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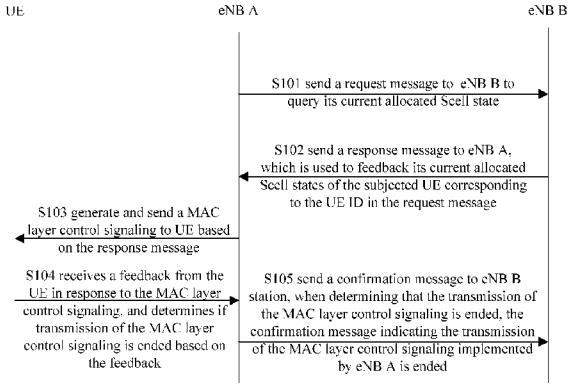

Fig.1

(57) Abstract: The invention provides a method, in a first base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the first base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising: sending a request message to other base stations, when the first base station will change a state of a secondary cell allocated to a user equipment by the first base station, the request message at least including ID of the user equipment; receiving a response message from the other stations, the response message at least including the ID of the user equipment, an index of a secondary cell allocated to the user equipment by the other base station, and a state of a secondary cell corresponding to the index; and generating and sending a MAC layer control signaling to the user equipment based on the response message, wherein the MAC layer control signaling indicating states of all secondary cells allocated to the user equipment.

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Method of Supporting Dual Connectivity in a Carrier Aggregation Based Communication System

Field of the invention

The present disclosure relates to communication technology and particularly to a method of supporting dual connectivity in a carrier aggregation based communication system.

Background of the invention

According to current state, the new R12 study item (SI: RP-121800)) on Small cell enhancement-high layer is being addressed in RAN2. One important objective of this SI is on "dual connectivity" feature supporting. For this feature, a user equipment (UE) will connect to at least two distributed base stations, which are connected by non-ideal backhaul.

To support dual connectivity, one possible solution is based on the frame of carrier aggregation. One potential scenario is a Macro cell and small cell(s) overlapped scenario which is regarded and proposed as higher priority for SCE SI study. According to the concept of carrier aggregation, the Macro cell is used as primary cell (Pcell) and the small cell is used as secondary cell (Scell). When UE enters or leaves small cell coverage, small cell can be allocated or released as Scell. The main benefit is decreased HO procedure due to no Pcell change when UE is in Macro cell coverage. And UE entering or leaving small cell is just treated by Scell adding or releasing operation. In sum, the primary base station and the secondary base station could control multiple carriers respectively. For example, the primary base station serves one primary cell, and/or zero or one or more secondary cells, and the secondary base station serves zero or one or more secondary cells.

According to the concept of carrier aggregation, there are two states

for Scell which is activated or de-activated. The former permits the data transmission on the Scell and for the later, no transmission will occur until it is activated once again. In R10/R11, activate/de-activate a Scell is set by a MAC layer control signaling and how to determine the state of a Scell is a totally eNB implementation issue. In general speaking, to activate/de-activate a Scell, multiple factors can be taken into account, such as radio situation, buffer state, Scell traffic load situation and etc. Considering dual connectivity scenario, after a secondary base station's Scell is added, the secondary base station can coarsely estimate its radio condition by UE's CQI feedback. And related UE's buffer state and subject Scell's traffic load situation are also available at the secondary base station. Hence it is reasonable to assume that the secondary base station (eNB_S) will be responsible to activate/de-activate its own Scell. Similarly, it is reasonable to assume the primary base station (eNB_M) will be responsible to activate/de-activate its own Scells. That is, eNB_S and eNB_M may be only clear on its own Scell's state but not know the state of others. According to R10 defined Scell activation/de-activation MAC layer control signaling, one byte (8 bits) is covered in the payload part which indicates the states of all current allocated Scell. And UE will read all bits in this MAC layer signaling to check the state of each currently allocated Scell. While in R12 when dual connectivity is supported, two distributed eNBs maybe only know its own allocated Scells' state. This will bring troubles for Scell activate/de-activate MAC layer signaling generation and transmission.

Summary of the invention

In view of this, according to a first aspect of the invention, there is proposed a method, in a first base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the first base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method

comprising:- sending a request message to other base stations, when the first base station will change a state of a secondary cell allocated to a user equipment by the first base station, the request message at least including ID of the user equipment;- receiving a response message from the other stations, the response message at least including the ID of the user equipment, an index of a secondary cell allocated to the user equipment by the other base station, and a state of a secondary cell corresponding to the index; and- generating and sending a MAC layer control signaling to the user equipment based on the response message, wherein the MAC layer control signaling indicating states of all secondary cells allocated to the user equipment.

Further, there is proposed a method, in a second base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the second base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising:- receiving a request message from a first base station, the request message at least including ID of a user equipment; and- sending a response message to the first base station based on the request message, the response message at least including the ID of the user equipment, an index of a secondary cell allocated to the user equipment by the secondary base station, and a state of a secondary cell corresponding to the index.

According to a second aspect of the invention, there is proposed a method, in a primary base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system the primary base station serves one primary cell and/or one or more secondary cells, and a secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:- generating and sending a first MAC layer control signaling to a user equipment, when the primary base station will change a state of a

secondary cell allocated to the user equipment by the primary base station, wherein the first MAC layer control signaling indicates that states of secondary cells allocated to the user equipment by the secondary base station are all in the activated state, and the first MAC layer control signaling further indicates state of the secondary cell allocated to the user equipment by the primary base station; or the method comprising the following steps:- receiving an indication message from the secondary base station, the indication message indicating the primary base station to send a second MAC layer control signaling including state of secondary cell allocated to the user equipment by the secondary base station to the user equipment, wherein the indication message at least including ID of the user equipment, an index of the secondary cell allocated to the user equipment by the secondary base station, and a state of the secondary cell corresponding to the index; and- generating and sending a second MAC layer control signaling to the user equipment based on the indication message, wherein the second MAC layer control signaling indicating states of all secondary cells allocated to the user equipment.

Further, there is proposed a method, in a secondary base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps: when the secondary base station will change a state of a secondary cell allocated to a user equipment by the secondary base station, generating and sending a MAC layer control signaling to the user equipment, if at least one secondary cell of secondary cells allocated to the user equipment by the secondary base station is in the activated state, wherein the MAC layer control signaling only indicates states of the secondary cells allocated to the user equipment by the secondary base station; sending an indication message to the primary

base station to make the primary base station send a MAC layer control signaling including states of secondary cells allocated to the user equipment by the secondary base station to the user equipment, if all secondary cells allocated to the user equipment by the secondary base station are in the de-activated state currently, wherein the indication message at least including ID of the user equipment, an index of the secondary cell allocated to the user equipment by the secondary base station, and a state of the secondary cell corresponding to the index.

Further, there is proposed a method, in a user equipment, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:- reading a MAC control signaling based on whether at least one secondary cell of secondary cells allocated to the user equipment by the secondary base station is in the activated state, the MAC control signaling indicating states of the secondary cells allocated to the user equipment.

According to a third aspect of the invention, there is proposed a method, in a first base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the first base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising: - setting indication bits in a MAC layer control signaling, which indicates a user equipment to read states of all secondary cells allocated to the user equipment in the MAC layer control signaling, or indicates the user equipment to only read states of secondary cells allocated to the user equipment by the first base station in the MAC layer control signaling; and- sending the MAC layer control signaling to the user equipment.

Further, there is proposed a method, in a user equipment, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a base station includes a primary secondary station and a secondary base station, the primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:- reading states of secondary cells allocated to the user equipment in a MAC layer control signaling based on indication bits in the MAC layer control signaling received from the primary base station or the secondary base station, wherein the indication bits indicates the user equipment to read states of all the secondary cells allocated to the user equipment in the MAC layer control signaling, or indicates the user equipment to only read states of secondary cells allocated to the user equipment by a base station which sends the MAC layer control signaling.

The respective aspects of the invention will become more apparent from the following description of particular embodiments.

Brief description of drawings

Other features, objects and advantages of the invention will become more apparent upon review of the following detailed description of non-limiting embodiments taken with reference to the drawings in which:

Fig.1 illustrates a flow chart of a method of supporting dual connectivity according to a first embodiment of the present invention;

Fig.2 illustrates a flow chart of a method of supporting dual connectivity according to a second embodiment of the present invention;

Fig.3 illustrates a flow chart of a method of supporting dual connectivity according to a third embodiment of the present invention;

Fig.4 illustrates a flow chart of a method of supporting dual connectivity according to a fourth embodiment of the present invention;

Fig.5 illustrates a format of a MAC layer control signaling according to one embodiment of the present invention; and

Fig. 6 illustrates a flow chart of a method of supporting dual connectivity according to a fifth embodiment of the present invention.

In the drawings, identical or like reference numerals denote identical or corresponding components or features throughout the different figures.

Detailed description of embodiments

In the present invention, it is provided three new handshaking rules between primary and secondary cell base stations to enable R10/R11 defined MAC control signaling format application in R12 SCE

Type1: new X2 signaling to enable requesting eNB to send indication to requested eNB to query Scell's state information, which should include ID of UE.

Type2: new X2 signaling to enable requested eNB to forward related Scells' state information to requsting eNB, which should carry at least the ID of UE, an index of a secondary cell allocated to the user equipment and a state of a secondary cell corresponding to the index.

Type3: new X2 signaling to indicate the transmission of the MAC layer signaling implemented by the requesting eNB is ended.

Besides, in the present invention, it is provided two new schemes to realize the MAC layer control signaling for indicating the state of the secondary cell.

Scheme 1: implicit solution based on new eNB and UE behavior.

Scheme 2: explicit solution by including indication bits in the MAC layer control signaling to guide UE behavior.

Lastly, in order to implement scheme 1 and scheme 2, two technologies are provided:

1. For scheme 1, new rule on eNB and UE are proposed.

2. For scheme 2, the "R" bit in MAC layer signaling (MAC CE) is redefined to guide UE how to read the MAC layer signaling payload.

As mentioned above, in R12 when dual connectivity is supported, it is reasonable to assume eNB_M and eNB_S will control its own Scells' activation/de-activation operation. This will lead to situation that each eNB only knows its own allocated Scell's state. Hence it is a problem about how to generate the related activated/de-activated MAC layer signaling, which should cover all Scells state information in one MAC layer signaling based on R10/R11 definition.

Another issue is how to send down MAC layer control signaling to UE in R12 situation. In R10/R11, there is no limitation on where to send down the activation/de-activation MAC layer control signaling to UE. That is, this MAC layer control signaling can be sent on either Pcell or any activated Scell. In R10, this MAC layer control signaling includes all current allocated Scell states. UE will check all bits in this MAC layer control signaling to know the state of each current allocated Scell.

In R12, it is reasonable that the MAC layer control signaling to activate/de-activate eNB_M's Scell will be sent on eNB_M due to Pcell is always activated. While regarding eNB_S's Scell state information transmission, it can be sent on either by eNB_M or eNB_S. The former refers to situation that there is no activated eNB_S Scell or no DL grant even activated eNB_S Scell is available. For the later, there is at least one activated Scell and Dl grant is available.

Based on above discussion, regarding R12 Scell activation/de-activation MAC control signaling content, two potential options are proposed as below:

Option 1: R10 MAC CE definition is reused, in which all allocated Scells of eNB_M and eNB_S are included in one MAC control signaling, but a new procedure/X2 signaling is defined to enable the handshaking between eNB_M and eNB_S.

Option 2: Scells' states allocated by each eNBs are separately transmitted to UE, which means one MAC control signaling E will only include state information of Scells belonging to a sending base station.

New behavior for both of eNB and UE should be defined to enable this option.

In the following, option 1 would be discussed at first.

For option 1, one MAC layer control signaling should contain all current allocated Scell's states as R10 defined. And as above mentioned, eNB_M /eNB_S may only know its own Scell states. When one base station (requesting base station: either of eNB_M or eNB_S) wants to change its allocated Scell state, it should shake hands with another one (requested base station: either eNB_S or eNB_M) to know his allocated Scell states so that the generated MAC layer control signaling will include all current allocated Scell states. To enable this option, a new X2 signaling should be designed to support the shaking hands between base stations, which is not supported in R11.

This new X2 signaling (requesting X2 signaling) should include at least UE ID so that requested base station knows which UE's Scell states should be forwarded back to requesting base station. And in response, requested eNB should indicate the related Scells' state information back to requesting eNB by a new X2 message, which should include at least the ID of UE, an index of a secondary cell allocated to the user equipment by the requested eNB and a state of a secondary cell corresponding to the index.

Additionally, to enable option 1, it should be set that the requested base station is forbid to the further potential activated/de-activated MAC control signaling generation/transmission until previous MAC control signaling generated by requesting base station is ended, that is, the requested eNB is not allowed to try to change state of the secondary cell allocated to the user equipment by the requested eNB again before the transmission of the MAC layer control signaling sent by the requesting eNB is ended. This means the requested eNB itself is not allowed to send the MAC layer control signaling, or to make other eNBs to send the MAC layer control signaling. This will avoid the situation where UE receives

multiple MAC control signalings in different order, so as to cause confusion. For example, due to the non-idea backhaul delay, the MAC control signaling generated by requesting eNB may be received later than the one generated by requested eNB, hence leading to confusion to UE operation. Therefore, it is necessary to define another handshaking between requested and requesting base stations: the requesting eNB receives a feedback from UE in response to the MAC layer control signaling, and determines if the transmission of the MAC layer control signaling is ended based on the feedback. When determining that the transmission of the MAC layer control signaling is ended, the requesting eNB will send a confirmation message to the requested eNB, which indicates the transmission of the MAC layer control signaling implemented by itself is ended. Then, the requested eNB can know that a MAC control signaling can be generated and sent safely, without influencing the UE operation.

Based on the above discussion, the following procedure will be applied, for example. Fig.1 illustrates a flow chart of a method of supporting dual connectivity according to a first embodiment of the present invention.

In step S101, when eNB A (eNB_M or eNB_S: requesting eNB) tends to change its allocated Scell's state, before the MAC layer control signaling is generated and sent down, it should send a request message to another eNB B(requested eNB) to query its current allocated Scell state by X2 interface. For this request, UE ID (UE C-RNTI) is mandatory which enables the requested eNB to feedback correct information.

In step S102, as response, the requested eNB B will feedback its current allocated Scell states of the subjected UE corresponding to the UE ID in the request message by X2 interface. This response message at least includes UE ID, an index or indexes of a Scell or Scells allocated to the user equipment by the requested eNB B and a state of a Scell corresponding to the index, to ensure a correct MAC layer signaling

would be generated and sent in the following step.

In step S103, based on the response message, the requesting eNB A generates and sends a MAC layer control signaling to the UE, wherein the MAC control signaling is used to indicate the states of all the Scells allocated to the UE, including states of the Scells allocated to the UE by eNB A itself and states of other Scells allocated to the UE by other eNBs (for example, eNB B).

In step S104, eNB A receives a feedback from the UE in response to the MAC layer control signaling, and determines if transmission of the MAC layer control signaling is ended based on the feedback.

In step S105, eNB A sends a confirmation message to eNB B station, when determining that the transmission of the MAC layer control signaling is ended, the confirmation message indicating the transmission of the MAC layer control signaling implemented by eNB A is ended. Therefore, the requested eNB B can try to change the states of Scells controlled by itself after then, for example, generate and send potential MAC layer control signaling or let other eNBs (for example, eNB A) to send MAC layer control signaling again.

The benefit of this scheme is that it has small impact to specification. Besides, a new X2 signaling is defined to enable the handshaking between two base stations. In the above embodiment, eNB A could be a primary base station or a secondary base station. Similarly, eNB B could be a primary base station or a secondary base station.

Now, option 2 would be discussed.

To solve the delay experience better, option 2 can be adopted. For this option 2, new rule is defined on activated/de-activated MAC layer signaling generating and sending scheme so that the Scell state of different eNBs are separately transmitted, which means one MAC layer signaling only includes state information of Scells belonging to the sending base station. Then information exchanging between different bases stations is not needed hence no extra delay is foreseen compared

with option 1. Another important issue for option 2 is to guarantee UE to only read part of the MAC control signaling payload and ignore remaining parts. That is, to realize option 2, it is necessary to let UE knows the MAC control signaling includes which base station's Scells' state information, and following two schemes can be considered:

Scheme 1: implicit solution based on new eNB and UE behavior.

Scheme 2: explicit solution by including indication bits in the MAC layer control signaling to guide UE behavior. In the following, the two schemes will be discussed in detail.

Scheme 1: a new solution for activated/de-activated MAC layer control signaling generation/transmission and UE operation which cannot be supported in R11 is proposed:

For the MAC layer control signaling sent from eNB_S of the secondary cell,

it only includes the states of the Scells allocated to UE in the Scells served by eNB_S; and

UE only reads the bits related to the above Scells, and ignores other bits.

While for the MAC layer control signaling sent from eNB_M, it is straightforward that is should include the states of the Scells allocated to UE in the Scells served by eNB_M. In some examples, eNB_M should also be responsible for carrying the states of the Scells allocated to UE by eNB_S. For example, this will be true if there is no activated Scell served by eNB_S, and in this situation eNB_S requests eNB_M to let eNB_M send the states of the Scells allocated to UE by eNB_S to UE. Besides, for the situation, in which all the Scells of eNB_S are in the de-activated state and eNB_S has not requested eNB_M to send the states of the Scells served by eNB_S allocated to UE, eNB_M sets the bits related to the Scells of eNB_S in the MAC layer control signaling sent by eNB_M to 0 (which means they all in the de-activated state). And this MAC layer control signaling will also indicate the states of the Scells allocated to UE

by eNB_M.

Therefore, for the MAC layer control signaling sent form eNB_S, there are following two situations:

Situation 1: the MAC layer control signaling only includes the states of Scells allocated to UE by eNB_M, and the states of the Scells allocated to UE by eNB_S have been set to de-activated;

Situation 2: the MAC layer control signaling includes the states of the Scells allocated to UE by eNB_S and eNB_M, which is similar to R11.

The question is how to enable UE to separate these two situations to correctly understand the received MAC layer control signaling sent from eNB_M. For this issue, a transmission scheme for the states of the Scells of eNB_S is proposed, which is not supported in R11.

When the Scells allocated to UE by eNB_S are all in the de-activated state, and if it is needed to send the MAC layer signaling, eNB_S must request eNB_M to implement MAC layer control signaling transmission. Thereby, the states of Scells related to eNB_S will be sent to eNB_M.

UE can implicitly separate above two situations based on whether or not there is at least one activated Scell of the Scells allocated to UE by eNB_S.

Based on the above new solution, new rules will be defined below:

Rules on the side of eNB which generates and sends the MAC layer control signaling:

1. The MAC layer signaling to change states of eNB_M's Scell(s) should be only sent by eNB_M, which is reasonable because there is at least Pcell on eNB_M which is always keeping activated.

2. The MAC layer signaling to change state of eNB_S's Scell(s) can be sent by eNB_M or eNB_S with principles below:

a. If all Scells allocated to UE by eNB_S are all in de-activated state currently, and if eNB_S requests eNB_M to send the states of the related Scells and informs the states of the related Scells to eNB_M, the MAC layer control signaling related to the states of the Scells of eNB_S will be

sent by eNB_M.

For this rule, eNB_S will send the states of the related Scells to eNB_M by X2 signaling, for example by the ways described in option 1, so that eNB_M can generate the related MAC layer control signaling.

Secondly, it is necessary to forbid eNB_S to try to change states of Scells allocated to UE by eNB_S again before receiving a message sent from eNB_M that indicates transmission of the MAC layer control signaling implemented by eNB_M is ended. That is, for example, it is necessary to forbid eNB_S to send a new MAC layer control signaling itself or forbid eNB_S to request eNB_M to send a new MAC layer control signaling. Herein, the handshaking applied in option 1 could be adopted.

b. If at least one Scell in the Scells allocated to UE by eNB_S is in the activated state, eNB_S generates and sends the MAC layer control signaling to UE, wherein the MAC layer control signaling only indicates the states of the Scells allocated to UE by eNB_S.

Similarly, new behavior procedure at the side of UE should be defined in order to guarantee the proper reception of the MAC layer control signaling.

1. For the MAC layer control signaling received from eNB_M,

- UE omits the states of Scells allocated to UE by eNB_S in the MAC layer control signaling received from eNB_M, when at least oen Scell of the Scells allocated to UE by eNB_S is in the activated state;

- UE reads the states of Scells allocated to UE by eNB_S in the MAC layer control signaling received from eNB_M, when all the Scells allocated to UE by eNB_S are in the de-activated state.

2. For the MAC layer control signaling received from eNB_S,

- UE only reads the states of Scells allocated to UE by that eNB_S in the MAC layer control signaling, and omits other bits in this MAC layer control signaling.

In the following, the embodiment according to scheme 1 will be

described according to figures.

Fig.2 illustrates a flow chart of a method of supporting dual connectivity according to a second embodiment of the present invention. In this embodiment, the MAC layer control signaling is sent by eNB_M.

In Fig.2, in step S201, eNB_M wants to change the state(s) of the Scell(s) allocated to UE, and generates a corresponding MAC layer control signaling. This MAC layer control signaling indicates the states of the Scells allocated to UE by eNB_M, and in this MAC layer control signaling the states of the Scells allocated to UE by eNB_S have been set as de-activated.

In step S202, UE reads the MAC layer control signaling based on whether at least one Scell of the Scells allocated to UE by eNB_S is in the activated state.

Specifically, UE omits the states of the Scells allocated to UE by eNB_S in the MAC layer control signaling received from eNB_M, when at least one Scell in the Scells allocated to UE by eNB_S is in the activated state. That is, UE only reads bits related to the Scells allocated to UE by eNB_M, and omits the bits, which have been all set as de-activated, related to the Scells allocated to UE by eNB_S.

UE reads the states of the Scells allocated to UE by eNB_S in the MAC layer control signaling received from eNB_M, when the states of all Scells allocated to UE by eNB_S are in the de-activated state. That is, in this situation, UE will read all bits related to the states of Scells allocated by eNB_M and eNB_S in the MAC layer control signaling.

Fig.3 illustrates a flow chart of a method of supporting dual connectivity according to a third embodiment of the present invention. In this embodiment, the MAC layer control signaling is sent by eNB_M.

In step S301, eNB_S sends an indication message to eNB_M, so that eNB_M sends a MAC layer control signaling including the state(s) of Scell(s) allocated to UE by eNB_S to UE, wherein the indication message at least includes the ID of UE, an index of a Scell allocated to UE by

eNB_S, and a state of a Scell corresponding to the index.

In step S302, based on the indication message, eNB_M generates and sends the MAC layer control signaling to UE, wherein the MAC layer control signaling is used to indicate states of all Scells allocated to UE, that is, including the states of Scells allocated to UE by eNB_M and eNB_S.

Now, as described above, since the states of Scells allocated to UE by eNB_S are all in de-activated state currently, UE will read all bits related to states of Scells allocated to UE by eNB_M and eNB_S in the MAC layer control signaling.

In step S303, eNB_M receives a feedback from UE in response to the MAC layer control signaling, and determines whether the transmission of the MAC layer control signaling is ended based on the feedback.

In step S304, eNB_M sends a confirmation message to eNB_S, if eNB_M determines the transmission of the MAC layer control signaling is ended. The confirmation message indicates the transmission of the MAC layer control signaling implemented by eNB_M is ended. Thereby, after then, eNB_S can try to change states of Scells served by eNB_S again, for example, generate a potential MAC layer control signaling or make eNB_M send the MAC layer control signaling again.

Fig.4 illustrates a flow chart of a method of supporting dual connectivity according to a fourth embodiment of the present invention. In this embodiment, the MAC layer control signaling is sent by eNB_S.

As shown in Fig.4, eNB_S will changes state(s) of Scell(s) allocated to UE by eNB_S, and at least one Scell of the Scells allocated to UE is in the activated state.

In step S401, eNB_S generates and sends the MAC layer control signaling to UE, wherein the MAC layer control signaling only indicates the states of the Scells allocated to UE by eNB_S.

In step S402, UE only reads the states of the Scells allocated to UE by that eNB_S in the MAC layer control signaling.

Scheme 2:

In order to avoid the limitation of scheme 1 and still retain the feature that the MAC layer control signaling in R10 could be sent on any activated cell, scheme 2 can be adopted. Herein, eNB will indicate explicitly the states of Scells of which eNB have been included in the MAC layer control signaling. This is implemented by redefining the reserved bit "R" in the MAC layer control signaling defined in R10.

In one embodiment of the present invention, in order to realize scheme 2, eNB sending the MAC layer control signaling will redefine the reserved bit "R" to indicate whether the MAC layer control signaling includes the states of Scells of other eNBs.

Fig.5 illustrates a format of a MAC layer control signaling according to one embodiment of the present invention.

As shown in Fig. 5:

R=1, the states of all the Scells allocated to UE by eNB_M and eNB_S are included in the MAC layer control signaling. Therefore, UE will read all bits in the MAC layer control signaling.

R=0, the MAC layer control signaling only includes the states of Scells allocated to UE by eNB sending this MAC layer control signaling. Therefore, UE will omit the bits related to other eNBs. For example, if eNB_M sends the MAC layer control signaling, UE will omit the bits related to states of Scells of eNB_S. If eNB_S sends the MAC layer control signaling, UE will only read the bits related to the states of the Scells of that eNB_S.

It is appreciated that, the definition for R=1 and R=0 above is only exemplary, but not limited. For example, the definition for R=1 and R=0 could be interchanged.

The related situations will be described below.

When eNB_M wants to change the states of Scells allocated to UE by itself, the following two operations may be involved:

Operation 1:

1. eNB_M generates and sends the MAC layer control signaling, for example, on the primary cell, and set R to 0, when eNB_M does not know the states of Scells allocated to UE by eNB_S. At the side of UE, since R=0 and this MAC layer control signaling is from eNB_M, UE will only notice the bits related to the states of Scells of eNB_M and omit other bits.

On the other hand, if eNB_M knows the states of Scells allocated to UE by eNB_S, R will be set as 1, so that UE will also read bits related to the states of the Scells of eNB_S in the MAC layer control signaling. This could be applied to the following situation, in which all the Scells of eNB_S are in the de-activated state, or there is no DL grant at eNB_S and eNB_S wants to change the state of the Scells served by itself. Additionally, for this situation, eNB_M will send a confirmation message indicating the transmission of the MAC layer control signaling is ended to eNB_S to allow the sending of the following MAC layer control signaling of eNB_S.

Operation 2:

If eNB_M wants to send the MAC layer control signaling at eNB_S, for example when there is no DL grant at eNB_M, eNB_M will send the states of the Scells allocated to UE by eNB_M to eNB_S. eNB_S will generate the MAC layer control signaling, and set R as 1. Thereby, at the side of UE, when receiving the MAC layer control signaling from eNB_S, UE will not omit the bits related to the states of the Scells of eNB_M.

When eNB_S wants to change the states of the Scells allocated to UE by itself, the following two operations may be involved:

If eNB_S does not know the states of the Scells allocated to UE by eNB_M, the MAC layer control signaling sent by eNB_S only covers the states of the Scells allocated to UE by eNB_M, and this MAC layer control signaling will be sent at eNB_S with R=0. At the side of UE, UE will only read the bits related to the states of the Scells of eNB_S.

On the other hand, if eNB_S knows the states of the Scells allocated to UE by eNB_M, (for example, eNB_M hopes eNB_S to inform UE of the states of the Scells of eNB_M), R will be set as 1. At the side of UE, UE will read the bits related to the states of all the Scells allocated to UE by eNB_S and eNB_M. Additionally, eNB_S will also inform eNB_M that the transmission of the MAC layer control signaling is ended, so that eNB_M can implement the sending of the following potential MAC layer control signaling of itself.

Besides, if there is no DL grant at the side of eNB_S, and no activated Scells, or there is no DL grant in spite of the activated Scells, eNB_S will request eNB_M to send the MAC control signaling to UE. At that time, at the side of eNB_M, the MAC control signaling will be generated with R=1, so that UE will read the bits related to all the Scells allocated to UE by eNB_M and eNB_S.

Based on these detail potential situations, scheme 2 has no limitation on where to generate/send the corresponding MAC layer control signaling. But non-ideal backhaul delay should be considered here. For example, in the situation where eNB_S sends the states of the Scells allocated to UE by eNB_S to eNB_M by X2 signaling, this signaling will experience at most 60ms delay. That is, the corresponding MAC layer control signaling will be sent after at least 60ms. If during this 60ms period DL grant of eNB_S is available, it is possible that eNB_S will send another MAC layer control signaling by itself. Due to HARQ retransmission issue, it possible that UE will receive the above two MAC layer control signaling in a different order, such that a wrong operation at the side of UE will be caused. Therefore, if one eNB requests another eNB to send the MAC layer control signaling, the requested eNB needs to inform the requesting eNB after it ends the transmission of the MAC layer control signaling. Therefore, at the time, the requesting eNB could begin the potential MAC layer control signaling of itself, so as to avoid the above problem.

In the following, scheme 2 will be describes in detail with reference to Fig.6. Fig. 6 illustrates a flow chart of a method of supporting dual connectivity according to a fifth embodiment of the present invention.

As shown in Fig.6, in step S601, eNB sets indication bits in a MAC layer control signaling, which indicates UE to read states of all Scells allocated to UE (states of Scells allocated to UE by eNB_M and eNB_S) in the MAC layer control signaling, or indicates UE to only read states of Scells allocated to UE by eNB sending the MAC layer control signaling. This eNB could be eNB_M or eNB_S.

For example, when eNB_M does not know the states of Scells allocated to UE by eNB_S, eNB_M will set the indication bits in the MAC layer control signaling to indicate UE to read only the states of Scells allocated to UE by eNB_M. In opposite, eNB_M will set the indication bits in the MAC layer control signaling to indicate UE read the states of all Scells allocated to UE in the MAC layer control signaling. For eNB_S, there is a similar situation and it will not be described in detail herein.

In step S602, eNB sends the MAC layer control signaling to UE.

In step S603, UE reads the states of Scells allocated to UE in the MAC layer control signaling based on the indication bits in the MAC layer control signaling received from eNB.

Specifically, when the indication bits indicate UE to read the states of all Scells allocated to UE in the MAC layer control signaling, UE reads all the related bits in the MAC layer control signaling.

When the indication bits indicate UE to read the states of the Scells allocated to UE by eNB sending the MAC layer control signaling, UE will only read the bits related to the states of the Scells of eNB sending this MAC layer control signaling.

It shall be appreciated that the foregoing embodiments are merely illustrative but will not limit the invention. Any technical solutions

without departing from the spirit of the invention shall fall into the scope of invention, including the use of different technical solutions appearing in different embodiments, and an apparatus and a method can be combined to advantage. Moreover any reference numerals in the claims shall not be construed as limiting the claims in question; and the term "comprising" will not preclude another device(s) or step(s) which is (are) listed in the other claim(s) or the description.

CLAIMS

1. A method, in a first base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the first base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising:

- sending a request message to other base stations, when the first base station will change a state of a secondary cell allocated to a user equipment by the first base station, the request message at least including ID of the user equipment;

- receiving a response message from the other stations, the response message at least including the ID of the user equipment, an index of a secondary cell allocated to the user equipment by the other base station, and a state of a secondary cell corresponding to the index; and

- generating and sending a MAC layer control signaling to the user equipment based on the response message, wherein the MAC layer control signaling indicating states of all secondary cells allocated to the user equipment.

2. A method according to claim 1, wherein the method further includes the following steps:

- receiving a feedback from the user equipment in response to the MAC layer control signaling, and determining if transmission of the MAC layer control signaling is ended based on the feedback; and

- sending a confirmation message to the other base stations, when determining that the transmission of the MAC layer control signaling is ended, the confirmation message indicating the transmission of the MAC layer control signaling implemented by the first base station is ended.

3. A method, in a second base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the second base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising:

- receiving a request message from a first base station, the request message at least including ID of a user equipment; and

- sending a response message to the first base station based on the request message, the response message at least including the ID of the user equipment, an index of a secondary cell allocated to the user equipment by the secondary base station, and a state of a secondary cell corresponding to the index.

4. A method according to claim 3, wherein the method further includes the following step:

- not trying to change state of the secondary cell allocated to the user equipment by the secondary base station again before receiving a confirmation message from the first base station, wherein the confirmation message indicates transmission of a MAC layer control signaling implemented by the first base station is ended.

5. A method, in a primary base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system the primary base station serves one primary cell and/or one or more secondary cells, and a secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state,

the method comprising the following steps:

- generating and sending a first MAC layer control signaling to a user equipment, when the primary base station will change a state of a secondary cell allocated to the user equipment by the primary base station, wherein the first MAC layer control signaling indicates that states of secondary cells allocated to the user equipment by the secondary base station are all in the activated state, and the first MAC layer control signaling further indicates state of the secondary cell allocated to the user equipment by the primary base station; or

the method comprising the following steps:

- receiving an indication message from the secondary base station, the

indication message indicating the primary base station to send a second MAC layer control signaling including state of secondary cell allocated to the user equipment by the secondary base station to the user equipment, wherein the indication message at least including ID of the user equipment, an index of the secondary cell allocated to the user equipment by the secondary base station, and a state of the secondary cell corresponding to the index; and

- generating and sending a second MAC layer control signaling to the user equipment based on the indication message, wherein the second MAC layer control signaling indicating states of all secondary cells allocated to the user equipment.

6. A method according to claim 5, wherein when receiving the indication message from the secondary base station, the method further includes the following steps:

- receiving a feedback from the user equipment in response to the second MAC layer control signaling, and determining if transmission of the second MAC layer control signaling is ended based on the feedback; and

- sending a confirmation message to the secondary base station, when determining that the transmission of the second MAC layer control signaling is ended, the confirmation message indicating the transmission of the second MAC layer control signaling implemented by the primary base station is ended.

7. A method, in a secondary base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:

when the secondary base station will change state of a secondary cell allocated to a user equipment by the secondary base station,

generating and sending a MAC layer control signaling to the user equipment, if at least one secondary cell of secondary cells allocated to the

user equipment by the secondary base station is in the activated state, wherein the MAC layer control signaling only indicates states of the secondary cells allocated to the user equipment by the secondary base station;

sending an indication message to the primary base station to make the primary base station send a MAC layer control signaling including states of secondary cells allocated to the user equipment by the secondary base station to the user equipment, if all secondary cells allocated to the user equipment by the secondary base station are in the de-activated state currently, wherein the indication message at least including ID of the user equipment, an index of the secondary cell allocated to the user equipment by the secondary base station, and a state of the secondary cell corresponding to the index.

8. A method according to claim 5, wherein when the secondary cells allocated to the user equipment by the secondary base station are all in the de-activated state currently, the method further includes the following steps:

not trying to change states of the secondary cells allocated to the user equipment by the secondary base station again before receiving a confirmation message from the primary base station, wherein the confirmation message indicates transmission of the MAC layer control signaling implemented by the primary base station is ended.

9. A method, in a user equipment, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:

- reading a MAC control signaling based on whether at least one secondary cell of secondary cells allocated to the user equipment by the secondary base station is in the activated state, the MAC control signaling indicating states of the secondary cells allocated to the user equipment.

10. A method according to claim 9, wherein step reading the MAC control signaling based on whether the at least one secondary cell of the

secondary cells allocated to the user equipment by the secondary base station is in the activated state further includes:

for the MAC layer control signaling received from the primary base station,

- omitting states of the secondary cells allocated to the user equipment by the secondary base station in the MAC layer control signaling received from the primary base station, and only reading states of the secondary cells allocated to the user equipment by the primary base station in the MAC layer control signaling, when the at least one secondary cell of the secondary cells allocated to the user equipment by the secondary base station is in the activated state;

- reading states of the secondary cells allocated to the user equipment by the primary base station and the secondary base station in the MAC layer control signaling received from the primary base station, when the secondary cells allocated to the user equipment by the secondary base station are all in the de-activated state currently; and

for the MAC layer control signaling received from the secondary base station,

- only reading states of the secondary cells allocated to the user equipment by the secondary base station in the MAC layer control signaling.

11. A method, in a first base station, of supporting dual connectivity in a carrier aggregation based communication system, wherein the first base station at least serves one or more secondary cells, and each secondary cell has an activated state and a de-activated state, the method comprising:

- setting indication bits in a MAC layer control signaling, which indicates a user equipment to read states of all secondary cells allocated to the user equipment in the MAC layer control signaling, or indicates the user equipment to only read states of secondary cells allocated to the user equipment by the first base station in the MAC layer control signaling; and

- sending the MAC layer control signaling to the user equipment.

12. A method according to claim 11, wherein the first base station is a

primary base station,

the primary base station sets the indication bits in the MAC layer control signaling to indicate the user equipment to only read states of the secondary cells allocated to the user equipment by the primary base station, when the primary base station does not know states of secondary cells allocated to the user equipment by the secondary base station; or

the primary base station sets the indication bits in the MAC layer control signaling to indicate the user equipment to read all the states of the secondary cells allocated to the user equipment in the MAC layer control signaling, when the primary base station knows the states of the secondary cells allocated to the user equipment by the secondary base station.

13. A method according to claim 11, wherein the first base station is a secondary base station,

the secondary base station sets the indication bits in the MAC layer control signaling to indicate the user equipment to only read states of the secondary cells allocated to the user equipment by the secondary base station, when the secondary base station does not know states of secondary cells allocated to the user equipment by the primary base station; or

the secondary base station sets the indication bits in the MAC layer control signaling to indicate the user equipment to read all the states of the secondary cells allocated to the user equipment in the MAC layer control signaling, when the secondary base station knows the states of the secondary cells allocated to the user equipment by the primary base station;

14. A method, in a user equipment, of supporting dual connectivity in a carrier aggregation based communication system, wherein in the communication system a base station includes a primary secondary station and a secondary base station, the primary base station serves one primary cell and/or one or more secondary cells, and the secondary base station serves one or more secondary cells, each secondary cell has an activated state and a de-activated state, the method comprising the following steps:

- reading states of secondary cells allocated to the user equipment in a

MAC layer control signaling based on indication bits in the MAC layer control signaling received from the primary base station or the secondary base station, wherein the indication bits indicates the user equipment to read states of all the secondary cells allocated to the user equipment in the MAC layer control signaling, or indicates the user equipment to only read states of secondary cells allocated to the user equipment by a base station which sends the MAC layer control signaling.

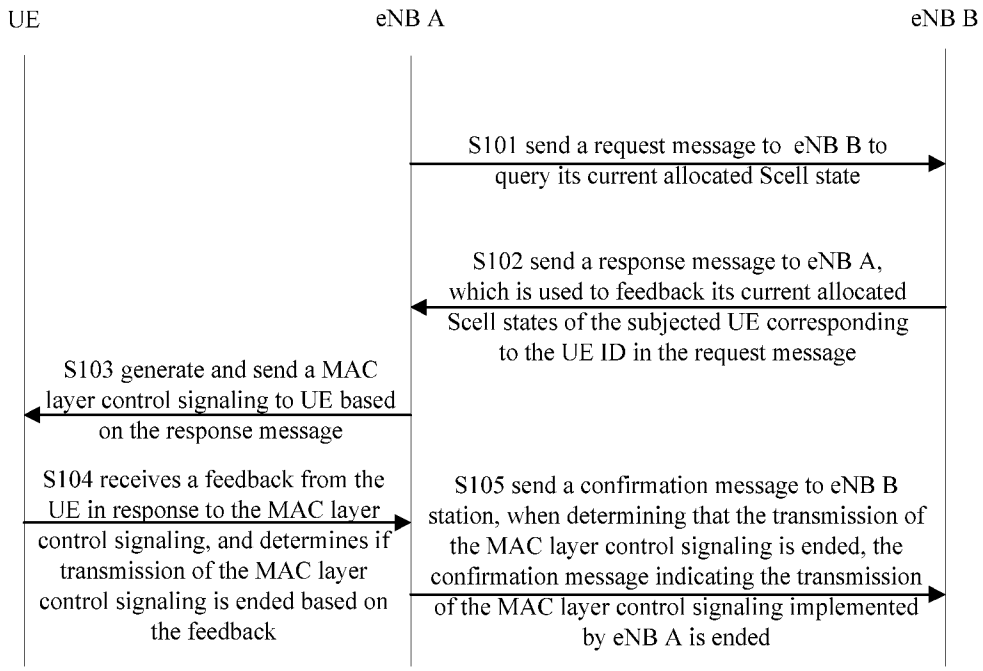
UE
eNB A
eNB B
S101 send a request message to eNB B to query its current allocated Scell state
S102 send a response message to eNB A, which is used to feedback its current allocated Scell states of the subjected UE corresponding to the UE ID in the request message
S103 generate and send a MAC layer control signaling to UE based on the response message
S104 receives a feedback from the UE in response to the MAC layer control signaling, and determines if transmission of the MAC layer control signaling is ended based on the feedback
S105 send a confirmation message to eNB B station, when determining that the transmission of the MAC layer control signaling is ended, the confirmation message indicating the transmission of the MAC layer control signaling implemented by eNB A is ended

Fig.1

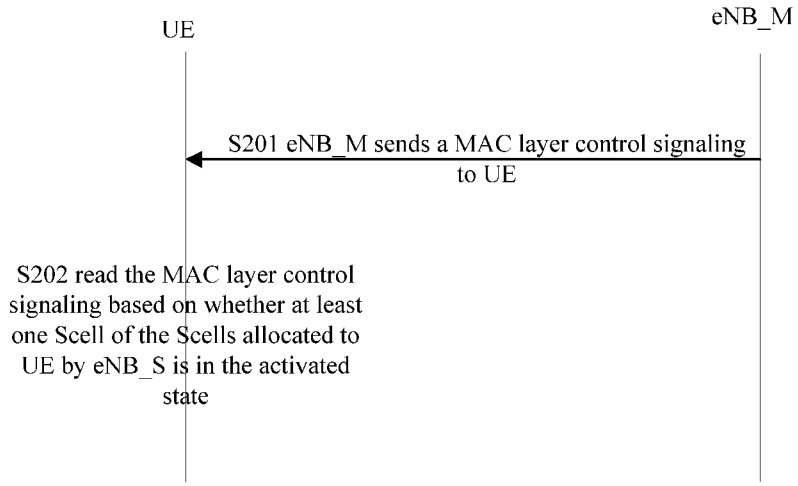
UE
eNB_M
S201 eNB_M sends a MAC layer control signaling to UE
S202 read the MAC layer control signaling based on whether at least one Scell of the Scells allocated to UE by eNB_S is in the activated state

Fig.2

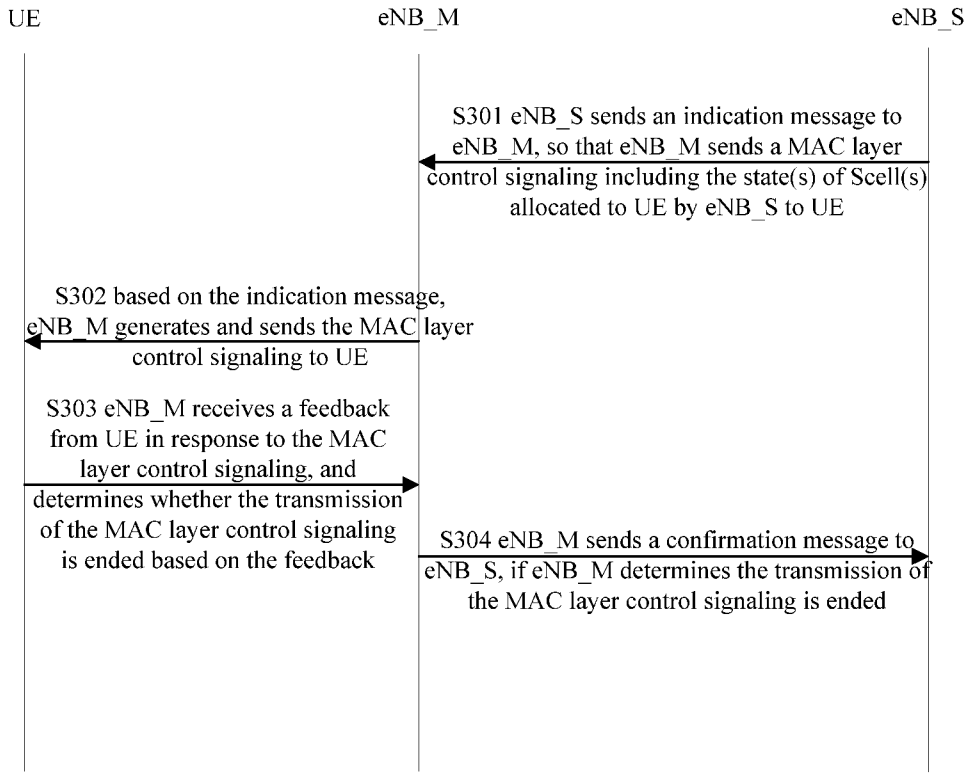
UE
eNB_M
eNB_S
S301 eNB_S sends an indication message to eNB_M, so that eNB_M sends a MAC layer control signaling including the state(s) of Scell(s) allocated to UE by eNB_S to UE
S302 based on the indication message, eNB_M generates and sends the MAC layer control signaling to UE
S303 eNB_M receives a feedback from UE in response to the MAC layer control signaling, and determines whether the transmission of the MAC layer control signaling is ended based on the feedback
S304 eNB_M sends a confirmation message to eNB_S, if eNB_M determines the transmission of the MAC layer control signaling is ended

Fig.3

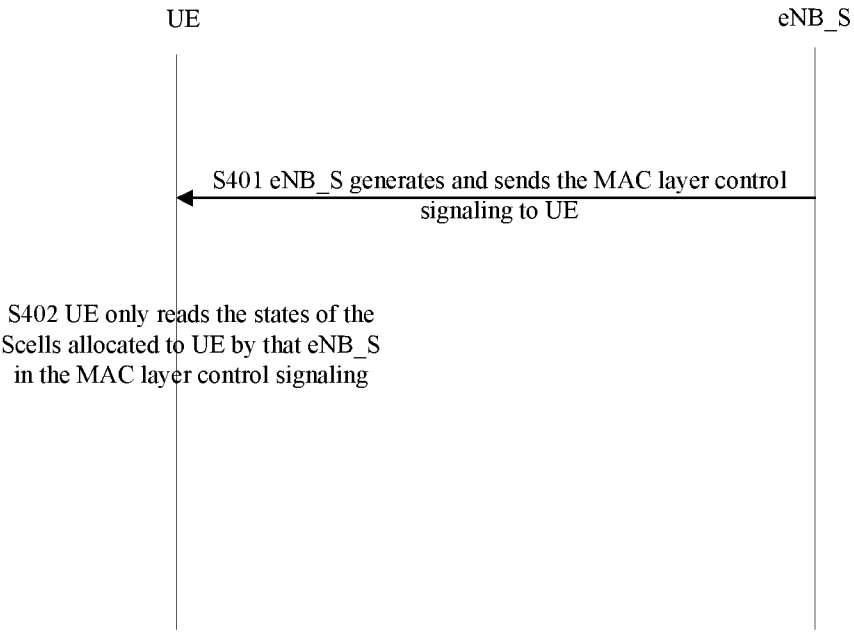
UE
eNB_S
S401 eNB_S generates and sends the MAC layer control signaling to UE
S402 UE only reads the states of the Scells allocated to UE by that eNB_S in the MAC layer control signaling

Fig.4

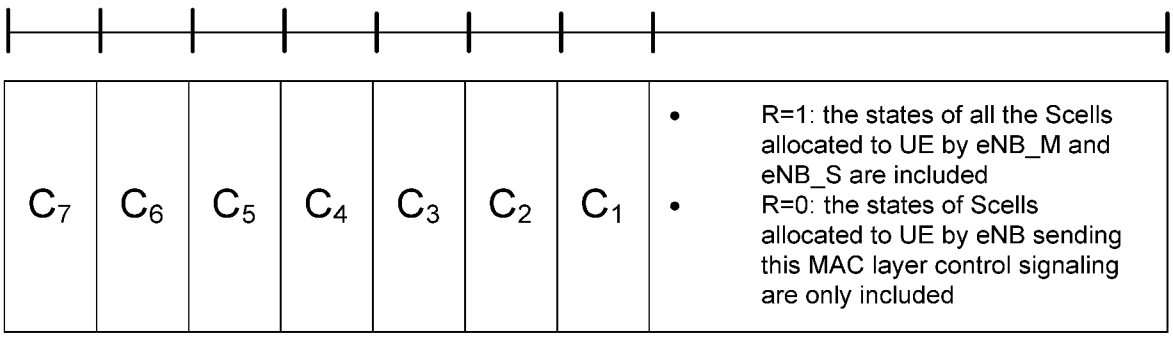
C7
C6
C5
C4
C3
C2
C1
R=1: the states of all the Scells allocated to UE by eNB_M and eNB_S are included
R=0: the states of Scells allocated to UE by eNB sending this MAC layer control signaling are only included

Fig.5

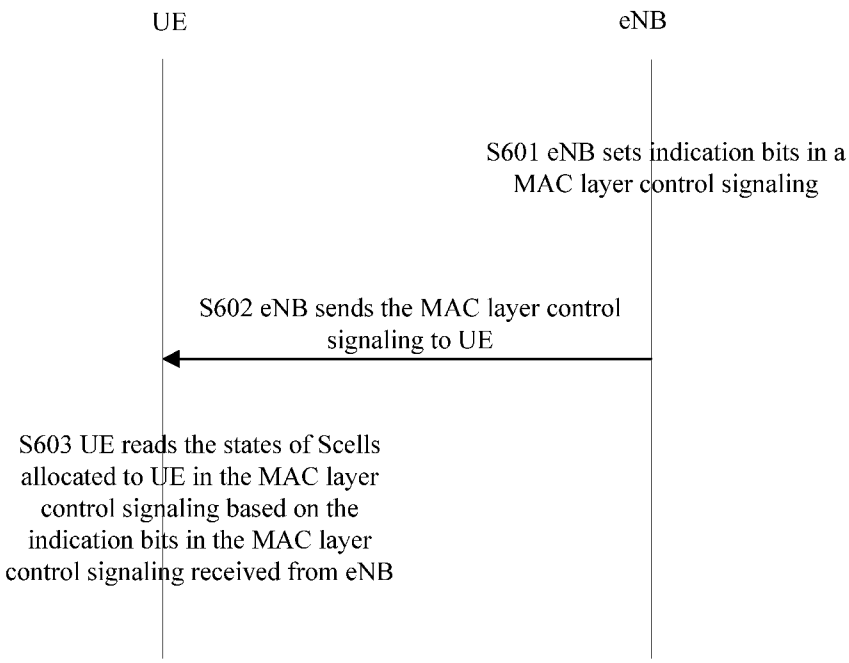
UE
eNB
S601 eNB sets indication bits in a MAC layer control signaling
S602 eNB sends the MAC layer control signaling to UE
S603 UE reads the states of Scells allocated to UE in the MAC layer control signaling based on the indication bits in the MAC layer control signaling received from eNB

Fig.6