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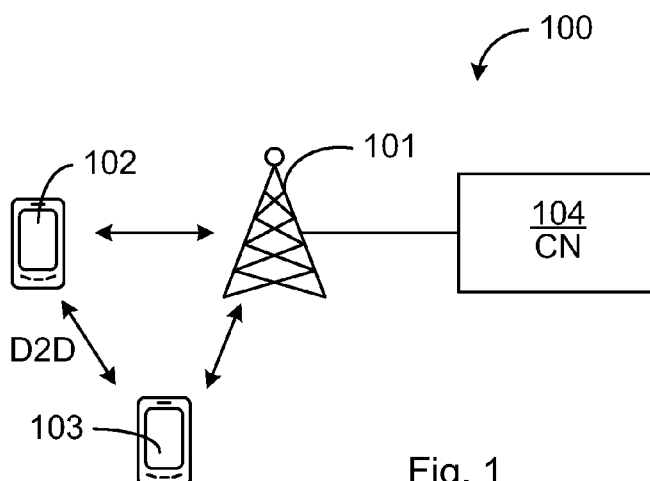


Fig. 1

(57) Abstract: The present disclosure relates to a method of radio communication between a first radio device (102) and a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), at least one of the radio devices being served by said network node. The method comprises determining a second frequency resource to use for non-network assisted device-to-device (D2D) communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The method also comprises determining a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.

METHOD FOR D2D RADIOCOMMUNICATION

TECHNICAL FIELD

The invention relates to a methods and devices of radio communication between a first radio device and a second radio device using a first frequency resource and a first communication protocol by means of a network node, at
5 least one of the radio devices being served by (or connected to) said network node.

BACKGROUND

Device-to-Device (D2D) communication refers to direct communication
10 between devices. In D2D communication, data to be transmitted from a first device to a second device is typically not relayed via any cellular network. Some examples of D2D communication of the prior art are Bluetooth communication, FlashlinQ communication, Wireless Local Area Network (WLAN, e.g. IEEE 802.11) communication (e.g. WIFI Direct).

15 Device-to-device communication may be applicable in various scenarios. One scenario is when a cellular radio access network is present, and able to set up a cellular connection between two devices. D2D communication may be a complement to the cellular communication in such scenarios.

There may be situations when D2D communication may provide better
20 performance (better signal quality, higher bit rate, lower latency, etc) than cellular communication. This may be due to proximity between the devices and/or specific signalling gain of the D2D protocol (e.g. hop gain).

In some situations, the network may have constraints (e.g. due to being heavily loaded) resulting in that a service cannot be provided at all using a
25 network connection. Then, D2D communication would be an alternative.

There may also be situations when D2D communication may be preferred by the user of a device (e.g. due to billing costs).

D2D communication may improve spectrum efficiency and reduce the network load for the cellular network, since the D2D connection typically uses another spectrum range (e.g. an unlicensed spectrum) than the cellular network (typically licensed spectrum). Furthermore, since cellular
5 communication uses an uplink-downlink pair for each of the two devices while a D2D connection would only use one link pair, spectrum efficiency is improved even if the D2D connection would use cellular spectrum resources. This would be true even for network assisted D2D communication where most of the data would be transmitted over the D2D connection and only a
10 small amount of information is to be transmitted over the network link.

D2D communication may be ad hoc or may be network assisted. For example, a cellular network may assist a D2D connection by establishing security of the D2D link and/or partly or fully controlling the setup of the D2D connection (e.g. device/peer discovery and resource allocation). A cellular network may
15 also assist D2D communication by controlling the interference environment. For example, if using licensed operator's spectrum for the D2D communication, higher reliability can be provided than when operating in unlicensed spectrum. To assist the D2D connection, the network may also provide synchronization and/or partial or full Radio Resource Management
20 (RRM - may e.g. comprise time and/or frequency resource allocation for the D2D communication).

In a typical cellular communication system, there are standardized procedures for connection setup and connection release (disconnection). There are typically also defined procedures for how to act in radio link failure
25 (RLF), a scenario when a radio link is lost in an uncontrolled way (without connection release being performed). Such scenarios may be encountered e.g. when a device goes out of coverage, due to erroneous device operation, due to battery removal, etc. D2D communication may e.g. be used in catastrophic situations or in National Security and Public Safety (NSPS) situation, used by
30 police or the like, where cellular coverage is not always available.

Radio link monitoring procedures is typically defined for prior art cellular systems. Such procedures may include the device monitoring the radio channel and synchronization status with the network and define how to proceed of e.g. the synchronization is lost.

- 5 For example in Wideband Code Division Multiple Access (WCDMA) and Long Term Evolution (LTE), the wireless communication device monitors the down link (DL) channel conditions and determines whether the DL is in-sync or out-of-sync. This determination may be based on whether the device can reliably decode the DL information. If out-of-sync is detected, the device is to
- 10 perform a number of actions, e.g. start higher layer connection release timers (indicating how long the device should try to re-synchronize before performing a formal connection release) and set transmission constraints (to limit the potential interference caused by the device if transmitting without reliable detection of DL power control information).
- 15 There is thus a need to improve the handling of a RLF during communication between two radio communication devices aided by a cellular network, either cellular communication or network (NW) assisted D2D communication.

SUMMARY

It is an objective of the present disclosure to provide improved methods and

20 devices for handling a RLF of a radio link to a cellular network during communication aided by said cellular network between two radio communication devices.

According to an aspect of the present disclosure, there is provided a method of radio communication between a first radio device and a second radio

25 device using a first frequency resource and a first communication protocol by means of a network node, at least one of the radio devices being served by said network node. The method comprises determining a second frequency resource to use for non-network assisted device-to-device (D2D) communication between the first and second radio devices in case of a radio

30 link failure between said at least one radio device and the network node. The

method also comprises determining a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.

- 5 In some embodiments, the method above is performed in the network node. Then the network node may send at least one message to the first radio device, the at least one message comprising information about the determined second frequency resource and second communication protocol, the information being intended to enable the first radio device to initiate non-
- 10 network assisted D2D communication with the second radio device using said determined second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node. In this way, the network node can inform the radio device of the determined second frequency resource and second
- 15 communication protocol, enabling the radio device to proceed with non-NW assisted D2D using said second frequency resource and second communication protocol if desired/needed.

- In some embodiments, the network node sends a message to the second radio device, the message comprising information about the determined second
- 20 frequency resource and second communication protocol, the information being intended to enable the second radio device to initiate non-network assisted D2D communication with the first radio device using said determined second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and
- 25 the network node. In this way, the network node can inform both of the radio devices about the determined second frequency resource and second communication protocol, facilitating the radio device proceeding with non-NW assisted D2D using said second frequency resource and second communication protocol if desired/needed. This may be an alternative to the
- 30 first radio device informing the second radio device of the determined second frequency resource and second communication protocol.

In some embodiments, the network node estimates the likelihood of it being possible to initiate non-network assisted D2D radio communication between the first and second radio devices, before the sending of a message to the first radio device. Unless the radio devices are able to communicate by non-NW
5 assisted D2D, it may be unnecessary to inform the device(s) of the determined second frequency resource and second communication protocol. The estimation may e.g. be based on the respective configurations of the first and/or second devices, or on the proximity of the devices to each other e.g. whether both devices are served by the same base station or based on
10 obtained geographical positions of one or both of the first and second devices.

In some other embodiments, the method is performed in the first radio device. The first radio device may additionally determine whether the radio link to the network node has failed. If it is determined that the radio link has failed, the first radio device may initiate non-network assisted D2D
15 communication with the second radio device, using the determined second frequency resource and the determined second communication protocol.

In some embodiments, the first radio device may send a first message to the second radio device. In response to the sent first message, the first radio device may receive a second message from the second radio device, the
20 received message containing information, on which information the determining of the second frequency resource and the second communication protocol is based. This exchange of messages may enable the first and second radio devices to discuss, negotiate and/or agree upon which second frequency resource and second communication protocol to determine for use in non-
25 network assisted D2D communication if desired/needed. In some embodiments, the first message is sent and the second message is received during setup of the communication by means of the network node with the second device. This implies that when communication which is aided by the network is set up between the first and second devices (cellular
30 communication or NW assisted D2D communication) the devices determine, already at this early stage, the second frequency resource and second communication protocol.

According to another aspect of the present disclosure, there is provided a method of a first radio device in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of a network node, the first radio device also being served by said
5 network node. The method comprises receiving, from the network node, information about a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between the first radio device and the network node. The method also comprises receiving, from the network node,
10 information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device and the network node. The method also comprises determining that the radio link to the network node has failed. The method also comprises initiating non-network
15 assisted D2D communication with the second radio device using the second frequency resource and the second communication protocol.

According to another aspect of the present disclosure, there is provided a computer program product comprising computer-executable components for causing a device, e.g. the first radio device or the network node, to perform an
20 embodiment of a method of the present disclosure when the computer-executable components are run on a processor comprised in the device.

According to another aspect of the present disclosure, there is provided a computer program for radio communication between a first radio device and a second radio device using a first frequency resource and a first
25 communication protocol by means of a network node, at least one of which radio devices being served by said network node. The computer program comprises computer program code which is able to, when run on a processor of a device e.g. the first radio device or the network node, cause the device to determine a second frequency resource to use for non-network assisted D2D
30 communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The computer program also causes the device to determine a second

communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.

According to another aspect of the present disclosure, there is provided a computer program for a first radio device in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of a network node, the first radio device being served by said network node. The computer program comprises computer program code which is able to, when run on a processor of the first radio device, cause said first radio device to receive, from the network node, information about a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between the first radio device and the network node. The computer program also causes the first radio device to receive, from the network node, information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device and the network node. The computer program also causes the first radio device to determine that the radio link to the network node has failed. The computer program also causes the first radio device to initiate non-network assisted D2D communication with the second radio device using the second frequency resource and the second communication protocol.

According to another aspect of the present disclosure, there is provided a computer program product comprising an embodiment of a computer program according to the present disclosure and a computer readable means on which the computer program is stored.

According to another aspect of the present disclosure, there is provided a network node configured for being served by a first radio device when the first radio device is in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of the network node. The network node comprises a processor, and a storage unit

storing instructions that, when executed by the processor, cause the network node to determine a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The instructions also cause the network not to determine a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node. The instructions also cause the network not to send at least one message to the first radio device, the at least one message comprising information about the determined second frequency resource and second communication protocol, the information being intended to enable the first radio device to initiate non-network assisted D2D communication with the second radio device using said determined second frequency resource and second communication protocol in the case of a radio link failure.

According to another aspect of the present disclosure, there is provided a first radio device configured for being in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of a network node, and for being served by said network node. The first radio device comprises a processor, and a storage unit storing instructions that, when executed by the processor, cause the radio device to determine a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The instructions also cause the first radio device to determine a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node. The instructions also cause the first radio device to determine that the radio link to the network node has failed. The instructions also cause the first radio device to initiate non-network assisted D2D communication with the second

radio device, using the determined second frequency resource and the determined second communication protocol.

According to another aspect of the present disclosure, there is provided a first radio device configured for being in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of a network node, and for being served by said network node. The first radio device comprises a processor, and a storage unit storing instructions that, when executed by the processor, cause the radio device to receive, from the network node, information about a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between the first radio device and the network node. The instructions also cause the first radio device to receive, from the network node, information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device and the network node. The instructions also cause the first radio device to determine that the radio link to the network node has failed. The instructions also cause the first radio device to initiate non-network assisted D2D communication with the second radio device using the second frequency resource and the second communication protocol.

It is advantageous to, in accordance with any of the above aspects of the present disclosure, determine a second frequency resource and a second communication protocol to use for non-NW assisted D2D communication in case of e.g. an RLF between any of the radio devices and the network. By enabling that the radio devices knows which frequency resource and communication protocol to hand over to in case needed, while still being served by the network, the handover can be initiated, and the D2D communication, may proceed smoothly even in case of an unexpected failure of the radio link to the NW. The on-going communication between the radio devices may then not be interrupted at all in case of an RLF, or the time period of any interruption can at least be reduced. Also, it is advantageous to

enable communication between two radio devices which can more easily be handed over between different kinds of communication and different resources depending on whether the devices are within coverage of a cellular network or not. The communication between the devices is then made more robust and the risk of interruption of the ability of the devices to communicate with each other is reduced. This can be important e.g. in National Security and Personal Safety (NSPS) scenarios, where for instance police radio communication could function more robustly, regardless of NW coverage, by means of the present disclosure.

10 In some embodiments, both the first and the second radio devices are served by the network node and the radio communication between the first and second radio devices is via said network node. This implies that the communication between the devices prior to any RLF or handover to D2D communication is cellular communication via the network.

15 In some other embodiments, the radio communication between the first and second radio devices is network assisted D2D communication by means of the network node. This implies that the communication between the devices prior to any RLF or handover to non-NW assisted D2D communication is D2D communication but that this D2D communication is assisted by the NW where the NW e.g. controls that the D2D communication is in sync with the NW and/or specifies the scheduling resources for the D2D communication.

In some embodiments, the network node is one of a base station, such as a Node B or evolved Node B, a radio access network (RAN) node, or a core network (CN) node. If the network node discussed herein is not a base station, 25 the first radio device may be served by the network node via a base station and/or other network node(s).

In some embodiments, the second frequency resource is within an unlicensed frequency band. Thus it may not interfere with communication within the licenced bands, e.g. with the cellular network of the network node discussed

herein. The unlicensed frequency band may e.g. be an industrial, scientific and medical (ISM) radio band.

In some embodiments, the second communication protocol is one of a Wireless Local Area Network protocol e.g. Wi-Fi Direct, a Bluetooth protocol,
5 or a Zigbee protocol. It is also conceivable that the second communication protocol may be a FlashlinQ protocol. In some other embodiments, the second communication protocol is an LTE D2D communication protocol. It is conceivable that an LTE standard for D2D communication, NW assisted as well as non-NW assisted, will be developed, possibly allowing D2D
10 communication to be performed in a licensed LTE frequency band. In general, the second communication protocol may be any protocol possible for non-NW assisted D2D communication, e.g. an *ad hoc* network protocol.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise
15 herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of
20 "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

25 The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram of a cellular network associated with two radio devices, according to the present disclosure.

Fig 2 is a schematic block diagram of an embodiment of a network node of
30 the present disclosure.

Fig 3 is a schematic block diagram of an embodiment of a radio device of the present disclosure.

Fig 4 is a schematic illustration of an embodiment of a computer program product of the present disclosure.

5 Fig 5 is a schematic flow chart of an embodiment of a method of the present disclosure.

Fig 6 is a schematic flow chart of an embodiment of a method of a network node, of the present disclosure.

10 Fig 7 is a schematic flow chart of an embodiment of a method of a radio device, of the present disclosure.

Fig 8 is a schematic flow chart of an embodiment of a method of a radio device, of the present disclosure.

Fig 9 is a schematic flow chart of an embodiment of a method of a network node, of the present disclosure.

15 DETAILED DESCRIPTION

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth
20 herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

Radio link failure (RLF) as discussed herein relates to a failure in a radio link
25 between the first and/or the second radio device and the network (NW), e.g. the network node discussed herein.

There are herein discussed three different types of communications or communication paths between the first and second radio devices:

1. Cellular radio communication, where the data which is transmitted between the two radio devices passes via the network.
- 5 2. Network assisted D2D communication, where at least one of the radio devices is served by and in sync with the network, and exchanges information with the network for maintaining a D2D communication with the other radio device where at least a part of the data transmitted between the radio devices is transmitted directly and does not pass via
10 the network.
3. Non-NW assisted D2D, where the first and second devices communicates directly with each other without involving the NW.

When it is herein stated that the radio communication between the first radio device and the second radio device is by means of a network node, this
15 includes both the situation 1. of cellular radio communication and the situation 2. of network assisted D2D. In both cases, the communication is by means of/aided by/controlled by the network, e.g. by the network node or higher up in the network via the network node. The present disclosure relates to facilitating a handover (HO) from one of the situation 1. and 2. to the
20 situation of 3. in case of an RLF.

It should be noted that it is conceivable that network assisted D2D may be performed even if only the first radio device is covered by the NW (is served by the network node). In that case, the first radio device can forward information from the network node to the second radio device, just as the
25 first radio device can forward any information received from the network node about the second frequency resource and communication protocol to the second radio device.

It should also be noted that in some embodiments of the present disclosure, one or both of the first and second radio devices determine the second

frequency resource and communication protocol without involving the network or network node, while in other embodiments of the present disclosure, the second frequency resource and communication protocol are determined by the network e.g. the network node to which the first radio
5 device is connected.

A frequency resource as discussed herein is frequency/frequencies or one or more frequency band(s)/spectrum(s) which is used or can be used by the first and/or second radio devices for communicating with each other, either (in case of the first frequency recourse) via the network or D2D. In case of an
10 Orthogonal Frequency Division Multiplexing (OFDM) system, a frequency resource may be a set of sub-carriers. For instance in LTE, the frequency resource may be a set of resource blocks (each resource block consisting of e.g. 12 sub-carriers).

Similarly, a communication protocol is any communication protocol or
15 standard or radio access technology (RAT) which can be used by the first and/or second radio devices for communicating with each other, either (in case of the first communication protocol) via the network or D2D. Examples of communication protocols include Long Term Evolution (LTE) standards and Wideband Code Division Multiple Access/High Speed Packet Access
20 (WCDMA/HSPA) standards.

Non-assisted D2D communication may be in accordance with one of a Wireless Local Area Network protocol e.g. Wi-Fi Direct, a Bluetooth protocol, a FlashlinQ protocol, or a Zigbee protocol. It is also conceivable that an LTE D2D communication protocol is used. It is conceivable that an LTE standard
25 for D2D communication, NW assisted as well as non-NW assisted, will be developed, possibly allowing D2D communication to be performed in a licenced LTE frequency band.

Non-assisted D2D communication may be performed within an unlicensed frequency band. Thus it may not interfere with communication within the
30 licenced bands, e.g. with the cellular network of the network node discussed

herein. The unlicensed frequency band may e.g. be an industrial, scientific and medical (ISM) radio band.

The radio device may be any device, mobile or stationary, enabled to communicate over a radio channel, for instance but not limited to e.g. mobile
5 phone, smart phone, modem, sensors, meters, vehicles, household appliances, medical appliances, media players, cameras, or any type of consumer electronic, for instance but not limited to television, radio, lighting arrangements, tablet computer, laptop, or PC.

The cellular NW which comprises the NW node discussed herein, may be any
10 cellular network, in accordance with any communication standard, able to communicate with a radio device over a radio interface. Examples of communication standards are the 3GPP standards, such as an LTE or Wideband Code Division Multiple Access/High Speed Packet Access (WCDMA/HSPA) standard.

15 Figure 1 schematically illustrates an embodiment of a cellular network 100 comprising a radio access network (RAN) comprising a base station 101, which may be the network node discussed herein, to which a first radio device 102 is connected (as indicated by the double-headed arrow between the node 101 and the radio device 102). The network node/base station 101 is
20 connected to a core network 104 of the network 100. The first radio device 102 is involved in D2D communication with a second radio device 103 (as indicated by the double-headed arrow there between). The second radio device 103 may also be served by the network node 101 (as indicated by the double-headed arrow between the node 101 and the second radio device 103).
25 Alternatively, the second radio device 103 is not served by the network node, or to the network at all. The second radio device may then receive network information via the first radio device 102. In case of an RLF between the network node 101 and the first and/or second radio device, the radio devices may in accordance with the present disclosure proceed communicating with
30 each other by means of a handover to non-NW assisted D2D communication

using the second frequency resource and the second communication protocol as discussed herein.

Figure 2 is schematically illustrates an embodiment of a network node 101, e.g. similar to the base station 101 of figure 1. As mentioned above, the network node 101 may e.g. be part of the core network 104 or the radio access network (RAN) such as be comprised in the radio base station of figure 1. The network node 101 comprises a processor 201 e.g. a central processing unit (CPU). The processor 201 may comprise one or a plurality of processing units in the form of microprocessor(s). However, other suitable devices with computing capabilities could be comprised in the processor 201, e.g. an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or a complex programmable logic device (CPLD). The processor 201 is configured to run one or several computer program(s) or software stored in a storage unit 202 e.g. a memory. The storage unit is regarded as a computer readable means and may e.g. be in the form of a Random Access Memory (RAM), a Flash memory or other solid state memory, or a hard disk. The processor 201 is also configured to store data in the storage unit 202, as needed. The network node 101 also comprises a communication interface 203. The communication interface is configured for communication with the network 100. If the network node is located in a base station, the communication interface 203 is used to enable communication with the core network (CN) 104 and/or the radio devices 102 and 103 served by the base station. If the communication interface 203 is located in the CN, e.g. in a core network node, it may be used to communicate information to the radio device(s) via the base station.

Figure 3 schematically illustrates an embodiment of a first radio device 102 of the present disclosure. It is noted that the description of the first radio device with reference to figure 3 is also relevant to the second radio device 103. The radio device 102 comprises a processor or central processing unit (CPU) 301. The processor 301 may comprise one or a plurality of processing units in the form of microprocessor(s). However, other suitable devices with computing capabilities could be used, e.g. an application specific integrated circuit

(ASIC), a field programmable gate array (FPGA) or a complex programmable logic device (CPLD). The processor 301 is configured to run one or several computer program(s) or software stored in a storage unit or memory 302. The storage unit is regarded as a computer readable means and may e.g. be in the form of a Random Access Memory (RAM), a Flash memory or other solid state memory, or a hard disk. The processor 301 is also configured to store data in the storage unit 202, as needed. The radio device 102 also comprises a transmitter 303, a receiver 304 and an antenna 305, which may be combined to form a transceiver or be present as distinct units within the radio device 102. The transmitter 303 is configured to cooperate with the processor to transform data bits to be transmitted over a radio interface to a suitable radio signal in accordance with the RAT used by the RAN via which the data bits are to be transmitted. The receiver 304 is configured to cooperate with the processor 301 to transform a received radio signal to transmitted data bits. The antenna 305 may comprise a single antenna or a plurality of antennas, e.g. for different frequencies and/or for MIMO (Multiple Input Multiple Output) communication. The antenna 305 is used by the transmitter 303 and the receiver 304 for transmitting and receiving, respectively, radio signals.

Figure 4 illustrates a computer program product 400. The computer program product 400 comprises a computer readable medium 402 comprising a computer program 401 in the form of computer-executable components 401. The computer program/computer-executable components 401 may be configured to cause a device, e.g. a network node 101 or a radio device 102 or 103 as discussed above, to perform an embodiment of a method of the present disclosure. The computer program/computer-executable components may be run on the processing unit 201 or 301 of the device for causing the device to perform the method. The computer program product 400 may e.g. be comprised in a storage unit or memory 202 or 302 comprised in the device and associated with the processing unit 201 or 301. Alternatively, the computer program product 400 may be, or be part of, a separate, e.g. mobile, storage means, such as a computer readable disc, e.g. CD or DVD or hard disc/drive, or a solid state storage medium, e.g. a RAM or Flash memory.

Figure 5 is a schematic flow chart of embodiments of a method of the present disclosure. The method of figure 5 may e.g. be performed by the first radio device 102 or the network node 101. The first radio device 102 is in radio communication with the second radio device 103 by means of the network
5 node 101, either cellular communication or NW assisted D2D communication. For this communication a first frequency resource and a first communication protocol is used. In this situation, the method embodiment of figure 5 can be applied. A second frequency resource is determined 1, for use for non-network assisted D2D communication between the first and second radio
10 devices in case of a radio link failure between said at least one radio device and the network node. A second communication protocol is determined 2, for use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.

15 Figure 6 is a schematic flow chart of embodiments of a method of the present disclosure. The method of figure 6 is performed in the network node 101. Again, the first radio device 102 is in radio communication with the second radio device 103 by means of the network node 101, either cellular communication or NW assisted D2D communication. For this
20 communication a first frequency resource and a first communication protocol is used. In this situation, the method embodiment of figure 6 can be applied. As in the method of figure 5, a second frequency resource is determined 1, for use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said at least one
25 radio device and the network node. A second communication protocol is determined 2, for use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node. Further, at least one message is sent 3 to the first radio device 102, the at least one message
30 comprising information about the determined 1 & 2 second frequency resource and second communication protocol, the information being intended to enable the first radio device to initiate non-network assisted D2D

communication with the second radio device 103 using said determined 1 & 2 second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node.

- 5 Figure 7 is a schematic flow chart of embodiments of a method of the present disclosure. The method of figure 7 is performed in the first radio device 102. Again, the first radio device 102 is in radio communication with the second radio device 103 by means of the network node 101, either cellular communication or NW assisted D2D communication. For this
- 10 communication a first frequency resource and a first communication protocol is used. In this situation, the method embodiment of figure 7 can be applied. As in the method of figures 5 and 6, a second frequency resource is determined 1, for use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said
- 15 at least one radio device and the network node. A second communication protocol is determined 2, for use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node. Further, it is determined 4 that the radio link to the network node 101 has
- 20 failed. Also, non-network assisted D2D communication is initiated 5 with the second radio device 103, using the determined 1 second frequency resource and the determined 2 second communication protocol. In some embodiments, the first radio device sends information about the determined 1 second frequency resource and the determined 2 second communication
- 25 protocol to the second radio device before initiating 5 the handover. In some embodiments, the first radio device sends information about the determined 1 second frequency resource and the determined 2 second communication protocol to the network node before initiating 5 the handover and/or before RLF.
- 30 Figure 8 is a schematic flow chart of embodiments of a method of the present disclosure. The method of figure 8 is performed in the first radio device 102 in an event that both the second frequency resource has been determined 1

and the second communication protocol has been determined 2 in the NW 100, e.g. in accordance with the embodiments of figure 5 or figure 6. Again, the first radio device 102 is in radio communication with the second radio device 103 by means of the network node 101, either cellular communication or NW assisted D2D communication. For this communication a first
5 frequency resource and a first communication protocol is used. In this situation, the method embodiment of figure 8 can be applied. Information about a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio
10 link failure between the first radio device and the network node is received 6 from the network node 101. Information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device 102 and the network node 101 is received 7 from the
15 network node 101. It is determined 4 whether the radio link to the network node 101 has failed. If it has been determined 4 that the radio link to the network node 101 has failed, non-network assisted D2D communication with the second radio device 103 is initiated 5, using the second frequency resource and the second communication protocol. In some embodiments, the
20 first radio device sends information about the determined 1 second frequency resource and the determined 2 second communication protocol to the second radio device before initiating 5 the handover.

Figure 9 is a schematic flow chart of embodiments of a method of the present disclosure. The method of figure 9 is performed in the network node 101.
25 Again, the first radio device 102 is in radio communication with the second radio device 103 by means of the network node 101, either cellular communication or NW assisted D2D communication. For this communication a first frequency resource and a first communication protocol is used. In this situation, the method embodiment of figure 9 can be applied.
30 As in the method of figures 5 , 6 and 7, a second frequency resource is determined 1, for use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said

at least one radio device and the network node. A second communication protocol is determined 2, for use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.

5 In some embodiments, the network node estimates 7 the likelihood of it being possible to initiate non-network assisted D2D radio communication between the first and second radio devices, before the sending 3 of a message to the first radio device. The estimation 7 may e.g. be based on the respective configurations of the first and/or second devices, or on the proximity of the
10 devices to each other e.g. whether both devices are served by the same base station or based on obtained geographical positions of one or both of the first and second devices. If the network node 101 has estimated 7 that the radio devices 102 and 103 are likely to be able to initiate non-network assisted D2D radio communication with each other, the network node (as in the
15 embodiment of figure 6) sends 3 at least one message to the first radio device 102, the at least one message comprising information about the determined 1 & 2 second frequency resource and second communication protocol, the information being intended to enable the first radio device to initiate non-network assisted D2D communication with the second radio device 103 using
20 said determined 1 & 2 second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node. In some embodiments, a message is sent 6 to the second radio device 103, the message comprising information about the determined 1 & 2 second frequency resource and second communication
25 protocol, the information being intended to enable the second radio device to initiate non-network assisted D2D communication with the first radio device 102 using said determined second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node.

30 The non-NW assisted D2D communication being initiated/set up in accordance with an embodiment of the present disclosure, such as in accordance with any of the figures 5-9 may be in accordance with any of the

D2D communication protocols discussed herein, such as a WLAN protocol, a Bluetooth protocol, a Zigbee protocol or an LTE D2D protocol.

In an embodiment, the NW node 101 decides, based on for instance device capability of the first radio device 102 (information that the NW node may
5 receive once the first radio device 102 connects to the NW) to use WIFI direct, Bluetooth or LTE D2D. In another embodiment, the choice of second frequency resource and/or communication protocol is preconfigured by the NW node 101, or by the currently used communication standard/protocol. In yet another embodiment, the NW node 101 decides, based on some external
10 information received, e.g. from radio devices 102 and/or 103 (or measured by the NW node 101), which second frequency resource and/or communication protocol that is best based on e.g. interference situation/load in the second frequency resource. The same approaches/methods above may be used additionally or alternatively for determining the second frequency resource to
15 use.

Below follow some other embodiments of the present disclosure.

According to an aspect of the present disclosure, there is provided a network node configured for being served by a first radio device when the first radio device is in radio communication with a second radio device using a first
20 frequency resource and a first communication protocol by means of the network node. The network node comprises means for determining a second frequency resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The network
25 node also comprises means for determining a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node. The network node also comprises means for sending at least one message to the first radio device,
30 the at least one message comprising information about the determined second frequency resource and second communication protocol, the

information being intended to enable the first radio device to initiate non-network assisted D2D communication with the second radio device using said determined second frequency resource and second communication protocol in the case of a radio link failure.

5 According to an aspect of the present disclosure, there is provided a first radio device configured for being in radio communication with a second radio device using a first frequency resource and a first communication protocol by means of a network node, and for being served by said network node. The first radio device comprises means for determining a second frequency
10 resource to use for non-network assisted D2D communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node. The first radio device also comprises means for determining a second communication protocol to use for the non-network assisted D2D communication between the first and
15 second radio devices in the case of a radio link failure between said at least one radio device and the network node. The first radio device also comprises means for determining that the radio link to the network node has failed. The first radio device also comprises means for initiating non-network assisted D2D communication with the second radio device, using the determined
20 second frequency resource and the determined second communication protocol.

According to an aspect of the present disclosure, there is provided a first radio device configured for being in radio communication with a second radio device using a first frequency resource and a first communication protocol by
25 means of a network node, and for being served by said network node. The first radio device comprises means for receiving, from the network node, information about a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between the first radio device and
30 the network node. The first radio device also comprises means for receiving, from the network node, information about a second communication protocol to use for non-network assisted D2D communication between the first and

second radio devices in the case of a radio link failure between the first radio device and the network node. The first radio device also comprises means for determining that the radio link to the network node has failed. The first radio device also comprises means for initiating non-network assisted D2D
5 communication with the second radio device using the second frequency resource and the second communication protocol.

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible
10 within the scope of the invention, as defined by the appended patent claims.

CLAIMS

1. A method of radio communication between a first radio device (102) and a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), at least one of the
5 radio devices (102, 103) being served by said network node (101), the method comprising:

determining (1) a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices (102, 103) in case of a radio link failure between said at least one
10 radio device and the network node (101); and

determining (2) a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices (102, 103) in the case of a radio link failure between said at least one radio device and the network node (101).

15 2. The method of claim 1, wherein the method is performed in the network node (101), the method further comprising:

sending (3) at least one message to the first radio device (102), the at least one message comprising information about the determined (1, 2) second frequency resource and second communication protocol, the information
20 being intended to enable the first radio device to initiate non-network assisted D2D communication with the second radio device (103) using said determined (1, 2) second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node (101).

25 3. The method of claim 2, further comprising:

sending (6) a message to the second radio device (103), the message comprising information about the determined (1, 2) second frequency resource and second communication protocol, the information being intended to enable the second radio device to initiate non-network assisted

D2D communication with the first radio device (102) using said determined second frequency resource and second communication protocol in the case of a radio link failure between said at least one radio device and the network node (101).

5 4. The method of claim 2 or 3, further comprising:

estimating (7) the likelihood of it being possible to initiate non-network assisted D2D radio communication between the first and second radio devices, before the sending (3) of a message to the first radio device.

10 5. The method of claim 1, wherein the method is performed in the first radio device (102), the method further comprising:

determining (4) that the radio link to the network node (101) has failed; and
initiating (5) non-network assisted D2D communication with the second radio device (103), using the determined (1) second frequency resource and the determined (2) second communication protocol.

15 6. The method of claim 5, wherein the determining (1) a second frequency resource and the determining (2) a second communication protocol comprises:

sending a first message to the second radio device (103) and, in response to the sent message,

20 receiving a second message from the second radio device (103), the received message containing information, on which information the determining (1, 2) of the second frequency resource and the second communication protocol is based.

25 7. The method of claim 6, wherein the first message is sent and the second message is received during setup of the communication, by means of the network node (101), with the second device (103).

8. A method of a first radio device (102) in radio communication with a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), the first radio device also being served by said network node, the method comprising:
- 5 receiving (6), from the network node (101), information about a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between the first radio device (102) and the network node (101);
- receiving (7), from the network node (101), information about a second
- 10 communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device (102) and the network node (101);
- determining (4) that the radio link to the network node (101) has failed; and
- 15 initiating (5) non-network assisted D2D communication with the second radio device (103) using the second frequency resource and the second communication protocol.
9. The method of any preceding claim, wherein both the first and the second radio devices (102, 103) are served by the network node (101) and the
- 20 radio communication between the first and second radio devices is via said network node.
10. The method of any preceding claim, wherein the radio communication between the first and second radio devices (102, 103) is network assisted D2D communication by means of the network node (101).
- 25 11. The method of any preceding claim, wherein the network node (101) is one of a base station, such as a Node B or evolved Node B, a radio access network node, or a core network (104) node.

12. The method of any preceding claim, wherein the second frequency resource is within an unlicensed frequency band.
13. The method of any preceding claim, wherein the second communication protocol is one of a Wireless Local Area Network protocol e.g. Wi-Fi Direct, a Bluetooth protocol, a FlashlinQ protocol or a Zigbee protocol.
14. The method of any claim 1-12, wherein the second communication protocol is a long term evolution, LTE, D2D communication protocol.
15. A computer program product (400) comprising computer-executable components (401) for causing a device (101; 102) to perform the method of any one of claims 1-14 when the computer-executable components are run on a processor (201; 301) comprised in the device.
16. A computer program for radio communication between a first radio device (102) and a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), at least one of which radio devices being served by said network node (101), the computer program comprising computer program code (401) which is able to, when run on a processor (201; 301) of a device (101; 102), cause the device to:
- determine (1) a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node;
- determine (2) a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node.
17. A computer program for a first radio device (102) in radio communication with a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), the first radio device being served by said network node (101), the

computer program comprising computer program code (401) which is able to, when run on a processor (301) of the first radio device (102), cause said first radio device to:

5 receive (6), from the network node, information about a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between the first radio device and the network node;

10 receive (7), from the network node, information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device and the network node;

determine (4) that the radio link to the network node has failed; and

15 initiate (5) non-network assisted D2D communication with the second radio device using the second frequency resource and the second communication protocol.

18. A computer program product (400) comprising a computer program (401) according to claim 16 or 17 and a computer readable means (402) on which the computer program is stored.

20 19. A network node (101) configured for being served by a first radio device (102) when the first radio device is in radio communication with a second radio device (103) using a first frequency resource and a first communication protocol by means of the network node (101), the network node comprising:

a processor (201); and

25 a storage unit (202) storing instructions that, when executed by the processor (201), cause the network node (101) to:

determine (1) a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio

devices in case of a radio link failure between said at least one radio device and the network node;

determine (2) a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in
5 the case of a radio link failure between said at least one radio device and the network node; and

send (3) at least one message to the first radio device, the at least one message comprising information about the determined second frequency resource and second communication protocol, the information being
10 intended to enable the first radio device to initiate non-network assisted D2D communication with the second radio device using said determined second frequency resource and second communication protocol in the case of a radio link failure.

20. A first radio device (102) configured for being in radio communication
15 with a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), and for being served by said network node, the first radio device comprising:

a processor (301); and

a storage unit (302) storing instructions that, when executed by the processor
20 (301), cause the radio device (102) to:

determine (1) a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between said at least one radio device and the network node;

25 determine (2) a second communication protocol to use for the non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between said at least one radio device and the network node;

determine (4) that the radio link to the network node has failed; and

initiate (5) non-network assisted D2D communication with the second radio device, using the determined second frequency resource and the determined second communication protocol.

- 5 21. A first radio device (102) configured for being in radio communication with a second radio device (103) using a first frequency resource and a first communication protocol by means of a network node (101), and for being served by said network node, the first radio device comprising:

a processor (201); and

- 10 a storage unit (202) storing instructions that, when executed by the processor (201), cause the radio device (102) to:

receive (6), from the network node, information about a second frequency resource to use for non-network assisted device-to-device, D2D, communication between the first and second radio devices in case of a radio link failure between the first radio device and the network node;

- 15

receive (7), from the network node, information about a second communication protocol to use for non-network assisted D2D communication between the first and second radio devices in the case of a radio link failure between the first radio device and the network node;

- 20 determine (4) that the radio link to the network node has failed; and

initiate (5) non-network assisted D2D communication with the second radio device using the second frequency resource and the second communication protocol.

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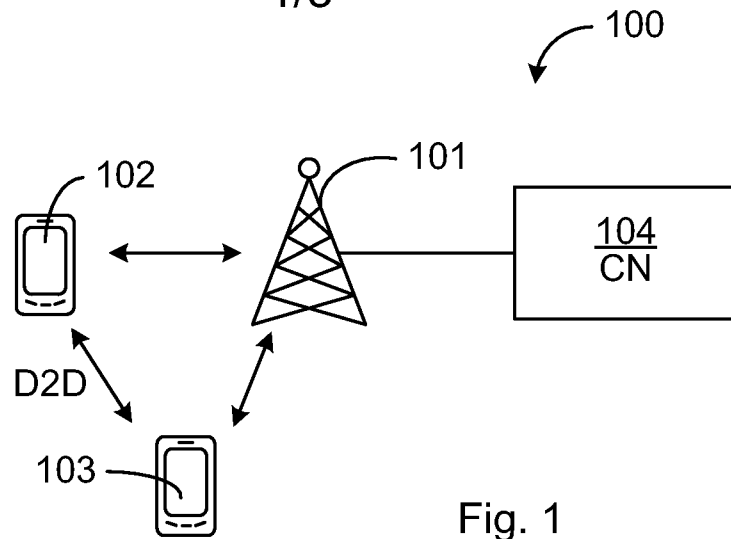


Fig. 1

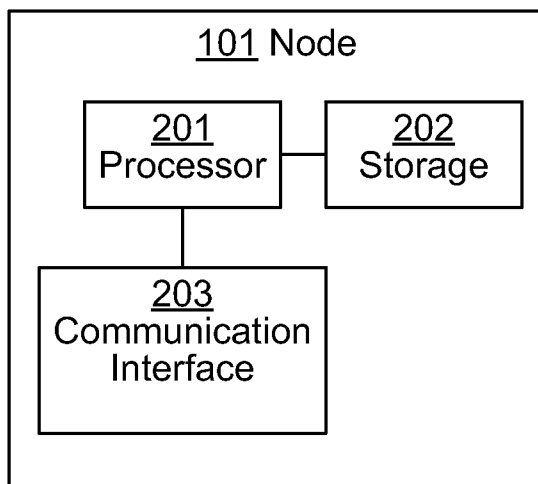


Fig. 2

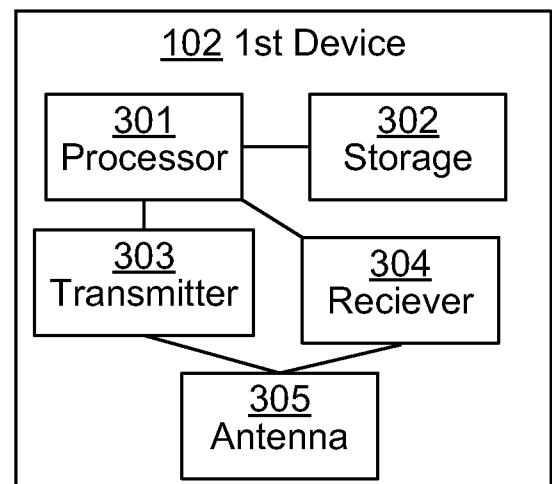


Fig. 3

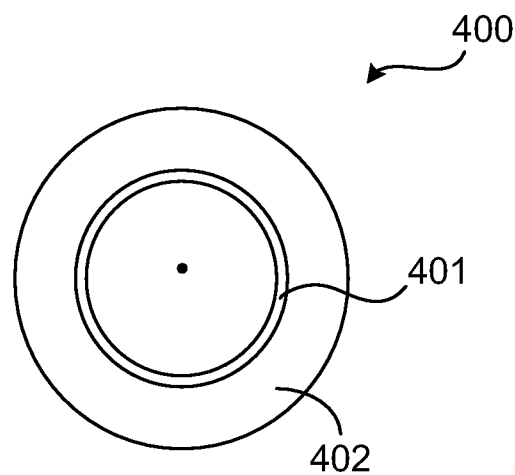


Fig. 4

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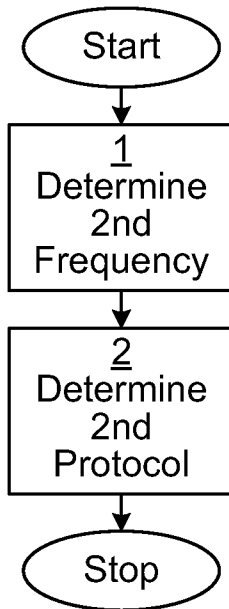


Fig. 5

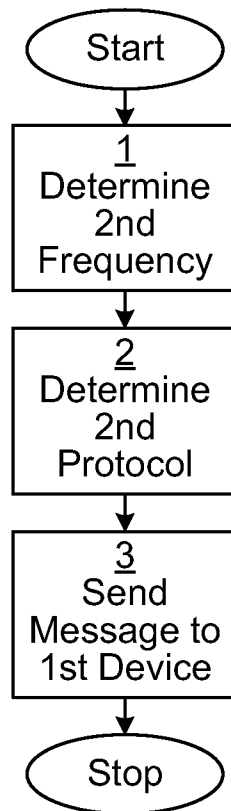


Fig. 6

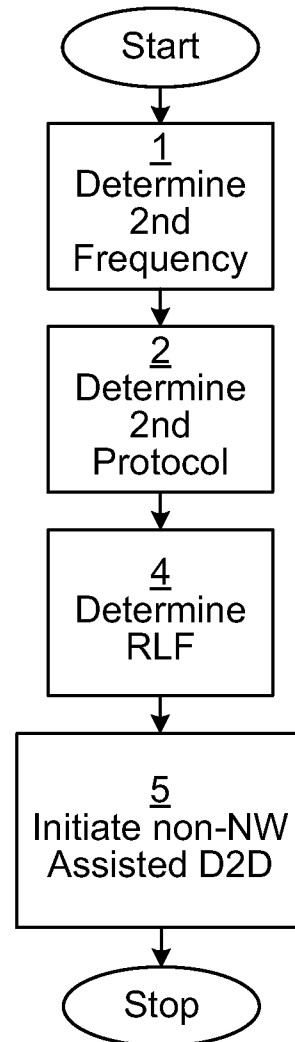


Fig. 7

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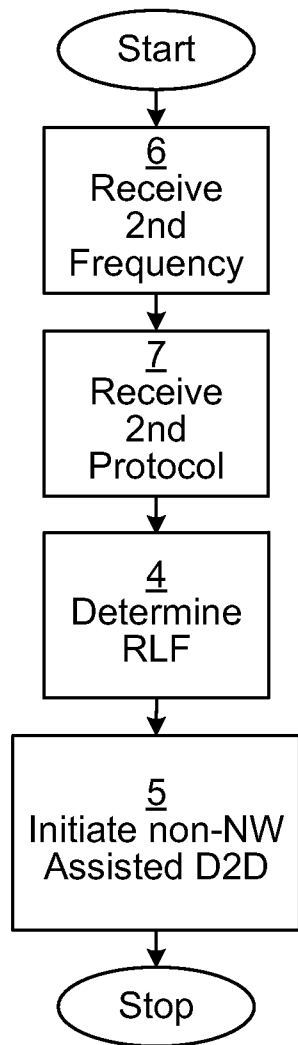


Fig. 8

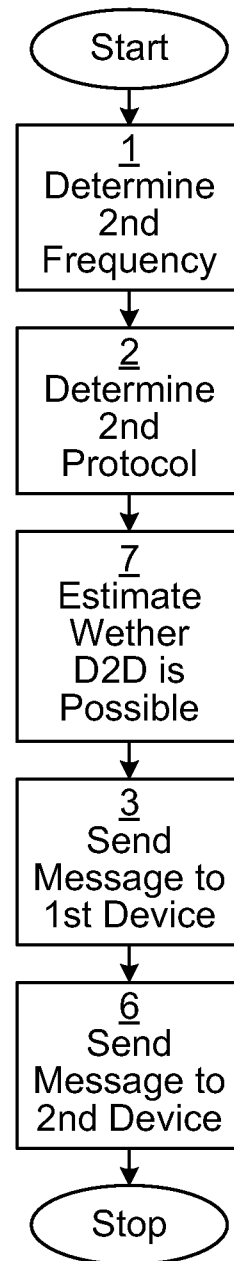


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/082391

A. CLASSIFICATION OF SUBJECT MATTER

H04L 29/06 (2006.01)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)

IPC: H04L 29/-, H04M 3/-, H04W 72/-, H04W 28/-

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)

VEN,CPRSABS, CNKI: D2D, device w to w device, radio, communication, frequency, protocol, resource, cellular,
network, failure**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010279672 A1 (NOKIA CORP) 4 Nov. 2010 (04.11.2010) See paragraphs [0023], [0034], [0055]-[0058] in the description, figure 7	1-21
A	CN 102083138 A (UNIV BEIJING POSTS&TELECOM) 1 Jun. 2011 (01.06.2011) See the whole document	1-21

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

* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier application or patent but published on or after the international filing date	“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
“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)	“&” document member of the same patent family
“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	

Date of the actual completion of the international search 30 May 2013(30.05.2013)	Date of mailing of the international search report 11 Jul. 2013 (11.07.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer LI, Jinxian Telephone No. (86-10)62411739

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/082391

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
US 2010279672 A1	04.11.2010	WO 2010125458 A1	04.11.2010
		US 8213360 B2	03.07.2012
CN 102083138 A	01.06.2011	NONE	