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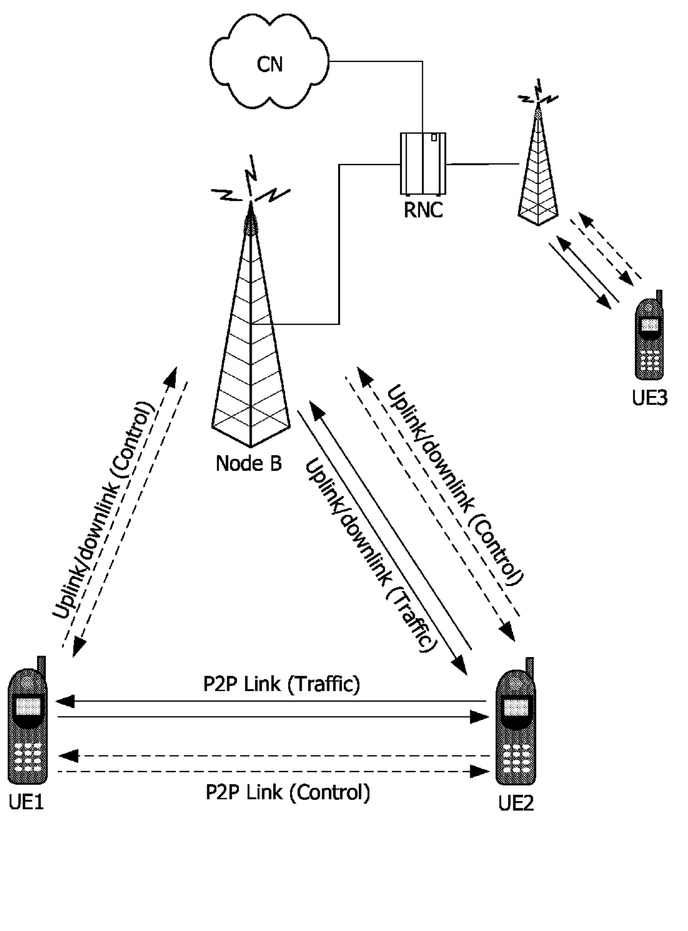

(57) Abstract: The present invention discloses a method and apparatus of establishing two-hop relaying communication in a wireless communication system, the method including the steps of: receiving from a first UE a request for communicating with a communication device via multi-hop relaying; selecting a second UE as a relaying device according to predefined criterion; and establishing corresponding links to make the first UE can communicate with the communication device via the relaying of said second UE. According to the method and apparatus of the present invention, qualified relaying routes can be found to meet users' demands on higher data transmission rate.

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METHOD AND APPARATUS OF REALIZING TWO-HOP RELAYING COMMUNICATION IN WIRELESS COMMUNICATION SYSTEMS

FIELD OF THE INVENTION

The present invention relates to the wireless communication field, and more particularly, to a method and apparatus of realizing two-hop relaying communication in wireless communication systems.

BACKGROUND OF THE INVENTION

In conventional cellular communication systems, regardless of the distance between two communicating User Equipments (UEs), a UE has to communicate with another UE only via the relaying of a base station. Fig. 1 illustrates the conventional communication scheme, where UE1 and UE2 communicate with each other via the Universal mobile telecommunications system Terrestrial Radio Access Network (UTRAN) consisting of the base station (Node B) and the Radio Network Controller (RNC). This communication scheme is also called Uplink-Base Station-Downlink scheme.

In the fundamental structure of cellular mobile communication, traffic QoS (Quality of Service), including data transmission rate, is guaranteed mainly by wireless signal processing techniques. However, due to the characteristics of radio propagation, it is hard to improve traffic QoS, e.g. data transmission rate, by wireless signal processing techniques, to meet demands of video and other new wireless traffic, which require much higher QoS.

To solve the above problem, both academia and industrial community propose some new concepts for the wireless network architecture.

One of the new concepts is to apply peer-to-peer (P2P) communication to a wireless network by referring to P2P communication in a fixed network. Fig. 2 illustrates a P2P communication scheme. As shown in Fig. 2, the dashed line represents control link, the solid line represents traffic link, and the arrowhead represents the direction of information flow. There is only control link between the UTRAN and the UEs, while only traffic link exists between two communicating UEs. Comparing with the conventional communication scheme as shown in Fig. 1, P2P communication can save almost half of the radio resources. Moreover, since the distance between two P2P communicating UEs (mobile terminals) is usually short, P2P communication can achieve better transmission quality and transmission delay than being relayed/forwarded by a base station, thereby achieving a higher data transmission rate. However, application of P2P communication is rather limited for the reason that P2P communication is performed only when two UEs are close to each other.

Another new concept is to adopt multi-hop relaying for communication between UEs in a wireless communication network. In a multi-hop wireless communication network, direct communication, namely P2P communication, is available between two UEs when they are all in their respective communication coverage. However, due to the limit of the communication coverage of a UE, when two UEs that are far away from each other desire to communicate, the communication has to be forwarded by an third UE between the two UEs. Thus, in the multi-hop wireless communication network, the third UE also serve as a router, which assumes the duty of searching routes and forwarding messages. Since the communication range of each UE is rather limited in the multi-hop network, only via the forwarding of a plurality of UEs, will data reach to the destination.

Communication can be carried out by means of freely networking among UEs in the multi-hop wireless communication network, without the support of wired infrastructure such as base station and the like. The appearance of multi-hop wireless communication network not only gives impetus to the course of free communication under any situations, but also provides an effective solution to military communication, disaster rescue and temporary communication. However, in the multi-hop wireless communication network, each UE needs to know routes for reaching all other UEs and all UEs can be moving, so maintaining the dynamically varying route information demands enormous control overheads.

Therefore, it is an object of the present invention to overcome the defects mentioned above.

OBJECT AND SUMMARY OF THE INVENTION

To achieve the aforesaid object, the present invention proposes a method of establishing two-hop relaying communication in a wireless communication system, the method comprising the steps of: receiving from a first UE a request for communicating with a communication device via multi-hop relaying; selecting a second UE as a relaying device according to predefined conditions; and establishing corresponding links to make the first UE can communicate with said communication device via the relaying of the second UE.

The present invention also provides an apparatus of establishing two-hop relaying communication in a wireless communication system, the apparatus comprising: receiving means, for receiving from a first UE a request for communication with a communication device via multi-hop relaying; determining means, for selecting a second UE as a relaying device according to predefined conditions; and link establishing means, for establishing corresponding links to make the first UE can communicate with the communication device via the relaying of the second UE.

The present invention further provides a method of establishing two-hop relaying communication in a wireless communication system, the method comprising the steps of: sending to a network system a request for communicating with a communication device via multi-hop relaying; receiving from the network system corresponding confirmation information, wherein the confirmation information contains information about a UE that serves as a relaying device; and establishing link with the relaying device to make communication with the communication device via the relaying of the relaying device.

The present invention further proposes a UE, the UE comprising: estimating means, for estimating data transmission rate of conventional uplink/downlink traffic link; conventional communication means for, if the data transmission rate of the conventional uplink/downlink traffic link is less than a predetermined value, sending to a network system a request for communication with a communication device via multi-hop relaying and receiving from the network system corresponding confirmation information, wherein the confirmation information contains information about a UE that serves as a relaying device; and P2P communication means, for establishing a link with the relaying device to make communication with the communication device through the relaying of the relaying device.

Other objects and effects of the present invention will become more apparent and comprehensible from the following description taken in conjunction with the accompanying drawings, the contents in the claims and a more complete understanding of the present invention.

BRIEF DESCRIPTION ON THE DRAWINGS

Hereinafter, the preferred embodiments of the present invention will be described with reference to the accompanying drawings, wherein,

Fig. 1 is a schematic diagram showing a conventional uplink/downlink communication scheme relayed by a base station;

Fig. 2 is a schematic diagram showing a P2P communication scheme in a wireless communication system;

Fig. 3 is a schematic diagram showing a P2P-based two-hop relaying wireless communication scheme according to the first embodiment of the present invention;

Fig. 4 is a flow chart showing the process for establishing two-hop relaying wireless communication of the UE requesting for relaying according to the first embodiment of the present invention;

Fig. 5 is a flow chart showing the process for establishing two-hop relaying wireless communication of a relaying candidate according to the first embodiment of the present invention;

Fig. 6 is a flow chart showing the process for establishing two-hop relaying wireless communication of the network, namely the UTRAN, according to the first embodiment of the present invention;

Fig. 7 is a schematic diagram showing a P2P-based two-hop relaying wireless communication scheme according to the second embodiment of the present invention;

Fig. 8 is a flow chart showing the process for establishing two-hop relaying wireless communication of the UE requesting for relaying according to the second embodiment of the present invention;

Fig. 9 is a flow chart showing the process for establishing two-hop relaying wireless communication of a relaying candidate according to the second embodiment of the present invention;

Fig. 10 is a flow chart showing the process for establishing two-hop relaying wireless communication of a cell on which the UE requesting for relaying is camping according to the second embodiment of the present invention;

Fig. 11 is a flow chart showing the process for establishing two-hop relaying wireless communication of a cell on which a relaying candidate is camping according to the second embodiment of the present invention;

Fig. 12 is a schematic diagram showing the corresponding functional units in a UE according to the present invention; and

Fig. 13 is a schematic diagram showing the functional units of an apparatus of establishing two-hop relaying communication in a wireless communication system.

In all of the above accompanying drawings, the same numerals represent identical, like or corresponding features or functions.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 3 is a schematic diagram showing a P2P-based two-hop relaying wireless communication scheme according to the first embodiment of the present invention. In the first embodiment, the UE requesting for relaying and the relaying UE are camping in the same cell.

As illustrated in Fig.3, in the uplink direction (from UE1 to the base station), if wants to communicate with UE3, UE1 delivers its traffic to relaying UE2 via P2P link, while relaying UE2 is responsible for forwarding the traffic to the base station (Node B) and finally sending to UE3 via the network. In the downlink (from the base station to UE1) direction, relaying UE2 receives from the base station traffic of UE3 sent from the network and then forwards the received traffic to UE1 via P2P link.

P2P communication between UE1 and relaying UE2 may either employ the conventional air interface, i.e. the air interface between relaying UE2 and the base station, or employ another one, such as IEEE802.11a. Choosing a different air interface can avoid interference, but it puts additional requirement on RF modules. In order to reuse existing hardware and reduce costs as much as possible, it is a preferred solution of the present invention to choose a conventional air interface for P2P communication between UE1 and relaying UE2.

Relaying UE2 in Fig. 3 is a mobile terminal. Of course, those skilled in the art should understand that the relaying UE may also be a fixed terminal. The following description is based on the case in which a mobile terminal is used as a relaying device.

The UEs used in the present invention have both P2P communication capability and capability of conventional communication with a base station.

According to the present invention, a UE can choose to be or not to be relayed to get higher data transmission rate. UEs with relaying capability volunteer to relay for others.

Selection of an appropriate relaying device is determined by a higher-data-transmission-rate-oriented strategy performed at both the network (hereinafter referred to as UTRAN) side and the relaying device side.

The decision at the UTRAN is made according to the following criterion:

$$R\_MAX = \max_{i \in S}\{\min\{R2(i), R12(i)\} \mid R2(i) \geq R\_EXP, R12(i) \geq R\_EXP\}$$

wherein,

R_MAX is the maximum available data transmission rate for the two-hop relaying communication;

R_EXP is the expected data rate of the UE requesting for relaying;

i is the index of relaying candidates;

S is the set of all relaying candidates;

R2(i) is the estimated available data transmission rate for conventional link of the i^{th} relaying candidate;

R12(i) is the estimated available data transmission rate for P2P link with the UE requesting for relaying of the i^{th} relaying candidate.

Each relaying candidate will first estimate available data transmission rates for the two-hop relaying communication. When it is estimated that both the available data transmission rate R2(i) of conventional link with the UTRAN and the available data transmission rate R12(i) of P2P link with the UE requesting for relaying are larger than the expected data rate R_EXP of the UE requesting for relaying, the relaying candidate can report the minimum value of R2(i) and R12(i) to the UTRAN. Then the UTRAN will select a relaying device with the maximum data transmission rate from all relaying candidates according to above-mentioned formula.

The available data rates are evaluated by the relaying candidate based on an overall criterion including SIR (Signal to Interference Ratio), available radio resources, transmission power loss and other factors. Although distance and path loss are often used as criterions for route selecting in the prior arts, they are only a part of factors contributing to the data rate. In the present invention, it cares about available radio resources for each hop that may affect data rate.

Hereinafter, the process for establishing two-hop relaying communication will be described in detail with reference to Figs. 4-6. Among these figures, Fig. 4 is a flow chart showing the process of the UE requesting for relaying, Fig. 5 is a flow chart showing the process of each relaying candidate, and Fig. 6 is a flow chart showing the process of the network, namely the UTRAN.

Referring now is given to Fig. 4, first, UE1 establishes conventional uplink/downlink communication with the UTRAN as shown in step S401. If UE1 has already connected to the UTRAN, the flow directly starts with the next step without step S401.

After the establishment of link, UE1 maintains its link with the UTRAN, and keeps measurements and monitors data transmission rate of the link at regular intervals, just as shown step S402.

Next, UE1 determines whether the average data transmission rate (R1) over a certain period of time is larger than its lowest acceptable data transmission rate threshold (R_LOW), just as shown in step S403. If R1 is larger than or equal to R_LOW, UE1 keeps original link with the UTRAN, i.e., the flow returns to step S402.

Otherwise, if R1 is less than R_LOW, the flow goes to step S404. In this step, UE1 sends an INITIAL_RELAYING_REQUEST message to the UTRAN, indicating that the conventional uplink/downlink communication with the UTRAN cannot meet its demands on data transmission rate and two-hop relaying communication is needed in order to satisfy its demands on data transmission rate. The INITIAL_RELAYING_REQUEST message contains UE1's identity and its expected data rate R_EXP.

Then, the flow goes to step S405. In this step, UE1 takes further actions based on the response from the UTRAN.

If the message UE1 receives from the UTRAN is not an INITIAL_RELAYING_CONFIRM message, UE1 stops relaying attempt and returns to its conventional communication state, just as shown in step S412.

If UE1 receives the INITIAL_RELAYING_CONFIRM message from the UTRAN, UE1 begins to search for possible two-hop relaying route, i.e., begins to search for a most suitable relaying device.

As shown in step S406, UE1 broadcasts a RELAYING_ROUTE_REQUEST message to other UEs in its surrounding areas, so as to search for a most suitable relaying device. The format of the RELAYING_ROUTE_REQUEST message is assumed known to all UEs and should contain at least the information of UE1's identity and its expected data rate (R_EXP). In general, R_EXP is larger than the aforesaid threshold R_LOW. Sending power of this message should be controlled within a suitable range in order to reach a certain range of potential candidate relaying UEs.

Next, UE1 starts a timer T1 as shown in step S407. This timer sets the waiting time for receiving indication from the UTRAN.

As shown in step S408, UE1 waits for reply from the UTRAN. If UE1 receives a RELAYING_ROUTE_REJECT message from the UTRAN before T1 expires, it stops relaying attempt and returns to its conventional communication with the UTRAN, just as shown in steps S409, S410 and S412.

If UE1 receives the RELAYING_ROUTE_INDICATION message before TI expires, then it extracts related information from the indication and negotiates with the relaying device on allocated channel to establish P2P link, just as shown in steps S409, S413 and S414. After the relaying device has established conventional link with the UTRAN, UE1 starts two-hop relaying communication with the UTRAN relayed by the relaying device, just as shown in step S415.

When TI expires, if UE1 has not received the RELAYING_ROUTE_INDICATION message or the RELAYING_ROUTE_REJECT message from the UTRAN, then UE 1 stops relaying attempt and returns to its conventional communication with the UTRAN, just as shown in steps S409, S410, S411 and S412.

Reference is now given to Fig. 5. According to the foregoing description, UEs in the vicinity of UE1 may receive the RELAYING_ROUTE_REQUEST message from UE1, just as shown in step S501.

On receiving this message, these UEs first decide whether they are willing to or capable of relaying, just as shown in step S502.

If a UE is not willing to or capable of relaying, it does not respond to the RELAYING_ROUTE_REQUEST message and returns to its original state, just as shown in step S509.

If a UE, for example, UE2, is willing to and capable of relaying, it estimates available data transmission rates for its conventional link with the UTRAN (R2) and P2P link with UE1 (R12) according to the measurement of each link and its available radio resources required to support both links, just as shown in step S503.

After that, the UE, UE2 for example, decides whether the minimum value of R2 and R12 is larger than expected data transmission rate R_EXP of UE1, just as shown in step S504.

If the minimum value of R2 and R12 is larger than or equal to R_EXP, the UE, UE2 for example, sends a CANDIDATE_ RELAYING_REPORT message to the UTRAN and starts a timer T2, just as shown in step S505. The CANDIDATE_RELAYING_REPORT message contains the identities of UE1 and UE2, and estimated available data transmission rate R_MIN, where $R\_MIN = \min\{R2, R12\}$. Timer T2 sets the waiting time for the indication from the UTRAN.

If a relaying candidate receives the RELAYING_ROUTE_INDICATION message from the UTRAN before T2 expires, then it extracts related information from the message and negotiates with UE1 on allocated channel to establish P2P link and establishes conventional link with the UTRAN, just as shown in steps S506, S507, S510, S511, S512 and S513.

When T2 expires, if a relaying candidate has not received the RELAYING_ROUTE_INDICATION message from the UTRAN, then it stops relaying attempt and returns to its original state, just as shown in steps S506, S507, S508 and S509.

Reference is now given to Fig. 6. After the UTRAN receives in step S601 the INITIAL_RELAYING_REQUEST message from UE1, the UTRAN extracts from the message the identity information of UE1 and its expected data transmission rate R_EXP as shown in step S602.

Next, the UTRAN decides in step S603 whether it can provide two-hop relaying communication for UE1 with the expected data transmission rate.

If the UTRAN can not provide two-hop relaying communication for UE1, it sends to UE1 a RELAYING_ROUTE_REJECT message to notify UE1 that it can not provide two-hop relaying communication, as shown in step S619, and then returns to its original state as shown in step S620.

If the UTRAN can provide two-hop relaying communication for UE1, it sends to UE1 an INITIAL_RELAYING_CONFIRM message to notify UE1 that it can provide two-hop relaying communication, just as shown in step S604.

Next, the UTRAN prepares an empty list L1 for UE1 to record the information of possible relaying candidates, just as shown in step S605.

Then, the UTRAN starts a timer T3 for UE1 as shown in step S606, and waits for reports from possible relaying candidates as shown in step S607.

If the UTRAN receives CANDIDATE_RELAYING_REPORT message(s) from one or several relaying candidates, which are capable of providing relaying service for UE1, before T3 expires, the UTRAN extracts the candidate's identity and its available data transmission rate R_MIN and then records identity of the relaying candidate and the data transmission rate R_MIN into list L1, just as shown in steps S608, S609 and S610.

The UTRAN keeps a watch on whether T3 expires just as shown in step S611.

When T3 expires, the UTRAN checks whether the list L1 used for recording relaying candidates for UE1 is empty, just as shown in step S612.

If L1 is empty, the UTRAN sends to UE1 a RELAYING_ROUTE_REJECT message indicating that two-hop relaying communication cannot be performed, and returns to its original state, just as shown in steps S619 and S620.

If L1 is not empty, the UTRAN selects the relaying candidate with maximum data transmission rate as the relaying device for UE1. That is, the UTRAN selects from the relaying candidates the relaying device according to the above-mentioned formula, i.e.

$$R\_MAX = \max_{i \in S}\{\min\{R2(i), R12(i)\} \mid R2(i) \ge R\_EXP, R12(i) \ge R\_EXP\}$$

After selecting the relaying device, the UTRAN begins to allocate radio resources for two-hop relaying communication, including the conventional link between the relaying device and the UTRAN, and the P2P link between UE1 and the relaying device, just as shown in step S615.

If resources allocation for the two-hop link is successful, the UTRAN sends a RELAYING_ROUTE_INDICATION message to UE1 and the relaying device respectively, as shown in step S616. The RELAYING_ROUTE_INDICATION message contains the identities of UE1 and the relaying device, the allocated radio resources, and available data transmission rate R_MAX. Afterwards, the UTRAN begins to establish conventional link with the relaying device, and based on this, establishes two-hop relaying communication with UE1 relayed by the relaying device, just as shown in steps S617 and S618.

If resources allocation fails, the UTRAN sends a RELAYING_ROUTE_REJECT message to UE1 and returns to its original state, just as shown in steps S619 and S620.

One thing needing some explanation is that all the messages mentioned above are generally transmitted on control channel, including control channel between UE1 and the UTRAN, control channel between the relaying candidates, the relaying device and the UTRAN, and control channel between UE1 and the relaying candidates, the relaying device. In particular, the RELAYING_ROUTE_REQUEST message sent out from the UE requesting for relaying (namely UE1) is broadcasted on a certain common control channel assigned by the UTRAN for the purpose of relaying, which is also scanned regularly by each UE in the cell.

Another thing needing some explanation is that due to the possible mobility of the relaying device and UE1, the two-hop relaying communication might be unstable. If UE1 detects that the two-hop relaying communication is no longer satisfactory to support its expected data transmission rate, UE1 may request another two-hop relaying communication, or switch to the conventional uplink/downlink communication.

The proposed two-hop relaying communication scheme can be used to provide a value-added service to attract mobile users with high speed data service demand. When a mobile user cannot achieved expected data transmission rate from conventional uplink/downlink communication with the network, this service can help to find a qualified relaying route to satisfy the user’s need.

The proposed scheme can further be utilized to enhance effective service coverage range for deployed network. Due to dynamic and unpredictable changes of environment conditions and population distribution, the coverage range of a mobile network especially for high speed data transmission service often becomes unsatisfactory. This invention can be applied to alleviate this problem without additional construction cost.

Fig. 7 is a schematic diagram showing a P2P-based two-hop relaying wireless communication scheme according to the second embodiment of the present invention. In the second embodiment, UE1 that requests for relaying and UE2 that serves as the relaying device are not in the same cell. That is, UE1 that requests for relaying is under the control of base station 1 of CELL 1, while UE2 is under the control of base station 2 of CELL 2.

The difference between the second embodiment shown in Fig. 7 and the first embodiment shown in Fig. 3 is that: in the two-hop relaying wireless communication scheme as shown in Fig. 7, UE1 that requests for relaying and UE2 that serves as the relaying device are in different cells.

The second embodiment according to the present invention has the following advantages:

It can increase the possibility of finding a qualified relaying device for the UE1 requesting for relaying. When two-hop relaying communication in the same cell is unavailable, the proposed inter-cell two-hop relaying communication scheme will provide additional relaying possibility to increase data transmission rate for the UE1 requesting for relaying.

It can divert traffic from one cell to a neighboring cell for the sake of load balance. When a cell is heavily loaded, requests for higher data transmission rate service in this cell may become unavailable. By using the proposed inter-cell two-hop relaying communication scheme, the traffic of the UE1 requesting for relaying can be diverted to a neighboring cell.

It should be noted that the proposed inter-cell two-hop relaying communication scheme is based on the cooperation of two cells. The UE1 requesting for relaying and the relaying device are under control of their camping cells respectively. The information of allocated radio resources is exchanged between the two cells via wired link between base stations, and then forwarded to the two UEs by each cell.

Hereinafter, the two-hop relaying communication establishment process according to the second embodiment of the present invention will be described in detail with reference to Figs. 8-11. Among them, Fig. 8 is a flow chart showing the process of the UE requesting for relaying, for example UE1; Fig. 9 is a flow chart showing the process of a relaying candidate, for example UE2; Fig. 10 is a flow chart showing the process of the base station in a cell which the UE requesting for relaying is camping on, for example base station 1 in CELL 1; and Fig. 11 is a flow chart showing the process of the base station of a relaying candidate cell, base station 2 in CELL 2 for example.

Before describing in detail the proposed two-hop relaying wireless communication scheme according to the second embodiment of the present invention, the following assumptions are made:

1. Suppose that the UE requesting for relaying (UE1) is camping on CELL 1 and has conventional uplink/downlink communication with base station 1 of the CELL 1, but data transmission rate of the conventional uplink/downlink communication cannot satisfy

UE1's demands. Furthermore, it is assumed that UE1 has requested for relaying to increase data transmission rate, but failed to find any qualified relaying device in CELL 1 on which it is camping.

2. Suppose CELL 1 has several neighboring cells, e.g. CELL 2, CELL 3, etc.. These cells may work in different frequency bands, e.g. f1, f2, f3, etc., configured by the network. Furthermore, it is assumed that these cells know the exact radio frequency information of each other.

3. Base station 1 and base stations of these neighboring cells, e.g. base station 2 and base station 3, may connect to one or several radio network controllers (RNC). For the sake of simplicity, it is hereby assumed that only one common RNC is in charge of radio resources allocation for all these neighboring cells.

4. Suppose the system reserves a certain number of radio channels (referred to as relaying probing channel) for broadcasting and listening to relaying probing messages. Each cell that can support inter-cell relaying may broadcast relevant system information such as relaying probing channel identity, the format of relaying probing message, initial sending power of probing message and so on. Therefore UEs can scan the relaying probing channels periodically to detect possible relaying request. A UE requesting for relaying must be granted by the base station thereof before it can use a relaying probing channel to broadcast relaying probing message.

Reference is now given to Fig. 8. First, UE1 establishes conventional uplink/downlink communication with the base station 1 of CELL 1 on which UE1 is camping, as shown in step S801.

After establishment of the communication, UE1 keeps conventional communication with base station 1, and regularly measures and monitors data transmission rate, as shown in step S802.

Next, UE1 decides whether the average data transmission rate (R1) over a certain period of time is less than its lowest acceptable data rate threshold (R_LOW) as shown in step S803. If R1 is larger than or equal to R_LOW, UE1 keeps its original communication with base station 1, i.e. returns to step S802.

If R1 is less than R_LOW, the flow goes to step S804. In this step, UE1 tries to establish two-hop relaying communication inside CELL 1.

If UE1 successfully establishes two-hop relaying communication inside CELL 1, UE1 enters relaying state as shown in steps S805 and S806.

If UE1 fails to establish two-hop relaying communication inside CELL 1, UE1 tries inter-cell relaying communication as shown in steps S805 and S807.

As shown in step S807, UE1 sends an INITIAL_INTERCELL_RELAYING_REQUEST message to base station 1 of CELL 1 on which UE1 is camping. This message contains UE1's identity, its expected data transmission rate (R_EXP) and pilot signal power level table of neighboring cells (RXLEV2, RXLEV3, etc.). Optionally, this message may also include UE1's current position information. In general, R_EXP is larger than the threshold R_LOW.

Then, UE1 waits for response from base station 1. If UE1 receives the INTERCELL_RELAYING_REJECT message from base station 1, UE1 stops relaying attempt and returns to its conventional communication state, just as shown in steps S815 and S816.

If UE1 receives the CANDIDATE_RELAYING_CELL_INFO message from base station 1, UE1 extracts the information of candidate cell(s). Then, UE1 tunes to the frequency band of a candidate cell, and broadcasts an INTERCELL_RELAYING_ROUTE_REQUEST message to the surrounding areas of the candidate cell on the reserved relaying probing channel of the candidate cell, using initial relaying probing transmission power, just as shown in steps S808 and S809. This message contains UE1's identity and its expected data transmission rate (R_EXP).

If there are more than one candidate cell in the CANDIDATE_RELAYING_CELL_INFO, UE1 performs the above-mentioned procedure one by one for every candidate cell, that is, tunes to the frequency band of a candidate cell, and broadcasts an INTERCELL_RELAYING_ROUTE_REQUEST message to the surrounding areas of the candidate cell on the reserved relaying probing channel of the candidate cell, using initial relaying probing transmission power.

Then, UE1 waits for response from base station 1 as shown in step S810. If UE1 receives the INTERCELL_RELAYING_ROUTE_INDICATION message from base station 1, UE1 extracts relaying route information from the message, tunes to the radio frequency band of best relaying cell, and negotiates with best relaying UE to establish P2P link on an assigned radio channel, as shown in steps S811, S812 and S813.

Afterwards, UE1 starts inter-cell two-hop relaying communication relayed by the best relaying UE, and keeps on monitoring control channel with base station 1.

Reference is now given to Fig. 9. UEs camping on candidate relaying cell(s) in the vicinity of UE1 may receive the INTERCELL_RELAYING_ROUTE_REQUEST message from UE1 by scanning relaying probing channel, as shown in step S901.

If a UE is not willing to or capable of relaying, it does not respond to the INTERCELL_RELAYING_ROUTE_REQUEST message and returns to its original state as if it has not received this message, just as shown in steps S902 and S908.

If a UE is willing to and capable of relaying, it estimates available data transmission rates for the P2P link with UE1 (R12) and for the conventional link with its camping base station (R2), based on signal-to-interference-ratio (SIR), available radio resources and other information related to channel quality, as shown in steps S902 and S903.

Then, the UE compares the minimum value of R12 and R2, i.e. $R\_MIN = \min\{R2, R12\}$, with the expected data transmission rate R_EXP of UE1.

If R_MIN is less than R_EXP, the UE stops relaying procedures regarding UE1 and returns to its original state as shown in steps S904 and S908.

If R_MIN is larger than or equal to R_EXP, the UE sends a CANDIDATE_INTERCELL_RELAYING_REPORT message to its base station as shown in steps S904 and S905. This message contains the identities of UE1 and the UE, and estimated available data transmission rate R_MIN.

It should be understood that each UE willing to and capable of relaying sends the above CANDIDATE_INTERCELL_RELAYING_REPORT message to the base stations of their camping cells, respectively.

Then, each UE waits for indication from their respective camping cells as shown in step S906.

If a candidate UE does not receive the INTERCELL_RELAYING_ROUTE_INDICATION message from its base station over a certain period of time, it stops relaying attempt and returns to its original state, as shown in steps S907 and S908.

If a candidate UE receives the INTERCELL_RELAYING_ROUTE_INDICATION message from its base station over a certain period of time, it extracts related information from the message and negotiates with UE1 to establish P2P link on an assigned radio channel and establish conventional link with its base station, just as shown in steps S907, and S909-S911.

When both links are established, the best relaying UE provides relaying for the inter-cell two-hop relaying communication, as shown in step S912.

Reference is now given to Fig. 10. On receiving the INITIAL_INTERCELL_RELAYING_REQUEST message from UE1, base station 1 extracts from the message the identity of UE1 and its expected data transmission rate R_EXP, as shown in steps S1001 and S1002.

Next, in step S1003, base station 1 prepares an empty candidate relaying cell list to record the identities of its neighboring cells that can be used for inter-cell relaying, and base station 1 negotiates with its neighboring cells via RNC to select a set of candidate cells for inter-cell relaying according to the following criteria:

Candidate Relaying Cell Selection Criteria:

a) A candidate cell should support inter-cell relaying functions;

b) A candidate cell should be able to reserve sufficient radio resources for relaying to satisfy UE1's expected data transmission rate R_EXP;

c) A candidate cell should not be too far from UE1 requesting for relaying to establish stable relaying communication. More specifically, base station 1 should compare pilot signal power level RXLEV2, RXLEV3, etc. of each neighboring cell received by UE1 with a minimum level RXLEV_MIN. The pilot signal power level of a candidate cell should satisfy: $RXLEV \geq RXLEV\_MIN$;

d) Optionally, in order to establish a more stable inter-cell relaying communication, base station 1 may also select candidate cells according to the geographic locations of neighboring base stations specified by network planning, and the current position of UE1. For example, base station 1 can utilize Global Position System (GPS) or other location estimation techniques to calculate the relative distance between UE1 and the base station of a neighboring cell.

Base station 1 decides whether each neighboring cell can be a candidate relaying cell. Each neighboring cell satisfying the above criteria will be selected by base station 1 as a candidate relaying cell, and the identity thereof is added into candidate relaying cell list, just as shown in steps S1004-S1009.

Upon completion of the above steps, base station 1 decides whether the candidate relaying cell list is empty, as shown in step S1010.

If the candidate relaying cell list is empty, base station 1 sends to UE1 an INTERCELL_RELAYING_REJECT message indicating that inter-cell relaying communication cannot be performed, and returns to its original connection state, just as shown in steps S1011 and S1012.

If the candidate relaying cell list is not empty, base station 1 notifies the base station of each candidate relaying cell to prepare for inter-cell relaying, and prepares for UE1 a candidate relaying UE list to record information of possible candidate relaying UEs delivered from candidate cells, just as shown in steps S1013 and S1014.

Next, as shown in step S1015, base station 1 sends to UE1 a CANDIDATE_RELAYING_CELL_INFO message. This message contains the candidate relaying cell list together with the radio frequency band and reserved relaying probing channel information of each candidate relaying cell.

Then, in step S1016, base station 1 waits for relaying information from candidate relaying cells.

If base station 1 does not receive information of best candidate relaying UE from the base stations of each candidate cell over a certain period of time, it will send the INTERCELL_RELAYING_REJECT message to UE1 to indicate that inter-cell relaying communication cannot be performed, and returns to its original state, just as shown in steps S1017, S1011 and S1012.

If base station 1 receives information of best candidate relaying UE from the base station(s) of one or more candidate relaying cells over a certain period of time, it will record the identity of each candidate relaying UE and corresponding available data transmission rate R_MAX (cell j) into the candidate relaying UE list prepared for UE1, as shown in step S1018.

As shown in step S1020, after base station 1 receives information of best candidate relaying UEs from all candidate relaying cells, it compares the available data rates of all candidate relaying UEs to select a best relaying UE with the maximum available data transmission rate as the relaying device, i.e. selects a relaying device according to:

$$R\_MAX = \max_{j \in C}\{R\_MAX(cell\ \ j)\}$$

where j is the index of a candidate cell, and C is the set of candidate cells.

After selecting a best relaying UE for UE1, base station 1 notifies the base station of the best relaying UE to reserve radio resources for relaying, waits for response from the base station, and notifies base stations of other candidate cells that they are not selected for relaying to make them return to their original states, just as shown in step S1021.

Afterwards, base station 1 waits for the message indicating whether radio resources allocation is successful from the base station of the relaying UE.

If radio resources allocation at the best relaying cell is not successful, base station 1 sends an INTERCELL_RELAYING_REJECT message to UE1 to indicate that inter-cell relaying communication can not be performed, and returns to its original state, just as shown in steps S1022, S1011 and S1012. In practical application, the system can also be set such that after failure of radio resources allocation at the best relaying cell, one cell is selected from other candidate relaying cells as a best relaying cell for radio resources allocation.

If radio resources allocation at the best relaying cell is successful, base station 1 sends an INTERCELL_RELAYING_ROUTE_INDICATION message to UE1, indicating that inter-cell relaying communication can be performed. This message contains the identity information about the base station of the best relaying cell and about the best relaying UE, as well as allocated radio resources, just as shown in steps S1022 and S1023.

In the subsequent inter-cell relaying communication procedure, base station 1 keeps the control link with UE1 as shown in step S1024.

Reference is now given to Fig. 11. According to the foregoing description, base stations of cells in the vicinity of CELL 1 may receive a relaying request from base station 1 of CELL 1. On receiving the relaying request message from base station 1, these base stations begin to negotiate with base station 1 to know if they can become relaying cells respectively, just as shown in steps S1101 and S1102.

If a cell has not been selected as relaying cell for relaying UE1, its base station returns to its original state as if it has not received the relaying request message, just as shown in steps S1103 and S1111.

If a cell has been selected as relaying cell for relaying UE1, its base station prepares an empty candidate relaying UE list L1 for UE1, just as shown in steps S1103 and S1104.

Then, the base station waits for candidate relaying UE's report from its own UEs as shown in step S1105.

If the base station does not receive CANDIDATE_INTERCELL_RELAYING_REPORT messages from its UEs, the base station returns to its original state, stops relaying and reports to base station 1 that it cannot provide inter-cell relaying communication, just as shown in steps S1106 and S1111.

If a base station receives CANDIDATE_INTERCELL_RELAYING_REPORT message(s) from its UEs, including one or more UEs, the base station extracts the identity information and estimated available data transmission rate R_MIN from its UEs which can serve as relaying candidates, and records the information into its candidate relaying UE list L1, just as shown in steps S1106 and S1108.

As shown in step S1110, after receiving one or several CANDIDATE_INTERCELL_RELAYING_REPORT messages from its UEs within a certain time duration, the base station selects the best candidate UE with the maximum available data transmission rate according to:

$$R\_MAX(cell\ j) = \max_{i \in S_j}\{\min\{R2(i), R12(i)\} \mid R2(i) \geq R\_EXP, R12(i) \geq R\_EXP\}$$

where,

j is the index of a candidate cell;

S_j is the set of candidate relaying UE of cell j,

i is the index of candidate relaying UE,

R2(i) is the estimated available data transmission rate of conventional link between candidate relaying UEi and corresponding base station thereof,

R12(i) is the estimated available data rate of P2P link between candidate relaying UEi and UE1;

R_EXP is the expected data transmission rate of UE1 requesting for relaying.

Next, the base station delivers to base station 1 the information about the best candidate relaying UE under its management, together with the available data transmission rate R_MAX(cell j), and waits for response from base station 1, as shown in S1112.

If a candidate relaying cell is not selected by base station 1 for relaying, base station of the cell stops relaying procedures and returns to its original state, just as shown in steps S1113 and S1111.

If a candidate relaying cell is selected by base station 1 for relaying, base station of the cell performs radio resources allocation under the control of the RNC for the inter-cell two-hop relaying communication, just as shown in steps S1113 and S1114.

If radio resources allocation is not successful, the base station of the best relaying UE notifies base station 1 of information about unsuccessful resources allocation, stops relaying procedures, and returns to its original state, just as shown in steps S1115, S1120 and S1111.

If radio resources allocation is successful, the base station of the best relaying UE notifies base station 1 of the information about radio resources allocation, sends an INTERCELL_RELAYING_ROUTE_INDICATION message to the best relaying UE. This message contains radio resources information assigned for the two-hop relaying communication, just as shown in steps S1115-S1117.

Subsequently, the base station of the best relaying UE establishes conventional link with this best relaying UE and starts inter-cell two-hop relaying communication, as shown in steps S1118 and S1119.

As shown in Fig. 7, after the inter-cell two-hop relaying communication is established, base station 1, the base station of best relaying cell, base station 2 for example, and UE1 should respectively do the following:

Base station 1 is no longer in charge of traffic data for UE1, and hence can release traffic channel for UE1. But base station 1 should still maintain control channel for UE1 and exchange control information regarding UE1 with base station 2.

Base station 2 should be in charge of the traffic forwarding between UE1 and Core Network. Base station 2 only communicates with best relaying UE, for example UE2, via traffic and control channels, and has no direct link with UE1. In case base station 2 needs to send control information to UE1, base station 2 may forward this information to base station 1, and then base station 1 will forward this information to UE1 via control channel in CELL 1.

UE1 works in the frequency band of best relaying cell and communicates only with UE2 via P2P traffic and control channels. Meanwhile, UE1 also periodically monitors its original control channel with base station 1 to exchange control information with base station 1 at the frequency band of CELL 1.

One thing needing some explanation is that all the messages mentioned above are generally transmitted on control channel.

Another thing needing some explanation is that the inter-cell two-hop relaying communication might be unstable due to mobility effect of relaying device and UE1. In case UE1 detects that the inter-cell two-hop relaying communication become unsatisfactory, UE1 may negotiate with base station 1 to perform handover procedures to another two-hop relaying communication from the current two-hop relaying communication, or switch back to conventional communication with base station 1.

The above-described inter-cell two-hop relaying communication scheme can benefit traffic load distribution of a multi-cell communication system. When a cell is heavily loaded and becomes no longer capable of providing higher data rate, inter-cell two-hop relaying communication may divert part of load to neighboring cells that have available radio resources and appropriate relaying UEs.

Fig.12 is a schematic diagram showing the corresponding functional units in a UE according to the present invention. As illustrated in Fig.12, the UE1200 comprises: a P2P communication unit 1203, for performing P2P communication with another UE; a conventional communication unit 1204, for performing conventional uplink/downlink communication with a base station; an estimating unit 1202, for estimating data transmission rate of links; a controlling unit 1201, for controlling the estimating unit 1202, the P2P communication unit 1203 and the conventional communication unit 1204; and a forwarding unit 1205 for, under the control of the controlling unit 1201, forwarding traffic data from the P2P communication unit 1203 to the conventional communication unit 1204, and vice versa, so that another UE's traffic received via P2P link can be forwarded to a base station, and vice versa.

Fig. 13 is a schematic diagram showing the functional units of an apparatus of establishing two-hop relaying communication in a wireless communication system. In the embodiments of the present invention, the apparatus 1300 is at the UTRAN.

As illustrated in Fig. 13, the apparatus 1300 comprises: receiving means 1301, for receiving a two-hop relaying communication request; determining means 1302, for determining a UE as a relaying device after the receiving means 1301 receives the two-hop relaying communication request; and link establishing means 1303, for establishing corresponding links so as to enable two-hop data transmission be performed via the relaying device, if the determining means 1302 determines a relaying device.

Various variations and modifications can be made without departing from the concept and scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments thereof except as defined in the appended claims.

CLAIMS:

1. A method of establishing multi-hop relaying communication in a wireless communication system, the method comprising the steps of:

(a) receiving from a first UE a request for communicating with a communication device via multi-hop relaying;

(b) selecting a second UE as a relaying device according to predefined conditions; and

(c) establishing corresponding links to make said first UE communicate with said communication device via the relaying of said second UE.

2. The method as claimed in claim 1, wherein in step (b), selection of said relaying device is made according to the criterion of having a higher data transmission rate than the current data transmission rate of said first UE.

3. The method as claimed in claim 1, wherein link between said first UE and said second UE is Peer-to-Peer (P2P) communication link.

4. The method as claimed in claim 1, wherein said first UE and said second UE are located in the same cell.

5. The method as claimed in claim 1, further comprising the step of:

(d) if an appropriate second UE in the cell of said first UE cannot be determined as a relaying device, determining an appropriate second UE in a neighboring cell of the cell of said first UE as a relaying device.

6. The method as claimed in claim 5, wherein the pilot signal power level from said neighboring cell is larger than a predetermined value.

7. The method as claimed in claim 5, wherein in step (d), selection of said relaying device is made in said neighboring cell according to the criterion of having a higher data transmission rate than the current data transmission rate of said first UE.

8. An apparatus of establishing multi-hop relaying communication in a wireless communication system, the apparatus comprising:

receiving means, for receiving from a first UE a request for communicating with a communication device through multi-hop relaying;

determining means, for selecting a second UE as a relaying device according to predefined conditions; and

link establishing means, for establishing corresponding links to make said first UE communicate with said communication device via the relaying of said second UE.

9. The apparatus as claimed in claim 8, wherein said determining means selects said relaying device according to the criterion of having a higher data transmission rate than the current data transmission rate of said first UE.

10. The apparatus as claimed in claim 8, wherein said determining means selects said relaying device in the cell of said first UE.

11. The apparatus as claimed in claim 8, wherein if an appropriate second UE in the cell of said first UE cannot be determined as a relaying device, said determining means determines an appropriate second UE in a neighboring cell of the cell of the first UE as a relaying device.

12. The apparatus as claimed in claim 11, wherein the pilot signal power level from said neighboring cell is larger than a predetermined value.

13. The apparatus as claimed in claim 11, wherein said determining means selects a relaying device in said neighboring cell according to the criterion of having a higher data transmission rate than the current data transmission rate of said first UE.

14. A network equipment in a wireless communication system, wherein said equipment comprises the apparatus of establishing multi-hop relaying communication in a wireless communication system as claimed in any one of claims 8-13.

15. A method of establishing multi-hop relaying communication in a wireless

communication system, the method comprising the steps of:

(a) sending to a network system a request for communicating with a communication device via multi-hop relaying;

(b) receiving corresponding confirmation information from said network system, wherein said confirmation information contains information about a UE that serves as a relaying device; and

(c) establishing a link with said relaying device so as to make communication with said communication device via the relaying of said relaying device.

16. The method as claimed in claim 15, further comprising the steps of:

estimating data transmission rate of conventional uplink/downlink traffic link; and

sending said multi-hop relaying communication request to said network system if the data transmission rate of said conventional uplink/downlink traffic link is less than a predetermined value.

17. The method as claimed in claim 15, wherein said link with said relaying device is P2P link.

18. The method as claimed in claim 15, wherein in step (c), said link with said relaying device is established in the same cell.

19. The method as claimed in claim 15, wherein in step (c), said link with said relaying device is established in a different cell.

20. A user equipment, comprising:

estimating means, for estimating data transmission rate of conventional uplink/downlink traffic link;

conventional communication means for, when the data transmission rate of said conventional uplink/downlink traffic link is less than a predetermined value, sending to a network system a request for communication with a communication device via multi-hop relaying and receiving from said network system corresponding confirmation information, wherein said confirmation information contains information about a UE that serves as a relaying device; and

P2P communication means, for establishing a link with said relaying device to make communication with said communication device via the relaying of said relaying device.

21. The user equipment as claimed in claim 20, further comprising:

controlling means, for controlling said conventional communication means and said P2P communication means; and

forwarding means for, under the control of said controlling means, forwarding traffic data from said P2P communication means to said conventional communication means, and forwarding traffic data from said conventional communication means to said P2P communication means.

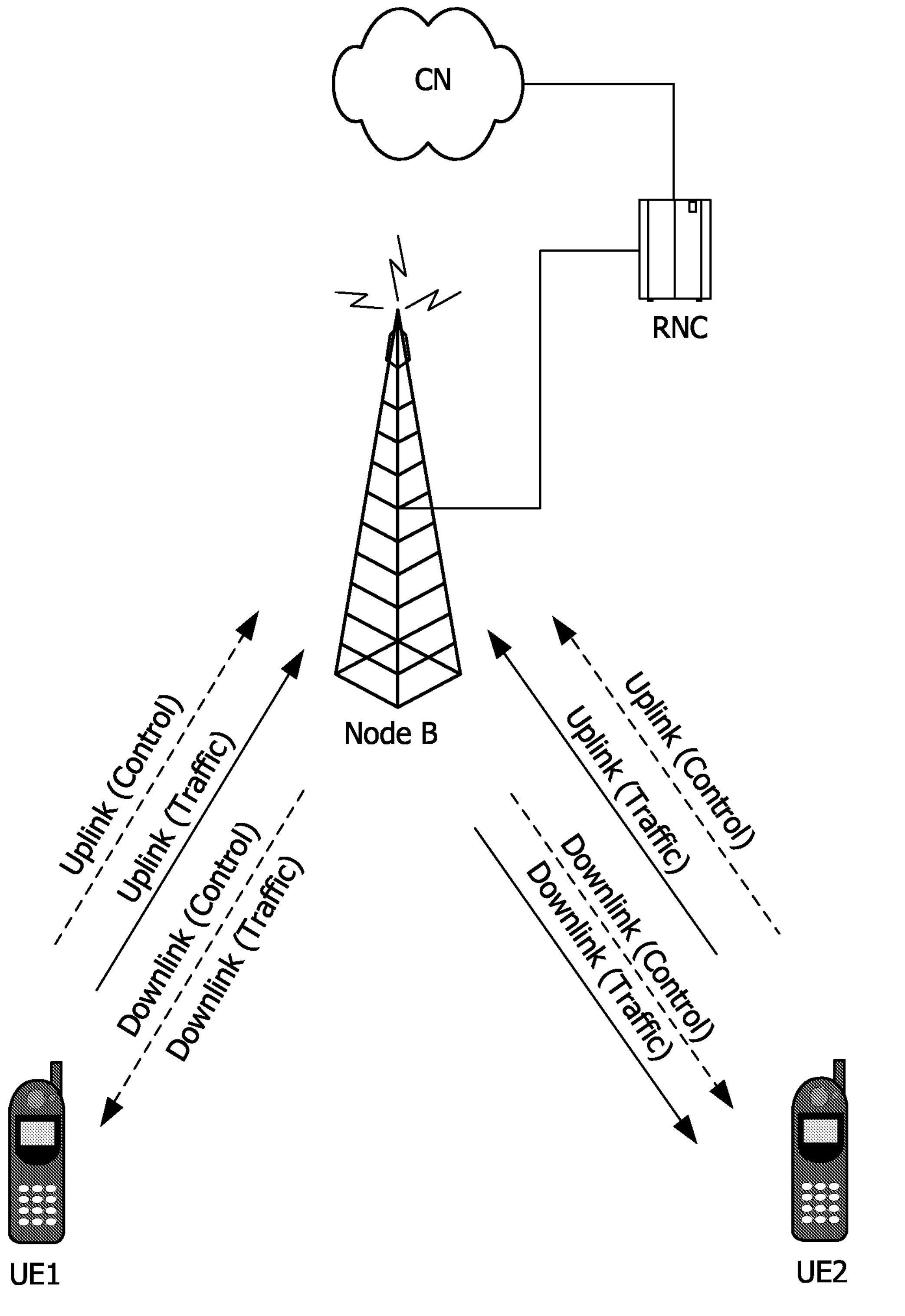
CN
RNC
Node B
Uplink (Control)
Uplink (Traffic)
Downlink (Control)
Downlink (Traffic)
Uplink (Control)
Uplink (Traffic)
Downlink (Control)
Downlink (Traffic)
UE1
UE2

FIG. 1

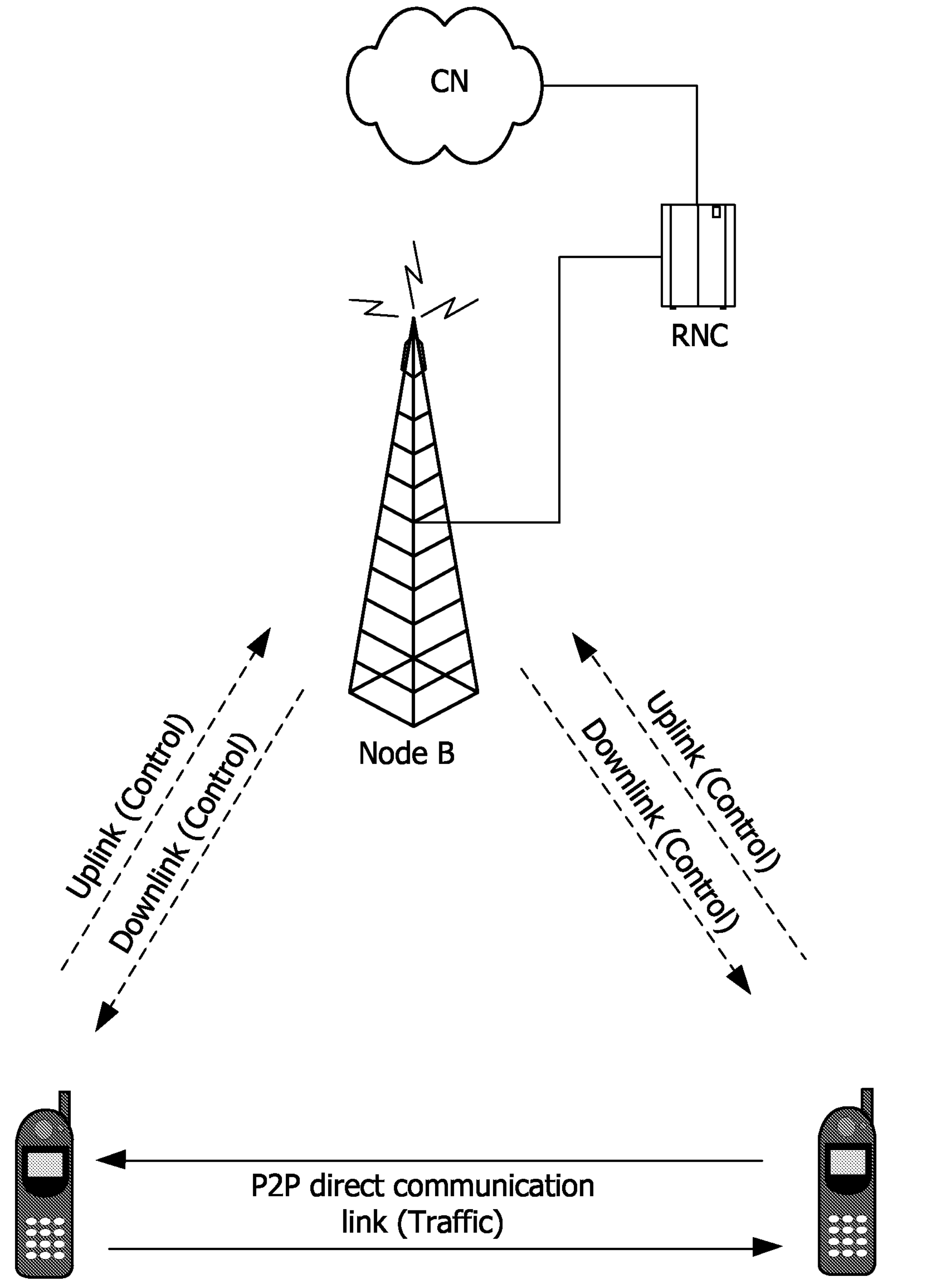
CN
RNC
Node B
Uplink (Control)
Downlink (Control)
Uplink (Control)
Downlink (Control)
P2P direct communication
link (Traffic)
UE1
UE2

FIG. 2

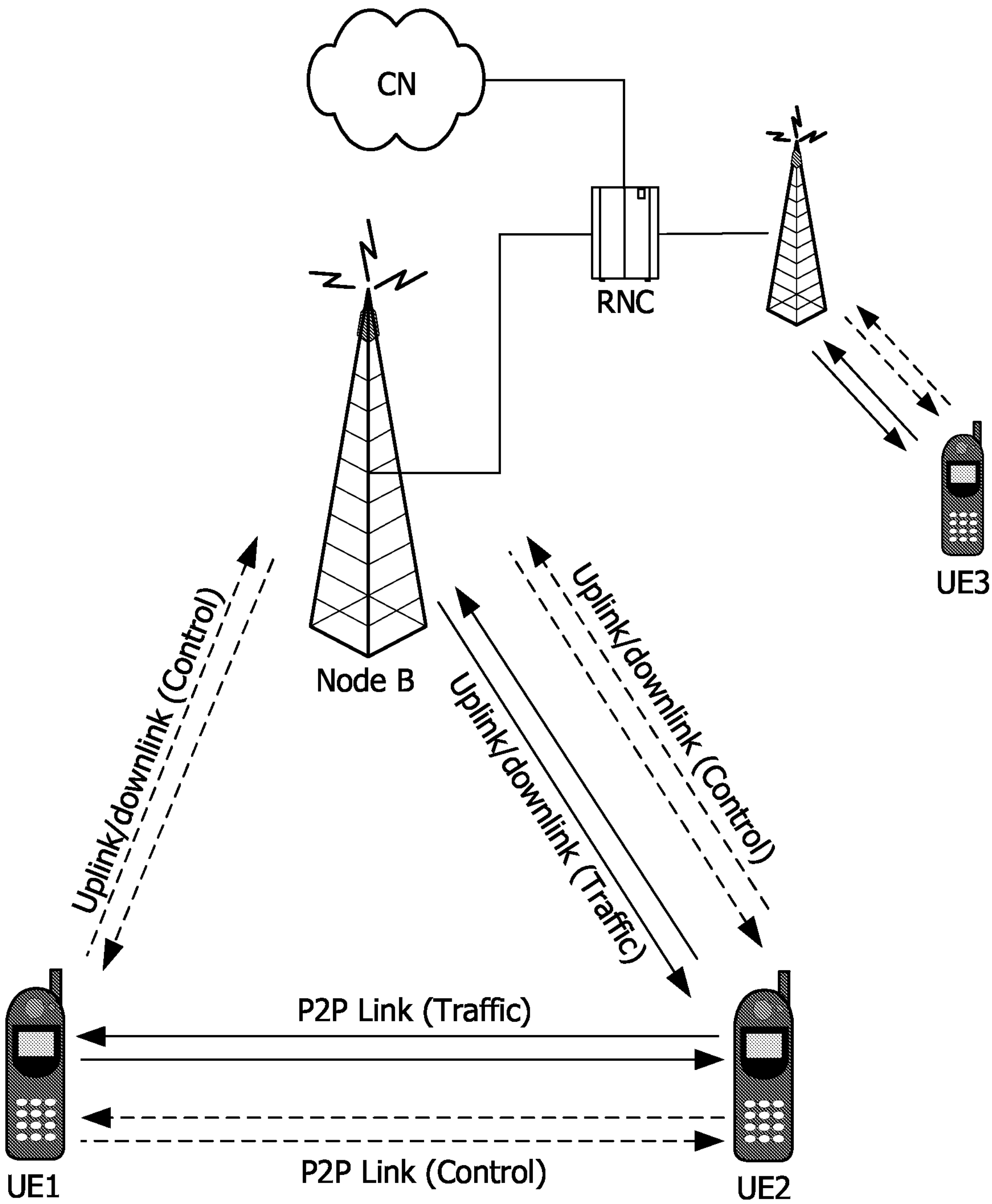
CN
RNC
Node B
UE3
Uplink/downlink (Control)
Uplink/downlink (Traffic)
Uplink/downlink (Control)
P2P Link (Traffic)
P2P Link (Control)
UE1
UE2

FIG. 3

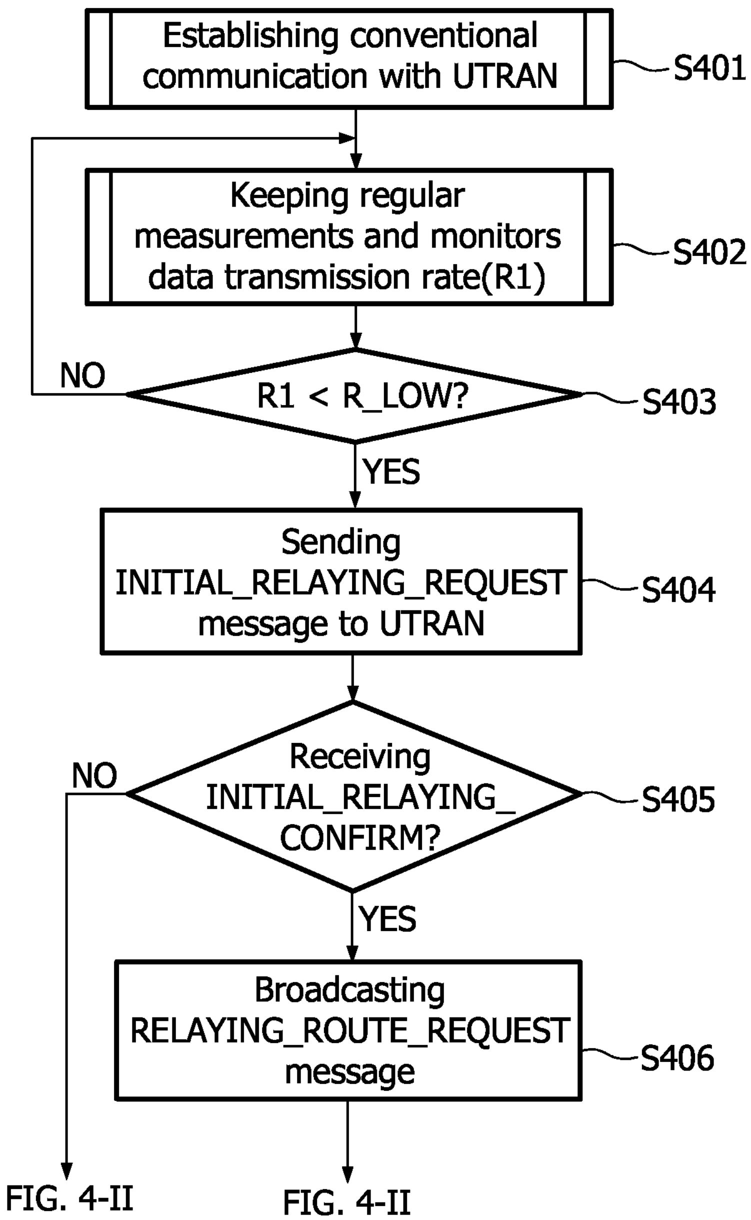
Establishing conventional communication with UTRAN
S401
Keeping regular measurements and monitors data transmission rate(R1)
S402
NO
R1 < R_LOW?
S403
YES
Sending INITIAL_RELAYING_REQUEST message to UTRAN
S404
NO
Receiving INITIAL_RELAYING_CONFIRM?
S405
YES
Broadcasting RELAYING_ROUTE_REQUEST message
S406
FIG. 4-II
FIG. 4-II

FIG. 4-I

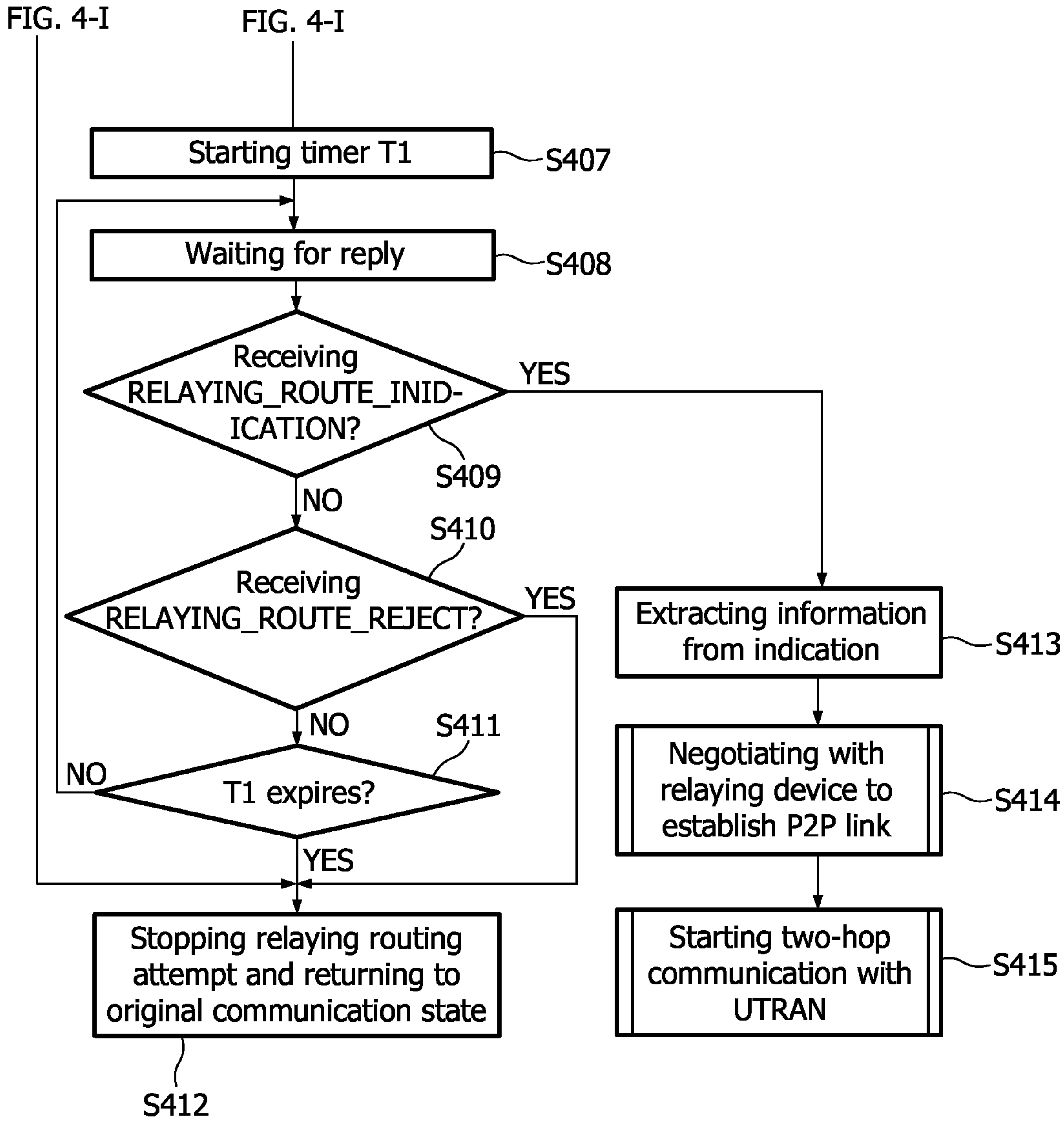
FIG. 4-I
FIG. 4-I
Starting timer T1
S407
Waiting for reply
S408
Receiving RELAYING_ROUTE_INID-ICATION?
S409
YES
NO
S410
Receiving RELAYING_ROUTE_REJECT?
YES
NO
S411
NO
T1 expires?
YES
Stopping relaying routing attempt and returning to original communication state
S412
Extracting information from indication
S413
Negotiating with relaying device to establish P2P link
S414
Starting two-hop communication with UTRAN
S415

FIG. 4-II

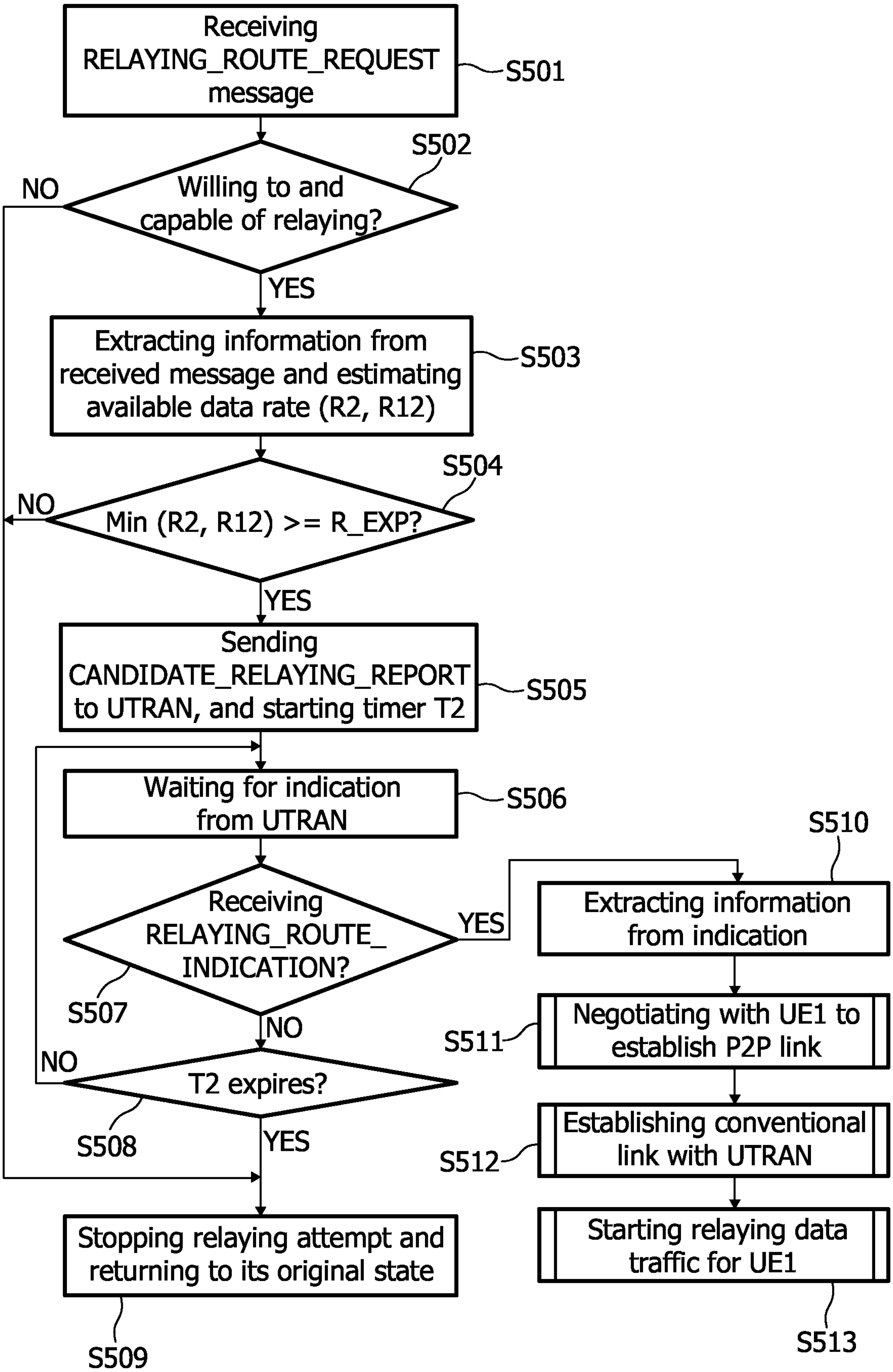
Receiving RELAYING_ROUTE_REQUEST message
S501
Willing to and capable of relaying?
S502
NO
YES
Extracting information from received message and estimating available data rate (R2, R12)
S503
Min (R2, R12) >= R_EXP?
S504
NO
YES
Sending CANDIDATE_RELAYING_REPORT to UTRAN, and starting timer T2
S505
Waiting for indication from UTRAN
S506
Receiving RELAYING_ROUTE_INDICATION?
S507
YES
NO
T2 expires?
S508
NO
YES
Stopping relaying attempt and returning to its original state
S509
Extracting information from indication
S510
Negotiating with UE1 to establish P2P link
S511
Establishing conventional link with UTRAN
S512
Starting relaying data traffic for UE1
S513

FIG. 5

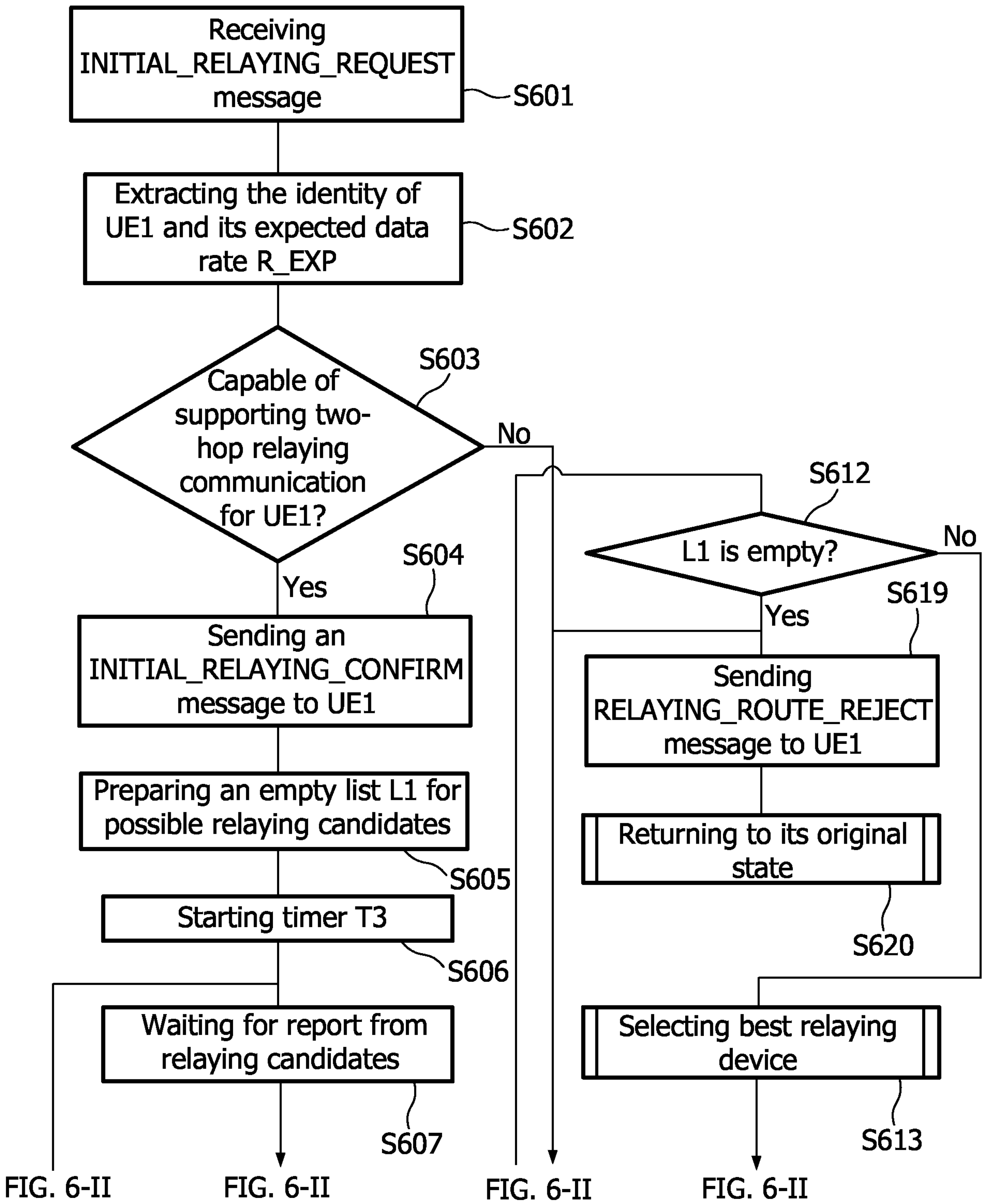
Receiving INITIAL_RELAYING_REQUEST message
S601
Extracting the identity of UE1 and its expected data rate R_EXP
S602
Capable of supporting two-hop relaying communication for UE1?
S603
No
Yes
S604
Sending an INITIAL_RELAYING_CONFIRM message to UE1
Preparing an empty list L1 for possible relaying candidates
S605
Starting timer T3
S606
Waiting for report from relaying candidates
S607
S612
L1 is empty?
No
Yes
S619
Sending RELAYING_ROUTE_REJECT message to UE1
Returning to its original state
S620
Selecting best relaying device
S613
FIG. 6-II
FIG. 6-II
FIG. 6-II
FIG. 6-II

FIG. 6-I

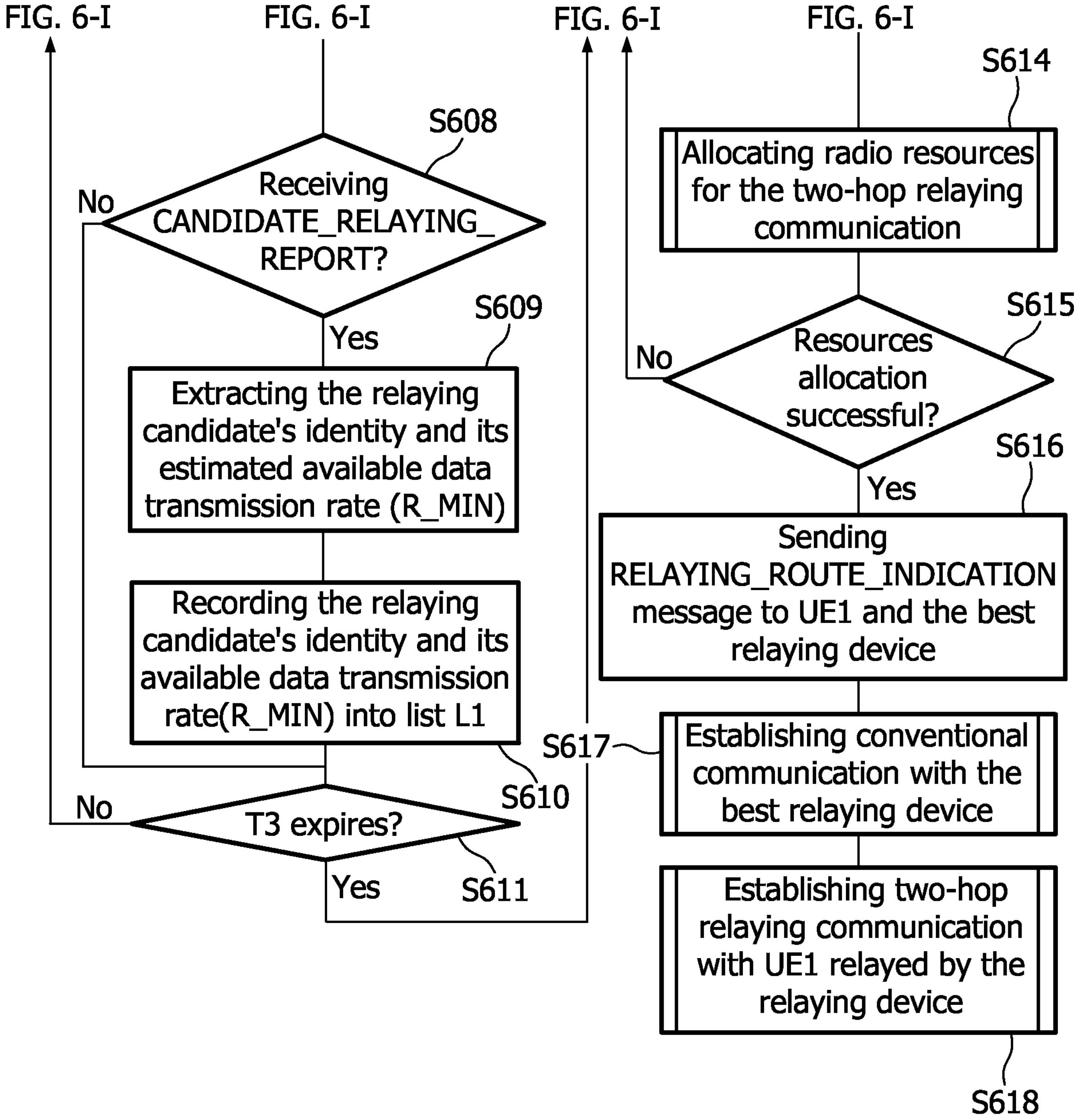
FIG. 6-I
FIG. 6-I
FIG. 6-I
FIG. 6-I
S608
Receiving CANDIDATE_RELAYING_REPORT?
No
Yes
S609
Extracting the relaying candidate's identity and its estimated available data transmission rate (R_MIN)
Recording the relaying candidate's identity and its available data transmission rate(R_MIN) into list L1
S610
T3 expires?
No
Yes
S611
S614
Allocating radio resources for the two-hop relaying communication
S615
Resources allocation successful?
No
Yes
S616
Sending RELAYING_ROUTE_INDICATION message to UE1 and the best relaying device
S617
Establishing conventional communication with the best relaying device
Establishing two-hop relaying communication with UE1 relayed by the relaying device
S618

FIG. 6-II

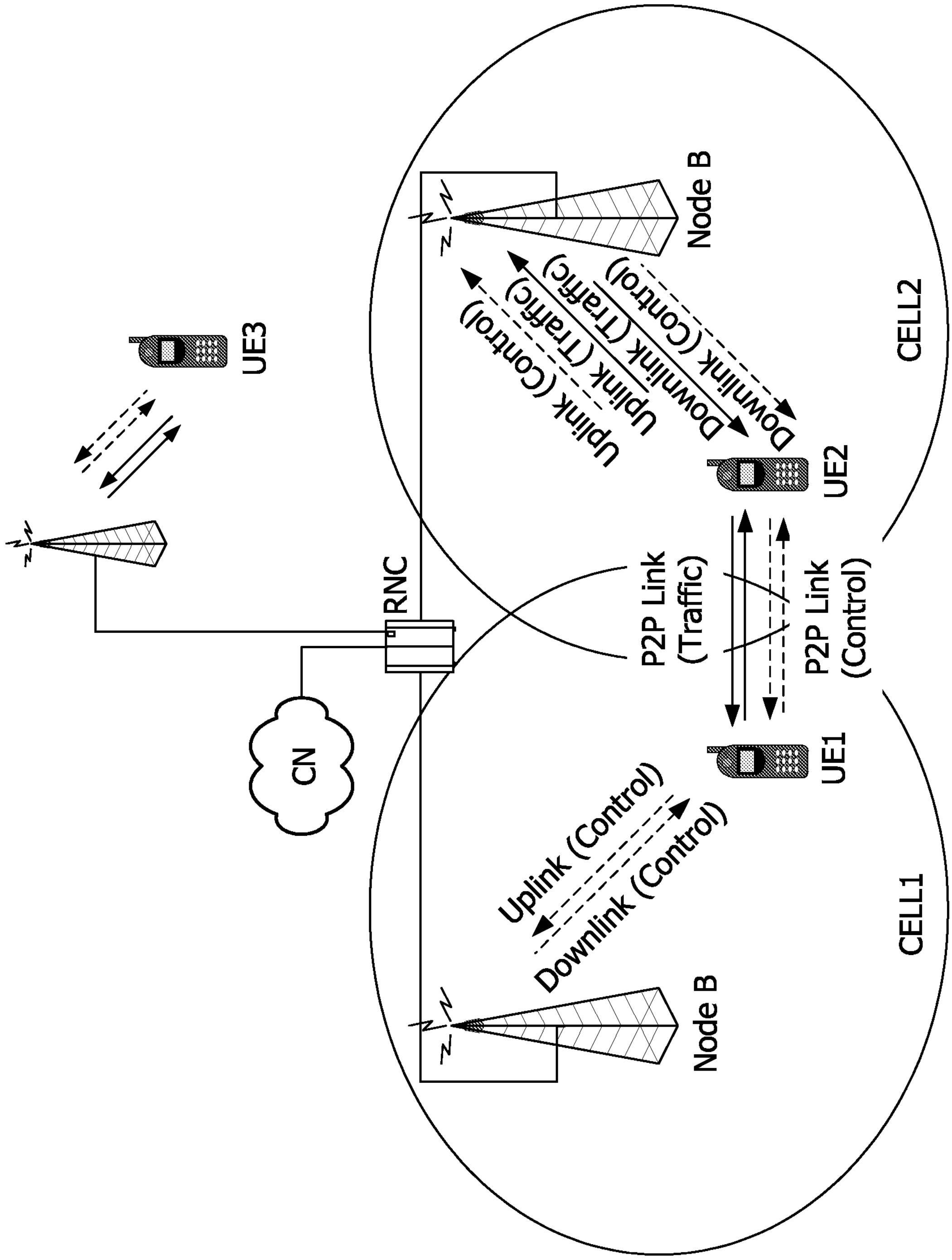
Node B
Downlink (Control)
Downlink (Traffic)
Uplink (Traffic)
Uplink (Control)
UE3
UE2
CELL2
RNC
P2P Link (Traffic)
P2P Link (Control)
UE1
CN
Uplink (Control)
Downlink (Control)
CELL1
Node B

FIG. 7

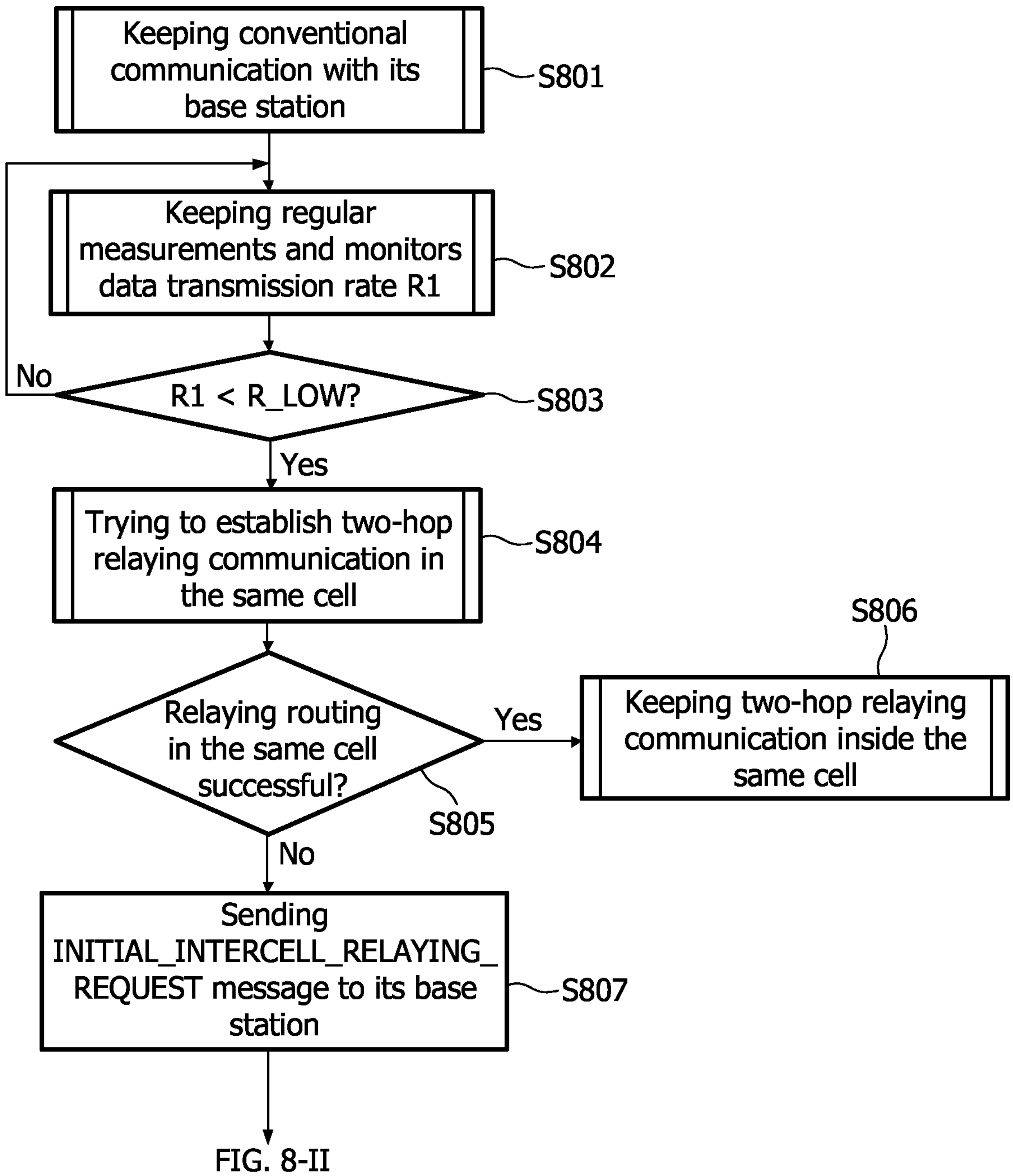
Keeping conventional communication with its base station
S801
Keeping regular measurements and monitors data transmission rate R1
S802
No
R1 < R_LOW?
S803
Yes
Trying to establish two-hop relaying communication in the same cell
S804
S806
Relaying routing in the same cell successful?
Yes
Keeping two-hop relaying communication inside the same cell
S805
No
Sending INITIAL_INTERCELL_RELAYING_REQUEST message to its base station
S807
FIG. 8-II

FIG. 8-I

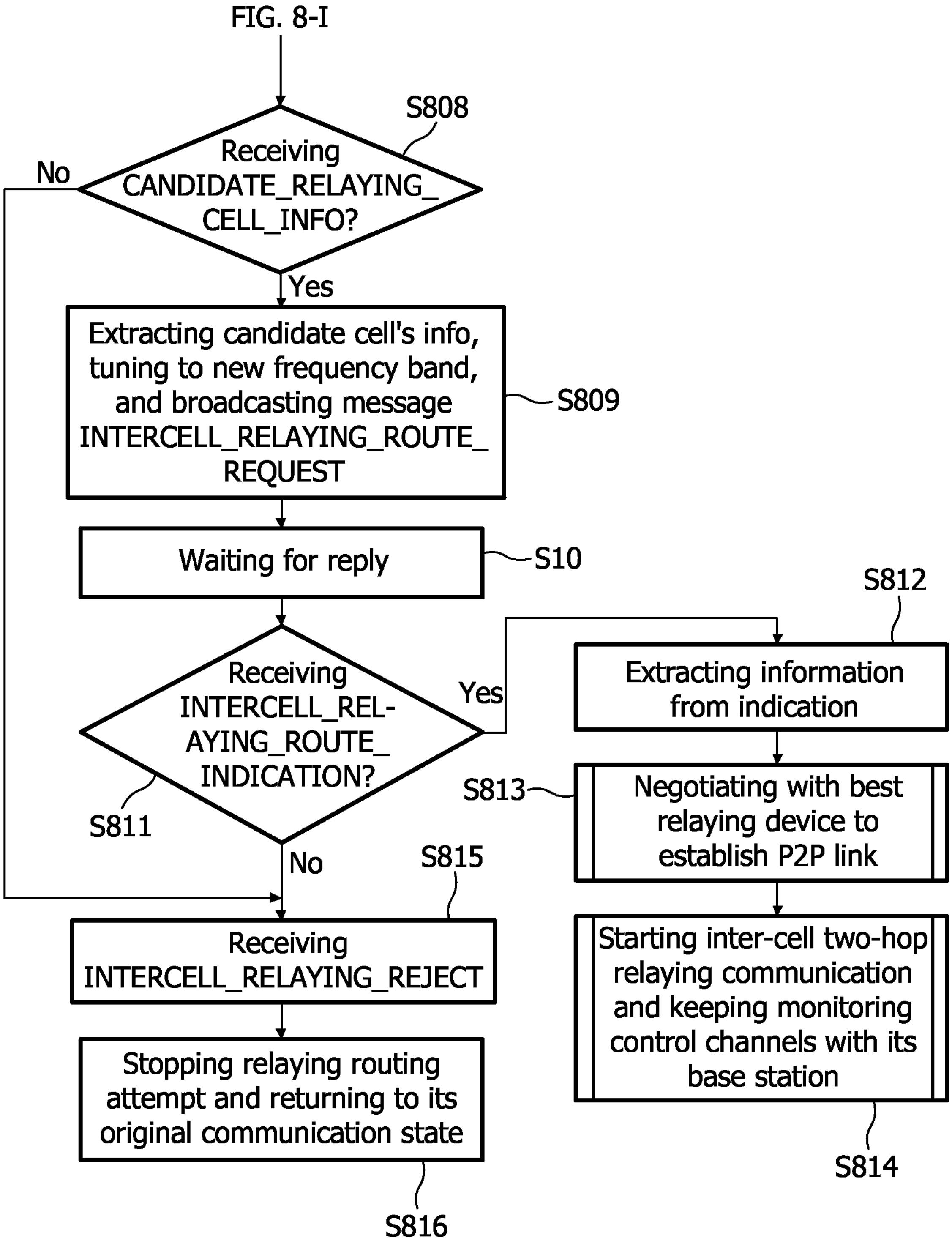
FIG. 8-I
S808
Receiving CANDIDATE_RELAYING_CELL_INFO?
No
Yes
Extracting candidate cell's info, tuning to new frequency band, and broadcasting message INTERCELL_RELAYING_ROUTE_REQUEST
S809
Waiting for reply
S10
S812
Receiving INTERCELL_REL-AYING_ROUTE_INDICATION?
Yes
Extracting information from indication
S813
Negotiating with best relaying device to establish P2P link
S811
No
S815
Receiving INTERCELL_RELAYING_REJECT
Starting inter-cell two-hop relaying communication and keeping monitoring control channels with its base station
Stopping relaying routing attempt and returning to its original communication state
S814
S816

FIG. 8-II

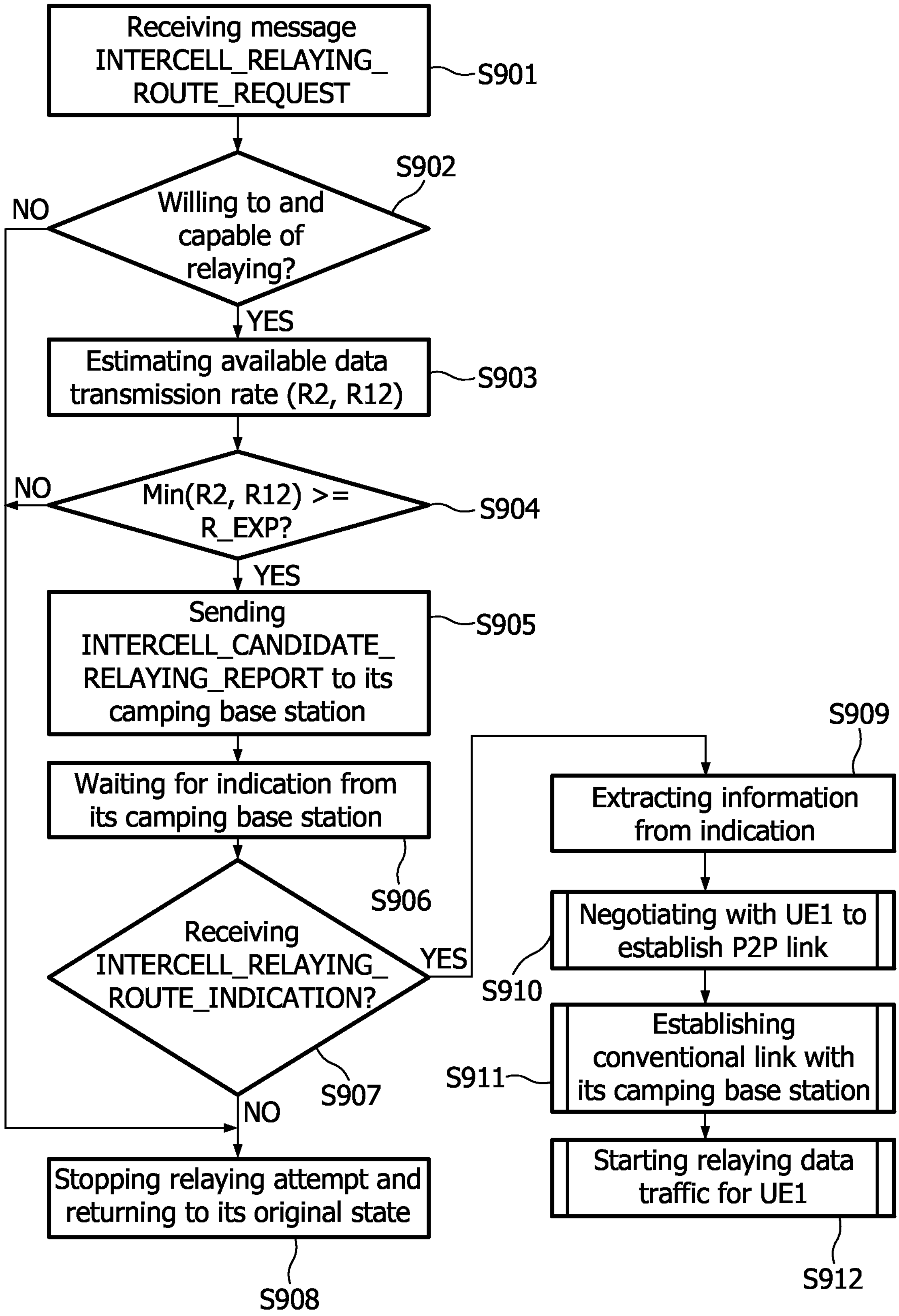
Receiving message INTERCELL_RELAYING_ROUTE_REQUEST
S901
Willing to and capable of relaying?
S902
NO
YES
Estimating available data transmission rate (R2, R12)
S903
Min(R2, R12) >= R_EXP?
S904
NO
YES
Sending INTERCELL_CANDIDATE_RELAYING_REPORT to its camping base station
S905
Waiting for indication from its camping base station
S906
Receiving INTERCELL_RELAYING_ROUTE_INDICATION?
S907
YES
NO
Stopping relaying attempt and returning to its original state
S908
Extracting information from indication
S909
Negotiating with UE1 to establish P2P link
S910
Establishing conventional link with its camping base station
S911
Starting relaying data traffic for UE1
S912

FIG. 9

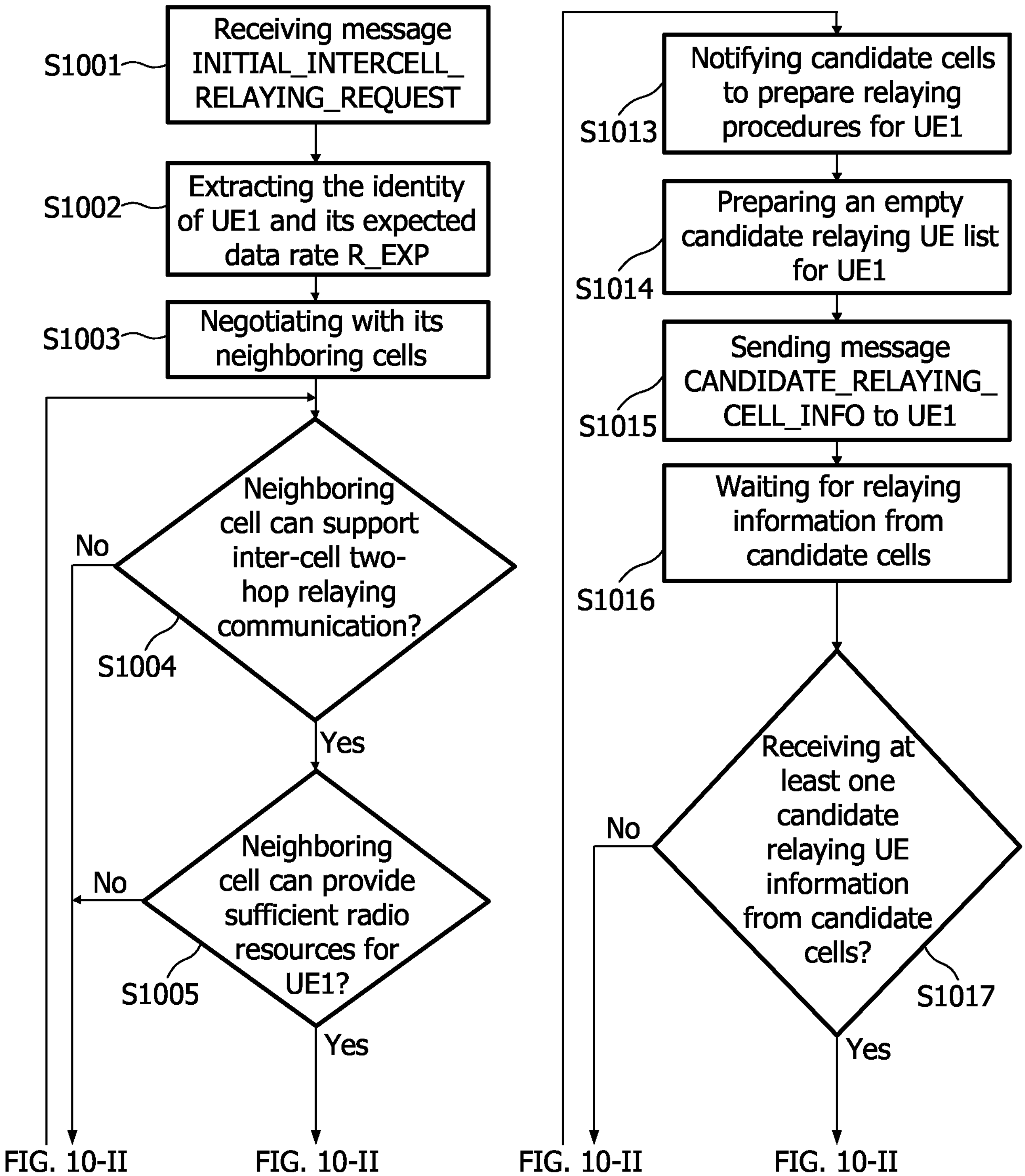
Receiving message INITIAL_INTERCELL_ RELAYING_REQUEST
S1001
Extracting the identity of UE1 and its expected data rate R_EXP
S1002
Negotiating with its neighboring cells
S1003
Neighboring cell can support inter-cell two-hop relaying communication?
S1004
No
Yes
Neighboring cell can provide sufficient radio resources for UE1?
S1005
No
Yes
FIG. 10-II
FIG. 10-II
Notifying candidate cells to prepare relaying procedures for UE1
S1013
Preparing an empty candidate relaying UE list for UE1
S1014
Sending message CANDIDATE_RELAYING_ CELL_INFO to UE1
S1015
Waiting for relaying information from candidate cells
S1016
Receiving at least one candidate relaying UE information from candidate cells?
S1017
No
Yes
FIG. 10-II
FIG. 10-II

FIG. 10-I

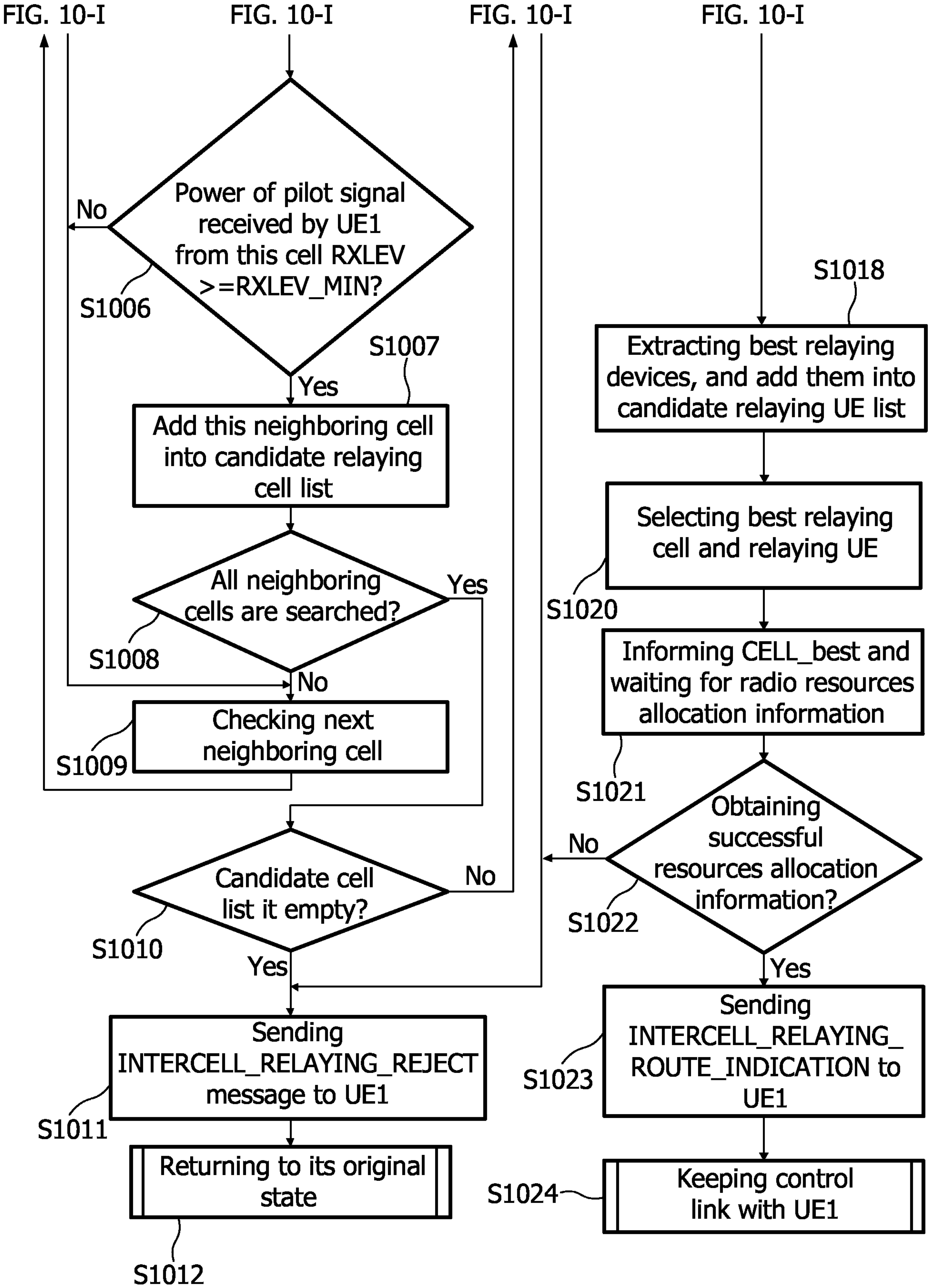
FIG. 10-I
FIG. 10-I
FIG. 10-I
FIG. 10-I
Power of pilot signal received by UE1 from this cell RXLEV >=RXLEV_MIN?
No
S1006
Yes
S1007
Add this neighboring cell into candidate relaying cell list
All neighboring cells are searched?
Yes
S1008
No
Checking next neighboring cell
S1009
Candidate cell list it empty?
No
S1010
Yes
Sending INTERCELL_RELAYING_REJECT message to UE1
S1011
Returning to its original state
S1012
S1018
Extracting best relaying devices, and add them into candidate relaying UE list
Selecting best relaying cell and relaying UE
S1020
Informing CELL_best and waiting for radio resources allocation information
S1021
Obtaining successful resources allocation information?
No
S1022
Yes
Sending INTERCELL_RELAYING_ROUTE_INDICATION to UE1
S1023
Keeping control link with UE1
S1024

FIG. 10-II

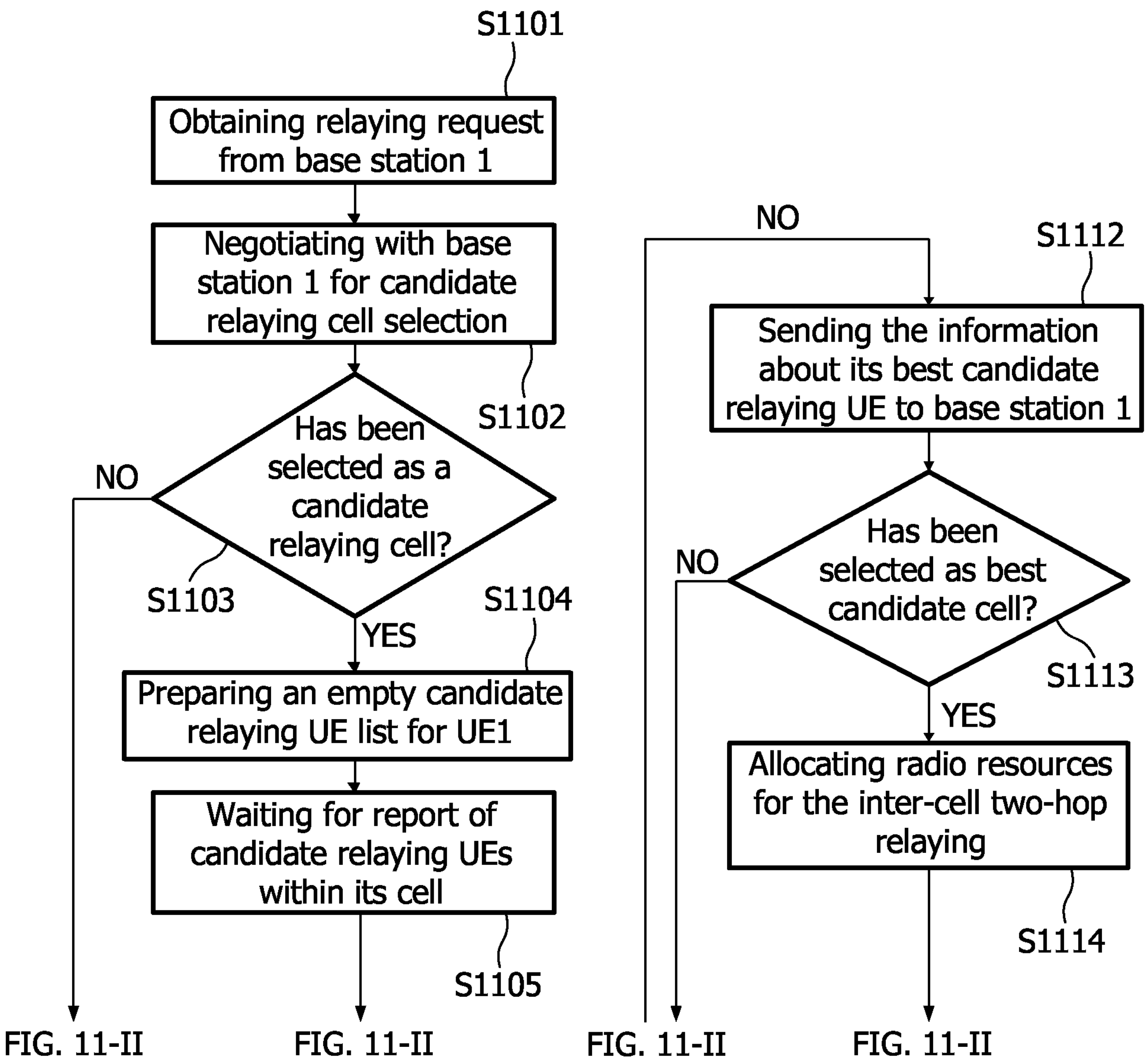
S1101
Obtaining relaying request from base station 1
Negotiating with base station 1 for candidate relaying cell selection
S1102
Has been selected as a candidate relaying cell?
NO
S1103
YES
S1104
Preparing an empty candidate relaying UE list for UE1
Waiting for report of candidate relaying UEs within its cell
S1105
NO
S1112
Sending the information about its best candidate relaying UE to base station 1
Has been selected as best candidate cell?
NO
S1113
YES
Allocating radio resources for the inter-cell two-hop relaying
S1114
FIG. 11-II
FIG. 11-II
FIG. 11-II
FIG. 11-II

FIG. 11-I

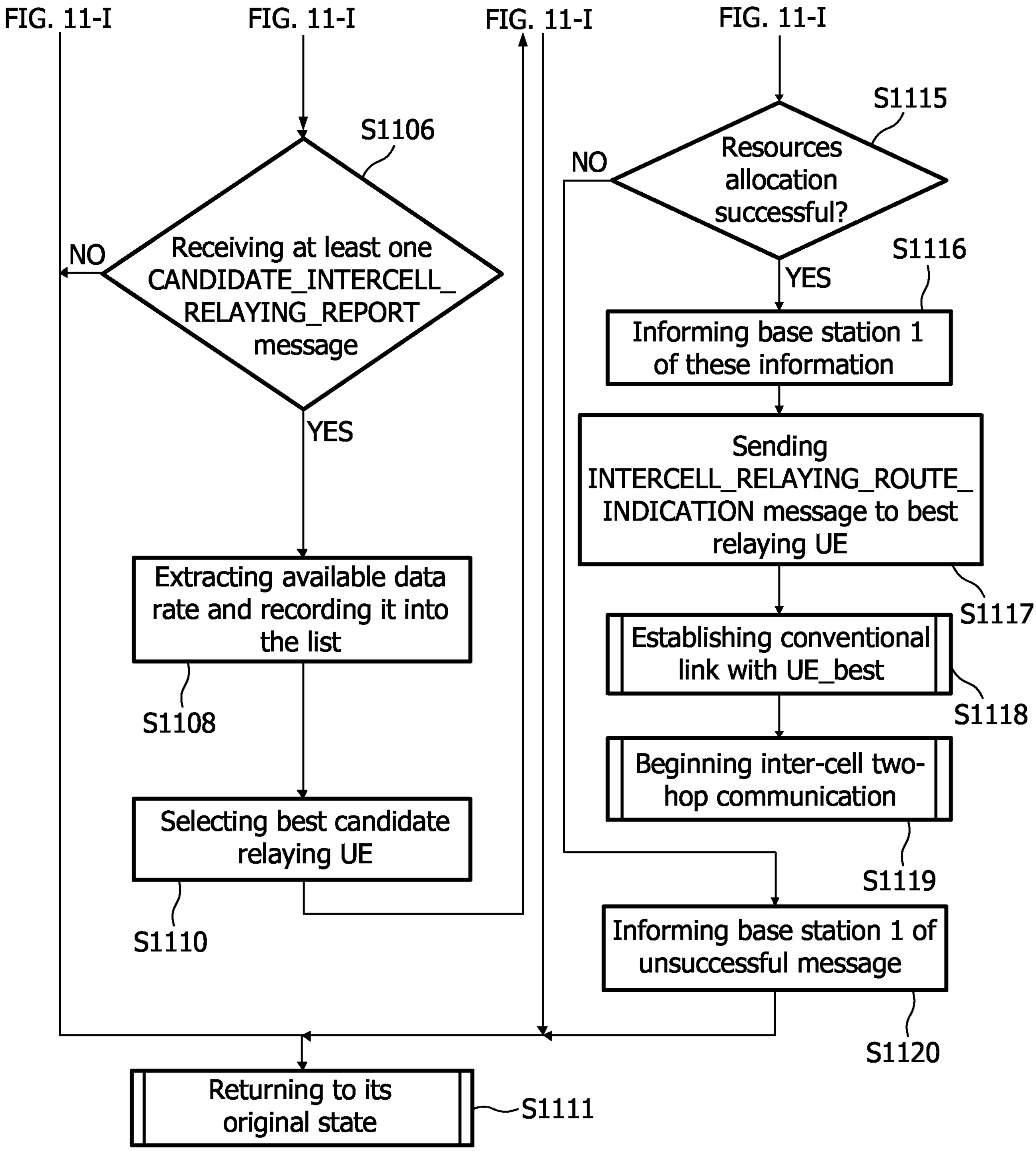
FIG. 11-I
FIG. 11-I
FIG. 11-I
FIG. 11-I
S1106
Receiving at least one CANDIDATE_INTERCELL_RELAYING_REPORT message
NO
YES
Extracting available data rate and recording it into the list
S1108
Selecting best candidate relaying UE
S1110
S1115
Resources allocation successful?
NO
YES
S1116
Informing base station 1 of these information
Sending INTERCELL_RELAYING_ROUTE_INDICATION message to best relaying UE
S1117
Establishing conventional link with UE_best
S1118
Beginning inter-cell two-hop communication
S1119
Informing base station 1 of unsuccessful message
S1120
Returning to its original state
S1111

FIG. 11-II

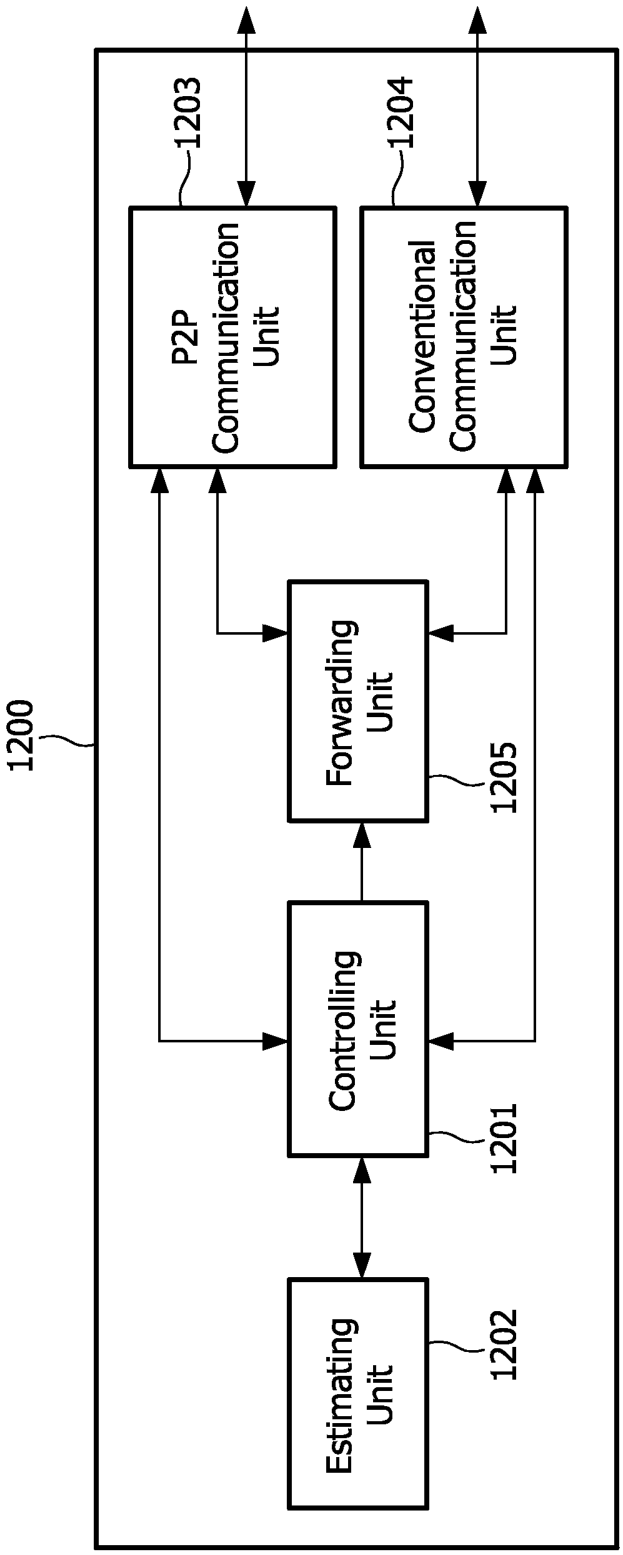
1200
1203
P2P Communication Unit
1204
Conventional Communication Unit
Forwarding Unit
1205
Controlling Unit
1201
Estimating Unit
1202

FIG. 12

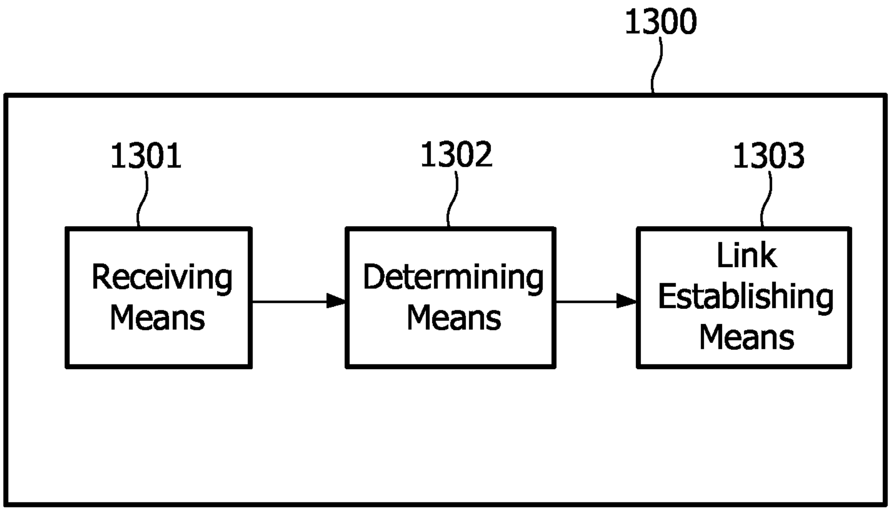
1300
1301
1302
1303
Receiving Means
Determining Means
Link Establishing Means

FIG. 13