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(54) Title: INITIATING AND SELECTING A RELAY UE FOR D2D COMMUNICATIONS

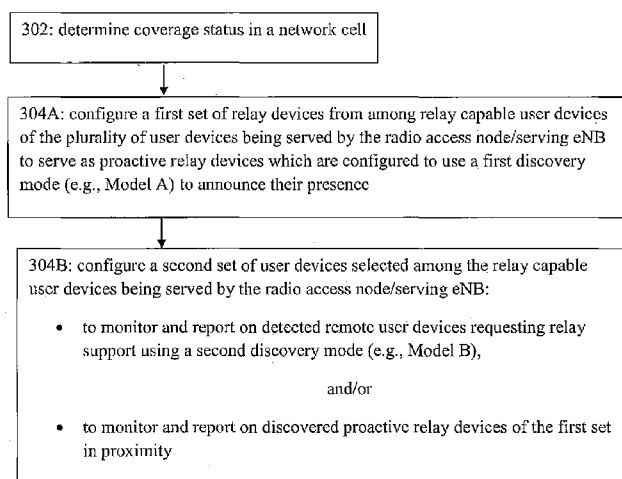


FIG. 3

(57) **Abstract:** A serving radio access node initiates and selects of a plurality of user devices to act as relay devices for other remote user devices in proximity, where D2D communications between a relay device and a remote device provide the remote device access to network services. Based on a determining coverage status in a network cell, the serving radio access node a) configures a first set of relay devices from among relay capable user devices to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and b) configures a second set of user devices selected among the relay capable user devices to monitor and report on detected remote user devices requesting relay support using a second discovery mode and/or on discovered proactive relay devices of the first set in proximity.



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INITIATING AND SELECTING A RELAY UE FOR D2D COMMUNICATIONS

TECHNOLOGICAL FIELD:

[0001] The described invention relates to wireless communications, and more particularly to device-to-device (D2D) communications that are relayed through an intermediary user equipment (UE).

BACKGROUND:

[0002] Acronyms used herein are listed below following the detailed description. D2D communications are direct between user equipments and represent an important aspect of utilizing existing radio spectrum in a more efficient way to accommodate future increases in data volumes and numbers of users. One particular aspect of D2D being developed for use in future iterations of 3GPP radio access technologies relates to proximity services (ProSe) D2D enhancements; see for example document RP-150441 by Qualcomm, Inc. entitled *Revised WI: Enhanced LTE Device to Device Proximity Services* [3GPP TSG RAN MEETING #67; Shanghai, China; 9-12 March 2014]. One of the stated objectives at section 4.1 of this work item is to define D2D enhancements so that the extension of network coverage can be supported “using L3-based UE-to-Network Relays, including service continuity (if needed), based on Release 12 D2D communication, considering applicability to voice, video. [RAN2, RAN1, RAN3]. (RAN3 involvement pending on progress in the other groups).”

[0003] Much of the 3GPP discussions in this regard have focused on activities related to the UE-to-Network Relay (relay UE) including relay UE initiation, discovery and selection/reselection. Various suggestions have differed over how much of network control is allowed on the relay UE and on the remote UE, as is summarized more particularly in document R2-153764 by the (ZTE) Rapporteur entitled *Report of email discussion [90#25][LTE-ProSe] Relay UE initiation, discovery and selection/re-selection* [3GPP TSG-RAN WG2 MEETING #91; Beijing, China; 24-28 August 2015].

[0004] While D2D communications traditionally are directly between UEs with no intermediary node between them, utilization of a relay node that is not a network entity (e.g., a relay UE) between the UE endpoints does not for purposes herein remove a communication

between those UE endpoints from being considered D2D, as is consistent with current developments in 3GPP.

[0005] Embodiments of the teachings herein address the above objective from document RP-150441, but are not limited only to the 3GPP ProSe D2D enhancements but can be used anytime a UE is enabled to be a D2D relay. Further detail concerning the relevant network architecture for future improvements of E-UTRAN can be seen at 3GPP TR 23.713 v1.6.0 (2015-09) entitled *3rd Generation partnership Project; Technical Specification Group Services and System Aspects; Study on extended architecture support for proximity-based services (Release 13)*.

SUMMARY:

[0006] According to a first aspect of these teachings there is a method for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device. The method is performed by a serving radio access node and comprises: based on a determining coverage status in a network cell, configuring a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the radio access node to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and configuring a second set of user devices selected among the relay capable user devices being served by the radio access node to monitor and report on detected remote user devices requesting relay support using a second discovery mode and/or on discovered proactive relay devices of the first set in proximity.

[0007] According to a second aspect of these teachings there is a computer readable memory storing computer program instructions that, when executed by one or more processors, cause a serving radio access node to perform actions directed to controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device. More specifically, these actions include: based on a determining coverage status in a network cell, configuring a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the radio access node to serve as

proactive relay devices which are configured to use a first discovery mode to announce their presence; and configuring a second set of user devices selected among the relay capable user devices being served by the radio access node to monitor and report on detected remote user devices requesting relay support using a second discovery mode and/or on discovered proactive relay devices of the first set in proximity.

[0008] According to a third aspect of these teachings there is an apparatus for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device. The apparatus comprises at least one computer readable memory storing computer program instructions and at least one processor. The computer readable memory with the computer program instructions is configured, with the at least one processor, to cause the apparatus to perform actions comprising: based on a determined coverage status in a network cell, configure a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the apparatus to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and configure a second set of user devices selected among the relay capable user devices being served by the apparatus to monitor and report on detected remote user devices requesting relay support using a second discovery mode and/or on discovered proactive relay devices of the first set in proximity.

[0009] According to a fourth aspect of these teachings there is an apparatus for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device. The apparatus comprises configuring means for configuring, based on a determined coverage status in a network cell: a) a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the apparatus to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and also for configuring b) a second set of user devices selected among the relay capable user devices being served by the apparatus to monitor and report on detected remote user devices requesting relay support using a second discovery mode and/or on discovered proactive relay devices of the first set in proximity. In one particular embodiment the

apparatus is a serving eNB and the configuring means comprises: at least one memory storing computer program instructions; at least one processor; and at least one radio

BRIEF DESCRIPTION OF THE DRAWINGS:

[0010] FIG. 1 is a schematic diagram illustrating an example radio environment in which embodiments of these teachings may be practiced.

[0011] FIG. 2 is a signaling diagram illustrating signaling between the network access node, the D2D relay capable UE and the remote UE according to certain embodiments of these teachings.

[0012] FIG. 3 is a process flow diagram summarizing certain of the above teachings from the perspective of the serving eNB.

[0013] FIG. 4 is a high level schematic block diagram illustrating certain apparatus/devices that are suitable for practicing certain of these teachings.

DETAILED DESCRIPTION:

[0014] One issue resolved by certain embodiments of these teachings is how the eNB (or other type of radio access node if not a LTE-type radio access network) may initiate and select UEs to act as ProSe D2D relay UEs in an efficient way, where efficiency is considered in term of utilization of network resources and also the limited battery energy of the relay UEs. In this case the relay UEs support remote UEs that have certain quality of service (QoS) requirements. Of course for implementations that are to be adopted system-wide such as via a published radio access technology (RAT) standard the standardization efforts should be affordable, and as will be seen these teachings can be embodied in software and so may be implemented even in legacy UEs via an over-the-air software update.

[0015] FIG. 1 is a schematic overview of an example radio environment in which embodiments of these teachings may be practiced to advantage. There is a serving eNB 20 whose coverage area is delineated by the dotted line at the cell edge which defines the coverage area of the serving eNB 20. Beyond the coverage area is a remote UE which is not able to communicate with the eNB 20 directly, and for example if the edge of the cell is along a coastline there may be no other cells/eNBs in range for this remote UE to establish a

connection. In this case a relay UE that does have contact with the eNB 20 may enter into D2D communications with the remote UE in order to enable the remote UE to communicate with the network/eNB 20. As another example assume there is a building or terrain obstructing some of the signal from the serving eNB 20 to the extent it results in a coverage hole, as shown by the shaded trapezoid region in FIG. 1. In this case a remote UE located in that coverage hole may need to utilize a relay UE located outside the hole to communicate with the network, similar as described for the remote UE beyond the cell edge. In either case one defining characteristic of the remote UE is that the radio network/eNB has limited if any control over it.

[0016] In current discussions for future developments of the E-UTRAN system the D2D link between the remote UE and the relay UE may be termed a PC5 (ProSe D2D) interface, while the link between the relay UE and the network remains a conventional Uu interface. Embodiments of these teachings are primarily directed towards the Uu interface between the relay UE and the network, but some also concern how the relay UE is to discover remote UEs that are proximate to it and/or how the relay UE should make itself known to any proximate remote UEs that may be present.

[0017] The inventors herein consider that many of the suggested solutions summarized in document R2-153764 focus only on individual sub-issues that may be useful towards satisfying the stated objective of document RP-150441, whereas these teachings consider the problem from the overall 'big-picture' perspective and work an overall solution with increasing granularity towards such sub-issues. In the 3GPP discussions related to ProSe D2D enhancements there are generally two models for how a remote UE can discover a relay UE that might be suitable for providing UE-to-Network relay for the remote UE or, i.e., relaying D2D communications between the remote UE and the relay UE, and these models will be used herein below:

- Model A uses only a single discovery protocol message, such as for example an Announcement message that the relay UE sends in order that remote UEs might discover it as a relay UE potentially for its use in relaying communications between the remote UE and the network;

- Model B uses at least two discovery protocol messages, for example a Solicitation message sent by the remote UE seeking a relay UE and a Response message sent by an available relay UE in reply to hearing a solicitation message.

[0018] In general terms certain embodiments of these teachings provide an efficient self-organized network (SON)-based relay initiation and selection. These teachings can be implemented to configure and use Model A and Model B for ProSe D2D relay discovery, as described in the above-referenced 3GPP TR 23.713, for initiating and selecting (activating/deactivating) relay UEs to serve remote UEs in a SON-based, efficient and QoS enhancing way. The term 'selecting' a relay UE refers to activating and deactivating that UE for relay purposes; this is how the 3GPP uses the term with regard to relay UEs and it accounts for the limited battery power of UEs which are mobile devices.

[0019] Firstly, for the serving eNB arrangement shown at FIG. 1, it is assumed the serving eNB 20 is configured to be aware of the network coverage status over its cell. As mentioned above, the eNB can be aware that one cell edge is a coastline at which there is no neighbor eNB available, or of coverage holes due to signal shadowing by terrain, buildings, tunnels or caves. Since the D2D range between a remote UE and a relay UE would typically be somewhat limited, knowing the cell coverage status enables the eNB to know the locations at which it would be suitable to change a D2D relay capable UE to a proactive relay UE that will be advertising itself as a relay UE or listening to discover if there are any remote UEs. Changing D2D relay capable UEs to proactive relay UEs should be done judiciously due to the limited battery power of UEs in general.

[0020] There are other cases apart from the above seaside/coastline scenario in which there may be no adjacent neighbor cell; for example a cell may be isolated in that there is no network coverage beyond its cell edge due to a lack of infrastructure or lack of roaming agreements with competing carriers that operate different networks in adjacent cells. This is also part of the eNB's knowledge of the network coverage status in the cell, and in this case the eNB would more likely change a D2D relay capable UE located near that isolated cell edge to a proactive relay UE as compared to some other D2D relay capable UE that is located in the middle of solid network coverage (all else being equal).

[0021] In an embodiment, the serving eNB 20 may indicate the determined network coverage status towards the relevant UEs, along with other configuration and control information for supporting ProSe D2D relays. One manner of doing this may be in a broadcasted system information block (SIB), or alternatively the serving eNB 20 can provide this information via direct signaling to UE's moving towards the coverage-lacking area. This information can be provided in various forms, particularly when broadcast in system information.

[0022] Based on the current awareness of the network coverage status, the eNB may configure ProSe D2D relay capable UEs in the cell with ProSe D2D Relay related resources and triggers for monitoring/measurement and reporting and initiating ProSe D2D relay support. The serving cell is aware of the capabilities of UEs attached to it and additionally the UEs may provide an indication of battery level to the serving eNB which the serving eNB can use to exclude UEs with a low battery level from being configured as a relay-capable UE.

[0023] In one particular embodiment the serving eNB can configure those D2D relay capable UEs as follows. First consider cells with pre-determined coverage issues such as isolated cells or nomadic cells, or those with cell-edge or coverage hole issues as shown in FIG. 1. For these known coverage problem cells, in an embodiment there may be some special UE devices, referred to herein as agents, that are preconfigured or specifically deployed to act as discovery agents and relays for ProSe D2D based UE-to-Network relays pro-actively. In this case the relay UE shown at FIG. 1 would be one such agent if we assume there is no neighbor cell available at the cell edge between it and the remote UE. In one example a cell having coverage along a coastline border may have several such agents deployed along the coastline, or in another example a cell having some short but deep tunnels or caves within the radius of its coverage area may have one or more such agents deployed at the doors or surface entryways of those tunnels or caves such that the agents remain in the open. In these examples those agents would be configured to operate according to Model A above. This process may also be referred to as pro-active relay initiation and selection.

[0024] In this case according to an embodiment the deployed UE agents should establish a connection with and inform the serving eNB of its contexts, and obtain from the serving eNB all necessary cell specific configurations including for example some relay-specific configurations such as some designated or dedicated reference signal(s) or discovery signal(s)

or identity(ies) to send over the air and indicate to other relevant UEs such as relay capable UEs which may or may not yet be selected to act as relay UEs and remote UEs inside the cell coverage about their presence and pro-active role already acting as relay UEs for remote UEs.

[0025] The serving eNB can also advertise about those agents to the relevant UEs in the cell. This advertising can be for example via a SIB, or dedicated signaling which can be directed towards UEs that are moving toward the regions of the cell that have coverage issues. This enables the relevant UEs to efficiently monitor and discover those agents for certain purposes, which can serve as preconditions or triggers upon discovering those advertised agents.

[0026] The serving eNB may also select among those relay capable UEs which ones are to report back to the eNB according to some configured measurement-and-reporting triggers, where in these examples the measurement and reporting triggers are related to the ProSe D2D Relay function. These selected relay capable UEs may be those located near to the positions of the coverage problem(s), and the eNB's selection criteria may for example be based on the UE's reported proximity discovery of some agents as indicated by the eNB, and/or based on the UE's reported location information, and the like. These selected relay capable UEs can then be configured to operate as proactive relay UEs using Model A as mentioned above.

[0027] On the other hand, those relay capable UEs which are not (yet) selected to act as a relay UE are configured to discover and report to the eNB on the other agents or proactive relay UEs that these non-selected UEs discover when the selected proactive relay UEs/agents transmit their announcement message per Model A. This enables the eNB to dynamically update its database of D2D UEs and relay capable UEs with their locations relative to one another and their relative proximity to one another. This, in turn, can be used to optimize selection and reselection of D2D relay capable UEs to act as relay UEs in providing efficient service coverage extension for remote UEs, aiming for, e.g., best possible service coverage extension with minimum number of active relay UEs which are determined as most suitable and preferable to be selected.

[0028] For the case in which a relay UE is actually serving one or more remote UEs, that relay UE is considered as a proactive and serving relay UE and it is configured to indicate to relevant UEs, for discovery and SON based relay selection purposes, that it is actively

serving some remote UE. In this case the active serving relay UE does not need to (or no longer needs to) discover other proactive UEs, including the agents mentioned above.

[0029] The relay capable UEs which are not yet selected to act as a relay UE are configured to monitor remote UEs in Model B as well as to discover proactive relay UEs or active serving relay UEs. These relay capable UEs will report back to the serving eNB if they discover a remote UE in Mode B or a proactive relay UE or an active serving relay UE. Based on this report, the eNB may determine and configure the reporting UE to first response to the remote UE in Mode B and then act as a proactive relay to serve the discovered remote UE that may be requesting relay support. Or in the case the discovered UE is some other serving relay UE, the reporting UE can be configured by the eNB to act as proactive relay UE in order to provide remote UE which is served by the discovered serving relay UE an option for possible relay reselection, if the remote UE may need to change relay UEs at some future point in time. This latter aspect provides a SON based dynamic service coverage extension and therefore enhances the mobility robustness for the existing remote UEs.

[0030] The proactive relay UE which is not serving any remote UE is configured to discover other proactive relay UEs, including the agents mentioned above, that are nearby. These proactive relay UEs will also report back to the serving eNB if they discover more than a certain predetermined number N of proactive relay UEs which are also not serving any remote UE. From this information the eNB may determine to deactivate the reporting UE or some of those proactive UEs that were reported. Or the eNB may determine to keep the reporting UE and/or some of those proactive UEs that were reported as relay UEs, but configure those relay UEs to use Model B instead of Model A so that these Model A configured relay UEs can serve the remote UEs immediately after monitoring and receiving remote UE discovery requests, without reporting back to the serving eNB as is detailed above.

[0031] There is a slightly different protocol for cells with normal, full network coverage; that is, no coverage problems or at least none that are known. In these cells the relay capable UEs or the configured relay UEs which are not yet selected to act as a proactive relay UE are initially configured to monitor for remote UEs using Model B, and to discover proactive relay UEs and active serving relay UEs and report back this information to the serving eNB, as mentioned above. Once a proactive relay UE is configured, it should follow the operations

detailed above. The remote UE can be configured to discover proactive UEs first (for example using Model A) and if none are found then it may start using Model B.

[0032] Further, in certain embodiments when the eNB (or serving network) configures relay capable UEs to be proactive relays, the radio resource control (RRC) state of those relay capable UEs can be taken into account. This is because the UEs in the RRC CONNECTED state may have a better chance or priority to be selected and configured as relay UEs, while UEs in the RRC IDLE state/mode may have more resources (power, processing time, etc.) to discover remote UEs in need of relay services, or to discover other proactive relay UEs that may be nearby. Thus, UEs in IDLE mode may be configured with more frequent periodic discovery and/or more relaxing threshold-based triggers for less frequent event-trigger measurement and reporting; and the UEs in the CONNECTED state may be configured the other way around with less frequent periodic discovery and/or less relaxing threshold-based triggers for more frequent event-trigger measurement and reporting.

[0033] FIG. 2 is a signaling diagram illustrating an overview of the signaling involved with certain of the above teachings. Firstly at processing block 202 the serving eNB that controls the cell determines the coverage status in the cell. This is what drives how the serving eNB will configure the various D2D relay capable UEs in the cell, and whether there will be any relay agents in the cell as detailed more particularly above. Then based on the determined cell coverage status at block 202, the serving eNB signals a configuration message 204 to a D2D relay capable UE which gives it resources such as radio channel slots/symbols to use when relaying of D2D relay communications, or a dedicated cover code, or any of various radio resources available to the eNB. The configuration message also indicates to the D2D relay capable UE the various triggers it is to use when monitoring for remote UEs that may need D2D relay support, or when measuring other D2D relay UEs that are operating in the area, or triggers for when to report this information back to the eNB, or when or under what conditions the D2D relay capable UE is to begin operating as a D2D relay UE. There are many other more specific configurations in the embodiments detailed above.

[0034] Further at FIG. 2 the serving eNB can advertise to presence of relay agents that may be operating in the cell at message 206, which may be a broadcast SIB or may be dedicated signaling to the relevant UEs such as relay capable UEs which may or may not yet be selected to act as relay UEs and remote UEs inside the cell coverage.

[0035] FIG. 2 also has the D2D relay capable UE, which depending on the configuration message 204 may be operating as a D2D relay UE, announcing its availability as a D2D relay UE at message 208 or discovering remote UEs at messages 201A/210B. Specifically, the announcement message 208 is unsolicited and is consistent with the Model A discovery protocol; while the D2D relay solicitation message 210A is how the D2D relay capable UE discovers the presence of a remote UE seeking D2D support under the Model B protocol. Further in that model B protocol the D2D relay UE would reply to the solicitation message 201A with a Response message 210B, if in fact that D2D relay UE were available for providing D2D relay support at that time. The Model A and Model B discovery protocols may be considered as specific examples of the more generic first and second discovery modes.

[0036] Finally in the FIG. 2 signaling diagram the D2D relay capable UE which may (already) or may not (yet) be selected as a relay UE which is further characterized as a proactive relay UE or agent, actually serving or not yet serving a remote UE, sends its reports 212 back to the serving eNB. As detailed more particularly above, these reports can indicate presence of other remote UEs the D2D relay capable UE has discovered, or of other D2D relay UEs it has discovered, which remote UEs the reporting D2D relay UE is serving, and the like. These reports 212 are sent according to the configuration message 204, which may have a periodicity for when the reports are to be sent (if there is any data to report), a value of N for how many other proactive D2D relay UEs the D2D relay UE needs to discover before reporting them, and the like for other reporting triggers.

[0037] FIG. 3 is a process flow diagram that summarizes some of the above aspects from the perspective of the serving eNB or other radio access node of a network. FIG. 3 details a method for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity. The relay is based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device. At block 302 coverage status in a network cell is determined, and based on that at block 304A the eNB configures a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the radio access node (the serving eNB) to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence. For example that first

discovery mode may be Model A noted above. Also based on the determined coverage status at block 302, at block 304B the eNB configures a second set of user devices selected among the relay capable user devices being served by the radio access node (the serving eNB) to monitor and report on detected remote user devices requesting relay support using a second discovery mode, and/or to monitor and report on discovered proactive relay devices of the first set in proximity.

[0038] In one embodiment the eNB itself determines the coverage status. In another embodiment at least one relay device of the first set of relay devices is a relay agent that is preconfigured in the cell for providing preconfigured service coverage extension for remote user devices seeking D2D relay support. These relay agents may be configured to advertise their availability as a proactive relay device by sending unsolicited relay discovery announcements in the cell. And the eNB can also advertise in the cell, via broadcast system information or dedicated signaling, that the relay agent or agents are present and operating in the cell.

[0039] In some embodiments the eNB can also configure only those devices of the first set of relay devices that are actively serving as a relay device for at least one remote user device to not perform discovery and reporting on remote UEs which uses the second discovery mode nor perform discovery and reporting on other proactive relay UEs. And in a further embodiment it can also configure only these same devices of the first set that are actively serving as a relay device for at least one remote user device to indicate to other relevant UEs, for discovery and SON based relay selection purposes, and to the eNB information about the active serving, for example, 1-bit indication of being actively serving some remote UE to other relevant UEs or which remote user devices it is serving, link quality, etc., to the serving eNB.

[0040] As mentioned above, if the second discovery mode is similar to model B above then this mode comprises listening for a solicitation message from remote user devices.

[0041] In some embodiments the eNB can change a user device from the second set of block 304B to the first set of block 304A based on the report the eNB receives from that user device concerning the remote user devices it detected.

[0042] And in a still further embodiment the eNB can configure one or more user devices in the first set of block 304A that is/are not also actively serving any remote user devices to discover relay devices in the first set and report said discovered relay devices to the eNB only once a predefined number N of relay devices have been discovered.

[0043] For the case in which the coverage status in the network cell is determined to be normal with no coverage gaps, in one embodiment the eNB can initially configure the relay capable user devices to: a) monitor for remote user devices by listening for a solicitation message from said remote user devices; b) discover other relay user devices; and c) report said monitored remote user devices and said other relay user devices that are discovered back to the eNB.

[0044] Various of these aspects may be practiced individually or in any of various combinations. While the above description and FIG. 3 are from the perspective of the eNB configuring the D2D relay capable user devices (and/or those that are also D2D relay user devices or agents), the skilled artisan will recognize that these support corresponding behavior on the part of the configured entities. So for example a D2D relay capable user device receiving the configuration at block 304B of FIG. 3 will operate in the cell consistent with that configuration. If it is configured to advertise its availability by sending Announcement messages per discovery Mode A, then the D2D relay capable user device will receive the configuration and in response it will transmit announcement messages according to this configuration it received from the eNB.

[0045] Fig. 4 is a schematic diagram illustrating some components of the eNB and the relay UE shown at FIG. 1, but designated in FIG. 4 as a radio access node 20 and a D2D relay capable UE 10. In the wireless system/cell a wireless network is adapted for communication over a wireless link 11 with an apparatus such as a mobile communication device which may be referred to as a D2D relay capable UE 10, via a radio network access node such as a Node B (base station), and more specifically an eNB 20. The network may include a network control element (NCE, not shown) that may include mobility management entity/serving gateway (MME/S-GW) functionality, and which provides connectivity with a further network such as a telephone network and/or a data communications network (e.g., the internet).

[0046] The D2D relay capable UE 10 includes a controller, such as a computer or a data processor (DP) 10D, a computer-readable memory medium embodied as a memory (MEM) 10B that stores a program of computer instructions (PROG) 10C, and a suitable wireless interface, such as radio frequency (RF) transmitter/receiver combination 10D for bidirectional wireless communications with the eNB 20 via one or more antennas.

[0047] The wireless link between the D2D relay UE 10 and the remote UE(s) can be checked for link quality by comparing a measurement of it (for example, received signal strength or quality) against some minimum threshold before the D2D relay capable UE 10 begins actively serving as a D2D relay for that remote UE. Further, the D2D relay capable UE 10 includes a galvanic power supply or other portable power supply whose current reserve level may be checked also, prior to this D2D relay capable UE 10 initiating actively serving as a D2D relay for that remote UE. For example, the serving eNB 20 can base its decision whether or not to configure a given D2D relay capable UE as a D2D relay UE on that given UE's current battery level. In one implementation the serving eNB can assume all D2D relay capable UEs have a sufficient battery level unless signaled to the contrary by individual UEs, all of which check their own current battery level and current activity level against thresholds established for D2D relay purposes. Another implementation assumes the opposite and the serving eNB will only consider those D2D relay capable UEs that have positively reported that their battery level is adequate as candidates for being configured as D2D relay UEs.

[0048] The eNB 20 also includes a controller, such as a computer or a data processor (DP) 20A, a computer-readable memory medium embodied as a memory (MEM) 20B that stores a program of computer instructions (PROG) 20C, and a suitable wireless interface, such as RF transmitter/receiver combination 20D for communication with the D2D relay capable UE 10 (as well as other UEs) via one or more antennas. The eNB 20 is coupled via a data/control path (not shown) to the NCE and this path may be implemented as an interface. The eNB 20 may also be coupled to another eNB via another data/control path, which may be implemented as a different interface.

[0049] At least one of the PROGs 10C/20C is assumed to include program instructions that, when executed by the associated DP 10A/20A, enable the device to operate in accordance with exemplary embodiments of this invention as detailed above. That is, various

exemplary embodiments of this invention may be implemented at least in part by computer software executable by the DP 10A of the D2D relay capable UE 10; by the DP 20A of the eNB 20, or by hardware or by a combination of software and hardware (and firmware). If a local cell 211 is present in the network cell arrangement it may have the same type of components as shown in FIG. 4 for the eNB 20.

[0050] In various exemplary embodiments the UE 10 and/or the eNB 20 may also include dedicated processors, for example a RRC module, a RF front end, and the like. There may also be one or more modules that is/are constructed so as to operate in accordance with various exemplary embodiments of these teachings.

[0051] The computer readable MEMs 10B/20B may be of any type suitable to the local technical environment and may be implemented using any one or more suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, electromagnetic, infrared, or semiconductor systems. Following is a non-exhaustive list of more specific examples of the computer readable storage medium/memory: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[0052] The DPs 10A/20A may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multicore processor architecture, as non-limiting examples. The wireless interfaces (e.g., the radios 10D/20D) may be of any type suitable to the local technical environment and may be implemented using any suitable communication technology such as individual transmitters, receivers, transceivers or a combination of such components.

[0053] In general, the various embodiments of the UE 10 can include, but are not limited to, smart phones, machine-to-machine (M2M) communication devices, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable

computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions. Any of these may be embodied as a hand-portable device, a wearable device, a device that is implanted in whole or in part, a vehicle-mounted communication device, and the like.

[0054] It should be understood that the foregoing description is only illustrative. Various alternatives and modifications can be devised by those skilled in the art. For example, features recited in the various dependent claims could be combined with each other in any suitable combination(s). In addition, features from different embodiments described above could be selectively combined into an embodiment that is not specifically detailed herein as separate from the others. Accordingly, the description is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

[0055] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

3GPP	Third Generation Partnership Project
D2D	device-to-device
E-UTRAN	evolved UMTS radio access network
L3	layer 3 (radio resource control/non-access stratum in E-UTRAN)
LTE	long term evolution (of E-UTRAN)
M2M	machine-to-machine
ProSe	proximity services
QoS	quality of service
RAN	radio access network
SON	self-organized network
UMTS	universal mobile telecommunications service

CLAIMS:

What is claimed is:

1. A method for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device, the method performed by a serving radio access node and comprising:

based on a determined coverage status in a network cell, configuring a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the radio access node to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and

configuring a second set of user devices selected among the relay capable user devices being served by the radio access node to monitor and report on at least one of detected remote user devices requesting relay support using a second discovery mode and discovered proactive relay devices of the first set in proximity.

2. The method according to claim 1, the method further comprising the serving radio access node determining the coverage status.

3. The method according to any of claims 1-2, wherein at least one relay device of the first set of relay devices is a relay agent that is preconfigured in the cell for providing preconfigured service coverage extension for remote user devices seeking D2D relay support.

4. The method according to claim 3, the method further comprising configuring each said relay agent to advertise its availability as a proactive relay device by sending unsolicited relay discovery announcements in the cell.

5. The method according to any of claims 3-4, the method further comprising the radio access node advertising in the cell via broadcast system information or dedicated signaling that the relay agent or agents are present and operating in the cell.

6. The method according to any of claims 1-5, the method further comprising:
the radio access node configuring only those devices of the first set of relay devices that are actively serving as a relay device for at least one remote user device to not perform discovery or reporting on remote user devices which use the second discovery mode nor on other proactive relay user devices.
7. The method according to claim 6, the method further comprising:
the radio access node further configuring only those devices of the first set of relay devices that are actively serving as a relay device for at least one remote user device to indicate to other relevant user devices for discovery and self-organized network based relay selection purposes, and to the radio access node, information about the active serving.
8. The method according to any of claims 1-7, wherein the second discovery mode comprises listening for a solicitation message from remote user devices.
9. The method according to any of claims 1-8, the method further comprising:
changing a user device from the second set to the first set based on the respective report on detected remote user devices.
10. The method according to any of claims 1-9, the method further comprising:
configuring at least one user device in the first set that is not also actively serving any remote user devices to discover relay devices in the first set and report said discovered relay devices to the radio access node only once a predefined number N of relay devices have been discovered.
11. The method according to any of claims 1-10, wherein for the case the coverage status in the network cell is determined to be normal with no coverage gaps, the method further comprises initially configuring the relay capable user devices to:
monitor for remote user devices by listening for a solicitation message from said remote user devices;
discover other relay user devices; and
report said monitored remote user devices and said other relay user devices that are discovered to the radio access node.

12. A computer readable memory storing computer program instructions that, when executed by one or more processors, cause a serving radio access node to perform the method according to any of claims 1-11.

13. An apparatus for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device, the apparatus comprising:

at least one memory storing computer program instructions; and

at least one processor;

wherein the at least one memory with the computer program instructions is configured with the at least one processor to cause the apparatus to perform actions comprising:

based on a determined coverage status in a network cell, configure a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the apparatus to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and

configure a second set of user devices selected among the relay capable user devices being served by the apparatus to monitor and report on at least one of detected remote user devices requesting relay support using a second discovery mode and discovered proactive relay devices of the first set in proximity.

14. The apparatus according to claim 13, the actions further comprising determining the coverage status.

15. The apparatus according to any of claims 13-14, wherein at least one relay device of the first set of relay devices is a relay agent that is preconfigured in the cell for providing preconfigured service coverage extension for remote user devices seeking D2D relay support.

16. The apparatus according to claim 15, the actions further comprising configuring each said relay agent to advertise its availability as a proactive relay device by sending unsolicited relay discovery announcements in the cell.

17. The apparatus according to any of claims 15-16, the actions further comprising the apparatus advertising in the cell via broadcast system information or dedicated signaling that the relay agent or agents are present and operating in the cell.
18. The apparatus according to any of claims 13-17, the actions further comprising:
the apparatus configuring only those devices of the first set of relay devices that are actively serving as a relay device for at least one remote user device to not perform discovery or reporting on remote user devices which use the second discovery mode nor on other proactive relay user devices.
19. The apparatus according to claim 18, the actions further comprising:
the apparatus further configuring only those devices of the first set of relay devices that are actively serving as a relay device for at least one remote user device to indicate to other relevant user devices for discovery and self-organized network based relay selection purposes, and to the apparatus, information about the active serving.
20. The apparatus according to any of claims 13-19, wherein the second discovery mode comprises listening for a solicitation message from remote user devices.
21. The apparatus according to any of claims 13-20, the actions further comprising:
changing a user device from the second set to the first set based on the respective report on detected remote user devices.
22. The apparatus according to any of claims 13-21, the actions further comprising:
configuring at least one user device in the first set that is not also actively serving any remote user devices to discover relay devices in the first set and report said discovered relay devices to the apparatus only once a predefined number N of relay devices have been discovered.
23. The apparatus according to any of claims 13-22, wherein for the case the coverage status in the network cell is determined to be normal with no coverage gaps, the actions further comprise initially configuring the relay capable user devices to:
monitor for remote user devices by listening for a solicitation message from said remote user devices;

discover other relay user devices; and
report said monitored remote user devices and said other relay user devices that are discovered to the apparatus.

24. The apparatus according to any of claims 13-23, wherein the apparatus is a serving eNB.

25. An apparatus for controlling initiation and selection of a plurality of user devices to act as relay devices for other remote user devices in proximity, the relay based on direct device-to-device (D2D) communications between a relay device and a remote device for providing access to network services for the remote device, the apparatus comprising configuring means for configuring, based on a determined coverage status in a network cell:

a first set of relay devices from among relay capable user devices of the plurality of user devices being served by the apparatus to serve as proactive relay devices which are configured to use a first discovery mode to announce their presence; and also

a second set of user devices selected among the relay capable user devices being served by the apparatus to monitor and report on at least one of detected remote user devices requesting relay support using a second discovery mode and discovered proactive relay devices of the first set in proximity.

26. The apparatus according to claim 25, wherein the apparatus is a serving eNB and the configuring means comprises:

at least one memory storing computer program instructions;
at least one processor; and
at least one radio.

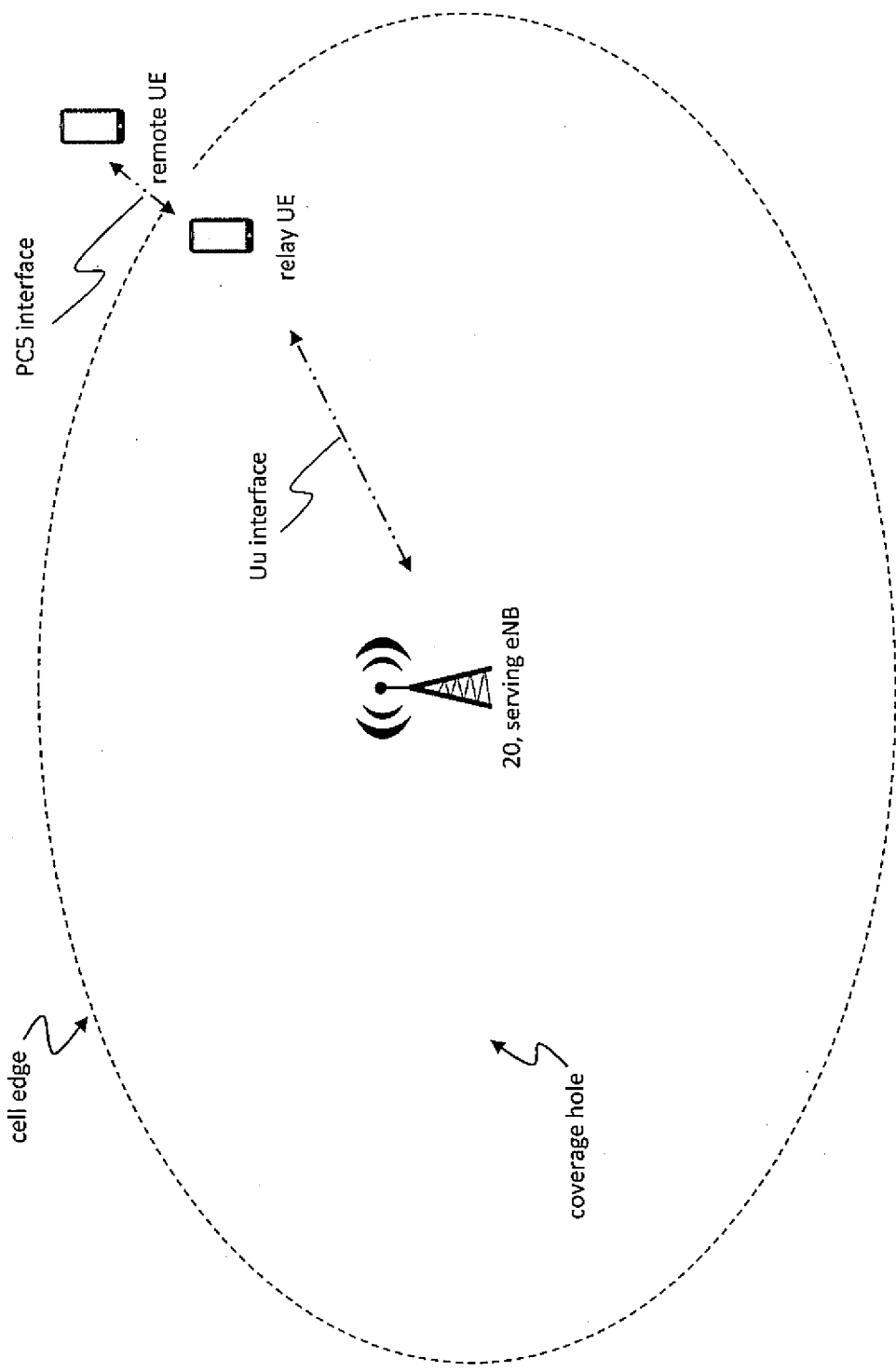


FIG. 1

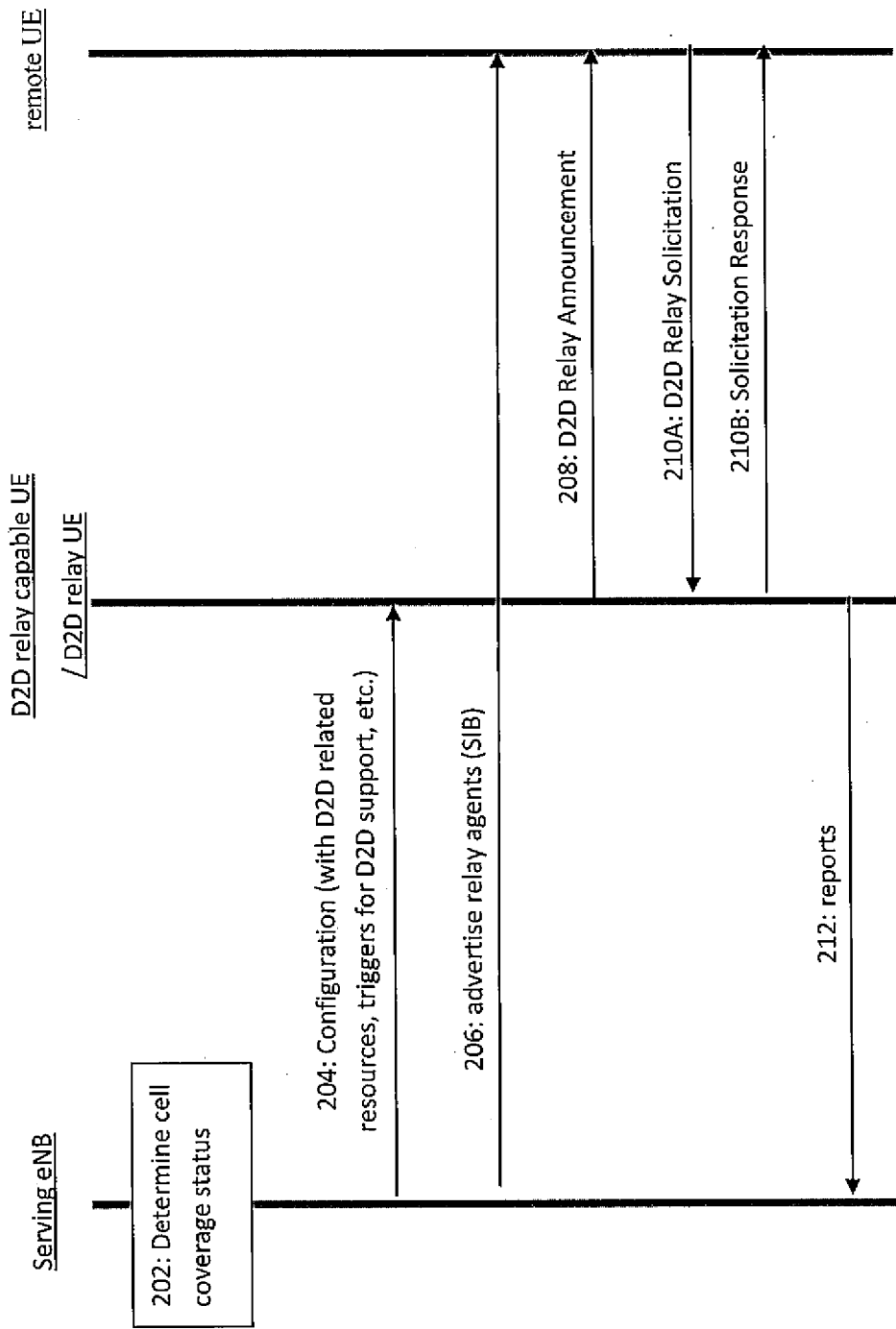
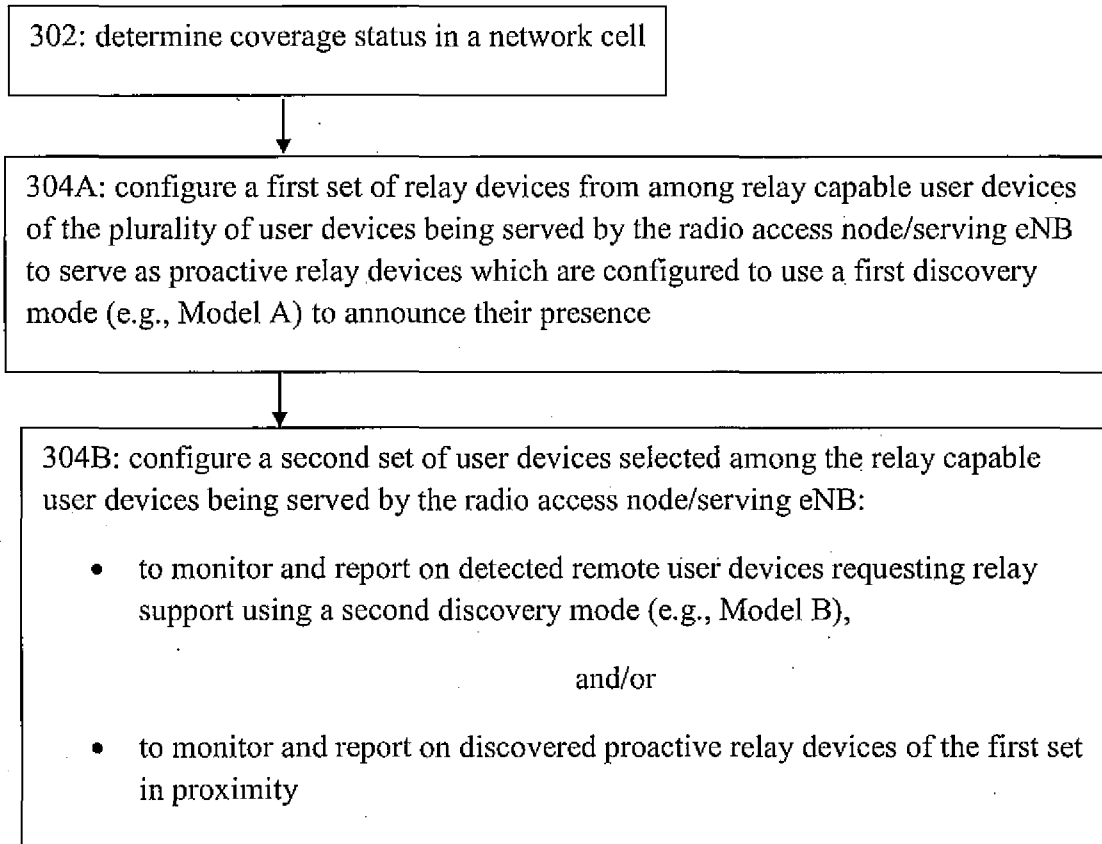


FIG. 2

**FIG. 3**

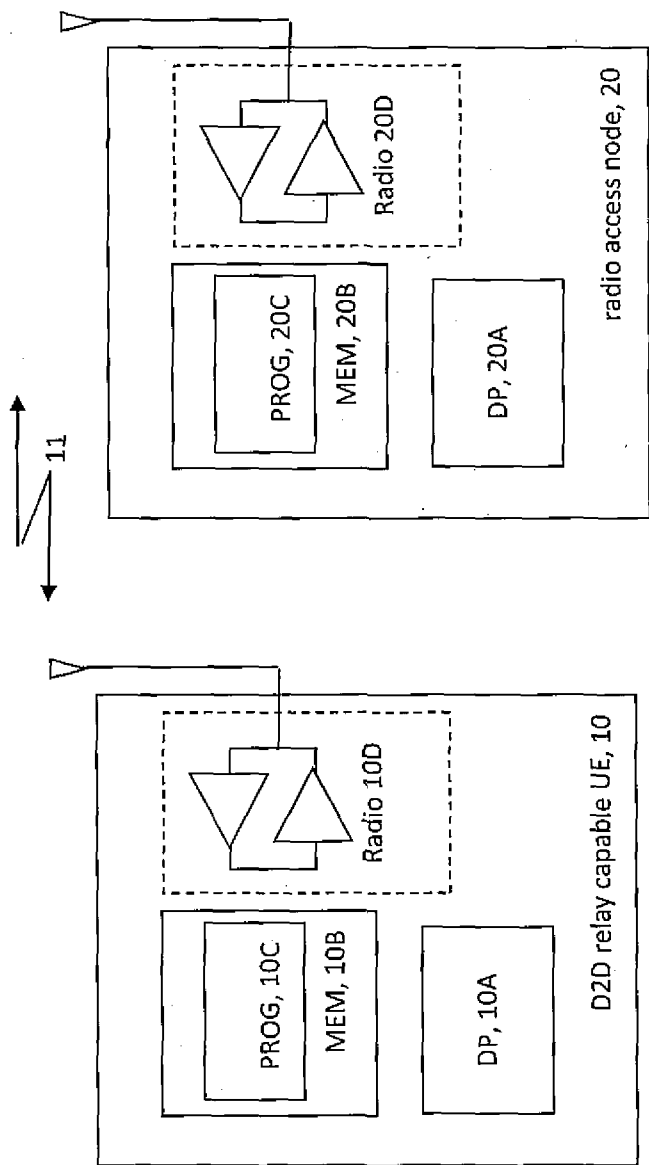


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US15/52120

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04W 48/14, 88/04; H04B 7/26 (2015.01)

CPC - H04W 8/005, 88/04; H04B 7/2606

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)

IPC(8): H04W 4/00, 48/14, 88/04; H04B 7/26 (2015.01)

CPC: H04W 4/008, 4/023, 8/005, 48/14, 52/0229, 88/04; H04B 7/2606

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)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google; Google Scholar; ProQuest; KEYWORDS: initiation selection user devices relay remote proximity device-to-device D2D communications access network node radio cell

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/0029866 A1 (HTC CORPORATION) January 29, 2015; abstract; paragraphs [0015, 0047, 0050, 0058, 0073-0079]	1-2, 3/1-3/2, 4/3/1-4/3/2, 13-14, 15/13-15/14, 16/15/13-16/15/14, 25-26
A	US 2014/0378123 A1 (STOJANOVSKI, A. et al.) December 25, 2014; entire document	1-2, 3/1-3/2, 4/3/1-4/3/2, 13-14, 15/13-15/14, 16/15/13-16/15/14, 25-26
A	US 2015/0148074 A1 (NOKIA SOLUTIONS AND NETWORKS OY) May 28, 2015; entire document	1-2, 3/1-3/2, 4/3/1-4/3/2, 13-14, 15/13-15/14, 16/15/13-16/15/14, 25-26



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

23 November 2015 (23.11.2015)

Date of mailing of the international search report

06 JAN 2016

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

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PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US15/52120

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 5-12, 17-24
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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. ☐ 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.