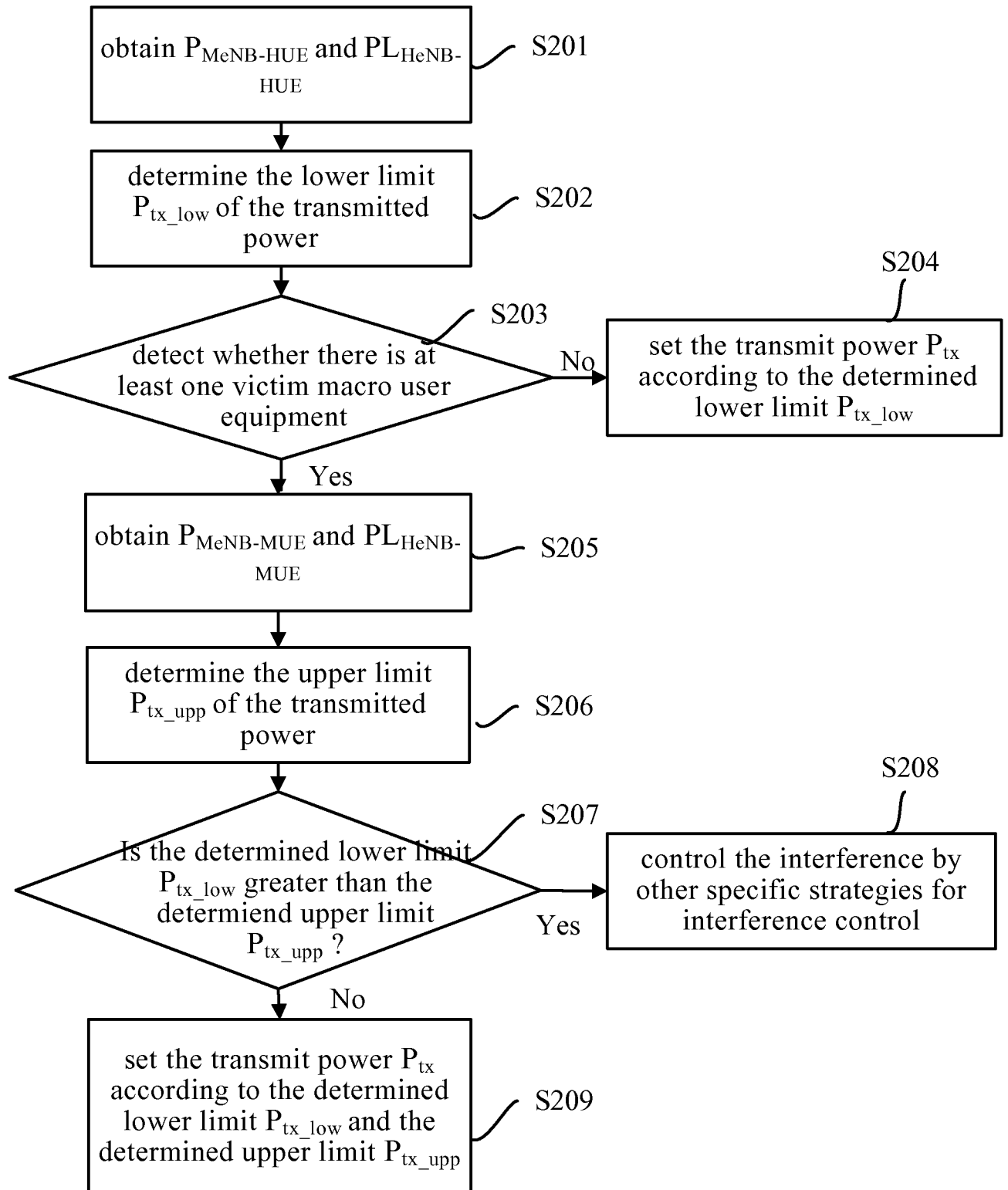


Fig.2

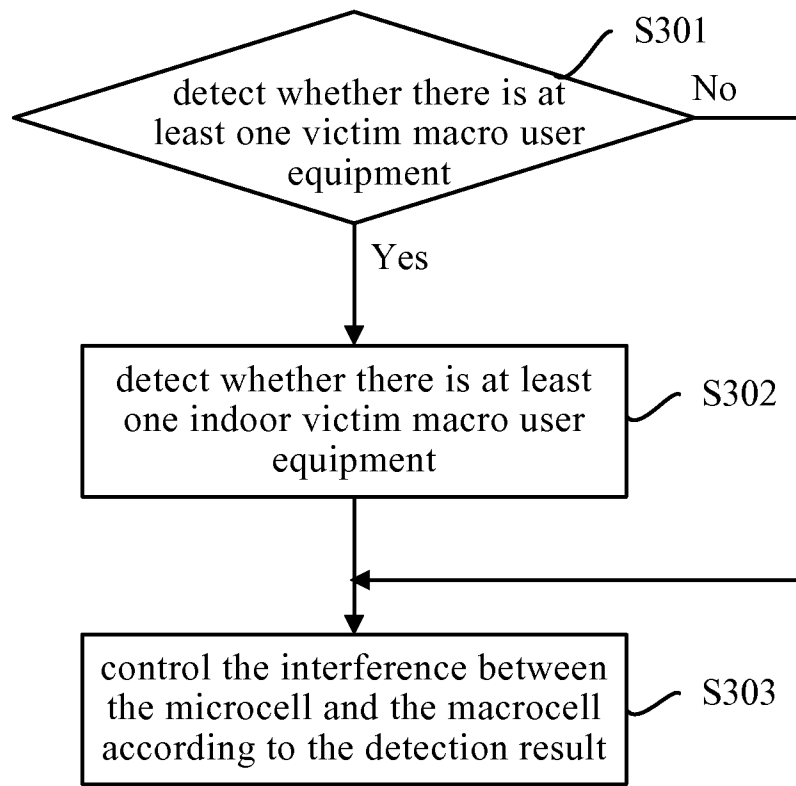


Fig.3