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- (71) **Applicant:** TELEFONAKTIEBOLAGET L M ERICSSON (publ) [SE/SE]; S-164 83 Stockholm (SE).
- (72) **Inventors:** SIOMINA, Iana; Ericsson AB, Färögatan 6, S-164 80 Stockholm (SE). KAZMI, Muhammad; Ericsson AB, Färögatan 6, S-164 80 Stockholm (SE). CALLENDER, Christopher; Ericsson Limited, Unit 4 Midleton Gate, Guildford Surrey GU2 8SG (GB).
- (74) **Agent:** BRUCE, Alexander; Unit 4 Midleton Gate, Guildford Business Park, Guildford Surrey GU2 8SG (GB).

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(54) **Title:** RELATING ACTIVITY PERIODS FOR A UE PERFORMING DEVICE-TO-DEVICE (D2D) AND CELLULAR OPERATIONS

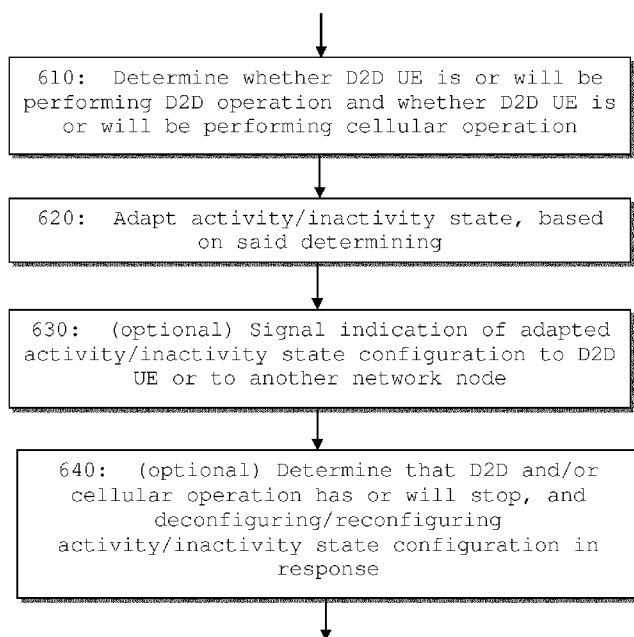


Figure 6

(57) **Abstract:** A method in a network node comprises determining (610) whether at least a first D2D capable UE is or will be performing a D2D operation, and determining whether the at least the first D2D capable UE is or will be performing cellular operation. The method comprises adapting (620) activity and/or inactivity state configurations for the at least the first D2D UE based on the determining.

RELATING ACTIVITY PERIODS FOR A UE PERFORMING DEVICE-TO-DEVICE (D2D) AND CELLULAR OPERATIONS

TECHNICAL FIELD

[0001] The present invention relates to wireless communication networks, such as are used
5 to provide cellular communication services to compatible devices, and particularly relates to
techniques for coordinating activity states of wireless devices having both device-to-device and
cellular communication capabilities.

BACKGROUND

[0002] Fig. 1 illustrates an example of two wireless devices using a “direct mode” of
10 communication, based on the two devices being in relatively close proximity to one another. In
an example case, the two devices are referred to as user equipments, or UEs. Each UE is
configured for operation in a Third Generation Partnership Project (3GPP) communication
network, e.g., a cellular communication network based on the Long Term Evolution (LTE)
specifications. Further, each UE is configured for Device-to-Device (D2D) communications,
15 which allows each device to talk to other devices having compatible D2D communication
capabilities. D2D communications may be network-assisted when one or both devices are
operating within the coverage of the cellular network.

[0003] Fig. 2 illustrates a variation on D2D communications between the two devices. This
variation is referred to as “locally-routed” communications, in that the signaling between the two
20 devices is conveyed through a serving base station—eNodeB in LTE. However, unlike
conventional cellular communication signaling between two devices, the signaling is not routed
through the default path, which includes the “core network” of the supporting cellular
communication network. See Fig. 3 for an example of this conventional default-path routing
case, where signaling between two devices is communicated through serving gateway (SGW) /
25 packet gateway (PGW) nodes in the core network associated with the Radio Access Network
(RAN) supporting the two UEs.

[0004] In device-to-device communication, the source and the target are wireless devices,
e.g., UEs. Some of the potential advantages are offloading of the cellular network, faster
communication, increased awareness of surrounding wireless devices of interest (e.g., running
30 the same application), higher-quality links due to a shorter distance, etc. Some appealing

applications of D2D communications are video streaming, online gaming, media downloading, peer-to-peer (P2P), file sharing, etc.

[0005] Fig. 4 illustrates a reference architecture for D2D operations, where “ProSe” denotes “Proximity Services” and indicates services available via D2D communication between devices in proximity to one another. See the 3GPP Technical Reference, TR 22.803, *Feasibility study for Proximity Services (ProSe)*, for example details regarding this architecture, and the above-described direct communications, locally routed communications, and default-path communications. Further, in the context of Fig. 4, “APP” denotes application, “E-UTRAN” denotes an Evolved Universal Terrestrial Radio Access Network, as used for the radio access part of LTE. “EPC” denotes Evolved Packet Core, as used for the core network part of LTE.

[0006] Numerous challenges attend the effective integration of D2D communications capability into the overall communication system framework. For example, it is recognized herein that “Discontinuous Reception” (DRX) presents a number of challenges and opportunities with respect to D2D-capable wireless devices. Discontinuous Reception (DRX) has been introduced as one of the key solutions for conserving battery power in wireless devices operating within a wireless communication network.

[0007] In the LTE example case, DRX is characterized by the following:

- Per UE mechanism (as opposed to per radio bearer);
- May be used in RRC_IDLE and RRC_CONNECTED; In RRC_CONNECTED, eNodeB/UE may initiate the DRX mode when there are no outstanding/new packets to be transmitted/received; in RRC_IDLE
 - o 2G and 3G terminal use discontinuous reception in idle state to increase battery life time. HSPA and LTE have introduced DRX also for connected state
- Available DRX values are controlled by the network and start from non-DRX up to x seconds.
- HARQ operation related to data transmission is independent of DRX operation and the UE wakes up to read the PDCCH for possible retransmissions and/or ACK/NAK signaling regardless of DRX. In the downlink, a timer is used to limit the time the UE stays awake awaiting for a retransmission;
- When DRX is configured, the UE may be further configured with an "on-duration" timer during which time the UE monitors the PDCCHs for possible allocations;

- When DRX is configured, periodic CQI reports can only be sent by the UE during the “active-time.” RRC can further restrict periodic CQI reports so that they are only sent during the on-duration;
- eNodeB does not transmit packets to UE during the sleep mode.

5 [0008] RRC_CONNECTED mode DRX should not be confused with DRX in idle mode, the latter of which the mobile is set into after a prolonged time of air interface inactivity. Idle mode DRX is also known as paging DRX, and specifies the time the mobile device can go to sleep between two paging intervals that could contain a command for the mobile to wake up again and change back to RRC_CONNECTED state. This DRX is much less fine grained than
10 RRC_CONNECTED mode DRX, and is measured in hundreds of milliseconds or even seconds.

Parameters Related to DRX

[0009] The following definitions apply to DRX in E-UTRAN:

- **on-duration:** duration in downlink subframes that the UE waits for, after waking up from
15 DRX, to receive PDCCHs. If the UE successfully decodes a PDCCH, the UE stays awake and starts the inactivity timer;
- **inactivity-timer:** duration in downlink subframes that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH, failing which it re-enters DRX. The UE shall restart the inactivity timer following a single successful
20 decoding of a PDCCH for a first transmission only (i.e. not for retransmissions).
- **active-time:** total duration that the UE is awake. This includes the “on-duration” of the DRX cycle, the time UE is performing continuous reception while the inactivity timer has not expired and the time UE is performing continuous reception while waiting for a DL retransmission after one HARQ RTT. Based on the above, the minimum active time is of
25 length equal to on-duration, and the maximum is undefined (infinite).

[0010] Of the above parameters, the on-duration and inactivity-timer are of fixed lengths, while the active-time is of varying lengths based on scheduling decisions and UE decoding success. Only on-duration and inactivity-timer duration are signaled to the UE by the eNodeB. Further, there is only one DRX configuration applied in the UE at any time. The UE shall apply
30 an on-duration on wake-up from DRX sleep.

[0011] DRX mode in LTE is illustrated in Fig. 5. DRX is triggered by means of an inactivity time known as DRX. As can be seen from Figure 5, the UE activity time may be extended if PDCCH is received during ON Duration time. However, it may also be shortened by a MAC DRX command, upon reception of which the UE stops onDurationTimer and drx-InactivityTimer.

5 **[0012]** If PDCCH has not been successfully decoded during the on-duration, the UE shall follow the DRX configuration (i.e. the UE can enter DRX sleep if allowed by the DRX configuration):

- This applies also for the sub-frames where the UE has been allocated predefined resources.

10 - If it successfully decodes a PDCCH for a first transmission, the UE shall stay awake and start the inactivity timer (even if a PDCCH is successfully decoded in the sub-frames where the UE has also been allocated predefined resources) until a MAC control message tells the UE to re-enter DRX, or until the inactivity timer expires. In both cases, the DRX cycle that the UE follows after re-entering DRX is given by the following rules:

15 ○ If a short DRX cycle is configured, the UE first follows the short DRX cycle and after a longer period of inactivity the UE follows the long DRX cycle; if short DRX cycle is used, the long cycle will be a multiple of the short cycle;

- Durations for long and short DRX are configured by the RRC. The transition between the short and long DRX cycles is determined by the eNodeB MAC commands (if the command is received and short DRX is configured, the UE will (re)start drxShortCycleTimer and use the Short DRX Cycle; otherwise long DRX will be used) or by the UE based on an activity timer

20

○ Else the UE follows the long DRX cycle directly.

25 **[0013]** Some parameters that may be configured by the network:

- onDurationTimer can be (in PDCCH subframes): 1, 2, 3, 4, 5, 6, 8, 10, 20, 30, 40, 50, 60, 80, 100, and 200

30 - drx-InactivityTimer can be (in PDCCH subframes): 1, 2, 3, 4, 5, 6, 8, 10, 20, 30, 40, 50, 60, 80, 100, 200, 300, 500, 750, 1280, 1920, 2560. A specific value may also be configured if the UE supports IDC (in-device co-existence)

- longDRX-CycleStartOffset (in subframes): depending on the cycle length, but up to 2559

- shortDRX-cycle (in subframes): 2, 5, 8, 10, 16, 20, 32, 40, 64, 80, 128, 160, 256, 320, 52, 640

UE Active Time and UE Transmissions when Using DRX

[0014] When a DRX cycle is configured, the Active Time includes the time while:

- 5 - *onDurationTimer* or *drx-InactivityTimer* or *drx-RetransmissionTimer* or *mac-ContentionResolutionTimer* is running; or
- a Scheduling Request is sent on PUCCH and is pending; or
- an uplink grant for a pending HARQ retransmission can occur and there is data in the corresponding HARQ buffer; or
- 10 - a PDCCH indicating a new transmission addressed to the C-RNTI of the UE has not been received after successful reception of a Random Access Response for the preamble not selected by the UE.

[0015] Generally, new transmissions can only take place during the active-time (so that when the UE is waiting for one retransmission only, it does not have to be “awake” during the RTT).

15 **[0016]** When not in Active Time, type-0-triggered SRS [2] shall not be reported.

[0017] If CQI masking (*cqi-Mask*) is setup by upper layers:

- when *onDurationTimer* is not running, CQI/PMI/RI/PTI on PUCCH shall not be reported,

else:

- 20 - when not in Active Time, CQI/PMI/RI/PTI on PUCCH shall not be reported.

[0018] That is, *cqi-Mask* is effectively limiting CQI/PMI/PTI/RI reports to the on-duration period of the DRX cycle, and the same one value applies for all serving cells (the associated functionality is common i.e. not performed independently for each cell).

[0019] There are a few exceptions:

- 25 - Regardless of whether the UE is monitoring PDCCH or not, the UE receives and transmits HARQ feedback and transmits type-1-triggered SRS when such is expected.
- A UE may optionally choose to not send CQI/PMI/RI/PTI reports on PUCCH and/or type-0-triggered SRS transmissions for up to 4 subframes following a PDCCH indicating a new transmission (UL or DL) received in subframe $n-i$, where n is the last subframe of
- 30 Active Time and i is an integer value from 0 to 3. After Active Time is stopped due to the reception of a PDCCH or a MAC control element a UE may optionally choose to

continue sending CQI/PMI/RI/PTI reports on PUCCH and/or SRS transmissions for up to 4 subframes. The choice not to send CQI/PMI/RI/PTI reports on PUCCH and/or type-0-triggered SRS transmissions is not applicable for subframes where *onDurationTimer* is running and is not applicable for subframes $n-i$ to n .

- 5 [0020] DRX mechanisms used in LTE (or in other cellular communications technologies) can be adapted for use in D2D communications. However, for a given wireless device, the DRX mechanism for D2D operation may be independent of a DRX cycle for cellular operations, since the wireless devices involved in D2D communications may be controlled by different cellular base stations, or by no base station at all.

10

SUMMARY

- [0021] In situations where a D2D device is involved in both cellular and D2D operations, excessive power consumption at the UE as well as suboptimal UE performance may be expected if the times or instances or durations over which the D2D capable UE has cellular activity over the UE-NW link and D2D activity over D2D communication link are not coordinated. This may
15 shorten the UE battery life and/or also degrade throughput and/or increase the amount of UE processing.

- [0022] According to some embodiments of the techniques and apparatus disclosed herein, when the UE is performing D2D operation or intends to perform a D2D operation, activity/inactivity configuration of the UE is adapted based on whether the UE is performing
20 D2D operation over D2D link, cellular operation over UE-NW link or both. The adaptation may be performed by the network node (e.g., when the UE is in a connected state with respect to the network) or by the UE (e.g., autonomously or when the UE is in an idle state with respect to the network node) or by both network node and the UE.

- [0023] Among the various aspects of the teachings herein, one example embodiment relates
25 to methods in a network node, comprising the steps of:

- determining (1) whether at least a first D2D capable UE is or will be performing a D2D operation;
- determining (2) whether the at least the first D2D capable UE is or will be performing cellular operation;
- 30 - adapting (3) activity and/or inactivity state configurations for the at least the first D2D UE based on the determining (1) and (2);

- (Optional) signaling of the adapted configuration to at least the first UE and/or another node;
- (Optional) determining (4) whether the at least the first UE with an adapted configuration (3) has stopped or will stop performing a D2D operation and a cellular operation with the network node; and
- (Optional) deconfiguring or reconfiguring the adapted activity and/or inactivity state configuration(s) (3) for the at least first D2D UE based on determining (4)

[0024] Another example embodiment relates to methods in a first D2D UE, comprising the steps of:

- determining (1) whether the first D2D UE is or will be performing a D2D operation;
- determining (2) whether the first D2D UE is or will be performing cellular operation with a network node;
- adapting activity and/or inactivity state configurations for the UE based on the determining (1) and (2);
- (Optional) signaling of the adapted configuration to at least a second D2D UE and/or another node;
- (Optional) determining (4) whether the first D2D UE with an adapted configuration (3) has stopped or will stop performing a D2D operation and a cellular operation with the network node; and
- (Optional) deconfiguring or reconfiguring the adapted activity and/or inactivity state configuration(s) (3) for the first D2D UE based on determining (4).

[0025] Of course, the present invention is not limited to the above features and advantages. Those of ordinary skill in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Fig. 1 is a block diagram illustrating a “direct mode” data path in Device-to-Device (D2D) communications between two wireless devices.

[0027] Fig. 2 is a block diagram illustrating a “locally routed” data path for D2D communications between two wireless devices.

[0028] Fig. 3 is a block diagram illustrating a “default” data path between two wireless devices, based on network communications rather than D2D communications.

[0029] Fig. 4 is an example network architecture that incorporates D2D functionality.

[0030] Fig. 5 is a diagram illustrating Discontinuous Reception (DRX) in a Long Term Evolution (LTE) context.

5 [0031] Fig. 6 is a logic flow diagram of one embodiment of a method of processing at a network node.

[0032] Fig. 7 is a logic flow diagram of one embodiment of a method of processing at a wireless device.

[0033] Fig. 8 is a block diagram of one embodiment of a network node and a wireless device configured to implement activity state control as taught herein.

10 [0034] Fig. 9 is a block diagram of another embodiment of the network node introduced in Fig. 6.

[0035] Fig. 10 is a block diagram for one embodiment of a wireless communication network, wherein a base station or other network node is configured to operate as the network node shown in Fig. 8.

15 DETAILED DESCRIPTION

Generalizations

[0036] Device-to-device (D2D). In some examples, the terms “D2D” and “proximity service” (ProSe) may be used interchangeably.

20 [0037] D2D UE or D2D device or interchangeably called UE or even D2D-capable UE in some embodiments herein, may comprise any entity capable of at least receiving or transmitting radio signals on a direct radio link, i.e., between this entity and another D2D capable entity. A D2D-capable device may also be comprised in a cellular UE, PDA, a wireless device, laptop, mobile, sensor, relay, D2D relay, or even a small base station employing a UE-like interface, etc. A D2D-capable is able to support at least one D2D operation.

25 [0038] D2D operation may comprise any action or activity related to D2D, e.g., transmitting or receiving a signal/channel type for D2D purpose, transmitting or receiving data by means of D2D communication, transmitting or receiving control or assistance data for D2D purpose, transmitting or receiving a request for control or assistance data for D2D, selecting a D2D operation mode, initiating/starting D2D operation, switching to D2D operation mode from a
30 cellular operation mode, configuring receiver or transmitter with one or more parameters for

D2D. D2D operation may be for a commercial purpose or to support public safety, using the data related to D2D. D2D operation may or may not be specific to a certain D2D service.

[0039] D2D transmission is any transmission by a D2D device. Some examples of D2D transmission are physical signals or physical channels, dedicated or common/shared, e.g., reference signal, synchronization signal, control channel, data channel, broadcast channel, paging channel, etc. A D2D transmission on a direct radio link is intended for receiving by another D2D device. A D2D transmission may be a unicast, groupcast, or broadcast transmission.

[0040] DL radio signal is a radio signal transmitted by a radio network node. UL radio signal transmitted by a UE. A radio signal transmitted by a D2D UE to another D2D UE is also considered herein an UL radio signal, though in some embodiments it may also be referred to as a direct radio signal.

[0041] A coordinating node: a node that schedules, decides, at least in part, or selects time-frequency resources to be used for at least one of: cellular transmissions and D2D transmissions.

The coordinating node may also provide the scheduling information to another node such as another D2D device, a cluster head, a radio network node such as eNodeB, or a network node (e.g. a core network node). The coordinating node may communicate with a radio network node.

[0042] Radio spectrum: Although at least some of the embodiments are described for D2D transmissions in the UL spectrum (FDD) or UL resources (TDD), the embodiments are not limited to the usage of UL radio resources, neither to licensed or unlicensed spectrum, or any specific spectrum at all.

[0043] A cellular network may comprise e.g. an LTE network (FDD or TDD), UTRA network, CDMA network, WiMAX, GSM network, any network employing any one or more radio access technologies (RATs) for cellular operation. The description herein is given for LTE, but it is not limited to the LTE RAT.

[0044] RAT (radio access technology): e.g. LTE, GSM, CDMA, WCDMA, WiFi, WLAN, WiMAX, etc.

[0045] A network node may be a radio network node or another network node. Some examples of a radio network node are a radio base station, a relay node, an access point, a cluster head, RNC, etc. A radio network node is comprised in a wireless communication network and may also support cellular operation. Some examples of a network node which is not a radio

network node: a core network node, MME, a node controlling at least in part mobility of a wireless device, SON node, O&M node, positioning node, a server, an application server, a D2D server (which may be capable of some but not all D2D-related features), a node comprising a ProSe function, a ProSe server, an external node, or a node comprised in another network.

5

Problems with Existing Solutions

[0046] A D2D capable UE may be configured in low activity mode e.g. with certain DRX cycle. The cellular communication performed by D2D UE over D2D to network node link (also known as UE-NW link) is typically independent of the D2D activity performed by the same D2D

10 UE over the D2D communication link. This means the same D2D UE may be active on its UE-NW link and D2D communication link at different times or partially overlapping times.

[0047] The prior art solutions do not coordinate cellular and D2D activity periods of a UE to optimize its power consumption. If the times or instances or durations over which the D2D capable UE has cellular activity over the UE-NW link and D2D activity over D2D

15 communication link are not coordinated, excessive power consumption at the UE as well as suboptimal UE performance may be expected. This may shorten the UE battery life and/or also degrade throughput and/or increase the amount of UE processing.

[0048] According to some embodiments of the techniques and apparatus disclosed herein, when the UE is performing D2D operation or intends to perform a D2D operation,

20 activity/inactivity configuration of the UE is adapted based on whether the UE is performing D2D operation over D2D link, cellular operation over UE-NW link or both. The adaptation may be performed by the network node (e.g., when the UE is in a connected state with respect to the network) or by the UE (e.g., autonomously or when the UE is in an idle state with respect to the network node) or by both network node and the UE.

25 [0049] The embodiments described herein may be combined with each other in any way.

Methods in a network node

[0050] According to one aspect of the inventive techniques disclosed herein, a network node:

- determines (step 1) whether at least a first D2D capable UE is or will be performing a D2D operation;

- determines (step 2) whether the at least the first D2D capable UE is or will be performing cellular operation with the network node;
- adapts (step 3) activity and/or inactivity state configurations for the at least the first D2D UE based on the determining (step 1) and (step 2);
- 5 - (Optional) signals (step 4) the adapted configuration to at least the first UE and/or another node;
- (Optional) determines (step 5) whether the at least the first UE with an adapted configuration (step 3) has stopped or will stop performing a D2D operation and a cellular operation with the network node; and
- 10 - (Optional) deconfigures or reconfigures (step 6) the adapted activity and/or inactivity state configuration(s) (3) for the at least first D2D UE based on determining (step 4).

[0051] The network node may be an eNodeB in an LTE network, for example. Examples of the aspects of an activity/inactivity configuration that can be adapted in various embodiments include: a DRX configuration, a DRX period, an active time, an on-duration, an inactivity timer, 15 a DTX cycle, a DTX ON duration, a DTX OFF duration, etc. The UE may be in a connected or idle state with respect to the cellular network node e.g. serving eNode B.

[0052] Details of the steps summarized above follow.

[0053] **Step 1** - In this step, the network node determines whether there is at least one D2D UE (say first D2D UE) which is or will be performing a D2D operation over D2D link. In some 20 examples, the D2D operation may be with a second D2D UE. In another example, e.g., broadcast, the D2D operation may not target any particular UE. The determination may be based, e.g., on one or more of:

- an implicit or explicit indication received from one or more of: the first D2D UE, the second D2D UE and another network node,
- 25 - a report indicating one or more second D2D UEs discovered by the first UE, the report received e.g. from the first UE or another network node,
- an indication of that the first UE is within a certain interest group for which a D2D operation is on-going or will start,
- radio measurements (e.g., detecting of a D2D-related signal from the UE),
- 30 - a resource request or service request for D2D operation received from the UE,

- scheduling information for D2D operation for the UE received from the UE or from another node (e.g., another UE or another network node),
- by retrieving configuration information from the network node in case the first D2D UE is configured and/or assigned resources for performing the D2D operation with another D2D UE e.g. the second D2D UE,
- a pattern of D2D activity between the first D2D UE and at least the second D2D UE e.g. periodic activity over P (e.g. P=5) subframes after every Q (e.g. Q=4) radio frames. The pattern of such cellular activity may be obtained by one or more of the following means:
 - o a pre-defined pattern,
 - o a configured or pre-configured pattern by the network node,
 - o a pattern acquired from another node, e.g., from any one or more of another network node, the first D2D UE and second D2D UE,
 - o historical data or previously detected activity levels on D2D link for the first D2D UE.

[0054] Step 2 - If in Step 1 it has been determined that there is at least the first D2D UE, which is or will be performing a D2D operation, the network node determines whether the at least first UE is also performing or will be performing a cellular operation over the D2D UE to network communication link (also known as UE-NW link). The determination may be based, e.g., on one or more of:

- scheduling information for a cellular operation for the first D2D UE,
- a pattern of cellular activity between the first D2D UE and network node e.g. periodic activity over R (e.g. R=10) subframes after every S (e.g. S=40) radio frames. The pattern of such cellular activity may be obtained by one or more of the following means:
 - o a pre-defined pattern,
 - o a configured or pre-configured pattern by the network node,
 - o a pattern acquired from another node, e.g., from any one or more of another network node, the first D2D UE and second D2D UE,
 - o historical data or previously detected activity levels on UE-NW link
- an unfinished on-going cellular operation which has been triggered earlier (e.g., handover),
- measurement configuration of the first D2D UE known to the network node,

- a request from the first D2D UE (e.g., RRC Connection Request),
- information derived from Radio Resource Management functions in the network (e.g., from an Admission Control function),
- an indication received from the second D2D UE, which is performing or is configured to perform D2D communication with the first D2D UE. The second D2D UE may be aware that the cellular operation is being performed or is expected to be performed by the first D2D UE over the UE-NW link. For example, the first D2D UE may indicate this to the second D2D UE.

[0055] Step 3 - This step is performed if there have been determined at least one D2D

operation and at least one cellular operation for the same first D2D UE in Step 1 and Step 2, respectively.

[0056] Based on the determining Steps 1 & 2, the network node may adapt the activity/inactivity state configuration for D2D operation (while keeping that for the cellular unchanged), for cellular operation (while keeping that for the D2D operation unchanged), or both operations. The adaptation may comprise, e.g.:

- aligning D2D and cellular (DL, UL, or both) active state periods, so that they overlap, at least in part;
- configuring orthogonal DRX ON periods for cellular and D2D, i.e., periods are non-overlapping or separated in time
 - In one embodiment there may also be a minimum separation in time, e.g., at least N subframes or X time units between D2D active state periods and cellular active state periods; the minimum time separation may be pre-defined, in one example;
 - In another embodiment there may also be a maximum separation in time, e.g., at most M subframes or Y time units between D2D active state periods and cellular active state periods; the maximum time separation may be pre-defined, in one example;
- configuring joint DRX ON period for cellular and D2D (e.g., by extending the DRX ON period to cover time periods with cellular and D2D operation), where the D2D and cellular operations may or may not overlap in time,
- configuring activity/inactivity state configuration to minimize the total active time of the UE,

- configuring a first DRX cycle and a second DRX cycle for operations on D2D link and UE-NW link, wherein the first and the second DRX cycles are related to by a relation.

Examples of such relations are:

- o the first and the second DRX cycles are of the same length,
- o if the first and the second DRX cycles are of the same length then their ON durations are separated by the length of the DRX cycle,
- o lengths of the first and the second DRX cycles are related by a relation. For example, the length of the first DRX cycle may be an integer multiple of the length of the second DRX cycle or vice versa.

10 **[0057]** The adaptation may also account, e.g., for some UE capability, e.g.,

- orthogonal DRX ON periods may be preferred for UEs not capable of simultaneous D2D and cellular operation in general or for certain type of operations,
 - orthogonal DRX ON periods may be preferred for UEs with 1 transmit branch,
 - orthogonal DRX ON periods may be preferred for UEs that may cause interruptions
- 15 when switching between D2D and cellular operation (one the same or different frequency carriers or RATs),
- aligned DRX ON periods may be preferred for UEs that are capable of simultaneous D2D and cellular operation either in general or for the type of operation being performed,

[0058] Step 4 - The adapted configuration may be signaled, e.g., to:

- 20 - the at least the first D2D UE or another second D2D UE, e.g., via unicast, multicast, or broadcast, or
- another radio network node (e.g., via X2 or via a UE) or core network node.

[0059] Step 5 - In this step it is determined whether the at least first D2D UE with an adapted configuration has stopped or will stop performing a D2D operation and a cellular

25 operation. The determination may be based, e.g., on one or more of:

- an implicit or explicit indication received from one or more of: the first D2D UE, the second D2D UE and another network node that D2D operations have ceased or are going to cease,
 - radio measurements indicating that D2D operations have ceased (e.g., detecting of a
- 30 D2D-related signal from the first D2D UE),

- an indication of the completion of a resource request or service request for D2D operation received from at least the first D2D UE,
- scheduling information for D2D operation for the first D2D UE received from any one or more of: the first D2D UE, the second D2D UE and from another node (e.g., another UE or another network node.

[0060] Step 6 - This step consists of deconfiguring or reconfiguring the adapted activity and/or inactivity state configuration(s) (3) for the at least one UE based on determining (4). The deconfiguration or reconfiguration may consist of:

- deconfiguring the DRX state, resulting in continuous reception by at least the first D2D UE
- restoring an earlier DRX configuration which was in use before simultaneous cellular and D2D operation commenced
- configuring any other DRX state that does not account for simultaneous D2D and cellular operation by the at least first D2D UE.

[0061] Figure 6 illustrates a generalized method suitable for implementation in a network node configured for operation in a wireless communication network. As shown at block 610, the method comprises determining whether a D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation. As shown at block 620, the network node then adapts an activity/inactivity state configuration for the D2D-capable UE, based on this determining. In some embodiments, the adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a cellular operation, and may more particularly comprise determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

[0062] In some embodiments, as shown at block 630, the method further comprises signaling an indication of the adapted activity/inactivity state configuration to the D2D-capable UE or to another network node. This need not occur in every instance or embodiment of the illustrated method, however. Likewise, as shown at block 640, the method may further comprise

determining that the D2D-capable UE with an adapted activity/inactivity state configuration has stopped or will stop performing a D2D operation and/or a cellular operation and, in response to said determining, deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

- 5 **[0063]** Any of the variations discussed above are applicable to the method illustrated in Figure 6.

Methods in a D2D UE

[0064] Other aspects of the inventive techniques and apparatus disclosed herein include methods carried out in a D2D-capable UE, the methods comprising the steps of:

- 10 - determining (step 1) whether the first D2D UE is or will be performing a D2D operation;
 - determining (step 2) whether the first D2D UE is or will be performing cellular operation;
 - adapting (step 3) activity and/or inactivity state configurations for the first D2D UE based on the determining (step 1) and (step 2);
 - (Optional) signaling (step 4) of the adapted configuration to the first D2D UE or another
 15 node (e.g. a network node and/or the second D2D UE);
 - (Optional) determining (step 5) whether the first D2D UE with an adapted configuration (3) has stopped or will stop performing a D2D operation and a cellular operation; and
 - (Optional) Deconfiguring (step 6) or reconfiguring the adapted activity and/or inactivity state configuration(s) (step 3) for the first D2D UE based on determining (step 5).

- 20 **[0065]** Examples of the aspects of an activity/inactivity configuration that can be adapted in various embodiments include: a DRX configuration, a DRX period, an active time, an on-duration, an inactivity timer, etc. The UE may be in a connected or idle state with respect to the cellular network.

[0066] Example details of the steps summarized above follow.

- 25 **[0067] Step 1** - In this step, the first D2D UE determines whether there is/will be at least one D2D operation performed by the first D2D UE. In some examples, the D2D operation may be with a second D2D UE. In another example, e.g., broadcast, the D2D operation may not target any particular UE. The determination may be based, e.g., on one or more of:
- 30 - scheduling of a D2D operation in the first D2D UE, e.g., triggered by an application program in the first D2D UE,

- at least one second D2D UE has been discovered by the first UE, with which the first UE can perform at least one D2D operation,
- a request is received from at least the second D2D UE for establishing D2D operation between the first and the second D2D UEs,
- 5 - a request for performing D2D operation is received from the network node, e.g., a serving network node,
- a periodic pattern of D2D operation, e.g., the first D2D UE performs D2D operation with the second D2D UE according to certain activity pattern, e.g., periodically over certain time duration with certain period,
- 10 - upon triggering of one or more events or when one or more conditions are met, e.g.:
 - o if the first D2D is in out of coverage of the network node,
 - o signal quality measured on the signals transmitted by the network node falls below a threshold,
 - o the first D2D UE has lost synchronization with the second D2D UE.
- 15 **[0068] Step 2** - If in Step 1 it has been determined that there is a D2D operation, the first D2D UE determines whether it is also performing or will be performing a cellular operation. The determination may be based, e.g., on one or more of:
 - scheduling information for a cellular operation in the first D2D UE, e.g. triggered by an application program in the first D2D UE or previously received information from the
 - 20 network node,
 - an unfinished on-going cellular operation which has been triggered earlier (e.g., handover),
 - measurement configuration of the first D2D UE,
 - a request for performing cellular operation (i.e., between the first D2D UE and the
 - 25 network node) is received from the second D2D UE. For example, the second D2D UE may be informed by the network node to relay such information to the first D2D UE via D2D link,
 - a periodic pattern of cellular operation e.g. the first D2D UE performs cellular operation with the network node according to a pattern of activity e.g. periodically over certain time
 - 30 duration with certain period,
 - upon triggering of one or more events or when one or more conditions are met, e.g.:

- new signal measurement result(s) are available in the first D2D UE. The measurement may be performed by the first D2D UE on the signals transmitted by the network node(s) and/or on signals transmitted by other D2D UEs.
- signal quality measured on the signals transmitted by the network node falls below a threshold,
- the first D2D UE has lost synchronization with the second D2D UE,
- the first D2D UE is unable to perform and/or maintain D2D operation with the second D2D UE.

[0069] Step 3 - This step is performed if it has been determined that at least one D2D

operation and at least one cellular operation for the first D2D UE are to be performed. Based on the determining Steps 1 & 2, the first D2D UE may adapt the activity/inactivity state configuration for D2D operation (while keeping that for the cellular unchanged), for cellular operation (while keeping that for the D2D operation unchanged), or both operations.

[0070] The adaptation may be autonomous in the first D2D UE or may be controlled by the network node or by another second D2D UE (e.g., the UE implementing Step 3 uses some control data from the network or the controlling UE, respectively, while performing the adaptation).

[0071] The adaptation may comprise, e.g.:

- aligning D2D and cellular (DL, UL, or both) active state periods, so that they overlap, at least in part;
- configuring orthogonal DRX ON periods for cellular and D2D, i.e., separated in time
 - In one embodiment there may also be a minimum separation in time, e.g., at least N subframes or X time units between D2D active state periods and cellular active state periods; the minimum time separation may be pre-defined, in one example;
 - In another embodiment there may also be a maximum separation in time, e.g., at most M subframes or Y time units between D2D active state periods and cellular active state periods; the maximum time separation may be pre-defined, in one example;
- configuring joint DRX ON period for cellular and D2D (e.g., by extending the DRX ON period to cover time periods with cellular and D2D operation), where the D2D and cellular operations may or may not overlap in time;

- configuring activity/inactivity state configuration to minimize the total active time of the UE,
- aligning a first DRX cycle with a second DRX cycle for operations on D2D link and UE-NW link, wherein the first DRX cycle is aligned with the second DRX cycles by a relation, which may be pre-defined, indicated by the network node or autonomously decided by the first D2D UE. Examples of such relations are:
 - o setting the first DRX cycle equal to the length of the second DRX cycle,
 - o shortening the first DRX cycle or changing to non-DRX during the time when the first D2D becomes active on the UE-NW link,
 - o shortening the first DRX cycle or changing to non-DRX during the time when inactivity timer related to the second DRX cycle is on.

[0072] The adaptation may also account, e.g., for some UE capability, e.g.:

- orthogonal DRX ON periods may be preferred for UEs not capable of simultaneous D2D and cellular operation in general or for certain type of operations,
- orthogonal DRX ON periods may be preferred for UEs with one transmit branch,
- orthogonal DRX ON periods may be preferred for UEs that may cause interruptions when switching between D2D and cellular operation (one the same or different frequency carriers or RATs),
- aligned DRX ON periods may be preferred for UEs that are capable of simultaneous D2D and cellular operation either in general or for the type of operation being performed.

[0073] Step 4 - The adapted configuration may be signaled, e.g., to:

- the at least the second D2D UE or another D2D UE, e.g., via unicast, multicast, or broadcast, or
- another radio network node (e.g., via X2 or via a UE) or core network node.

[0074] The UE signaling adapted configurations may signal multiple adapted configurations, from which another UE or radio network node selects a preferred adapted configuration.

[0075] Step 5 - In this step it is determined that either cellular operations have ceased or are going to cease, or that D2D operations have ceased or are going to cease. This may be determined by the first D2D UE, e.g., by:

- an RRC state transition e.g. to RRC idle state
- D2D scheduling information

- cellular scheduling information
- checking the duration over which a pattern of activity is valid, i.e., whether the pattern of activity has expired or is expected to expire at certain future time instance.

[0076] Step 6 - This step consists of deconfiguring or reconfiguring the adapted activity

and/or inactivity state configuration(s) (3) for the first D2D UE based on the determining in step 5. The deconfiguration or reconfiguration may consist of:

- deconfiguring the DRX state, resulting in continuous reception by the first D2D UE
- restoring an earlier DRX configuration which was in use before simultaneous cellular and D2D operation commenced,
- configuring any other DRX state which does not account for simultaneous D2D and cellular operation by the at least the first D2D UE,
- signaling to another radio network node or the first D2D UE that the adapted activity and/or inactivity state configurations for the first D2D UE are no longer required.

[0077] Figure 7 illustrates a generalized method suitable for implementation in a D2D-

capable user equipment (UE) that is also configured for operation in a wireless communication network. As shown at block 710, the method comprises determining whether the D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation. As shown at block 720, the network node then adapts an activity/inactivity state configuration for the D2D-capable UE, based on this

determining. In some embodiments, the adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a cellular operation, and may more particularly comprise determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

[0078] In some embodiments, as shown at block 730, the method further comprises signaling an indication of the adapted activity/inactivity state configuration to a network node or to another D2D UE. This need not occur in every instance or embodiment of the illustrated method, however. Likewise, as shown at block 740, the method may further comprise determining that

the D2D-capable UE with an adapted activity/inactivity state configuration has stopped or will stop performing a D2D operation and/or a cellular operation and, in response to said determining, deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

- 5 [0079] Any of the variations discussed above are applicable to the method illustrated in Figure 7.

Using UE capability for UE active state adaptation

- [0080] According to other aspects of the inventive techniques and apparatus disclosed herein, one or more D2D UE capabilities may be taken into account in the adaptation of the UE activity/inactivity state configuration. This aspect may be combined with the several methods described above, in which a network node or D2D UE adapts the UE's activity/inactivity state configuration.

[0081] Some examples of the UE capabilities that may be taken into account in the UE activity/inactivity state adaptation include:

- 15 - the UE's capability for simultaneous D2D operation (transmission or reception/sensing/measurement) with cellular operation (transmission or reception/measurement);
- the UE's carrier aggregation (CA) capability;
- the number of transmit/receive antennas in the UEs that may be used for D2D and/or cellular operation;
- 20 - a transmit power related capability, e.g.,
 - o a maximum power imbalance;
 - o a maximum allowed or the configured UE transmit power on D2D and/or cellular link;
- 25 - a receive power-related capability, e.g.:
 - o a maximum power imbalance
 - o the sensitivity of the UE receiver on the D2D link and/or the cellular link.
- device co-existence aspects, e.g., whether the D2D UE can also operate on non-cellular systems (e.g. WLAN, GNSS etc) in parallel with the D2D operation;

- whether the D2D UE needs to interrupt the reception and/or transmission of signals when performing transition or switching between operations on the D2D link and UE-NW link on the same carrier frequency or different carrier frequency. The interruption time may be S subframes or T time units, for example.
- 5 **[0082]** Any of the UE capabilities considered in this part of the invention may be, e.g.,:
- a signaled capability. In this case the D2D UE signals its capability to the network node and/or to another D2D UE e.g. radio network node, core network node;
 - a pre-defined capability, e.g., as declared or defined in a standard or in a manufacturer's specifications;
- 10 - a capability associated with a certain release and/or feature.

Methods of Meeting Pre-Defined Rules and Requirements

[0083] Examples of pre-defined requirements are measurement performance of measurements performed on the D2D link and/or on UE-NW link, reception performance for receiving certain signals (e.g., D2D PSS, SSS, control channel, discovery channel, D2D physical signal, etc.). For example, the measurement performance may be expressed as the time to do a measurement, measurement accuracy, number of correct measurement reports (e.g., number of ACK/NACK reports), BLER, etc. In one example, the first measurement time may be longer than the second and the third measurement times. In another example, the second measurement time may be shorter than the third measurement time

[0084] The D2D UE, when configured with certain activity level for D2D operation and UE-NW link operation, shall meet certain pre-defined requirements, also known as first set of pre-defined requirements, e.g., a first measurement time of a measurement. The first set of pre-defined requirements may be the same or different for the UE compared to when it is not configured with the UE-NW link operation and/or D2D operation.

[0085] The D2D UE, when configured to adapt certain activity level for D2D operation and UE-NW link operation according to the rules or procedures defined above for network node-based adaptation of activity, shall meet also certain pre-defined requirements, also known as second set of pre-defined requirements, e.g., a second measurement time of a measurement. The

second set of pre-defined requirements may be the same or different for the UE compared to when it is not configured with the UE-NW link operation and/or D2D operation.

[0086] The D2D UE, when configured to adapt certain activity level for D2D operation and UE-NW link operation according to the rules or procedures defined above for D2D UE-based adaptation of activity, shall meet also certain pre-defined requirements, also known as a third set of pre-defined requirements, e.g., a third measurement time of a measurement. The third set of pre-defined requirements may be the same or different for the UE compared to when it is not configured with the UE-NW link operation and/or D2D operation.

Example Network Node and Wireless Device Configurations

[0087] Fig. 8 illustrates example details for one embodiment of a network node 10 and a wireless device 12-1, which is shown in context with another wireless device 12-2. By way of non-limiting example, the network node 10 comprises a radio base station or other node configured for operation in a wireless communication network, such as a cellular communication network configured according to the Long Term Evolution (LTE) specifications, or other Third Generation Partnership Project (3GPP) specifications.

[0088] Correspondingly, the wireless device 12-1 is configured for operation in a wireless communication network, wherein it communicates with the network node 10 or other network nodes according to defined network communication protocols. The wireless device 12-1 is further configured for Device-to-Device (D2D) communications, wherein it communicates with one or more other wireless devices 12 using defined D2D communication protocols. In a non-limiting example, the wireless device 12-1 comprises a 3GPP User Equipment or UE, and is configured for operation in a 3GPP communication network, such as an LTE-based cellular communication network.

[0089] The illustrated network node 10 is configured to implement the network-side processing described above and in the “Example Embodiments” found below. Accordingly, for example, in one embodiment, the network node 10 is configured to determine whether a D2D-capable user equipment (UE) such as wireless device 12-1 is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation, and to adapt an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

[0090] Correspondingly, the illustrated wireless device 12-1 in some embodiments is configured to implement the device-side processing discussed above and described in the below “Example Embodiments.” In one example, the wireless device 12-1 is configured for operation in communication network and is further configured for D2D communications. In particular, the wireless device 12-1 may be further configured to determine whether wireless device 12-1 is or will be performing a D2D operation and whether the wireless device 12-1 is or will be performing a cellular operation, and to adapt an activity/inactivity state configuration for the wireless device 12-1, based on said determining.

[0091] Fig. 8 illustrates example circuit arrangements and it will be understood that the network node 10 and the wireless device 12-1 generally will include digital processing circuits (and associated memory or other computer-readable medium) for storing configuration data, operational or working data, and for storing computer program instructions. In at least some of the embodiments contemplated herein, the network-side and device-side functionality is realized at least in part through the programmatic configuration of digital processing circuitry, based on the execution by that circuitry of stored computer program instructions.

[0092] The example network node 10 includes a communication interface 20, a processing circuit 22 and an associated computer-readable medium (or media) 24 (e.g., one or more types of memory and/or storage devices, such as a mix of volatile, working memory and non-volatile configuration and program memory or storage). Example memory or storage devices include FLASH, EEPROM or Solid State Disk (SSD), for non-volatile storage, and DRAM or SRAM devices for volatile, working memory.

[0093] In at least one embodiment, the computer-readable medium 24 stores a computer program 26. In such embodiments, the network node 10 is at least partly configured to perform the network-side processing operations taught herein, based on its execution of computer program instructions comprising the stored computer program 26. Here, stored means “retained for future electronic retrieval,” such as being stored for execution. The term thus encompasses retention in either nonvolatile or volatile memory.

[0094] Implementation of the communication interface 20 depends on the nature of the network node 10. In embodiments where the network node 10 is an LTE eNodeB or other radio base station, the communication interface 20 comprises radiofrequency receiver circuitry 20-1 and radiofrequency transmitter circuitry 20-2, for communicating with wireless devices 12

according to defined network communication protocols—i.e., according to defined air interface timing and signaling formats, as used by the type of communication network in which the network node 10 is configured to operate.

[0095] In other embodiments, the network node 10 is a control node that communicates with eNodeBs or other radio base stations supporting the operation of wireless devices 12. For example, the network node 10 is a type of operations and maintenance node (O&M). Consider the example of Fig. 9, which identifies the network node 10 using the reference number 10-1 and illustrates the node 10-1 communicating with the wireless device 12-1 via another network node 10-2.

[0096] This arrangement contrasts with the example of Fig. 8, which suggests a direct communication with the wireless device 12-1. Fig. 9 also indicates that the network node 10-1 may be in communication with another network node 10-3 (but that fact also holds for the example of Fig. 8). In some embodiments, the network node 10-1 receives information from other network nodes 10 regarding the activity state(s) of wireless devices 12 with respect to D2D communications, e.g., for wireless devices 12 not being served or controlled by the network node 10-1.

[0097] In one or more embodiments, the communication interface 20 includes more than one type of communication interface. Consider the case where the network node 10 comprises a radio base station. In such cases, the communication interface 20 includes a radio interface (20-1, 20-2) for communicating with wireless devices 12, and further includes an inter-base-station communication interface for communicating with other radio base stations, along with a core network communication interface for communicating with one or more nodes in an associated core network—e.g., for communicating with packet gateways, mobility and authentication management servers, etc. In an LTE example, the communication interface 20 would include an “X2” interface to other eNodeBs, and one or more “S1” interfaces to the LTE core network, which is referred to as an EPC.

[0098] The processing circuit 22 comprises, for example, digital processing circuitry that is fixed or programmed to perform network-side processing as taught herein. In one embodiment, the processing circuit 22 comprises one or more microprocessors, Digital Signal Processors (DSPs), ASIC, FPGAs, etc., which are configured according to the teachings herein. In one or more particular embodiments, the computer-readable medium 24 stores a computer program 26.

Correspondingly, the processing circuit 22 is at least partly configured according to the teachings herein, based on its execution of the computer program instructions comprising the computer program 26.

[0099] Turning to the example wireless device 12-1, the device may be a cellular radiotelephone (smartphone, feature phone, etc.), a tablet or laptop computer, a network adaptor, card, modem or other such interface device, or essential device or other apparatus that is configured for wireless communication in the network 10, and further configured for D2D communications. In the 3GPP context, the wireless device 12-1 is referred to as a UE and it will be understood as including a communication interface 30, including a radiofrequency receiver circuitry 30-1 and a radiofrequency transmitter circuitry 30-2. This circuitry and the overall device 12-1 are configured for network communications according to the applicable network communication protocols, and are further configured for D2D communications according to the applicable D2D communication protocols.

[00100] The communication interface 30 may comprise a mix of analog and digital circuits. For example, the receiver 30-1 in one or more embodiments comprises a receiver front-end circuit (not explicitly shown in Fig. 6) that generates one or more streams of digital signal samples corresponding to antenna-received signals, and further includes one or more receiver processing circuits—e.g., baseband digital processing circuitry and associated buffer memory—which operate on the digital samples. Example operations include linearization or other channel compensation, possibly with interference suppression, and symbol demodulation/detection and decoding, for recovering transmitted information.

[00101] The wireless device 12-1 further includes a processing circuit 32 that is operatively associated with the communication interface 30. The processing circuit 32 includes or is associated with a computer-readable medium (or media) 34. The computer-readable medium 34 comprises, for example, a mix of volatile, working memory and non-volatile configuration and program memory. Non-limiting examples of the former include Static RAM or SRAM, while non-limiting examples of the latter include FLASH, EEPROM, and SSD storage.

[00102] The processing circuit 32 provides, for example, digital baseband processing for the receive (RX) signals and transmit (TX) data and control signals received and transmitted through the communication interface 30. The processing circuit 32 in this regard comprises digital processing circuitry and may be implemented as one or more microprocessors, DSPs, ASICs,

FPGAs, etc. More generally, the processing circuit 32 may be implemented using fixed circuitry or programmed circuitry, or a mix of both. In an example embodiment, the computer-readable medium 34 stores a computer program 36. The processing circuit 32 in such embodiments is at least partly configured according to the teachings herein, based on its execution of the computer program instructions comprising the computer program 36.

[00103] Regardless of its particular implementation details, the network node 10 in one embodiment is configured to implement one or more of the methods disclosed above, such as the method illustrated in Figure 6. Likewise, the wireless device 12-1 in some embodiments is configured to implement one or more of the methods disclosed above, such as the method illustrated in Figure 7.

[00104] Fig. 10 illustrates an example wireless communication network 40 that includes a Radio Access Network (RAN) 42 and a Core Network (CN) 44. The network 40 communicatively couples wireless devices 12 to one or more external networks 48, such as the Internet or another packet data network. The diagram is simplified for ease of discussion and it will be appreciated that the network 40 may include additional examples of any one or more of the illustrated entities and may include other entities not illustrated. For example, the CN 44 may include Mobility Management Entities or MMEs, Serving Gateways or SGWs, a Packet Gateway or PGW, and one or more other nodes, such as positioning nodes, O&M nodes, etc.

[00105] The RAN 42 includes a number of base stations 50-1, 50-2 and 50-3, which in the LTE context are referred to as eNBs or eNodeBs. Unless suffixes are needed for clarity, the reference number “50” will be used to refer to base stations in the singular and plural sense. Each base station 50 uses certain air interface resources—e.g., spectrum, carriers, channels, etc.—to provide service over a given area, referred to as a “cell.” Accordingly, in Fig. 11, the base station 50-1 provides a cell 52-1, the base station 50-2 provides a cell 52-2, and the base station 50-3 provides a cell 52-3. Unless suffixes are needed for clarity, the reference number “52” will be used herein to refer to cells in the singular and plural sense.

[00106] Of course, a given base station 50 may provide more than one cell 52, e.g., in the case of multi-carrier operation, and the teachings herein are not limited to arrangement of base stations 50 and cells 52 depicted in Fig. 11. For example, the cell sizes may be adaptive or non-uniform. In the latter case, the network 40 may comprise a heterogeneous network where one or more large cells, referred to as “macro” cells are overlaid by one or more smaller cells, referred

to a “micro,” “pico,” or “femto,” cells. These smaller cells are provided by low-power access points and may be used as service hotspots that provide higher data rate services and/or may be used to extend or fill in the service coverage provided by the macro cells. In some heterogeneous deployments, the micro cells use the same radio access technology used by the macro cells, e.g.,

5 LTE-based micro cells overlaying LTE-based macro cells.

[00107] In some embodiments of the wireless communication network 40, one or more of the base stations 50 operate as the aforementioned network node 10 or 10-1.

[00108] Notably, modifications and other embodiments of the disclosed invention(s) will come to mind to one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the
10 invention(s) is/are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of this disclosure. Although specific terms may be employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

15

EXAMPLE EMBODIMENTS

1. A method in a network node configured for operation in a wireless communication network, the method comprising:

determining whether a D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and

adapting an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

2. The method of embodiment 1, wherein said adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a cellular operation.

3. The method of embodiment 1 or 2, wherein determining whether the D2D-capable UE will be performing a D2D operation comprises determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

4. The method of any of embodiments 1-3, further comprising signaling an indication of the adapted activity/inactivity state configuration to the D2D-capable UE.

5. The method of any of embodiments 1-4, further comprising signaling an indication of the adapted activity/inactivity state configuration to another network node.

6. The method of any of embodiments 1-5, further comprising determining whether the D2D-capable UE with an adapted activity/inactivity state configuration has stopped or will stop performing a D2D operation and/or a cellular operation and, in response to said determining,

deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

7. The method of any of embodiments 1-6, wherein said determining whether the D2D-capable

5 UE is or will be performing a D2D operation is based on one or more of:

an implicit or explicit indication received from one or more of the D2D-capable UE, a second D2D UE, and another network node;

a report indicating that one or more additional D2D UEs have been discovered by the first UE;

10 an indication of that the D2D-capable D2D is within a certain interest group for which a D2D operation is ongoing or will start;

radio measurements;

a resource request or service request for D2D operation received from the D2D-capable UE;

15 scheduling information for a D2D operation for the D2D-capable UE;

a pattern of D2D activity between the D2D-capable UE and another D2D UE.

8. The method of any of embodiments 1-7, wherein said determining whether the D2D-capable UE is or will be performing a cellular operation is based on one or more of:

20 scheduling information for a cellular operation for the D2D-capable UE;

a pattern of cellular activity between the D2D-capable UE and a network node;

historical data or previously detected activity levels on a link between the D2D-capable UE and the wireless communication network;

an unfinished on-going cellular operation;

25 a measurement configuration of the D2D-capable UE;

a request from the D2D-capable UE to the wireless communication network;

information derived from Radio Resource Management functions in the wireless communication network;

30 an indication received from another D2D UE that is performing or is configured to perform D2D communication with the D2D-capable UE.

9. A method in a D2D-capable user equipment (UE) that is also configured for operation in a wireless communication network, the method comprising:

determining whether the D2D-capable UE is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and
5 adapting an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

10. The method of embodiment 9, wherein said adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a
10 cellular operation.

11. The method of embodiment 9 or 10, wherein determining whether the D2D-capable UE will be performing a D2D operation comprises determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining
15 whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

12. The method of any of embodiments 9-11, further comprising signaling an indication of the adapted activity/inactivity state configuration to another D2D-capable UE.

13. The method of any of embodiments 9-12, further comprising signaling an indication of the adapted activity/inactivity state configuration to a network node in the wireless communication
25 network.

14. The method of any of embodiments 9-13, further comprising determining whether the D2D-capable UE with an adapted activity/inactivity state configuration has stopped or will stop performing a D2D operation and/or a cellular operation and, in response to said determining,
30 deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

15. The method of any of embodiments 9-14, wherein said determining whether the D2D-capable UE is or will be performing a D2D operation is based on one or more of:

scheduling of a D2D operation in the D2D-capable UE;

5 the discovery, by the D2D-capable UE, of another D2D UE with which the first UE can perform at least one D2D operation;

receipt of a request from another D2D UE for establishing D2D operation;

receipt of a request for performing D2D operation from a network node;

a pattern of D2D operation;

10 determining that the D2D-capable UE is out of coverage of a network node;

determining that a signal quality measured on signals transmitted by a network node falls below a threshold;

determining that the D2D-capable UE has lost synchronization with the second D2D UE.

15 16. The method of any of embodiments 9-15, wherein said determining whether the D2D-capable UE is or will be performing a cellular operation is based on one or more of:

scheduling information for a cellular operation in the D2D-capable UE;

an unfinished on-going cellular operation;

a measurement configuration of the D2D-capable UE;

20 receipt of a request for performing cellular operation from another D2D UE;

a pattern of cellular operation;

a determination that new signal measurement result(s) are available in the D2D-capable UE;

25 a determination that signal quality measured on signals transmitted by a network node falls below a threshold;

a determination that the D2D-capable UE has lost synchronization with another D2D UE;

a determination that the D2D-capable UE is unable to perform and/or maintain D2D operation with another D2D UE.

30 17. The method of any of embodiments 1-16, wherein adapting the activity/inactivity state configuration comprises adapting any one or more of:

a discontinuous receive (DRX) configuration;
a DRX period;
an active time;
an on-duration;
5 an inactivity time;
a discontinuous transmit (DTX) configuration;
a DTX cycle time;
a DTX ON duration; and
a DTX OFF duration.

10 18. The method of any of embodiments 1-17, wherein adapting the activity/inactivity state configuration comprises one or more of:

aligning active state periods for D2D and cellular so that they overlap, fully or at least in
part;
15 configuring orthogonal DRX ON periods for cellular and D2D
configuring joint DRX ON period for cellular and D2D operations, where the D2D and
cellular operations may or may not overlap in time;
configuring activity/inactivity state configuration to minimize the total active time of the
UE; and
20 configuring a first DRX cycle and a second DRX cycle for operations on a D2D link and
UE-to-network link, respectively, where the first and the second DRX cycles are
related to by a relation.

19. The method of any of embodiments 1-18, wherein said adapting accounts for a capability or
25 preference of the D2D-capable UE, the capability or preference comprising one or more of:

that orthogonal DRX ON periods are preferred for UEs not capable of simultaneous D2D
and cellular operation in general or for certain type of operations;
that orthogonal DRX ON periods are preferred for UEs with one transmit branch;
that orthogonal DRX ON periods are preferred for UEs that may cause interruptions
30 when switching between D2D and cellular operation;

that aligned DRX ON periods may be preferred for UEs that are capable of simultaneous D2D and cellular operation either in general or for the type of operation being performed;

the D2D-capable UE's capability for simultaneous D2D operation and cellular operation

5 the D2D-capable UE's carrier aggregation (CA) capability;

the number of transmit/receive antennas in the D2D-capable UE that may be used for D2D and/or cellular operation;

a transmit power related capability of the D2D-capable UE;

a receive power-related capability of the D2D-capable UE;

10 whether the D2D-capable UE can also operate on one or more non-cellular systems in parallel with D2D operation;

whether the D2D-capable UE needs to interrupt reception and/or transmission of signals when performing transition or switching between operations on a D2D link and on a UE-to-network.

15

20. A network node configured for operation in a wireless communication network, said network node comprising:

a communication interface configured to communicate with wireless devices operating in the wireless communication network and/or to communicate with one or more other network nodes; and

20

a processing circuit operatively associated with the communication interface and configured to:

determine whether a D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and

25

adapt an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

21. The network node of embodiment 20, wherein the network node is configured to perform processing operations implementing any of the methods of embodiments 2-8.

30

22. A wireless device comprising:

a communication interface that is configured for communicating with a wireless communication network, according to defined network communication protocols, and configured for communicating with one or more other wireless devices via Device-to-Device (D2D) communications, according to defined D2D communication protocols; and

a processing circuit that is operatively associated with the communication interface and configured to:

determine whether the D2D-capable UE is or will be performing a D2D operation

and whether the D2D-capable UE is or will be performing a cellular operation; and

adapt an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

23. The wireless device of embodiment 22, wherein the processing circuit is configured to carry out processing operations implementing the method of any of embodiments 10-16.

Abbreviations

	D2D	Device-to-Device
	D2DSS	D2D synchronization signal
	D2DPSCH	D2D physical synchronization channel
5	ProSe	Proximity Service

Claims

1. A method in a network node configured for operation in a wireless communication network, the method comprising:

- 5 determining whether a D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and
 adapting an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

10

2. The method of claim 1, wherein said adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a cellular operation.

- 15 3. The method of claim 1 or 2, wherein determining whether the D2D-capable UE will be performing a D2D operation comprises determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second
20 predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

4. The method of any of claims 1-3, further comprising signaling an indication of the adapted activity/inactivity state configuration to the D2D-capable UE.

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5. The method of any of claims 1-4, further comprising signaling an indication of the adapted activity/inactivity state configuration to another network node.

6. The method of any of claims 1-5, further comprising determining whether the D2D-capable
30 UE with an adapted activity/inactivity state configuration has stopped or will stop performing a

D2D operation and/or a cellular operation and, in response to said determining, deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

7. The method of any of claims 1-6, wherein said determining whether the D2D-capable UE is or will be performing a D2D operation is based on one or more of:

an implicit or explicit indication received from one or more of the D2D-capable UE, a second D2D UE, and another network node;

a report indicating that one or more additional D2D UEs have been discovered by the first UE;

an indication of that the D2D-capable D2D is within a certain interest group for which a D2D operation is ongoing or will start;

radio measurements;

a resource request or service request for D2D operation received from the D2D-capable UE;

scheduling information for a D2D operation for the D2D-capable UE;

a pattern of D2D activity between the D2D-capable UE and another D2D UE.

8. The method of any of claims 1-7, wherein said determining whether the D2D-capable UE is or will be performing a cellular operation is based on one or more of:

scheduling information for a cellular operation for the D2D-capable UE;

a pattern of cellular activity between the D2D-capable UE and a network node;

historical data or previously detected activity levels on a link between the D2D-capable UE and the wireless communication network;

an unfinished on-going cellular operation;

a measurement configuration of the D2D-capable UE;

a request from the D2D-capable UE to the wireless communication network;

information derived from Radio Resource Management functions in the wireless communication network;

an indication received from another D2D UE that is performing or is configured to perform D2D communication with the D2D-capable UE.

9. A method in a D2D-capable user equipment (UE) that is also configured for operation in a wireless communication network, the method comprising:

determining whether the D2D-capable UE is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and
5 adapting an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

10. The method of claim 9, wherein said adapting is carried out based on determining that the D2D-capable UE is or will be performing a D2D operation and is or will be performing a cellular
10 operation.

11. The method of claim 9 or 10, wherein determining whether the D2D-capable UE will be performing a D2D operation comprises determining whether the D2D-capable UE will be performing a D2D operation within a first predetermined time interval and wherein determining
15 whether the D2D-capable UE will be performing a cellular operation comprises determining whether the D2D-capable UE will be performing a cellular operation within a second predetermined time interval, wherein the first and second predetermined time intervals may or may not be the same.

12. The method of any of claims 9-11, further comprising signaling an indication of the adapted activity/inactivity state configuration to another D2D-capable UE.

13. The method of any of claims 9-12, further comprising signaling an indication of the adapted activity/inactivity state configuration to a network node in the wireless communication network.

14. The method of any of claims 9-13, further comprising determining whether the D2D-capable UE with an adapted activity/inactivity state configuration has stopped or will stop performing a D2D operation and/or a cellular operation and, in response to said determining, deconfiguring or reconfiguring the adapted activity/inactivity state configuration for the D2D-capable UE.

15. The method of any of claims 9-14, wherein said determining whether the D2D-capable UE is or will be performing a D2D operation is based on one or more of:

- scheduling of a D2D operation in the D2D-capable UE;
- the discovery, by the D2D-capable UE, of another D2D UE with which the first UE can
- 5 perform at least one D2D operation;
- receipt of a request from another D2D UE for establishing D2D operation;
- receipt of a request for performing D2D operation from a network node;
- a pattern of D2D operation;
- determining that the D2D-capable UE is out of coverage of a network node;
- 10 determining that a signal quality measured on signals transmitted by a network node falls below a threshold;
- determining that the D2D-capable UE has lost synchronization with the second D2D UE.

16. The method of any of claims 9-15, wherein said determining whether the D2D-capable UE is or will be performing a cellular operation is based on one or more of:

- scheduling information for a cellular operation in the D2D-capable UE;
- an unfinished on-going cellular operation;
- a measurement configuration of the D2D-capable UE;
- receipt of a request for performing cellular operation from another D2D UE;
- 20 a pattern of cellular operation;
- a determination that new signal measurement result(s) are available in the D2D-capable UE;
- a determination that signal quality measured on signals transmitted by a network node falls below a threshold;
- 25 a determination that the D2D-capable UE has lost synchronization with another D2D UE;
- a determination that the D2D-capable UE is unable to perform and/or maintain D2D operation with another D2D UE.

17. The method of any of claims 1-16, wherein adapting the activity/inactivity state configuration comprises adapting any one or more of:

- a discontinuous receive (DRX) configuration;

a DRX period;
an active time;
an on-duration;
an inactivity time;
5 a discontinuous transmit (DTX) configuration;
a DTX cycle time;
a DTX ON duration; and
a DTX OFF duration.

- 10 18. The method of any of claims 1-17, wherein adapting the activity/inactivity state configuration comprises one or more of:
- aligning active state periods for D2D and cellular so that they overlap, fully or at least in part;
 - configuring orthogonal DRX ON periods for cellular and D2D
 - 15 configuring joint DRX ON period for cellular and D2D operations, where the D2D and cellular operations may or may not overlap in time;
 - configuring activity/inactivity state configuration to minimize the total active time of the UE; and
 - configuring a first DRX cycle and a second DRX cycle for operations on a D2D link and
 - 20 UE-to-network link, respectively, where the first and the second DRX cycles are related to by a relation.

19. The method of any of claims 1-18, wherein said adapting accounts for a capability or preference of the D2D-capable UE, the capability or preference comprising one or more of:
- 25 that orthogonal DRX ON periods are preferred for UEs not capable of simultaneous D2D and cellular operation in general or for certain type of operations;
 - that orthogonal DRX ON periods are preferred for UEs with one transmit branch;
 - that orthogonal DRX ON periods are preferred for UEs that may cause interruptions when switching between D2D and cellular operation;

that aligned DRX ON periods may be preferred for UEs that are capable of simultaneous D2D and cellular operation either in general or for the type of operation being performed;

the D2D-capable UE's capability for simultaneous D2D operation and cellular operation

5 the D2D-capable UE's carrier aggregation (CA) capability;

the number of transmit/receive antennas in the D2D-capable UE that may be used for D2D and/or cellular operation;

a transmit power related capability of the D2D-capable UE;

a receive power-related capability of the D2D-capable UE;

10 whether the D2D-capable UE can also operate on one or more non-cellular systems in parallel with D2D operation;

whether the D2D-capable UE needs to interrupt reception and/or transmission of signals when performing transition or switching between operations on a D2D link and on a UE-to-network.

15

20. A network node configured for operation in a wireless communication network, said network node comprising:

a communication interface configured to communicate with wireless devices operating in the wireless communication network and/or to communicate with one or more other network nodes; and

20

a processing circuit operatively associated with the communication interface and configured to:

determine whether a D2D-capable user equipment (UE) is or will be performing a D2D operation and whether the D2D-capable UE is or will be performing a cellular operation; and

25

adapt an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

21. The network node of claim 20, wherein the network node is configured to perform processing operations implementing any of the methods of claims 2-8.

30

22. A wireless device comprising:

a communication interface that is configured for communicating with a wireless communication network, according to defined network communication protocols, and configured for communicating with one or more other wireless devices via Device-to-Device (D2D) communications, according to defined D2D communication protocols; and

a processing circuit that is operatively associated with the communication interface and configured to:

determine whether the D2D-capable UE is or will be performing a D2D operation

and whether the D2D-capable UE is or will be performing a cellular operation; and

adapt an activity/inactivity state configuration for the D2D-capable UE, based on said determining.

23. The wireless device of claim 22, wherein the processing circuit is configured to carry out processing operations implementing the method of any of claims 10-16.

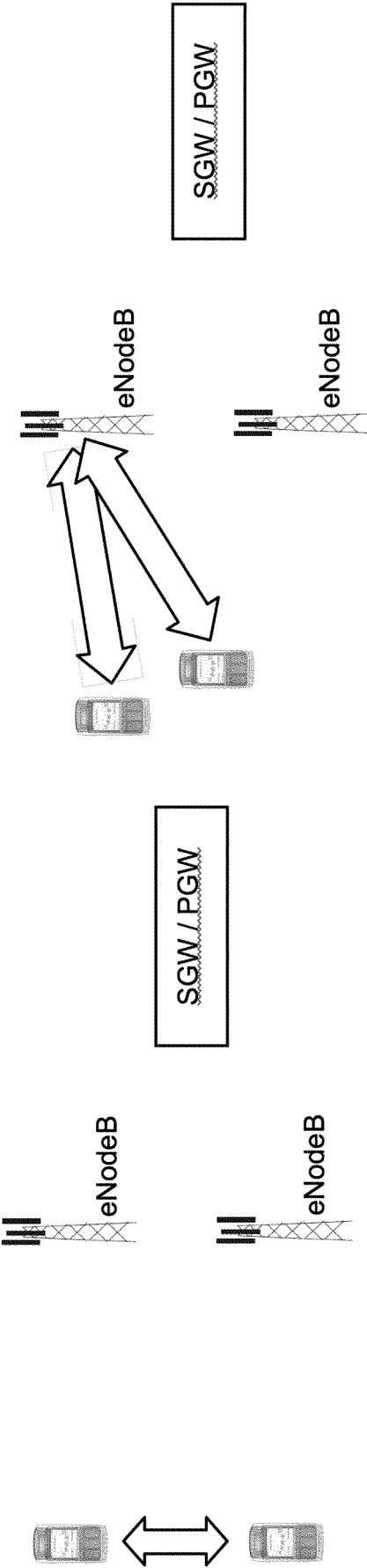


FIG. 1

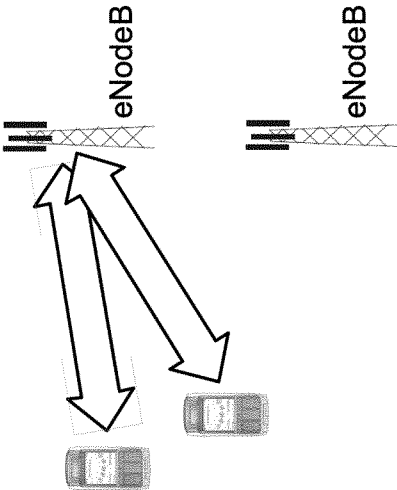


FIG. 2

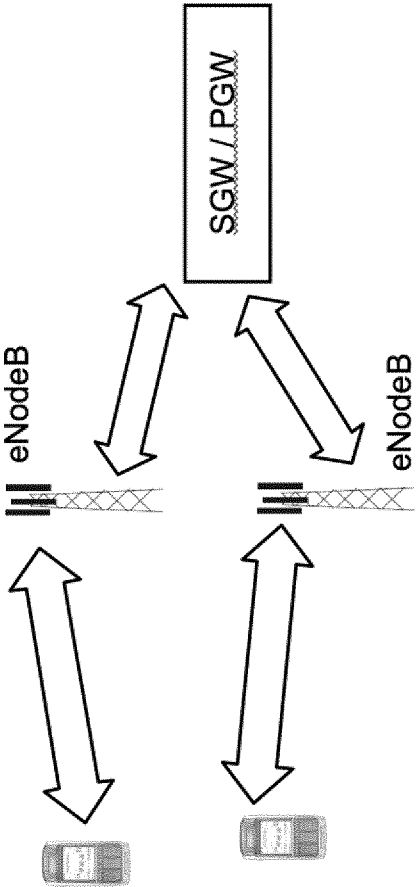


FIG. 3

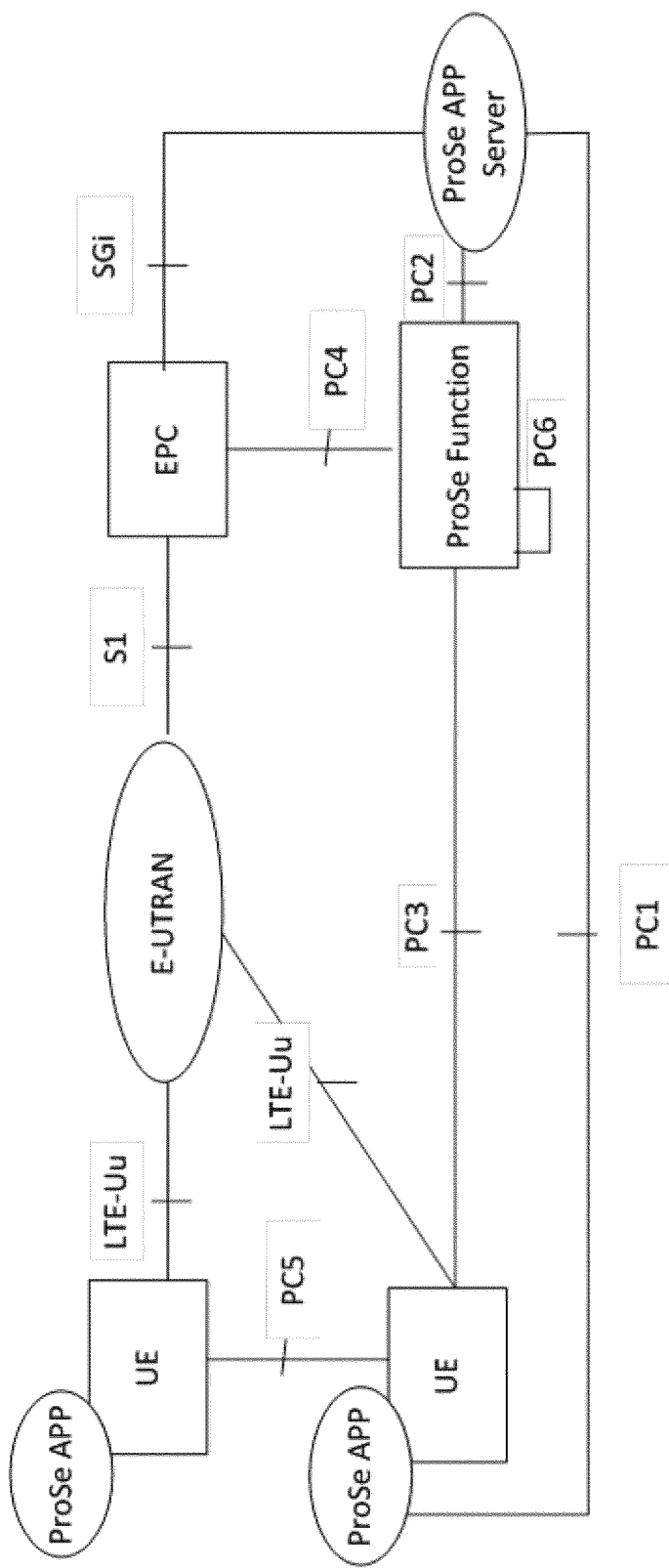


FIG. 4

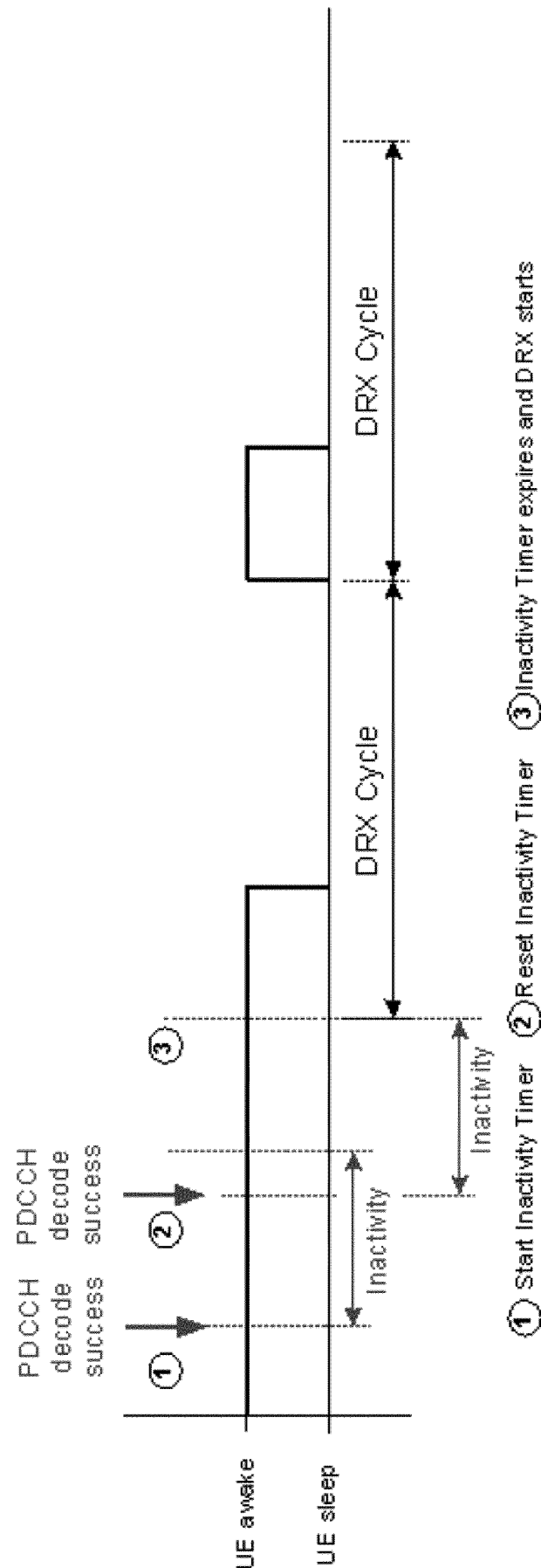
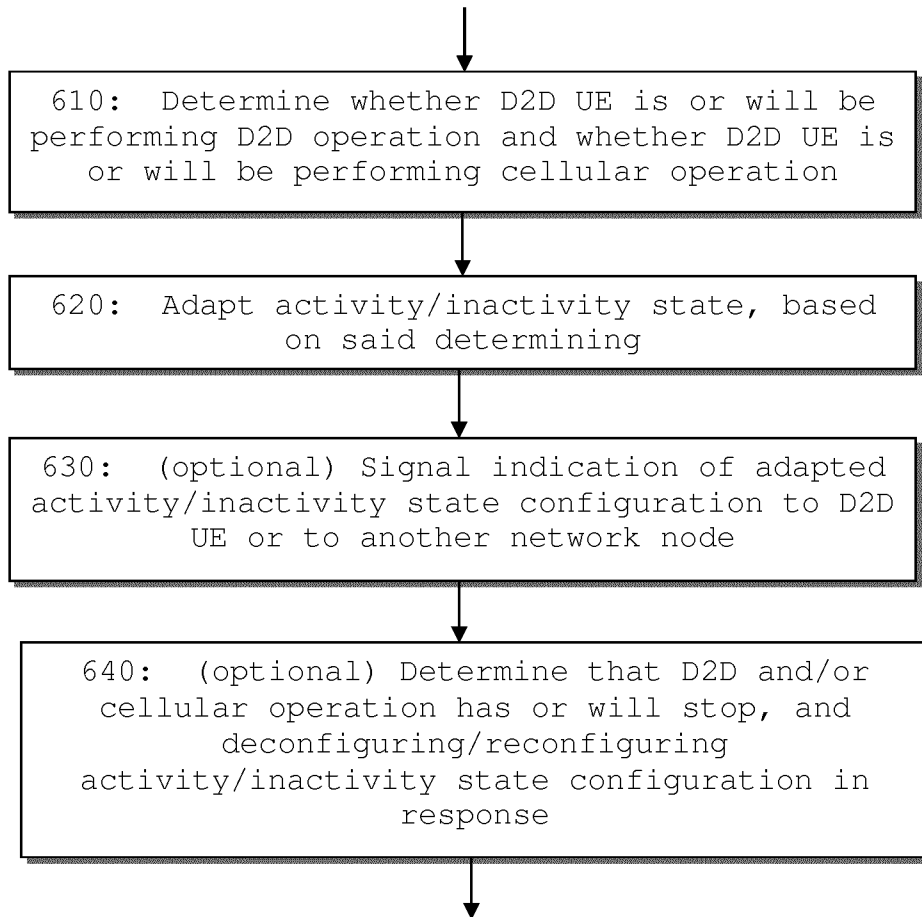
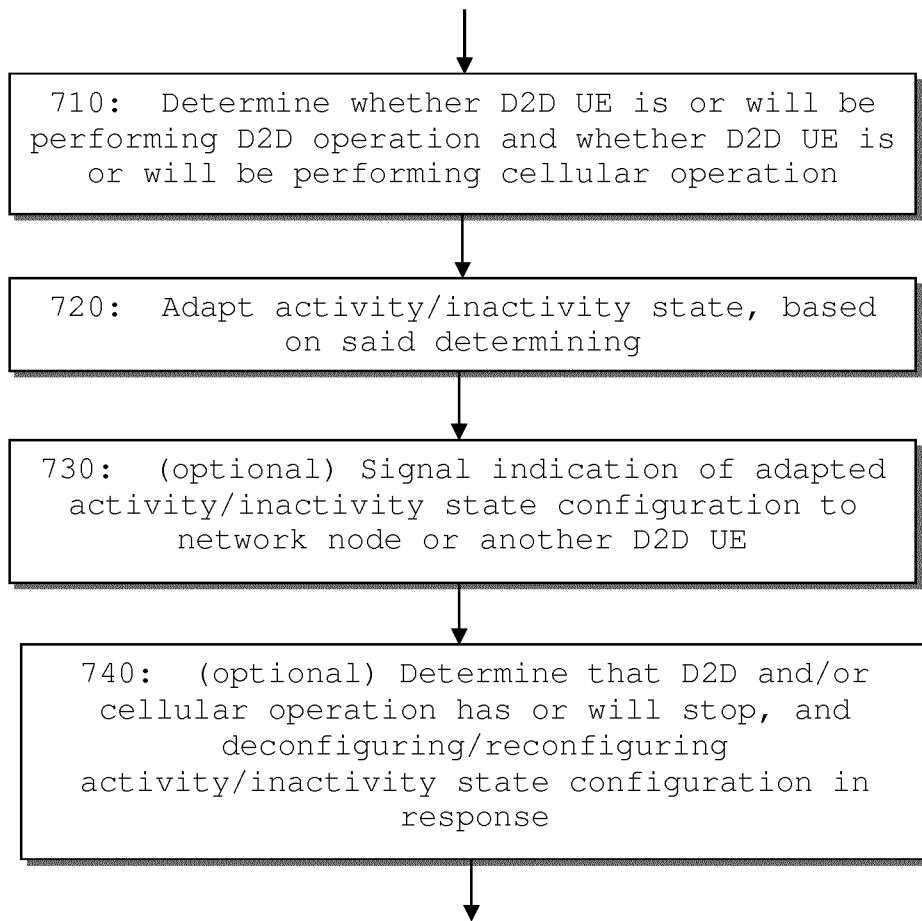


FIG. 5

**Figure 6**

**Figure 7**

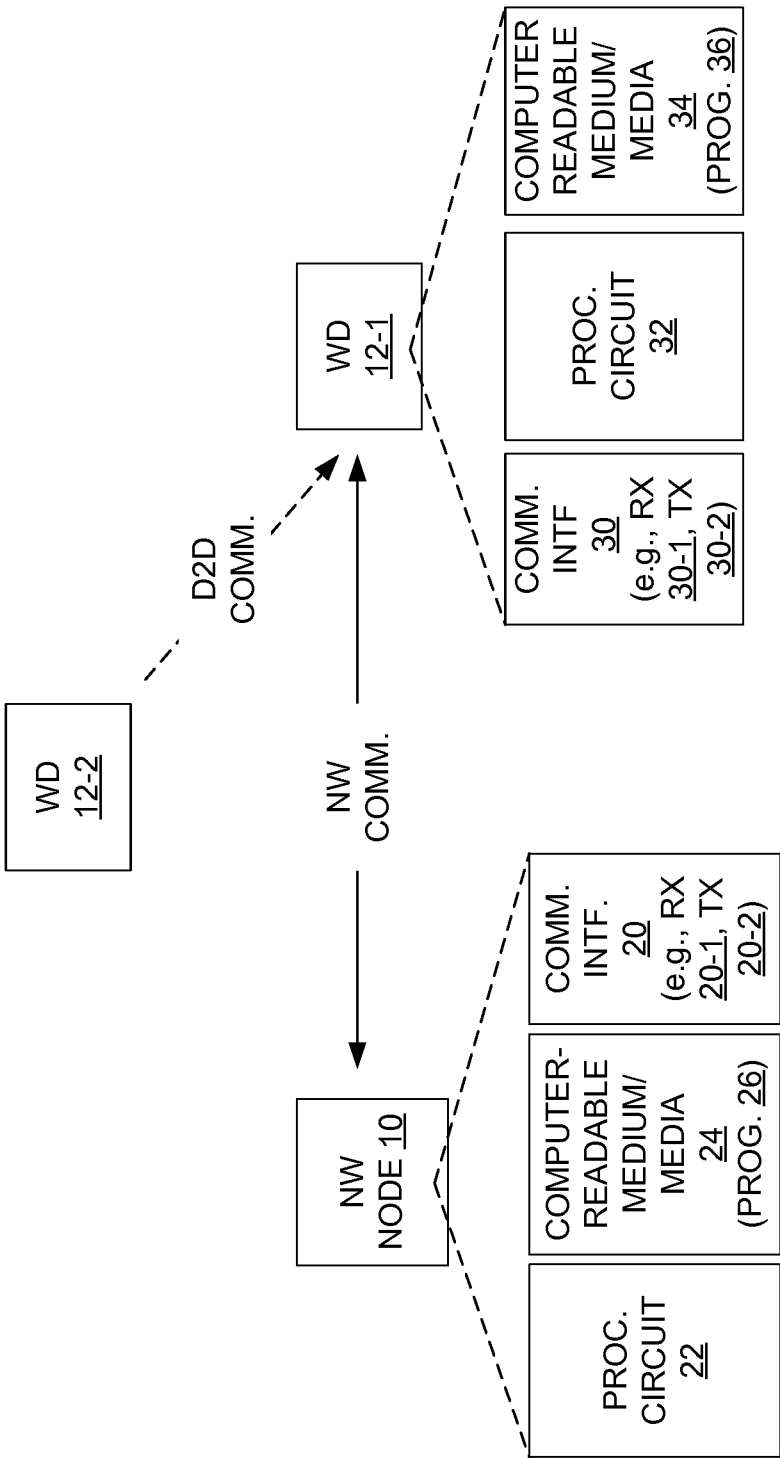


FIG. 8

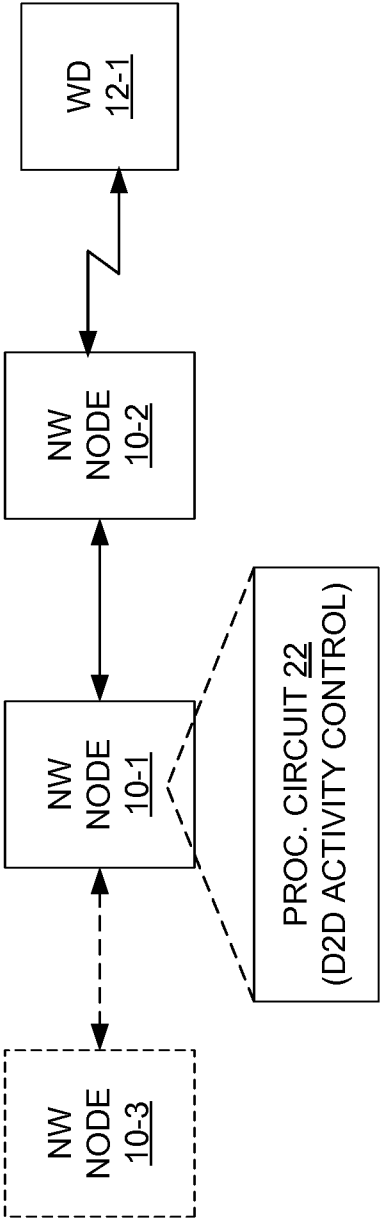


FIG. 9

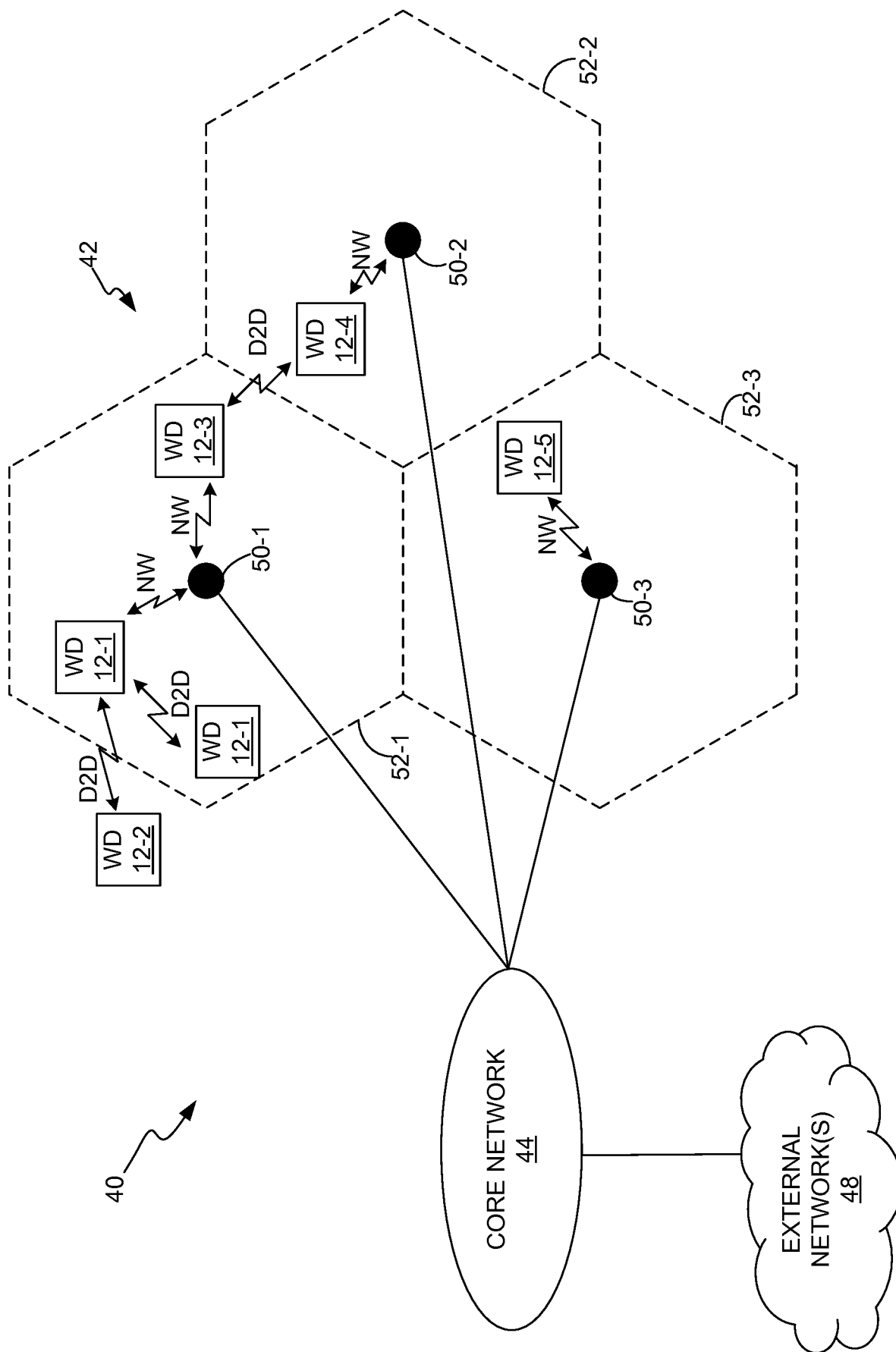


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/074418

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/04 H04W72/12
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/082114 A1 (NOKIA CORP [FI]; DOPPLER KLAUS FRANZ [FI]; KOSKELA TIMO KALEVI [FI]; H) 22 July 2010 (2010-07-22) page 8, line 17 - line 23 page 12, line 8 - page 18, line 21 -----	1-23
X	WO 2010/025774 A1 (NOKIA SIEMENS NETWORKS OY [FI]; HORNEMAN KARI [FI]; VAN PHAN VINH [FI]) 11 March 2010 (2010-03-11) page 2, line 1 - line 23 page 3, line 21 - page 5, line 16 page 7, line 13 - line 29 page 9, line 11 - page 16, line 25 -----	1-23
X	US 2013/170398 A1 (KWON YOUNG HOON [US]) 4 July 2013 (2013-07-04) paragraph [0019] - paragraph [0034] paragraph [0041] - paragraph [0043] ----- -/-	1-23



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

31 July 2015

Date of mailing of the international search report

07/08/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

López Pérez, Mariano

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/074418

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/074418

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