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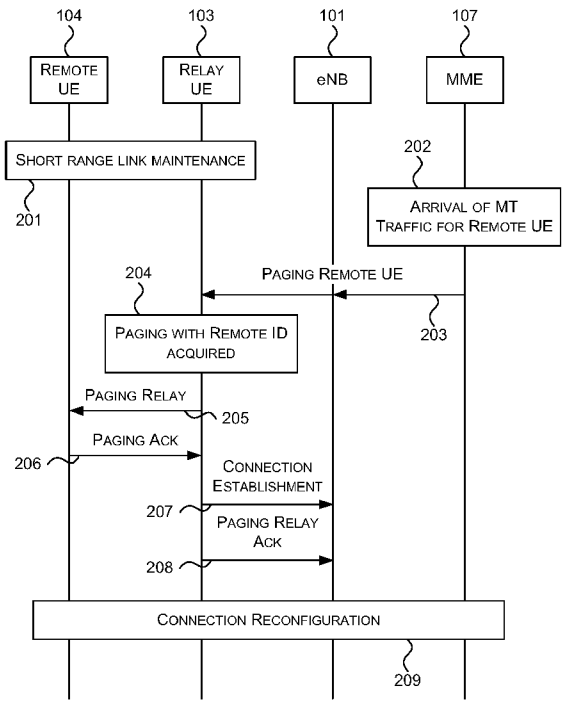


FIG. 2

(57) Abstract: A paging message for a remote User Equipment (104) sent by an eNB (101) on the remote UE's paging occasions is received by a relay User Equipment (103) and relayed to the remote User Equipment (104) over a sidelink (105). By aligning the paging occasions of the relay UE with the remote UE, power requirements for both User Equipments are minimized. Techniques for paging on the relay UE's paging occasions and for establishing a Mobile Originated connection are also provided.

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Paging and connection establishment via relay devices in a wireless communication system

Technical Field

Embodiments of the present invention generally relate to wireless communication systems and in particular to devices and methods for paging remote wireless communication devices using relay devices.

Background

Wireless communication systems, such as the third-generation (3G) of mobile telephone standards and technology are well known. Such 3G standards and technology have been developed by the Third Generation Partnership Project (3GPP). The 3rd generation of wireless communications has generally been developed to support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system. The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network where a macrocell is supported by a base station known as an eNodeB or eNB (evolved NodeB).

Traditional wireless networks for mobile devices (UEs) rely on a cellular infrastructure which supports UE communications. In these traditional networks, even if communication is between a pair of UEs, communication is managed by network nodes. Here uplink (UL) and downlink (DL) transmissions are always made between a UE and a network node (an eNB/eNodeB for example). As an alternative to communication between UEs via network nodes, direct communication uses a direct, short range link between UEs. Here, the only role of the network nodes, if any, is to establish the direct link and to assign resources. 3GPP LTE (Long Term Evolution) Release 12 onwards considers this type of non-centralised communication, where the term ‘sidelink’ is used to refer to direct links between UEs. A direct link between a pair of UEs is facilitated by the so-called 'PC5' interface at each UE.

An L2 relay architecture, which is built on top of a sidelink capability may be employed wherein a "relay" User Equipment, which is within the coverage area of a cell supported by an eNB of a wireless communication system, can relay communications from the eNB to another "remote" UE and/or vice versa. Typically, an association is established between the relay UE and the remote UE and the wireless communication system is aware of the association.

The remote UE, while being in RRC_IDLE mode is required to communicate with the wireless communication system at least in order to support establishment of Mobile Originated (MO) communication and the establishment of Mobile Terminated (MT)

communication. For legacy centralised communications, the MO communication is typically established using a Random Access (RA) procedure and the MT communication is initialised using paging controlled by the wireless communication system which is followed by a RA procedure. In an LTE system, for example, a UE must move from an RRC_IDLE mode to an RRC_CONNECTED mode if it wishes to communicate with the wireless communication system (MO communication) or if the wireless communication system wishes to communicate with the UE (MT communication).

In LTE, for MO Communication, a UE initiates an RA procedure in the cell that it has camped onto and then starts the MO communication. For MT communication, a UE is required to monitor the cell transmissions for paging (from an eNB) on predefined occasions known as the paging occasion (PO). Once paged, the UE is required to perform a RA procedure to enable the start of MT communication.

It has been proposed that a remote UE can initiate establishing a connection to a relay UE. It has further been proposed that either a remote UE or a node of a wireless communication system can initiate establishing a connection (or association) between the remote UE and a relay UE it has also been proposed that the remote UE is not required to be in RRC_CONNECTED mode while associated (or paired) with the relay UE: that the relay UE may be in RRC_IDLE mode whilst associated (paired) with the remote UE, in which case the remote UE is not in RRC_CONNECTED mode. Herein, the term RRC_CONNECTED when applied to a remote UE means that the remote UE has a context in a node (e.g. an eNB) of a wireless communication system.

While not acquiring paging, a UE in RRC_IDLE UE mode may switch to a power saving mode. In Rel-13 an extended discontinuous reception (eDRX) feature was introduced which added the notion of a Paging Time Window (PTW) and only during this time window is a UE required to monitor the paging occasion (PO), thus extending the duration of the power saving mode. The PTW configuration together with the PO configuration also defines an Idle mode extended DRX (IeDRX) configuration of the UE.

However, the process of paging monitoring and the following RA procedure still accounts for a significant part of the UE overall power consumption, especially if the data transmissions or receptions are relatively small. Therefore it would be advantageous to provide a means for reducing this power consumption.

Summary

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

According to a first aspect of the present invention there is provided a method for paging a first wireless communication device in a wireless communication system, the method comprising: maintaining a direct link between the first wireless communication device and a second communication device wherein the first wireless communication device is configured with a paging occasion; at a node of the wireless communication system, transmitting a paging message intended for the first wireless communication device over a channel and on a paging occasion configured to the first wireless communication device; at the second wireless communication device, monitoring a paging occasion configured to the first wireless communication device, receiving said paging message and relaying said paging message for reception by the first wireless communication device; and at the first wireless communication device, on receiving the relayed paging message, transmitting a paging acknowledgement for reception by the second wireless communication device; and at the second wireless communication device, receiving the paging acknowledgement and initiating a connection establishment with said node.

In one embodiment accordance with the first aspect, the paging message is relayed to the first wireless communication device from the second wireless communication device over the direct link. In another embodiment, the paging message is relayed using L2 communication maintenance pool resources provided to the second communication device by the wireless communication system.

The method according to the first aspect may further include, at the wireless communication system node, providing a sidelink configuration, and at the second wireless communication device, relaying the sidelink configuration over the direct link to the first wireless communication device.

The method according to the first aspect may further include, at the second wireless communication device sending a paging relay acknowledgement message for reception by the node.

In some embodiments, the method according to the first aspect may further include, at the first wireless communication device after acknowledging receipt of the paging message, reconfiguring a connection with the node. Such connection reconfiguration may comprise establishing secured relay bearers with the node of the wireless communication system.

The direct link may be a short range link (i.e. short compared with the range of a link between the node and either the first or the second wireless communication devices), such as a sidelink as defined by 3GPP technology or a Bluetooth (RTM) communication link or a WLAN communication link for example.

If the first wireless communication device (acting as a remote UE) detects that a direct link to the second wireless communication device (acting as a relay UE) is available, then the first wireless communication device is not required to monitor paging occasions on a centralized Uu channel. Instead, it can just monitor paging occasions on the direct link. This measure provides a power saving for a remote UE. During an RRC_IDLE mode, a relay UE's power consumption budget includes only the direct link level maintenance.

If the second wireless communication device (acting as a relay UE) detects that no direct link is available to another wireless communication device associated with it (i.e. a remote UE) then it need not monitor paging occasions for this remote UE on the centralised Uu channel. Once the direct link becomes unavailable, a remote UE may revert to monitoring the Uu channel for paging with no need for further configuration.

For a relay UE to be able to receive a paging message intended for a remote UE, the relay UE needs to monitor the Uu channel on at least one paging occasion configured to the remote UE. Hence, the relay UE needs to be either aware of the configuration of the remote UE's paging occasions or else there is an alignment of the paging occasions of the relay UE and of the remote UE.

Hence, in one embodiment, the method of the first aspect may further include configuring the second wireless communication device (e.g. a relay UE) with parameters relating to the first communication device (e.g. a remote UE) and , at the second communication device, calculating the paging occasion of the first communication device using said parameters. The parameters may be provided to the second wireless communication device by the wireless communication system, in a transmission from said node, for example. The parameters may comprise at least one of: an idle mode DRX cycle; nB value; System Information (SI); an identifier of the remote UE; the IMSI (International Mobile Subscriber Identifier) of the remote UE. The idle mode DRX cycle is useful if it was configured by the non-access strata (NAS) layer of the wireless communication system. If this is not the case, then the DRX cycle can be derived from System Information. It is preferable if the wireless communication system's NAS layer configures the relay UE's idle mode DRX cycle so as to avoid the situation where the relay UE and the remote UE acquire different idle mode DRX cycles from System Information because they are camped onto different cells. The nB value is useful if it was configured by the NAS layer of the wireless communication system. If this is not the case, then the nB value can be derived from SI.

In order that the second wireless communication device (e.g. a relay UE) may define a Paging Time Window (PTW) of the first wireless communication device (i.e. a remote UE) the method of the first aspect may further include configuring the relay UE with at least one of the following parameters relating to the first communication device: idle mode extended DRX (IeDRX) cycle (T_{eDRX}) as configured by the wireless communication system; an identifier of the remote UE (this could be derived from the S-TMSI (System Architecture Evolution - Temporary Mobile Subscriber Identifier and used for the calculation of the Hyper frame of a Paging Time Window and the PTW start); a Paging Time Window length of the remote UE configured by the NAS of the wireless communication system.

In order to achieve alignment of a paging occasion of the first wireless communication device with a paging occasion of the second wireless communication device, the method of the first aspect may further include configuring both the first and second wireless communication devices (i.e. a remote UE and a relay UE respectively) with parameters which allow such an alignment. For example, a remote UE may be configured with an idle mode DRX cycle which is equal to or a multiple of a relay UE idle DRX cycle.

The configuring of parameters for allowing alignment may be realised by a configuration message being sent from a wireless communication system node to the first and second wireless communication devices.

In some instances, it may be necessary to calculate a PO offset at the relay UE and at the Remote UE. A UE_ID which is normally required for this calculation may be replaced with a new ID which is common to both the relay UE and the remote UE. Using the same ID for both is a condition for both calculations to result with an aligned PO. Such a new ID may be based e.g. on an IMSI of the relay UE or a combination of the IMSIs of both the relay and remote UEs.

In a further example, if a relay UE has been configured with IeDRX, then one or more remote UEs are configured with an IeDRX cycle which is equal to or a multiple of the relay UE's IeDRX cycle. Configuring a remote UE with IeDRX cycle which is shorter than the IeDRX cycle of the relay UE should be avoided since this would result in the relay UE “sleeping” during PO of the remote UE and the subsequent failure of the paging relay operation.

IeDRX alignment minimises power consumption in the relay UE since the relay UE only needs to monitor the remote UE's paging occasion during a PTW. IeDRX PO alignment can be achieved as long as the wireless communication system has configured the relay UE's IeDRX cycle and has configured the remote UE(s) with IeDRX cycle which is equal to or a multiple of the Relay UE's IeDRX cycle. Preferably, the relay UE's Paging Time Window (PTW) length is at least equal to the remote UE's Paging Time Window length, if configured. A UE_ID_H used for PTW_Start calculation may be replaced with a new ID which is common for the relay

and remote UEs. This new ID may be based e.g. on the S-TMSI of the relay and remote UEs.

In other embodiments, the first wireless communication device (i.e. a remote UE) may be made aware of the availability of the direct link (e.g. a sidelink). This may be achieved by, at the second wireless communication device (i.e. a relay UE), sending periodic discovery messages over resources to the first wireless communication device which the latter attempts to decode. The resources used for sending such periodic discovery messages may comprise a dedicated discovery resource pool.

In one embodiment, the method includes configuring resources for the direct link assuming that only the remote UE is aware of the relay UE's proximity.

According to a second aspect of the invention, there is provided a method for paging a first wireless communication device in a wireless communication system, the method comprising: maintaining a direct link between the first wireless communication device and a second communication device; at a node of the wireless communication system, receiving a transmission intended for the first wireless communication device, transmitting a paging message to the second wireless communication device; at the second wireless communication device, establishing a connection with the node; at the node, following establishment of the connection, notifying the second wireless communication device of the transmission intended for the first wireless communication device; at the second wireless communication device relaying the paging message for reception by the first wireless communication device; and at the first wireless communication device, on receiving the relayed paging message, transmitting a paging acknowledgement.

The method according to the second aspect may further include, at the second wireless communication device sending a paging relay acknowledgement message for reception by the node.

The method according to the second aspect may further include, at the first wireless communication device after acknowledging receipt of the paging message, reconfiguring a connection with the node. Such connection reconfiguration may comprise establishing secured relay bearers with the node of the wireless communication system.

The method according to the second aspect may further include, at the wireless communication system node, providing a sidelink configuration, and at the second wireless communication device, relaying the sidelink configuration over the direct link to the first wireless communication device.

The direct link may be a short range link (i.e. short compared with the range of a link between the node and either the first or the second wireless communication devices). In certain embodiments, the direct link may comprise the sidelink as defined by 3GPP technology. In other embodiments, the direct link may comprise a Bluetooth (RTM) communication link or a WLAN communication link, for example.

If the first wireless communication device (acting as a remote UE) detects that a direct link to the second wireless communication device (acting as a relay UE) is available, then the first wireless communication device is not required to monitor paging occasions on a centralised Uu channel.

If the wireless communication system is not accessed by the second wireless communication device up to a certain timer expiry, then the node may page the first wireless communication device over the Uu channel if not had done so already.

If the second wireless communication device determines that the direct link is unavailable, that it may respond to the relay message sent by the node with a relay failure notification.

In another embodiment according to the second aspect, the wireless communication system (or eNB) may decide to page the first wireless communication device via the second communication device or directly over the Uu channel based on the last known direct link availability status;.e.g in the last RRC connection.

The direct link may be a short range link (i.e. short compared with the range of a link between the node and either the first or the second wireless communication devices), such as a sidelink as defined by 3GPP technology or a Bluetooth (RTM) communication link, for example.

In other embodiments, the first wireless communication device (i.e. a remote UE) may be made aware of the availability of the direct link (e.g. a sidelink). This may be achieved by, at the second wireless communication device (i.e. a relay UE), sending periodic discovery messages over resources to the first wireless communication device which the latter attempts to decode. The resources used for sending such periodic discovery messages may comprise a dedicated discovery resource pool.

According to a third aspect of the invention, there is provided a method for establishing a connection between a first wireless communication device and a node of a wireless communication system via a second wireless communication device, the method comprising: maintaining a direct link between the first and second wireless communication devices; at the first wireless communication device, sending to the second wireless communication device, over the direct link, a request for connection establishment; at the second wireless communication device, on

receiving the request for connection, establishing a connection with the node and sending an indication to the node that the connection is required for the first wireless communication device; at the node, sending a configuration for the direct link to the second wireless communication device; and at the second wireless communication device, relaying, over the direct link, the configuration for the direct link to the first wireless communication device.

The method of the third aspect may further include, configuring the first wireless communication device with at least one preconfigured connection establishment opportunity. Connection establishment opportunities may be provided on the direct link from resources from the L2 maintenance pool. These resources may be aligned (in time) with the paging occasions of the first and second wireless communication devices.

The method of the third aspect may further include, at the second wireless communication device, sending an acknowledgement of receipt of the request for connection establishment to the first wireless communication device over the direct link.

The method of the third aspect may further include, at the first wireless communication device after receiving the relayed configuration for the direct link, reconfiguring a connection with the node. Such connection reconfiguration may comprise establishing secured relay bearers with the node of the wireless communication system.

The direct link may be a short range link (i.e. short compared with the range of a link between the node and either the first or the second wireless communication devices). In some embodiments, the direct link is the sidelink as defined by 3GPP technology. In other embodiments, the direct link is a Bluetooth (RTM) communication link or a WLAN communication link, for example.

In other examples of methods in accordance with the third aspect, the first wireless communication device (i.e. a remote UE) may be made aware of the availability of the direct link (e.g. a sidelink). This may be achieved by, at the second wireless communication device (i.e. a relay UE), sending periodic discovery messages over resources to the first wireless communication device which the latter attempts to decode. The resources used for sending such periodic discovery messages may comprise a dedicated discovery resource pool.

Embodiments of the invention advantageously provide optimization for remote UE power saving while minimising the impact on the relay UE power consumption.

The invention may be utilised to provide a procedure for maintaining an optimised sidelink connection between a remote UE and a relay UE within an L2 architecture.

This then permits an optimised relayed paging and an optimised MO communication for the remote UE and for the relay UE.

The methods of the invention are applicable to a 3GPP sidelink technology or a non-3GPP technology such as Bluetooth (RTM) or any short range technology that is able to perform power efficient link level maintenance. In the case of 3GPP sidelink technology, the invention may provide a procedure for establishment of MO communication within an L2 relay architecture.

The invention provides a paging occasion (PO) procedure which can keep power requirements of a relay UE to a minimum. Typically, a UE returning from DRX “sleep” back to activity undergoes a series of activities such as hardware bring up, software stack reloading, synchronisation with the wireless communication system and SI (System Information) acquisition, all of which can consume more power than the actual PO monitoring. So by keeping the number of "wake-ups" to a minimum, power consumption can be minimised. In particular, embodiments of the invention can ensure that no further "wake-ups" are performed by a relay UE regardless of the number of remote UEs that it is required to support. This can be achieved by virtue of the alignment of the remote and relay UEs' paging occasions Furthermore, with only a minimal increase in computation cycles, the relay UE can monitor a remote UE's paging messages on the same paging occasion and decode them for itself.

Another benefit of the invention is a reduction in signalling and the complexity of the Radio Access Network side of a wireless communication system infrastructure. The wireless communication system does not need to be aware of the short range link status between a remote and a relay UE until communication establishment is required. The link status is maintained at the UEs only which means that the wireless communication system (an eNB for example) does not need to be updated on each status change.

Optional sidelink specific enhancements add procedures for power optimized sidelink maintenance based on PO alignment. PO alignment ensures that a Remote UE is “awake” for sidelink maintenance monitoring while it is awake for paging monitoring. It also ensures that a relay UE is awake for sidelink monitoring signal transmission while it is awake for monitoring paging messages for itself and for a remote UE with which it is associated.

Further power optimisation is provided with leDRX configuration where the maintenance of the direct link is performed only during a PTW. This means that for an leDRX configured remote UE, and the associated relay UE, sidelink maintenance is performed for only a small portion of the time e.g. for few seconds every tens of minutes.

A sidelink maintenance procedure may be performed over a special resource pool. This approach solves the issue of a relay UE and an associated remote UE having different resource pool allocation because they are served by different cells.

PO alignment permits a power optimized sidelink based MO communication procedure. For a remote UE the procedure is a necessity in order to support MO communication in cases where the remote UE is out of coverage and cannot perform a Random Access procedure. It can also be very power efficient in the case where a remote UE is in coverage and especially for UEs in CE (CoverageEnhancement) by saving power on repetitions. For a relay UE the procedure ensures that MO Opportunities co-incide with the times that the relay UE is awake for its own paging monitoring, regardless of the number of remote UEs that the relay UE may be supporting, i.e. the solution is also scalable.

The wireless communication system may be an LTE system and the node of the wireless communication unit may be an eNB or MME Mobility Management Entity. It will be understood by those skilled in the art that an MME provides an NAS configuration and triggers paging but transmissions are physically sent by an eNB.

According to a fourth aspect of the invention, there is provided a relay wireless communication device arranged to maintain a direct link with a remote wireless communication device which has been configured with a paging occasion and wherein the relay wireless communication device is further arranged to calculate the paging occasion of the remote communication device using first parameters, said first parameters including at least one of. idle mode DRX cycle; System Information; an identifier of the remote wireless communication device; an IMSI (International Mobile Subscriber Identifier) of the remote wireless communication device and align its paging occasion with that of the remote wireless communication device.

According to a fifth aspect of the invention, there is provided a non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to the first, second and third aspects.

The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

Brief description of the drawings

Further details, aspects and embodiments of the invention will be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

Figure 1 is a simplified block diagram of a wireless communication system operating in accordance with an example embodiment;

Figure 2 is a message sequence chart illustrating an exemplary method of paging on a remote UE's paging occasion;

Figure 3 shows timelines relating to the method of Figure 2;

Figure 4 is a message sequence chart illustrating an exemplary method of paging on a remote UE's paging occasion with sidelink configuration;

Figure 5 shows timelines relating to the method of Figure 4;

Figure 6 is a message sequence chart illustrating an exemplary method of paging on a relay UE's paging occasion;

Figure 7 is a message sequence chart illustrating an exemplary method of paging on a relay UE's paging occasion with sidelink configuration;

Figure 8 shows timelines relating to a method for sidelink status monitoring;

Figure 9 is a message sequence chart illustrating an exemplary method of establishing a Mobile Originated connection; and

Figure 10 shows timelines relating to the method of Figure 9.

Detailed description of the preferred embodiments

Those skilled in the art will recognise and appreciate that the specifics of the examples described are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings. Further, the timelines of Figures 3, 5 8 and 10 are schematic only and are not drawn to any particular scale.

Figure 1 shows a wireless communication system 100 which may be an LTE system The system 100 includes at least one eNB 101 and other network entities (not shown). The eNB 101 supports a cell 102 in which are located a relay UE 103 and a remote UE 104. A direct link 105 exists between the two UEs 103 and 104. A further wireless communications link 106 exists between the relay UE 103 and the eNB 101 and supports a Uu centralised communications channel. The eNB 101 is connected to a Mobility Management Entity (MME) 107. The relay UE 103 may typically be, for example, a smart phone or an aggregation node. The remote UE104 may typically be a wearable or an IoT (Internet of things) device e.g. a smart watch, a wireless music player or a tracking device or a domestic or industrial meter or sensor.

The relay UE 103 and the remote UE 104 are associated (or paired) with one another and the wireless communication system 100, and in particular the eNB101, is aware of the association. In some embodiments there are several remote UEs (not shown) which are all associated with the one relay UE 103. The relay UE 103 may be an eRelay UE (an evolved relay UE) and the remote UE 104 may be an eRemote UE (an evolved remote UE). Such "evolved" UEs implement the “evolved ProSe UE-to-Network Relay” feature introduced in an LTE Rel-15 study.

In some embodiments, there are two levels of association between the relay UE 103 and the remote UE 104. On a first level, a static association exists which can be

thought of as a "trust relationship" which is defined in higher layers between these two UEs that allows them to engage in "UE-to-Network" (via an eNB) relaying with each other. On a second level, the association is based on the direct link 105 level status between the remote UE 104 and the relay UE 103.

A trust relationship association type is not related to the direct link 105 level status and it can be considered as an NAS state. It can be handled either between the remote UE 104 and the relay UE 103 autonomously or it could be controlled by the NAS of the wireless communication system 100. The latter option allows the possibility of wireless communication system- controlled authentication, billing etc.

The direct link-level status is dependent not only on the proximity of the relay UE 103 and the remote UE 104 but also on the direct link level maintenance procedures used by the Radio Access Technology (RAT) providing the direct link 105. Some RATs have power optimised procedures for link level maintenance (e.g. Bluetooth) while other RATs are considered less power efficient (e.g. LTE Rel-13 sidelink).

An example of a method for paging a remote UE over a short range link on a paging occasion of the remote UE will now be described with reference to Figure 1 and the message sequence chart of Figure 2. In this example, the paging occasion (PO) of the remote UE 104 and the relay UE 103 are aligned with one another. (A method for alignment is described further below). At 201, the remote UE 104 and the relay UE 103 maintain a short range link status 105. At 202, MT (Mobile Terminated) traffic intended for the remote UE 104 arrives at the MME 107. At 203, paging of the remote UE 104 is performed on the remote UE's paging occasion (PO) by the eNB 101 sending the paging message for reception by the relay UE 103. At 204, the paging message with the remote UE's ID acquired is received at the relay UE 103. At 205, the relay UE 103 relays the paging message to the remote UE 104 over the short range link 105. At 206, the remote UE 104 acknowledges decoding of the relay paging message. At 207, the relay UE 103 establishes a connection with the eNB 101. At 208, the relay UE 103 sends an acknowledgement message to the eNB confirming a paging relay success. At 209, the remote UE 104 establishes secured relay bearers with the network comprising the eNB 101 and MME 107.

The timelines of Figure 3 further illustrate the relay paging procedure of Figure 2 where there is alignment between the paging occasions of the relay UE 103 and the remote UE 104. Timeline 301 shows the arrival at the eNB of data intended for the remote UE 104 followed by transmission of a paging message (including the remote UE's ID) by the eNB. It is assumed here that the relay UE 103 is a smart phone or aggregation node which is configured with IDRX and relatively frequent POs and that the Remote UE 104 is a wearable device such as mentioned above which is configured with IDRX and a less frequent PO than the relay UE 103. Timeline 302 shows the relatively frequent paging occasions of the relay UE 103, a relayed paging

procedure following its reception of the paging message sent by the eNB, followed by a relay operation. Timeline 303 illustrates the relatively infrequent paging occasions of the remote UE 104, its reception of the relayed paging message and the subsequent relay operation. Figure 3 can also apply to a remote UE (and in some instances a relay UE) configured with leDRX but then the figure captures only the time where the UEs have periodic POs according to the leDRX configuration i.e. only the PTW (Paging time window).

An example of a sidelink based method for paging a remote UE over a short range link on a paging occasion of the remote UE will now be described with reference to the message sequence chart of Figure 4. In this example, the paging occasion (PO) of the remote UE 104 and the relay UE 103 are aligned with one another. At 401, the relay UE 103 and the remote UE 104 maintain a remote status of a sidelink channel 105 (see Figure 1). At 402, MT traffic arrives for the remote UE 103. At 403, paging of the remote UE 104 is performed on the remote UE's paging occasion. At 404, the relay UE 103 receives the paging message sent at the timing of the remote UE PO with the remote UE's ID acquired. At 405, the relay UE 103 relays the paging message to the remote UE 104 over L2 UE-to-network relay communication maintenance pool resources. At 406, the remote UE 104 acknowledges decoding of the relayed paging message. At 407, the relay UE 103 establishes a connection with the eNB 101 and at 408 in an acknowledgement message, confirms a paging relay success. At 409, the eNB 101 provides a sidelink configuration for the relay connection and the relay UE 103 relays the sidelink configuration over the sidelink channel 105 to the remote UE 104. At 410, the remote UE 104 establishes secured relay bearers with the network comprising the MME 107 and the eNB 101.

The timelines of Figure 5 further illustrate the relay paging procedure of Figure 4, where an eNB pages the Remote UE ID on an aligned relay UE and remote UE PO. It is assumed here that Relay UE is e.g. a smartphone or aggregation node which is configured with IDRX and relatively frequent POs and the Remote UE is a wearable device e.g. as mentioned above configured with IDRX and less frequent PO. Timeline 501 shows the arrival at the eNB of data intended for the remote UE 104 followed by transmission of a paging message (including the remote UE's ID) by the eNB. Timeline 502 shows the relatively frequent paging occasions of the relay UE 103 and periodic sidelink status monitoring transmissions. Also shown on Timeline 502 is the relayed paging establishment on receipt of the paging message sent by the eNB, followed by a relay operation. Timeline 503 illustrates the relatively infrequent paging occasions of the remote UE 104 and periodic sidelink status monitoring receptions. Also shown on side link 503 is the relayed paging establishment on receipt of the relayed paging message followed by the relay operation. Figure 5 can also apply for a remote device (and in some instances to a relay device) configured with leDRX but then the figure captures only the time where the UEs have periodic POs according to the leDRX configuration i.e. only the PTW.

For the Relay UE to be able to monitor the Remote UE paging it needs to monitor the Uu channel during the Remote UE PO. This can be done with PO awareness or PO alignment. A PO awareness method relies on the relay UE being aware of the leDRX of the remote UE. The advantage of making the relay UE aware of the leDRX rather than just the lDRX means that the relay UE need only monitor the Uu channnel during the Paging Time Window (PTW).

A procedure for achieving both lDRX and leDRX awareness will now be described with reference to Figure 1. The MME 107 via the eNB 101 configures the relay UE 103 with the following Remote UE parameters to allow the Relay UE to calculate the Remote UE paging occasion: (1) Idle mode DRX cycle (T) if it was configured by the a network NAS layer, otherwise the DRX cycle is derived from SI (System Information); (2) UE_ID and/or IMSI; (3) nB value. It may be beneficial if the NAS layer configures the remote UE idle mode DRX cycle and nB value in order to avoid the situation where the relay UE 103 and Remote UE 103 are camped onto different cells and so acquire different nB values. The eNB 101 also configures the relay UE 103 with the following remote UE parameters to allow the Relay UE to calculate the Remote UE PTW: (1) Idle mode eDRX cycle i.e. the (T_{eDRX}) parameter configured by the network of which the eNB is a part; (2) UE_ID_H and/or S-TMSI; (3) Paging Time Window length (L) configured by NAS. From this information, the relay UE 103 knows when it should be monitoring the Uu channel for paging messages for the remote UE 104.

A procedure for achieving Paging Occasion alignment where a relay UE and remote UE(s) are configured with parameters to allow an alignment of the PO of the Relay UE and the Remote UE(s) will now be described with reference to Figure 1.

The MME 107 via the eNB 101 configures the remote UE 104 with Idle mode DRX cycle which is equal or a multiple of the relay UE 103 lDRX cycle

If the MME 107 via the eNB 101 configured the relay UE 103 with leDRX, then it also configures the remote U 104 with leDRX cycle which is equal or a multiple of the relay UE leDRX cycle

For lDRX formulas a Group ID (G_ID) value is used instead of UE_ID.

G_ID is calculated as a function of the relay UE IMSI and the IMSI of all of its associated Remote UEs. The function can be any binary operator with the associative property e.g. group IMSI (gIMSI) could be calculated as a bitwise XOR between the relay UE IMSI and the IMSI of all the remote UEs (104 and others , not shown) which are associated with the relay UE 103. The G_ID is derived by the relay UE 103 or the remote UE 104 from the gIMSI with the same calculation as UE_ID is derived from IMSI

For leDRX formulas a Group ID_H (G_ID_H) value is used instead of the UE_ID_H value.

G_ID_H is calculated as a function of the relay UE S-TMSI and the S-TMSI values of all of its associated remote UEs. The function can be any binary operator with the associative property e.g. Group S-TMSI (gS-TMSI) could be calculated as a bitwise XOR between the relay UE S-TMSI and the S-TMSI of all the remote UEs which are associated with the relay UE 103. The G_ID_H is derived by the relay UE or the remote UE from the gS-TMSI with the same calculation as UE_ID_H is derived from S-TMSI

The relay UE 103 is configured with IMSI values and/or S-TMSI values or with a LSB part of IMSI and/or S-TMSI of each of the remote UEs that the relay UE 103 is associated with and calculates G_ID and G_ID_H as described above.

The remote UE is configured with a gIMSI' that satisfies the following equation

gIMSI = f(gIMSI', IMSI)

where

gIMSI is the Group IMSI as defined above,

IMSI is the remote UE's own IMSI

'f' is a binary operator as defined above e.g. bitwise XOR

In order to calculate gIMSI, the Remote UE follows the equation above.

Remote UE is configured with a gS-TMSI' that satisfies the following equation

gIMSI = f(gS-TMSI', S-TMSI)

where

gS-TMSI is the Group S-TMSI as defined above,

S-TMSI is the remote UE's own S-TMSI

'f' is a binary operator as defined above e.g. bitwise XOR

In order to calculate gS-TMSI, the Remote UE follows the equation above.

Alternatively, the relay UE 103 and the remote UEs may be configured with the calculated G_ID and G_ID_H directly

In an alternative PO alignment method, a Paging Frame is calculated using an nB value signalled by the NAS layer. For a group of relay/remote UEs the nB values need to fulfil at least one of (1) nB/T >=1 for all the UEs in the group or (2) nB is equal for all the UEs in the group. This alternative may achieve alignment for deployments including CAT-M with any nB value.

Sidelink DRX alignment may be achieved by aligning only the "PC5 DRX" configuration" of a group of relay UEs and all associated remote UEs without taking into account the PO occasions. For example, the wireless communication system (via the eNB 101) can configure periodic intervals for sidelink inactivity for each of the associated Relay/Remote UEs in such a way that the sidelink activity intervals of Remote UEs are aligned or at least partialy aligned with the sidelink activity intervals of the Relay UEs. This option may however, be sub-optimal from power consumption perspective.

An example of a paging relay method for paging a remote UE over a (direct) short range link on a paging occasion of the relay UE will now be described with reference to Figure 1 and Figure 6. The short range link 105 may be a 3GPP sidelink or an alternative link such as Bluetooth (RTM). It is assumed that the technology providing the short range link is able to perform power efficient link level maintenance.

At 601, the relay UE 103 and remote UE 104 maintain a short range link status. At 602, MT traffic arrives for the remote UE. At 603, the relay UE 103 is paged by sending a paging message with the relay ID from the eNB 101. At 604, the relay UE receives the paging message sent at the timing of the relay UE PO with the relay ID acquired. At 605, the relay UE 103 establishes a connection to the eNB 101. At 606, the eNB 101 sends an indication to the relay UE 103 notifying it that MT communications for the remote UE 104 are pending. At 607, the relay UE 103 relays the paging message to the remote UE 104 over the short range link 105. At 608, the remote UE 104 sends a paging acknowledgement message to the relay UE 103 acknowledging decoding of the relay paging message. At 609, the relay UE 103 sends a paging relay acknowledgement message to the eNB 101 confirming a paging relay success. At 610, the remote UE 104 establishes secured relay bearers with the network comprising the eNB 101 and the MME 107.

An example of a sidelink-based paging relay method for paging a remote UE over a (direct) short range link on a paging occasion of the relay UE will now be described with reference to Figure 1 and Figure 7. The direct short range link 105 is a 3GPP side link channel.

At 701, the relay UE 103 and the remote UE 104 maintain a remote status of the side link channel 105. At 702, MT traffic arrives for the remote UE 104. At 703, the relay UE 103 is paged by sending a paging message with the relay ID from the eNB 101. At 704, the relay UE 103 receives the paging message with the relay ID acquired. At 705, the relay UE 103 establishes a connection to the eNB 101. At 706, the eNB 101 sends an indication to the relay UE 103 notifying it that MT communications for the remote UE 104 are pending. At 707, the relay UE 103 relays the paging message to the remote UE 104 over the sidelink 105 using L2 UE-to-Network relay maintenance pool resources. At 708, the remote UE 104 sends a paging acknowledgement message to the relay UE 103 acknowledging decoding of the relay paging message. At 709, the relay UE 103 sends a paging relay acknowledgement message to the

eNB 101 confirming a paging relay success. At 710, the eNB1 101 sends a side link configuration for the relay connection and the relay UE 103 relays this side link configuration over the side link channel 105 to the remote UE 104. At 711, the remote UE 104 establishes secured relay bearers with the network comprising the eNB 101 and MME 107.

A method of sidelink status maintenance will now be described with reference to Figure 8 which shows timelines illustrating activities of the relay UE 103 and the remote UE 104 (see Figure 1). Timeline 801 shows paging occasions and periodic status monitoring transmissions by the relay UE 103. Timeline 802 shows paging occasions of the remote UE 104 which are aligned with paging occasions of the relay UE 103 but occur less frequently. Also shown in timeline 802 is the reception of the periodic status monitoring transmissions from the relay UE 103. Figure 8 can also apply for a remote device (and in some instances to a relay device) configured with leDRX but then the figure captures only the time where the UEs have periodic POs according to the leDRX configuration i.e. only the PTW.

The purpose of this procedure is to make the remote UE 104 aware of the sidelink availability status. To this end, the relay UE 103 sends periodic (conventional Mode A) Discovery messages (Announcement) and the remote UE receives and attempts to decode them. Such a sidelink discovery announcement can be sent over resources from a discovery resource pool. The resource pool may be a new special pool denoted as an "evolved ProSe L2 UE-to-Network relay maintenance pool." Such a maintenance pool may be defined by the wireless communication system 100 for more than a single cell, e.g. it may be defined for all the cells supporting L2 UE-to-network relay in a tracking area (TA). This method allows the remote UE 104 and the relay UE 103 to communicate over the maintenance pool even after cell reselection and even when camped onto different cells. It would be beneficial if the sidelink communication conducted for the maintenance purpose is done at the same time that the UEs are "awake" for another purpose, for example, PO monitoring. Therefore, a maintenance pool may define resources (for reception and/or transmission) which are adjacent (in time) to the remote UE's 104 Paging Occasions (see timeline 802). That is to say that the sidelink is enhanced with DRX-like behaviour which is aligned with the Uu DRX behaviour. Since it is desirable for the “PC5 DRX” to be aligned with both remote UE DRX and relay UE DRX, the relay UE 103 needs to have remote UE paging occasion alignment (see timeline 801).

Sidelink DRX is aligned with the Uu Idle mode DRX of both the relay UE 103 and the remote UE 104. It is assumed here that relay UE 103 is e.g. a smartphone which is configured with IDRX and relatively frequent POs and the Remote UE (e.g. a wearable device) is configured with IDRX and less frequent PO. Figure 8 can also apply for e.g. a wireless device configured with leDRX but then the figure captures only the time where the wireless device has periodic POs according to the leDRX configuration i.e. only during the PTW.

If a status monitoring message is not received by the remote UE 104 within a defined period, then the sidelink is considered unavailable by the remote UE 104. It is not expected that the remote UE 104 should update the eNB 101 upon loss or regain of the sidelink 105 (or other short range RAT) availability since this may be power inefficient. However, the eNB 101 may request the remote UE 104 to report the sidelink availability when in RRC_CONNECTED mode. This may happen e.g. in the next remote UE TA registration. On the other hand, the eNB 101 may configure the relay UE 103 to stop or to restart the maintenance sidelink transmission. Another option is for the remote and relay UEs to use conventional "Mode B" discovery messages (solicitation & Response) to start or restart the sidelink monitoring procedure described above.

A method of sidelink-based mobile originated (MO) communication will now be described with reference to Figure 1, the message sequence chart of Figure 9 and the timelines of Figure 10. The purpose of the MO communication procedure is to allow the relay UE 103 to establish a relay connection with the eNB 101 without the need to first establish a Uu connection.

At 901, the relay UE and the remote UE 104 maintain a remote status of the sidelink channel 105. At 902, ("arrival of MO traffic from the application") the remote UE 104 receives a request for Mobile Originated transmission from a higher layer of the wireless communication system 100. At 903, the remote UE 104 relays the request to the relay UE 103 by utilising a preconfigured connection establishment opportunity to signal to the relay UE 103, over the side link 105, that a connection establishment is required. At 904, the relay UE 103 acknowledges that the connection request has been received. At 905, the relay UE 103 establishes a centralised connection with the eNB 101 and signals to the eNB 101 that the connection is required for the remote UE 104. At 906, the eNB provides sidelink resources for relay communication and the relay UE 103 relays the received sidelink configuration over the sidelink channel 105 to the remote UE 104. At 907, the remote UE 104 establishes a secured relay bearer with the network comprising the eNB 101 and MME 107.

If the remote UE 104 considers the sidelink status to be unavailable, the remote UE does not try to establish a relay connection. The preconfigured connection establishment opportunities can be provided on sidelink resources from a L2 network-to-UE relay communication maintenance pool. The connection establishment request (903) could be realised as a new type of sidelink message or with a discovery message. The connection establishment request may include a connection establishment cause field. If the remote UE 104 does not receive a connection request acknowledgment (904) up to a timer expiry, the remote UE 104 may try to establish a connection via a random access procedure. The remote UE 104 may also retry to signal the relay UE 103 over the sidelink that a connection establishment is required with some randomised back-off. If the UE is out of the cell coverage then this is the only option.

The relay UE 103, when establishing a centralised connection following a Remote UE request for connection establishment (903) may send an RRConnectionRequest with an establishment cause (if provided by the remote UE 104), otherwise the relay UE 103 may try to decode the incoming relay request. It would be beneficial if these opportunities are provided at the same time that the relay UE 103 is awake for another purpose; i.e. during relay UE PO monitoring, since it is desirable to reduce the number of relay UE "wake-ups" from a power consumption point of view. Connection establishment can be power costly but if the relay UE 103 is already connected to the eNB 101, the additional power/signalling to send a short range link level report over the sidelink 105 can be considered as marginal.

Figure 10 illustrates relay connection establishment opportunities provided by the relay UE 103 in addition to sidelink maintenance procedure with aligned paging occasions. The relay connection establishment opportunities are provided periodically and when the remote UE 104 is 'sleeping' i.e. regardless to the remote UE IDRX or IeDRX configuration. Timeline 1001 shows a relay operation occurring at the eNB 101. Timeline 1002 shows the relatively frequent periodic paging occasions of the relay UE 103 along with less frequent periodic status monitoring transmissions and connection establishment opportunities which are adjacent to the paging occasions. Timeline 1002 also shows a relayed establishment following reception of a relay request from the remote UE 104 during a connection establishment opportunity, followed by a relay operation. Timeline 1003 shows the relatively infrequent periodic paging occasions of the remote UE 104 which are aligned with a paging occasion of the relay UE 103. Timeline 1003 also shows reception of the periodic sidelink status monitoring transmissions sent by the relay UE 103 and received during periods adjacent to paging occasions. Timeline 1003 also shows MO traffic arrival which prompts a relay request transmission over the sidelink. Then follows relayed connection establishment and relay operation. Figure 10 can also apply for a remote device (and in some instances to a relay device) configured with IeDRX but then the figure captures only the time where the UEs have periodic POs according to the IeDRX configuration i.e. only the PTW.

The signal processing functionality of the embodiments of the invention especially the eNB and remote and relay UEs may be achieved using computing systems or architectures known to those who are skilled in the relevant art. Computing systems such as, a desktop, laptop or notebook computer, hand-held computing device (PDA, cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment can be used. The computing system can include one or more processors which can be implemented using a general or special-purpose processing engine such as, for example, a microprocessor, microcontroller or other control module.

The computing system can also include a main memory, such as random access memory (RAM) or other dynamic memory, for storing information and instructions to

be executed by a processor. Such a main memory also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor. The computing system may likewise include a read only memory (ROM) or other static storage device for storing static information and instructions for a processor.

The computing system may also include an information storage system which may include, for example, a media drive and a removable storage interface. The media drive may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a compact disc (CD) or digital video drive (DVD) read or write drive (R or RW), or other removable or fixed media drive. Storage media may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive. The storage media may include a computer-readable storage medium having particular computer software or data stored therein.

In alternative embodiments, an information storage system may include other similar components for allowing computer programs or other instructions or data to be loaded into the computing system. Such components may include, for example, a removable storage unit and an interface , such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit to computing system.

The computing system can also include a communications interface. Such a communications interface can be used to allow software and data to be transferred between a computing system and external devices. Examples of communications interfaces can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a universal serial bus (USB) port), a PCMCIA slot and card, etc. Software and data transferred via a communications interface are in the form of signals which can be electronic, electromagnetic, and optical or other signals capable of being received by a communications interface medium.

In this document, the terms ‘computer program product’, ‘computer-readable medium’ and the like may be used generally to refer to tangible media such as, for example, a memory, storage device, or storage unit. These and other forms of computer-readable media may store one or more instructions for use by the processor comprising the computer system to cause the processor to perform specified operations. Such instructions, generally referred to as ‘computer program code’ (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system to perform functions of embodiments of the present invention. Note that the code may directly cause a processor to

perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system using, for example, removable storage drive. A control module (in this example, software instructions or executable computer program code), when executed by the processor in the computer system, causes a processor to perform the functions of the invention as described herein.

Furthermore, the inventive concept can be applied to any circuit for performing signal processing functionality within a network element. It is further envisaged that, for example, a semiconductor manufacturer may employ the inventive concept in a design of a stand-alone device, such as a microcontroller of a digital signal processor (DSP), or application-specific integrated circuit (ASIC) and/or any other sub-system element.

It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to a single processing logic. However, the inventive concept may equally be implemented by way of a plurality of different functional units and processors to provide the signal processing functionality. Thus, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organisation.

Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors or configurable module components such as FPGA devices. Thus, the elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units.

Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term ‘comprising’ does not exclude the presence of other elements or steps.

Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather indicates that the feature is equally applicable to other claim categories, as appropriate.

Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality.

Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' or "including" does not exclude the presence of other elements.

Claims

1. A method for paging a first wireless communication device in a wireless communication system, the method comprising: maintaining a direct link between the first wireless communication device and a second communication device wherein the first wireless communication device is configured with a paging occasion; at a node of the wireless communication system, transmitting a paging message intended for the first wireless communication device over a channel and on a paging occasion configured to the first wireless communication device; at the second wireless communication device, monitoring a paging occasion configured to the first wireless communication device, receiving said paging message and relaying said paging message for reception by the first wireless communication device; and at the first wireless communication device, on receiving the relayed paging message, transmitting a paging acknowledgement for reception by the second wireless communication device; and at the second wireless communication device, receiving the paging acknowledgement and initiating a connection establishment with said node.

2. The method of any preceding claim including configuring the second wireless communication device with first parameters relating to the first communication device and, at the second communication device, and calculating the paging occasion of the first communication device using said first parameters.

3. The method of claim 2 wherein the first parameters comprise at least one of: an idle mode DRX cycle; System Information; an identifier of the first wireless communication device; the IMSI (International Mobile Subscriber Identifier) of the first wireless communication device, an nB value used by the first wireless communication device.

4. The method of any preceding claim including configuring the second wireless communication device with second parameters relating to the first communication device and, at the second communication device calculating a paging time window of the first communication device based on the second parameters.

5. The method of claim 4 wherein the second parameters include at least one of: idle mode extended DRX cycle (T_{eDRX}); an identifier of the first

wireless communication device; the UE_ID_H of the first wireless communication device; the S-TMSI of the first wireless communication device.

6. The method of any preceding claim including configuring the first wireless communication device with an idle mode DRX which is either equal to or multiple of an idle mode DRX cycle of the second wireless communication device.

7. A method for paging a first wireless communication device in a wireless communication system, the method comprising: maintaining a direct link between the first wireless communication device and a second communication device; at a node of the wireless communication system, receiving a transmission intended for the first wireless communication device, transmitting a paging message to the second wireless communication device; at the second wireless communication device, establishing a connection with the node; at the node, following establishment of the connection, notifying the second wireless communication device of the transmission intended for the first wireless communication device; at the second wireless communication device relaying the paging message for reception by the first wireless communication device; and at the first wireless communication device, on receiving the relayed paging message, transmitting a paging acknowledgement.

8. The method of any preceding claim including, at the second wireless communication device, sending a paging relay acknowledgement message for reception by the node.

9. The method of any preceding claim including, at the first wireless communication device, after transmitting the paging acknowledgement, reconfiguring a connection with the node.

10. The method of the claim 9 including establishing secured relay bearers with the node.

11. The method of any preceding claim including, at the wireless communication system node, providing a sidelink configuration, and at the second wireless communication device, relaying the sidelink configuration over the direct link to the first wireless communication device.

12. A method for establishing a connection between a first wireless communication device and a node of a wireless communication system

via a second wireless communication device, the method comprising: maintaining a direct link between the first and second wireless communication devices; at the first wireless communication device, sending to the second wireless communication device, over the direct link, a request for connection establishment; at the second wireless communication device, on receiving the request for connection, establishing a connection with the node and sending an indication to the node that the connection is required for the first wireless communication device; at the node, sending a configuration for the direct link to the second wireless communication device; and at the second wireless communication device, relaying, over the direct link, the configuration for the direct link to the first wireless communication device

13. The method of claim 12 including, configuring the first wireless communication device with at least one preconfigured connection establishment opportunity.

14. The method of claim 12 or claim 13 including, at the second wireless communication device, sending an acknowledgement of receipt of the request for connection establishment to the first wireless communication device over the direct link

15. The method of any of claims 12 to 14 including, at the first wireless communication device, after receiving the relayed configuration for the direct link, reconfiguring a connection with the node.

16. The method of any preceding claim including, at the second wireless communication device, sending periodic discovery messages for reception by the first wireless communication device. .

17. A relay wireless communication device arranged to maintain a direct link with a remote wireless communication device which has been configured with a paging occasion and wherein the relay wireless communication device is further arranged to calculate the paging occasion of the remote communication device using first parameters, said first parameters including at least one of. idle mode DRX cycle; System Information; an identifier of the remote wireless communication device; an IMSI (International Mobile Subscriber Identifier) of the remote wireless communication device, nB value used the remote wireless communication device, and align its paging occasion with that of the remote wireless communication device.

18. The relay wireless communication device of claim 17 and arranged to calculate a paging time window of the remote communication device using second parameters, said second parameters including at least one of: idle mode extended DRX cycle T_{eDRX}; an identifier of the remote wireless communication device; the UE_ID_H of the remote wireless communication device; the S-TMSI of the remote wireless communication device.

19. A non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to any of claims 1-16.

20. The non-transitory computer readable medium of claim 19 comprising at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

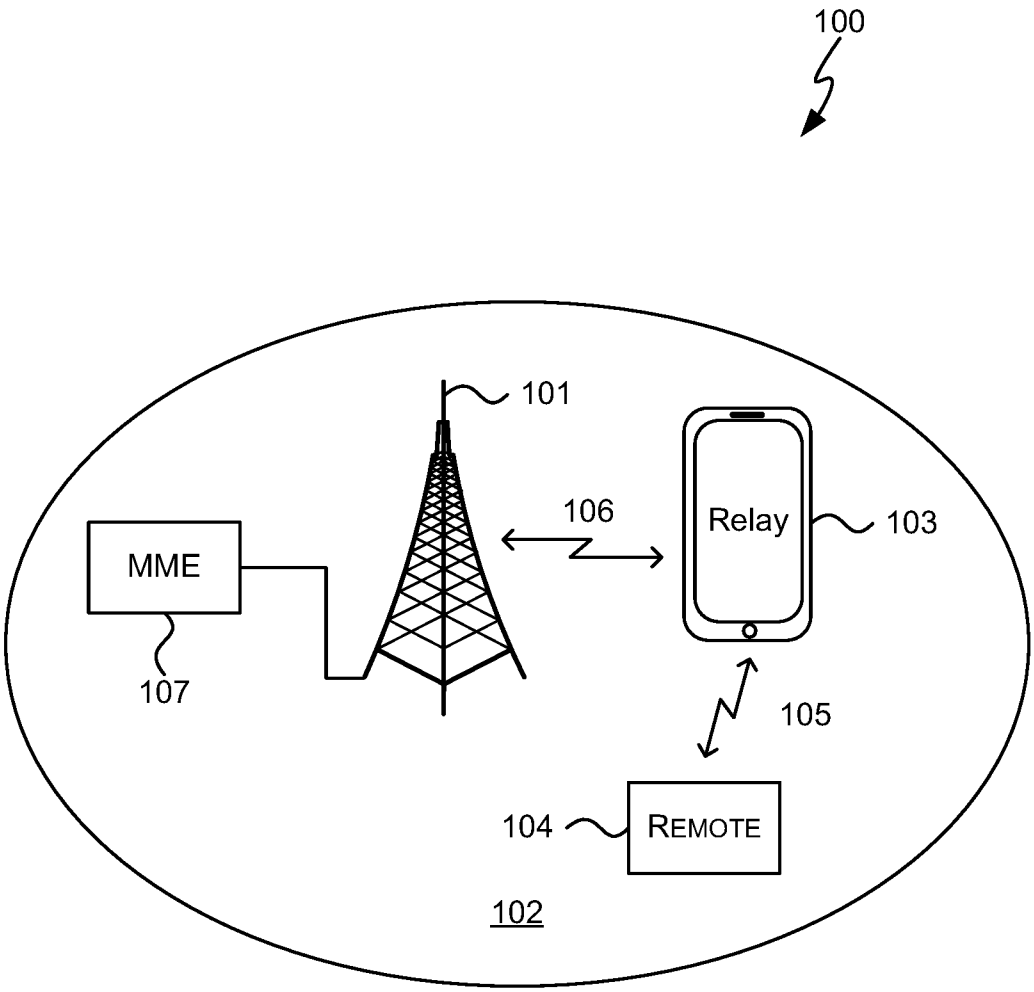


FIG. 1

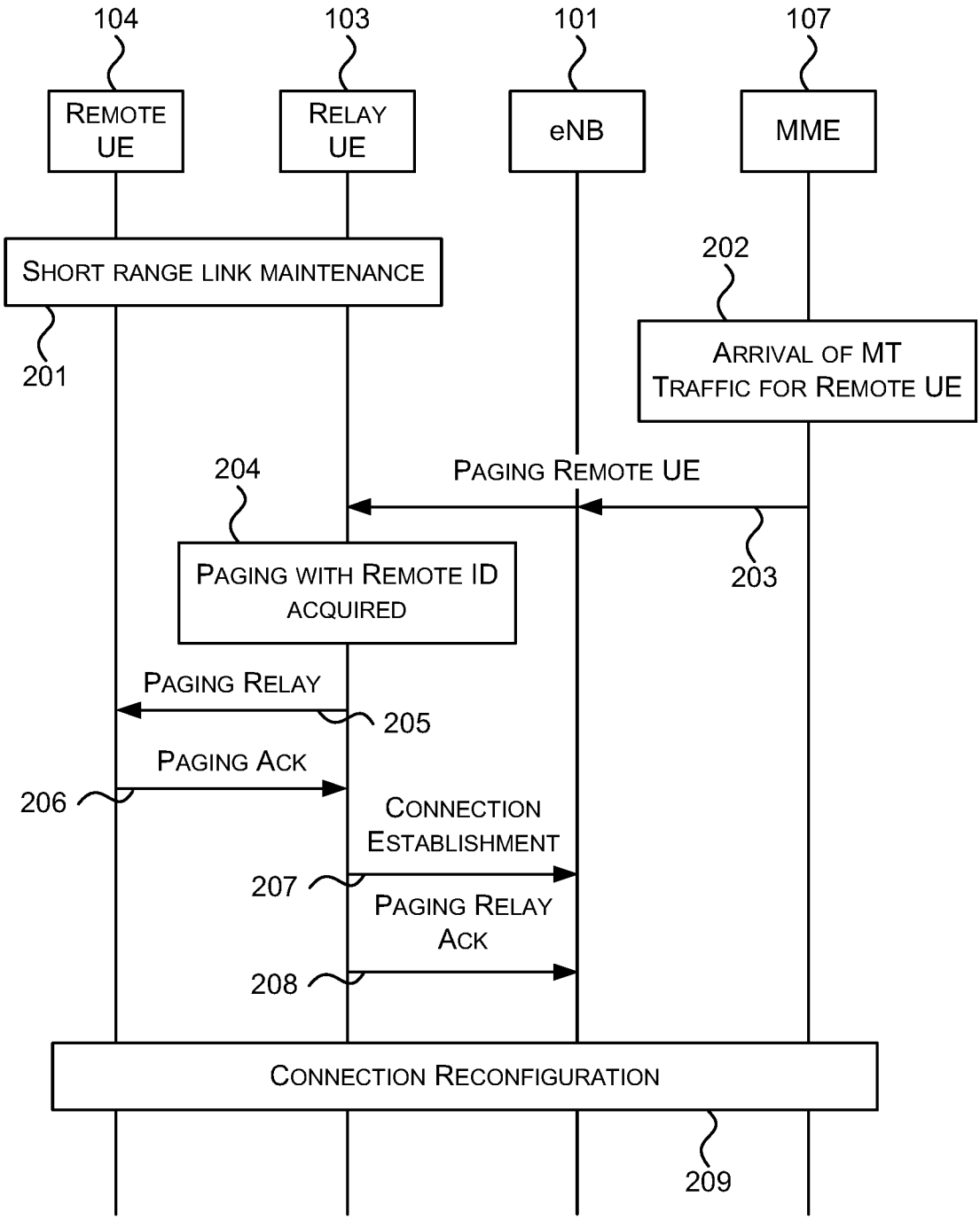

104
103
101
107
REMOTE UE
RELAY UE
eNB
MME
SHORT RANGE LINK MAINTENANCE
201
202
ARRIVAL OF MT TRAFFIC FOR REMOTE UE
204
PAGING REMOTE UE
203
PAGING WITH REMOTE ID ACQUIRED
PAGING RELAY
205
PAGING ACK
206
CONNECTION ESTABLISHMENT
207
PAGING RELAY ACK
208
CONNECTION RECONFIGURATION
209

FIG. 2

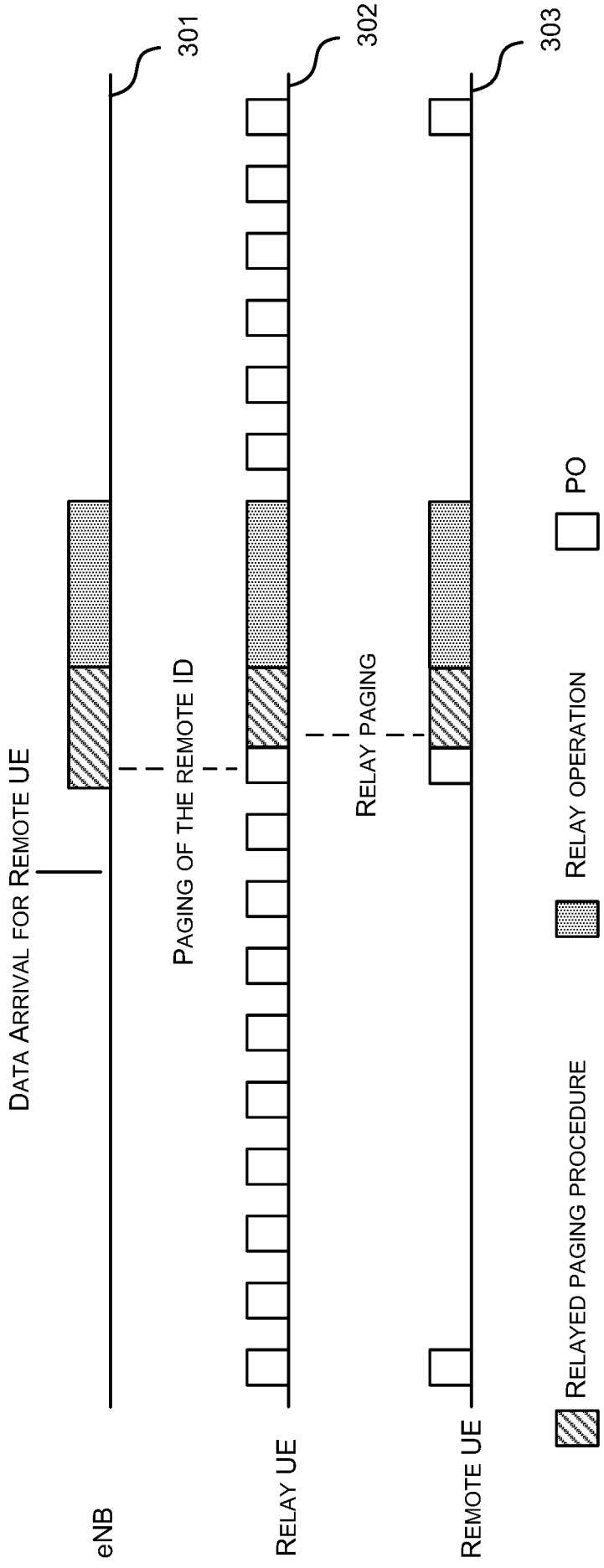

301
302
303
DATA ARRIVAL FOR REMOTE UE
PAGING OF THE REMOTE ID
RELAY PAGING
eNB
RELAY UE
REMOTE UE
RELAYED PAGING PROCEDURE
RELAY OPERATION
PO

FIG. 3

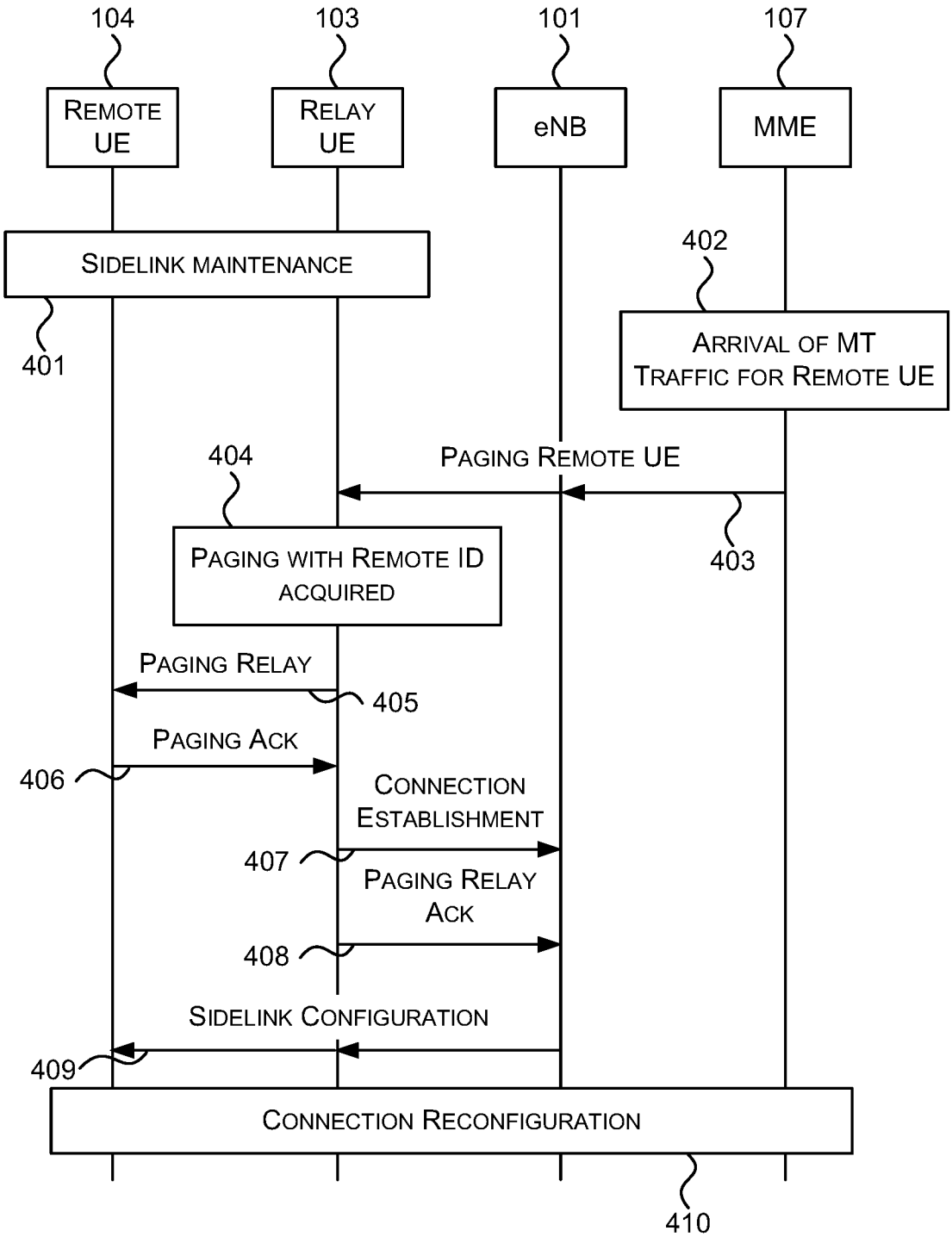

104
103
101
107
REMOTE UE
RELAY UE
eNB
MME
SIDELINK MAINTENANCE
401
402
ARRIVAL OF MT TRAFFIC FOR REMOTE UE
404
PAGING REMOTE UE
403
PAGING WITH REMOTE ID ACQUIRED
PAGING RELAY
405
PAGING ACK
406
CONNECTION ESTABLISHMENT
407
PAGING RELAY ACK
408
SIDELINK CONFIGURATION
409
CONNECTION RECONFIGURATION
410

FIG. 4

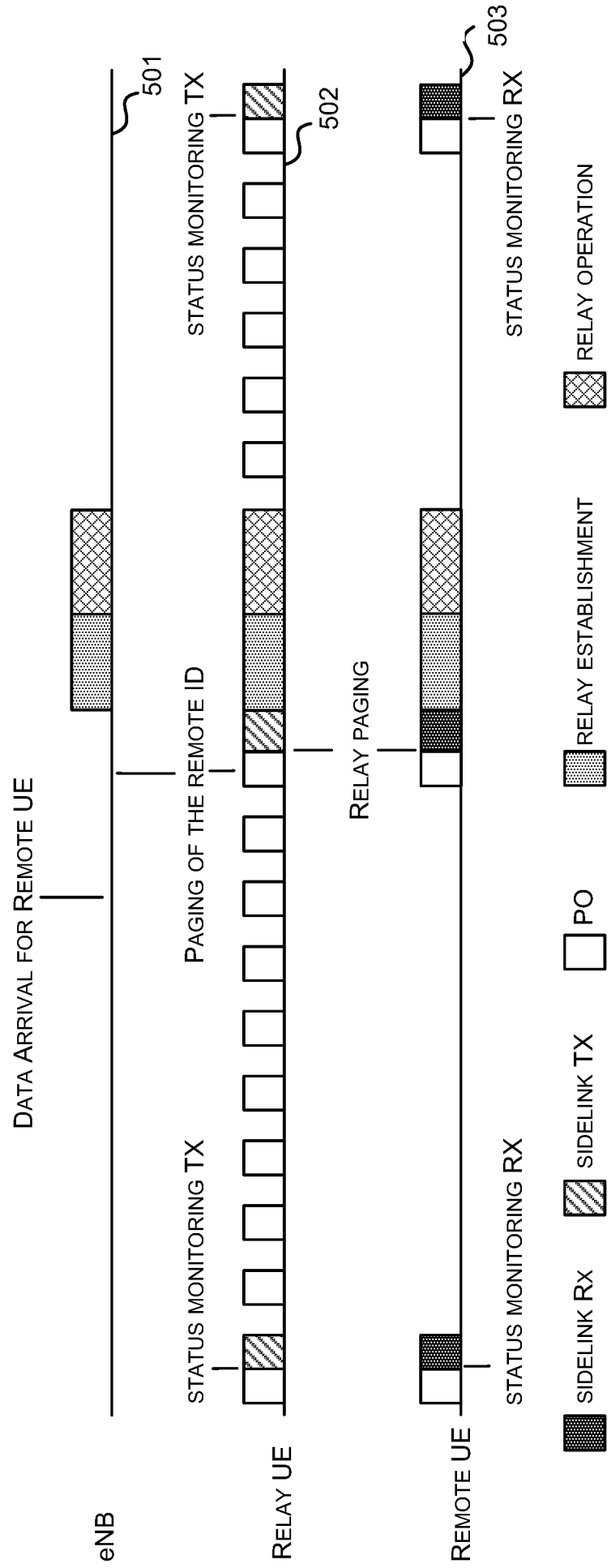

eNB
RELAY UE
REMOTE UE
DATA ARRIVAL FOR REMOTE UE
STATUS MONITORING TX
PAGING OF THE REMOTE ID
RELAY PAGING
STATUS MONITORING RX
501
502
503
STATUS MONITORING TX
STATUS MONITORING RX
SIDELINK RX
SIDELINK TX
PO
RELAY ESTABLISHMENT
RELAY OPERATION

FIG. 5

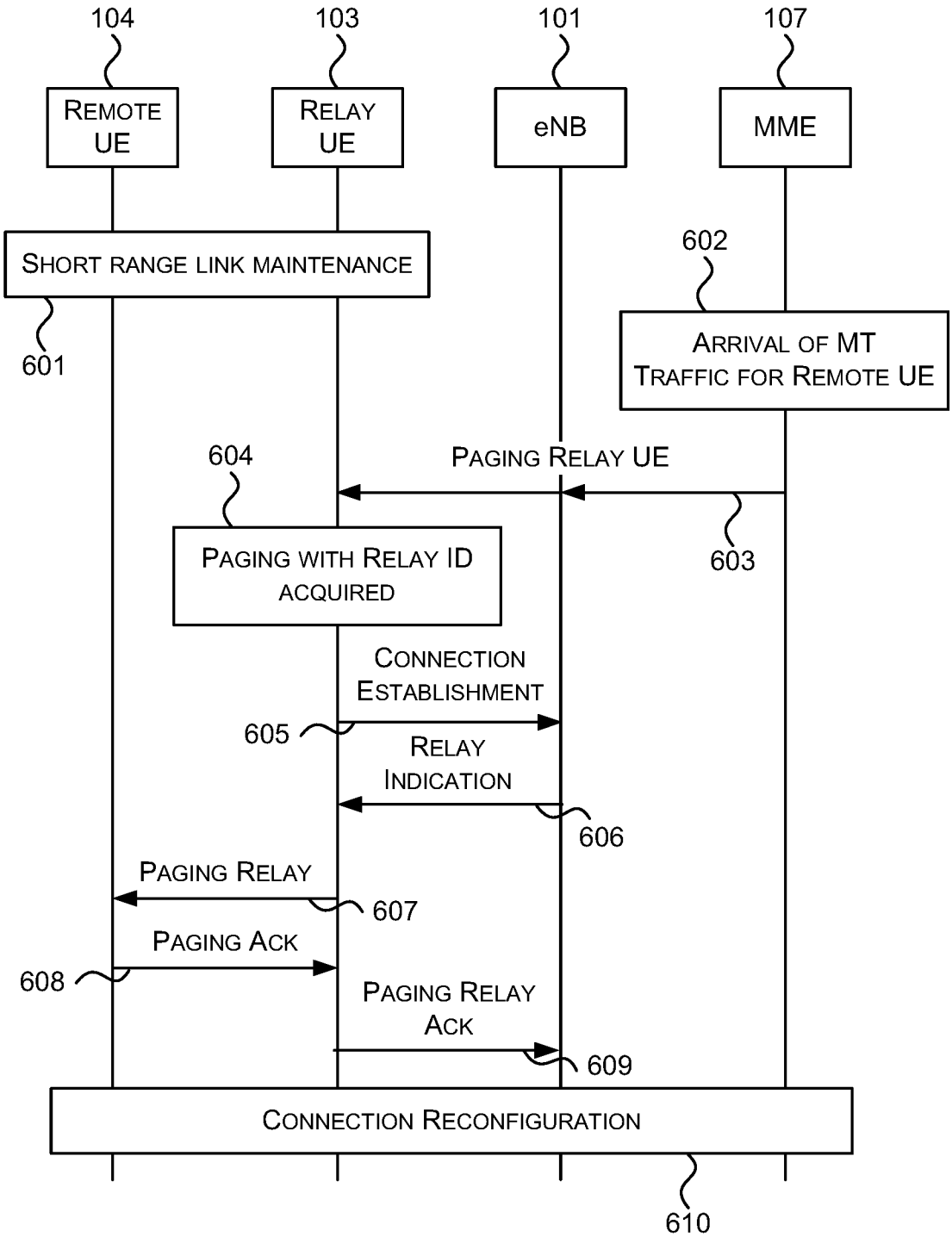

104
103
101
107
REMOTE UE
RELAY UE
eNB
MME
SHORT RANGE LINK MAINTENANCE
601
602
ARRIVAL OF MT TRAFFIC FOR REMOTE UE
604
PAGING RELAY UE
603
PAGING WITH RELAY ID ACQUIRED
CONNECTION ESTABLISHMENT
605
RELAY INDICATION
606
PAGING RELAY
607
PAGING ACK
608
PAGING RELAY ACK
609
CONNECTION RECONFIGURATION
610

FIG. 6

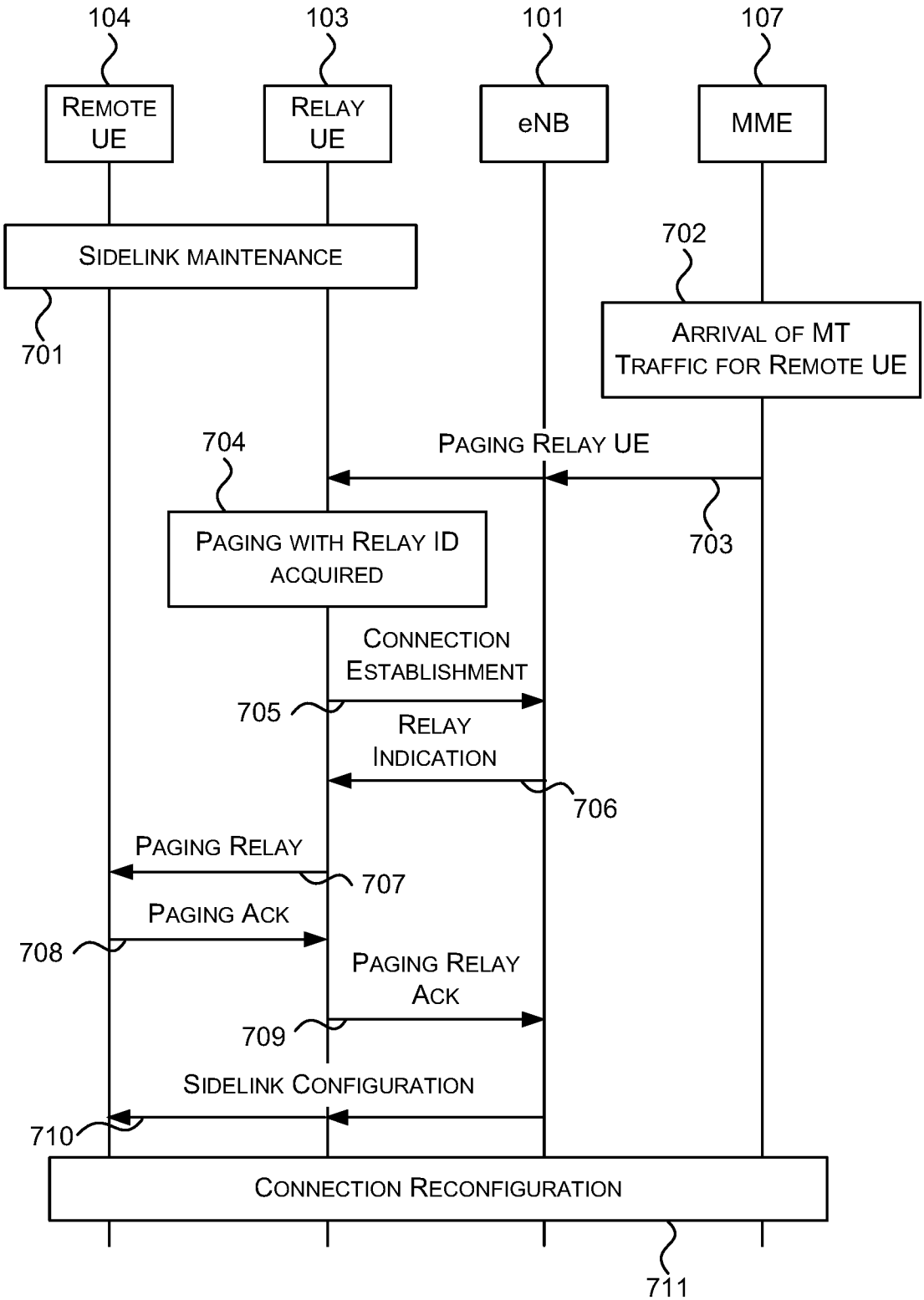

104
103
101
107
REMOTE UE
RELAY UE
eNB
MME
SIDELINK MAINTENANCE
701
702
ARRIVAL OF MT TRAFFIC FOR REMOTE UE
704
PAGING RELAY UE
703
PAGING WITH RELAY ID ACQUIRED
CONNECTION ESTABLISHMENT
705
RELAY INDICATION
706
PAGING RELAY
707
PAGING ACK
708
PAGING RELAY ACK
709
SIDELINK CONFIGURATION
710
CONNECTION RECONFIGURATION
711

FIG. 7

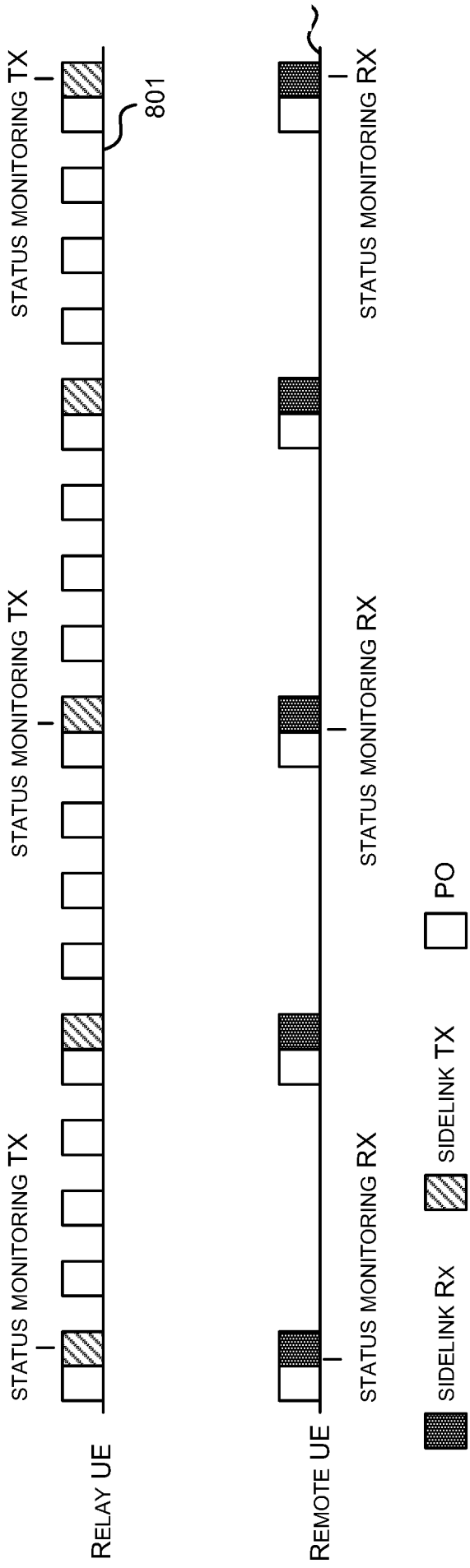

STATUS MONITORING TX
STATUS MONITORING TX
STATUS MONITORING TX
801
RELAY UE
STATUS MONITORING RX
STATUS MONITORING RX
STATUS MONITORING RX
REMOTE UE
SIDELINK RX
SIDELINK TX
PO

FIG. 8

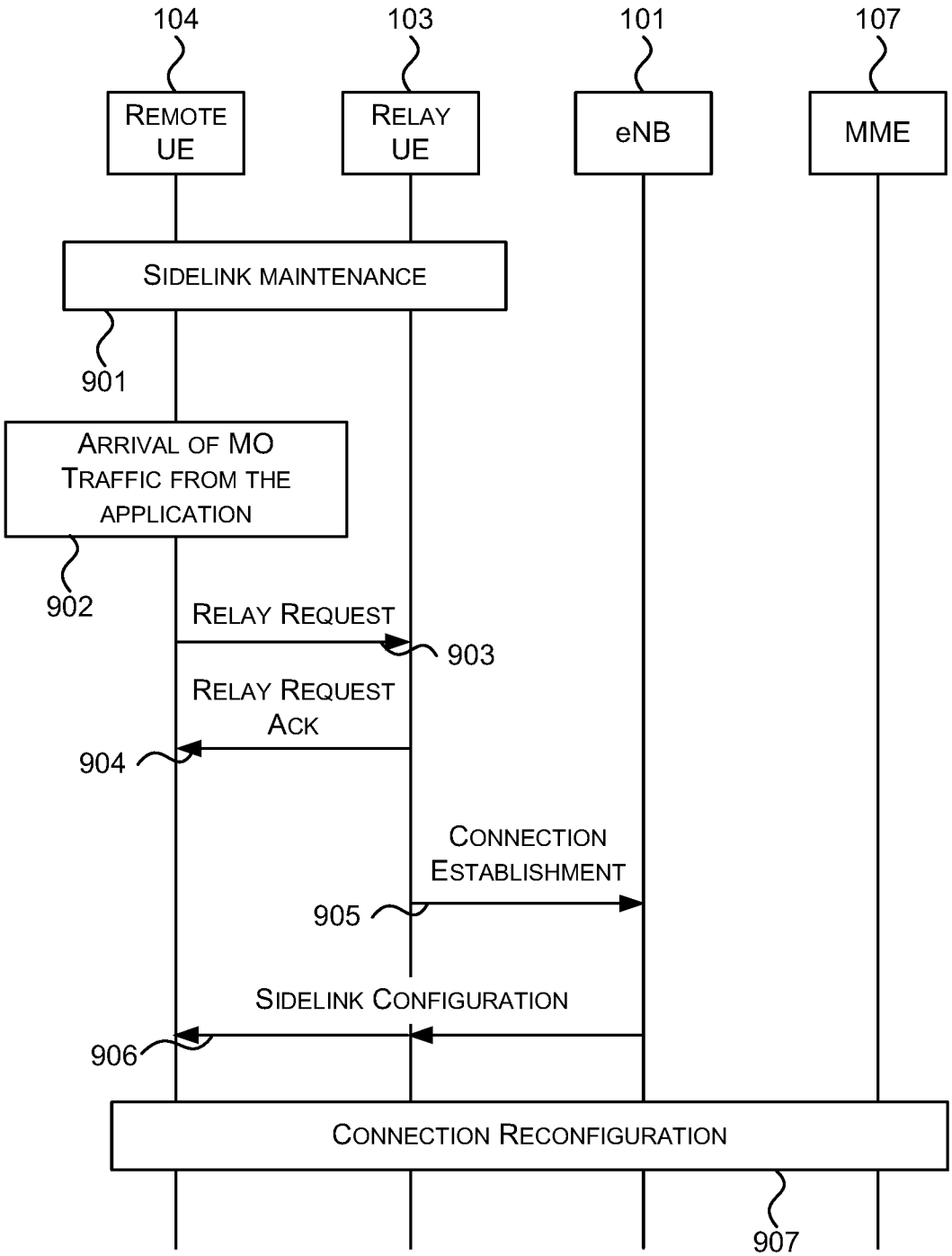

104
103
101
107
REMOTE UE
RELAY UE
eNB
MME
SIDELINK MAINTENANCE
901
ARRIVAL OF MO TRAFFIC FROM THE APPLICATION
902
RELAY REQUEST
903
RELAY REQUEST ACK
904
CONNECTION ESTABLISHMENT
905
SIDELINK CONFIGURATION
906
CONNECTION RECONFIGURATION
907

FIG. 9

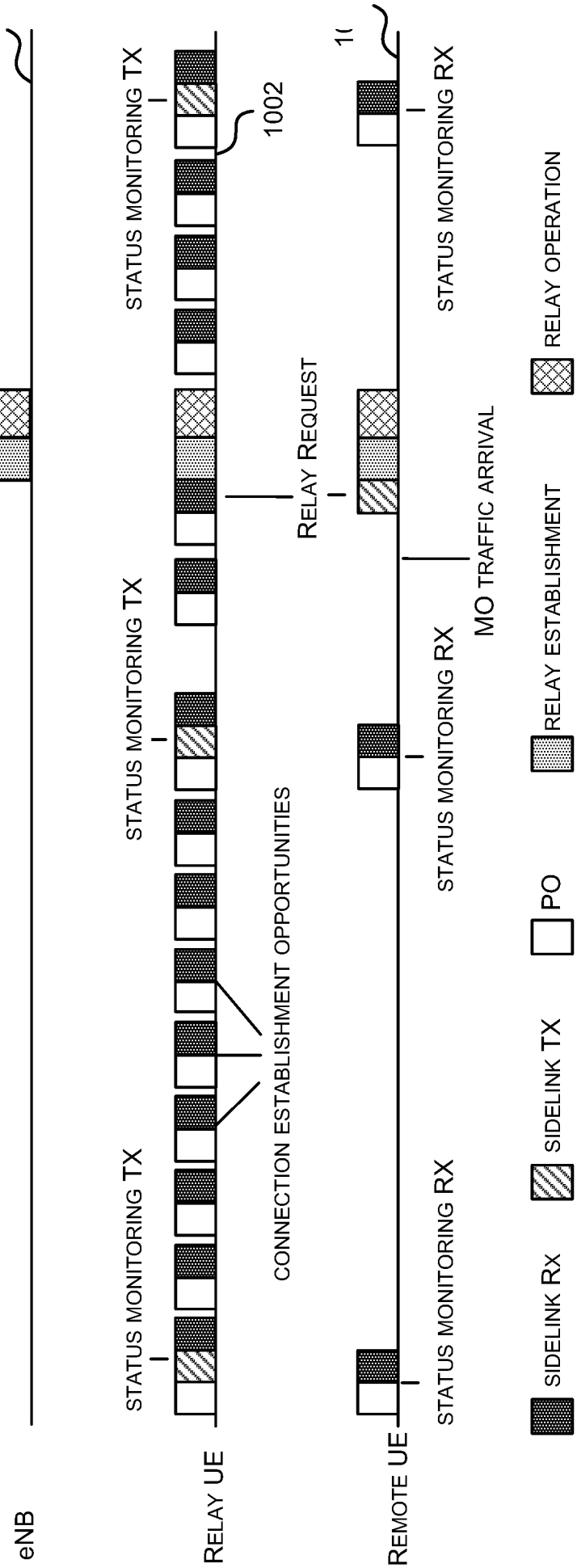

1001
1002
1
eNB
RELAY UE
REMOTE UE
STATUS MONITORING TX
STATUS MONITORING RX
STATUS MONITORING TX
STATUS MONITORING RX
STATUS MONITORING RX
CONNECTION ESTABLISHMENT OPPORTUNITIES
RELAY REQUEST
MO TRAFFIC ARRIVAL
SIDELINK RX
SIDELINK TX
PO
RELAY ESTABLISHMENT
RELAY OPERATION

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/108560

A. CLASSIFICATION OF SUBJECT MATTER

H04W 76/02(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q; H04L; H04J; H04B

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

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

CNPAT,CNKI,WPI,EPODOC: relay,terminal,paging,connection,first,second

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016019528 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 11 February 2016 (2016-02-11) description page 77 line 2 - page 80 line 7, figures.16-19	1-11, 16-20
X	WO 2016107205 A1 (ZTE CORPORATION) 07 July 2016 (2016-07-07) description page 13 line 20 - page 14 line 21, figure. 9	1-11, 16-20
A	CN 101110658 A (INTEL CORPORATION) 23 January 2008 (2008-01-23) the whole document	1-20
A	CN 102811497 A (CHINA MOBILE COMMUNICATION GROUP CORP.) 05 December 2012 (2012-12-05) the whole document	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2018	**25 January 2018**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**RAN,Jianguo**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62413873**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/108560

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

[1] Invention I: claim 1; Invention II: claim 7; Invention III: claim 12; Invention IV: claims 17. The same or corresponding technical features "paging", "wireless communication device", "wireless communication system", "maintaining a direct link between the first wireless communication device and a second communication device", "paging occasion", "node", "relaying" in claims 1,7,12,17 are common knowledge in the art and therefore claims 1, 7, 12, 17 do not have the same or corresponding specific technical features and do not meet the criteria set out in PCT Rule 13.

1. ☑ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☑ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/108560

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2016019528	A1	11 February 2016	CN	105493622	A	13 April 2016
				US	2017142686	A1	18 May 2017
				EP	3160211	A1	26 April 2017
WO	2016107205	A1	07 July 2016	CN	105828453	A	03 August 2016
CN	101110658	A	23 January 2008	EP	2062398	A1	27 May 2009
				JP	2009544219	A	10 December 2009
				WO	2008010855	A1	24 January 2008
				US	2008032625	A1	07 February 2008
				TW	200807958	A	01 February 2008
CN	102811497	A	05 December 2012	WO	2012163302	A1	06 December 2012