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(71) **Applicant: INTEL CORPORATION** [US/US]; 2200 Mission College Blvd., Santa Clara, California 95054 (US).

(72) **Inventors: KHORYAEV, Alexey;** Rybinskaya Street 75-34, Nizhny Novgorod, 603105 (RU). **PANTELEEV, Sergey;** Perekhodnikova str., 5-84, Nizhny Novgorod, 603065 (RU). **SOSNIN, Sergey;** Michurin street 8-22, Zavolzhie, 606520 (RU). **SHILOV, Mikhail;** N.Rybakova str, 16-59, Nizhny Novgorod, 603054 (RU).

(74) **Agent: HAYMOND, Alex W.;** Thorpe North & Western LLP, P.O. Box 1219, Sandy, Utah 84091 (US).

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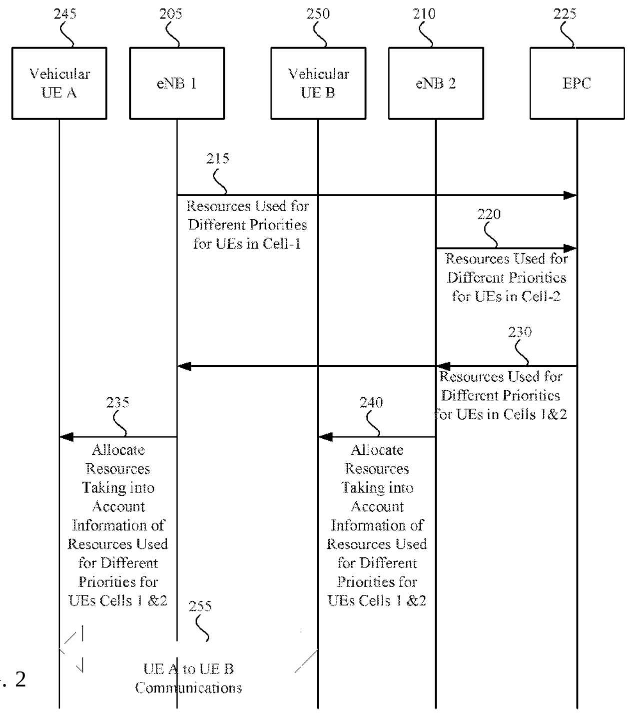

FIG. 2

(57) **Abstract:** Techniques for resource allocation to support prioritized communications for vehicle-to-vehicle proximity services. The resource allocation can be based on inter-cell coordination or vehicular based reporting.

WO 2017/196397 A1

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PRIORITIZED COMMUNICATIONS FOR VEHICULAR PROXIMITY SERVICES

BACKGROUND

[0001] Device-to-device communications in cellular telephone services can provide direct communication between nearby mobile devices. The direct communications between proximate devices can improve spectrum utilization, improve overall throughput and performance, improve energy consumption, and enable peer-to-peer and location-based applications and services.

[0002] In such proximity services, vehicle-to-vehicle communications is a fast and emerging field in wireless communication. Cars, busses, trucks and other vehicles can communicate with each other to support various applications ranging from road safety to autonomous driving. However, such applications and services will need highly reliable packet delivery within predefined target communication ranges for the vehicles' transmitters, all while subject to low packet transmission latency requirements. In addition, vehicle-to-vehicle services may also need to provide communications with vehicles outside the network coverage. Accordingly, there is a continuing need for improved proximity services for vehicle-to-vehicle communications that can provide for a range of performance characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

FIG. 1 depicts a wireless system, in accordance with an example;

FIG. 2 illustrates signaling in a wireless system supporting resource allocation for prioritized vehicle-to-vehicle transmission between vehicular user equipment, in accordance with an example;

FIG. 3 illustrates functionality of coordinating priority handling in vehicle-to-vehicle transmission for vehicular user equipment, in accordance with an example;

FIG. 4 depicts a wireless system, in accordance with another example;

FIG. 5 illustrates signaling in a wireless system supporting resource allocation for prioritized vehicle-to-vehicle transmission between vehicular user equipment, in accordance with another example;

FIG. 6 illustrates functionality of coordinating priority handling in vehicle-to-vehicle transmission for vehicular user equipment, in accordance with another example;

FIG. **7** illustrates a diagram of example components of a vehicular UE in accordance with an example;

FIG. 8 illustrates a diagram of an eNB and vehicular UE in accordance with an example; and

FIG. 9 illustrates a diagram of example components of a vehicular UE in accordance with an example.

DETAILED DESCRIPTION

[0004] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process actions, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating actions and operations and do not necessarily indicate a particular order or sequence.

DEFINITIONS

[0005] As used herein, the term "Evolved NodeB," "eNodeB," or "eNB," refers to a device or configured node of a mobile phone network that communicates wirelessly with User Equipment (UEs).

[0006] As used herein, the term "cellular telephone network' or "Long Term Evolution (LTE)" refers to wireless broadband technology developed by the Third Generation Partnership Project (3GPP).

EXAMPLE EMBODIMENTS

[0007] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0008] In one aspect, inter-cell vehicular UE to vehicular UE communication can include support for priority transmission scheduling. Prioritized communications can be supported by inter-cell coordination or vehicular based reporting. In inter-cell coordination, an Evolved NodeB (eNB) can exchange information about resource utilization for a plurality of priority levels with neighboring eNBs. The eNB can then allocate one or more resources to corresponding vehicular UEs for communications at one or more priority levels based on the exchanged information about resource utilization.

[0009] In vehicular based reporting, vehicular UEs can monitor transmissions by proximate vehicular UEs to detect resources utilized for communications at different priority levels. The vehicular UEs can send information to corresponding eNBs about the detected resources utilized for the different priority levels. Based on the information about the detected resource utilization, the eNB can allocate resources to respective vehicular UEs for communication by the vehicular UEs at one or more priority levels.

[0010] FIG. 1 depicts a wireless system, in accordance with an example. In one aspect, the wireless system includes one or more vehicular User Equipment (UE) 110, 115, 120, 125, communicatively coupled to one or more Base Stations (BS) 130, 135 by one or more wireless networks. The wireless system can also include one or more backend devices 140 for communicatively coupling the base stations 130, 135 together by one or more wired or wireless networks. In one aspect, the backend devices 140 can include one or more Evolved Packet Cores (EPC) that can include one or more serving gateways, one or more packet data network gateways, one or more mobility management entities, and other similar devices. In one aspect, the one or more base stations 130, 135 can be Long Term Evolution (LTE) Evolved NodeBs (eNB). In one aspect, the one or more vehicular UEs 110, 115, 120, 125 can be communicatively coupled to the one or more base stations 130, 135 by one or more Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) protocol based networks, typically referred to as cells 145, 150. In one aspect, the vehicular UEs 110, 115, 120, 125 can be located in autonomous cars, in-vehicle infotainment devices, in-vehicle navigation systems, in-vehicle internet of thing (IOT) devices, or similar in-vehicle wireless communication devices that are configured to provide communication services. As used herein, communications can include data and/or voice communications, as well as control information.

[0011] In one aspect, vehicular UEs that are within range of one or more other vehicular UEs to reliably send and receive communications directly between one or more of the vehicular UEs are considered to be within proximity to each other. The term "vehicular UE to vehicular UE" will be referred to herein after as V2V. In one aspect, the vehicular UEs are configured to communicate on a V2V basis using one or more channels of the 3GPP LTE protocol networks. In one aspect, the vehicular UEs may communicate with other proximate vehicular UEs using one or more uplink channels and/or timeslots within the uplink channels of the 3GPP LTE network protocol. In one aspect, the downlink channels, used for communication between the eNBs and UEs, can be protected by using the uplink channel and timeslots therein for V2V communication. The uplink channels used for V2V communications are also referred to as sidelink channels, which will be used herein after. In one aspect, one or more sidelink channels support one-to-one, broadcast, and relay communication modes between proximate vehicular UEs.

[0012] In one aspect, vehicular UEs can support a priority mechanism that provides different communication characteristics in terms of reliability, range and medium access. In one example, higher priority communications may be provided by transmission spectrum resources that provide a better radio quality than lower priority communications. In another example, higher priority communications may be permitted to transmit more frequently than lower priority communications.

[0013] However, the eNBs of different cells may not be aware of the priority of the scheduled transmission in other cells, particularly when the other cells are from different service providers. If eNBs are not aware of the scheduled resources of adjacent cells, transmission with different priority levels may collide on the same spectrum resources and thus the better quality of the high priority transmission may not be provided. In one aspect, priority support for inter-cell V2V communication can include inter-cell coordination.

[0014] In inter-cell coordination, eNB cells can coordinate priority transmission scheduling through services provided by one or more backhaul devices 140.

In one aspect, services of an Evolved Packet Core (EPC) 140 can coordinate information about the set of resources that are allocated and currently utilized for each priority level in a given eNB cell, so that neighboring cells can take the information into account when scheduling V2V transmission within the cell of the respective eNB to avoid scheduling communications with different priorities for different vehicular UEs on the same or adjacent set of resources.

[0015] In one aspect, a first eNB 130 can communicate with one or more vehicular UEs 110, 115 within its respective cell coverage area 145. A second eNB 135 can likewise communicate with one or more vehicular UEs 120 within its respective cell coverage area 150. The first and second eNBs 130, 135 can send information concerning resources allocated for sidelink transmissions by the one or more vehicular UEs 110, 115, 120 to one or more wireless networks, such as an Evolved Packet Core 140. The first and second eNBs 130, 135 may also send information concerning resources allocated for uplink transmission by the one or more vehicular UEs 110, 115, 120. For example, the first eNB 130 can send information concerning resources allocated for uplink and/or sidelink transmission by vehicular UEs 110, 115. The second eNB 135 can send information concerning resources allocated for uplink and sidelink transmission by vehicular UE 120. The Evolved Packet core 140 can forward the information concerning resource allocations, for uplink and sidelink transmission associated with each eNB, to respective adjacent eNBs. For example, the Evolved Packet Core 140 can send the information concerning resources allocated, for uplink and sidelink communications, by the first eNB 130 to the second eNB 135, and vice versa. Each eNB may utilize the received information, concerning allocation of uplink and sidelink transmission resources of adjacent eNBs, when allocating uplink and sidelink transmission resources for use by vehicular UEs in the particular eNB's respective cell coverage area. For example, the first eNB 130 can use the information concerning uplink and sidelink transmission resources allocated by the second eNB 135 to the vehicular UE 120, when the first eNB 130 is allocating uplink and/or sidelink transmission resources to vehicular UEs 110, 115. For instance, the first eNB 130 can allocate sidelink transmission resources to vehicular UEs 115 for V2V transmission to vehicular UE 120 based on the sidelink resources allocated by the second eNB 135 to vehicular UE 120. In addition, the first eNB 130 can allocate uplink and sidelink transmission resources to vehicular UE 110, so that transmissions by vehicular UE 110 do not interfere with one or more priority V2V transmissions between vehicular UE 115 and vehicular UE 120.

[0016] In another example, the second eNB 120 may utilize information concerning allocation of uplink and/or sidelink resource allocations by the first eNB 110, to re-allocate uplink and/or sidelink transmission resources for use by vehicular UE 120 if the uplink and/or sidelink transmission resources allocated to vehicular UE 110 interfere with one or more priority sidelink V2V communications by UE 120.

[0017] FIG. 2 illustrates signaling in a wireless system supporting resource allocation for prioritized V2V transmission between vehicular UEs. In one aspect, the eNBs 205, 210 of a wireless system can send information 215, 220 about resources utilized for different priority levels to a wireless network, such as an Evolved Packet Core (EPC) 225. In one instance, information about priority based resource allocation can be exchanged between the eNBs and EPC across an X2 interface using an X2 application protocol (AP). Alternatively, another type of interface and protocol may be used. In one instance, information about priority based resource allocations can be put into a container or message where a new information element can be introduced. The new information element can include information about occupied time frequency resources for each priority level including a set of Physical Resource Blocks (PRBs), subframe sets, set of resource pools, time patterns of transmission, time intervals or subchannels, and associated priority levels.

[0018] In one aspect, the EPC 225 can distribute the information 230 about resources utilized for different priority levels to the neighbor eNB 210, 205. For instance, the EPC 225 can distribute information about resources allocated by a first eNB 205 to a second eNB 210. In addition, the EPC 225 can distribute information about resources allocation by the second eNB 210 to the first eNB 205. In one aspect, the eNBs 205, 210 can take into account the distributed information about resources utilized for different priority level for the neighbor eNB 210, 205 when allocating 235, 240 resources to vehicular UEs 245, 250. In one aspect, the vehicular UEs 245, 250 can transmit prioritized communications 255 to other vehicular UEs 250, 245 using the resources allocated to the respective vehicular UE. The communications can be sent at sidelink messages on a physical sideline shared channel (PSSCH) or one or more time slots of the PSSCH.

[0019] FIG. 3 illustrates functionality of coordinating priority handling in V2V transmission for vehicular UEs. The coordination of priority handling can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions that when executed by the one or more processors perform one or more functionalities including the priority based resource allocation.

[0020] In one aspect, coordinating priority handling in V2V transmission for vehicular UEs, includes a resource allocation mechanism and a prioritized transmission mechanism. The resource allocation mechanism can include exchanging information about resource utilization for different communication priority levels between an eNB and one or more neighboring eNBs 310. In one instance, the resource utilization information may be exchanged between eNB over an X2 protocol interface. The new information element can include information about occupied time frequency resources for each priority level including set of PRBs, subframe sets, set of resource pools, time patterns of transmission, time intervals or subchannels and associated priority levels.

[0021] In one aspect, the eNB can allocate resources to one or more vehicular UEs within the wireless communication coverage of the eNB based on the exchanged resource utilization information 320. The allocated resources can include one or more communication priority levels for sidelink transmission between vehicular UEs based on the exchanged resource utilization. In one instance information about the allocated resource can be transmitted from the eNB to the vehicular UE using a Radio Resource Control (RRC) interface.

[0022] In one instance, L1 related parameters can be associated and configured according to the example of Table 1 for support of different priority levels. The example is based on four different priority levels. However, any number of different priority levels may be utilized in other instances.

- Transmission power
  - The higher priority UE may be configured to utilize higher transmission power to get an advantage in terms of communication range and thus access to resources.
- Thresholds for resource reselections
  - Priority specific threshold used to identify whether current resource can be used for transmission and should be added to candidate resource set for future resource selection.
- Range of SPS allocation windows
  - The higher priority UEs may have a larger range of values available for SPS allocation windows. Examples:

    High priority 0 - SPS allocation windows in the range, e.g. 100 ms - 1000 ms

    Low priority 3 - SPS allocation windows in the range, e.g. 500 ms - 2000 ms
- Range of transmission windows periods
  - The larger range of transmission windows may be configured for higher priority UE transmissions

    High priority 0 - transmission windows periods, e.g. 100 ms - 200 ms

    Low priority 3 - transmission windows periods, e.g. 300 ms - 500 ms
  - E.g. 100, 150, 200, 250, 300, 350, 450 ms etc.
- Range of transmission window duration
  - The larger range of transmission window durations may be configured for higher priority UE transmissions.

    High priority 0 - transmission windows duration, e.g. 30 ms - 60 ms

    Low priority 3 - transmission windows duration, e.g. 10 ms - 30 ms
  - E.g. 5, 10, 20, 30, 40, 50, 60 ms etc.
- Resource allocation size (e.g. number of PRBs, TTIs, duration of semi-persistent resource allocation window and period)
  - The lager range of resource allocation size may be configured for higher priority transmissions.

    High priority 0 - transmission windows duration, e.g. 5 - 50 PRBs; 1-4 TTIs

    Low priority 3 - transmission windows duration, e.g. 5 - 10 PRBs; 1-2 TTIs
  - E.g. up to 10 PRBs and 1 TTI
- Priority notification mechanism
  - Which priority levels may be broadcasted

    High priority 0 - enabled for 1,2,3

    Med priority 1 - enabled for 2,3

Low priority 3 - disabled

Table 1

[0023] In one aspect, a vehicular UE can receive an allocation of resources for communication with one or more other vehicular UEs 330. The resources allocated to the vehicular UE can include resource allocations for one or more priority levels for sidelink transmissions to other vehicular UEs. The processes of 310, 320 and 330 may be iteratively repeated. In one instance, an eNB may modify resource allocations as vehicular UEs enter, move about and/or leave the cell coverage area of the eNB. As eNBs modify resources allocations, the eNBs can exchange updated information about the changes to resource utilization, re-allocate resources based upon the updated information, and the affected vehicular UEs can receive the updated resource allocations. Alternatively, the eNBs may exchange updated information periodically or in response to one or more events.

[0024] The prioritized transmission mechanism can include determining a priority level for a communication to be transmitted by the eNB to one or more neighbor vehicular UEs 340. In one aspect, communications can be sent, using the allocated resources for the determined priority level for sidelink transmission, to one or more neighbor vehicular UEs 350. The communications can be sent at sidelink messages on a physical sideline shared channel (PSSCH) or one or more time slots of the PSSCH.

[0025] The vehicular UEs within the cellular communication area of eNBs can advantageously communicate with other proximate vehicular UEs to support various applications ranging from road safety to autonomous driving. The eNBs can exchange information concerning sidelink, and optionally uplink communications, to advantageously support priority based communications between proximate vehicular UEs. The resource allocation mechanism can be used to provide different transmission characteristics in terms of reliability, range and medium access for transmission with different priorities.

[0026] FIG. 4 depicts a wireless system, in accordance with another example. Those aspects of the wireless system depicted in FIG. 4 that are substantially similar to the wireless system depicted in FIG. 1 will not be described again hereinafter unless necessary for an understanding the different aspects illustrated in FIG. 4. Again, the wireless system, in one aspect, includes one or more vehicular UEs 410, 415, 420, 425, 430 communicatively coupled to one or more eNBs 435, 440. In one aspect, one or more vehicular UEs 425, 430 are not within range of one or more eNBs 435, 440.

[0027] In one aspect, vehicular UEs 410, 415, 420, 425, 430 can support a priority mechanism that provides different characteristics in terms of reliability, range, latency and medium access. In one example, higher priority communications may be provided with transmission spectrum resources that provide a better radio quality than lower priority communications. In another example, higher priority communications may be permitted to be transmitted more frequently than lower priority communication. In one aspect, priority support for inter-cell V2V communication can include vehicular UE reporting based priority handling.

[0028] In vehicular UE reporting based priority handling, one or more vehicular UEs 410, 415, 420 can report to respective service eNBs 440, 445, the set of resources that are utilized by one or more proximate vehicular UEs 425. In one aspect, each vehicular UE can monitor the transmissions of proximate vehicular UEs. For example, vehicular UE 415 may sense transmissions by vehicular UEs 410, 420 and 430 that are proximate to vehicular UE 415. However, vehicular UE 415 may not be to able sense transmissions by vehicular UE 430 because it is not with the reception area of vehicular UE 415. In one aspect, the vehicular UEs can detect priority levels of different transmission from each proximate vehicular UE.

[0029] In one aspect, for each vehicular UE within range of an eNB, the vehicular UE can report information about resources used for one or more priorities of communications by proximate vehicular UE. For example, vehicular UE 415 may be within range of eNB 435 and may sense the resources used for priority communications by vehicular UEs 410 and 425 that are within proximity to vehicular UE 415. In one aspect, the eNBs can utilize the information received from the vehicular UEs to allocate and/or reallocate resources for use associated with one on more priorities.

[0030] In one aspect, in order to enable vehicular UE based reporting, the reporting vehicular UE can identify which cell scheduled each of the one or more priority transmissions. In one instance, the priority transmission can include cell-specific information, such as a cell identifier, explicitly indicated in sidelink control information (SCI), media access control (MAC), Radio Link Control (RLC), or implicitly associated with Physical Sidelink Control Channel / Physical Sidelink Shared Channel (PSCCH/PSSCH) pool, configuration or pilot pattems. In one instance, the vehicular UE may inform the serving eNB of the cell-specific information for the one or more priority transmissions.

[0031] In another aspect, the vehicular UE can report information about monitored resources that are utilized for transmission of given priority levels, without cell-specific information. In one instance, the vehicular UEs can collect the resource information for prioritized communication and report it to respective eNBs jointly with a group identifier, L1 identifier, source and destination identifier or address. The respective eNBs can determine whether the reported information concerns transmissions scheduled from other cells or not. The eNBs can recognize neighbor cell transmissions given that each eNB is aware of its own scheduling decisions.

[0032] In one aspect, the vehicular UEs can autonomously report priority information and associated resource measurements as detected, in response to one or more predetermined events, and/or periodically for one or more priority levels. In another aspect, the eNBs can configure the vehicular UEs to report priority information and associated resource measurements (e.g., power level of received reference signal or received signal strength indicator measured on resources of the PSCCH/PSSCH). In yet another aspect, the vehicular UEs can report the priority information in response to an explicit request from respective eNBs.

[0033] In one aspect, vehicular UE sensing operations can be characterized by sensing windows, transmission windows, transmission window periods, semi-persistent resource allocation windows, and sidelink Semi-Persistent Scheduling (SPS) processes. In one aspect, the sensing window can be the set of sub-frames used by the vehicular UE to monitor and collect information from PSCCH transmissions of other vehicular UEs and conduct corresponding energy measurements. The window may be configurable by the network, predefined by specification or preconfigured in case of out of coverage operation. The sensing window may be common across vehicular UEs. In order to accommodate a low V2V message rate of lHz, the sensing window duration in one instance can be in the order of 100 ms, 1000 ms or above.

[0034] In one aspect, the transmission window can be the set of subframes where a vehicular UE performs resource selection for transmission of transport blocks (TB) including potential retransmission (e.g., packet transmission window). The transmission window can be configurable by the network, predefined by specification or preconfigured for out of coverage operation. The transmission window length can be less than 100 ms, in one instance, to satisfy V2V latency constraints. The typical value, however, may be in the rage of 5 ms to 500 ms.

[0035] In one aspect, the transmission window period can be a resource allocation period that indicates the periodicity of transmission windows (e.g., packet transmission windows) with semi-persistent resource allocation window. The transmission window period can be aligned with the V2V message generation rate and meet latency requirements for periodic traffic transmission.

[0036] In one aspect, the semi-persistent resource allocation window can be a vehicular UE specific parameter that may depend on the traffic pattern at the vehicular UE side. The maximum value of this window may be configurable by the network or determined by the vehicular UE autonomously. In general, the value of the semi-persistent resource allocation window can be limited and may be in the range of 100 ms to 1000 ms in order to cope with the mobility effects in vehicular environments.

[0037] In one aspect, the sidelink SPS process is a UE specific process for transmission of PSCCH and PSSCH within the semi-persistent resource allocation window. The vehicular UE may trigger multiple SPS processes each associated with and carried within the semi-persistent resource allocation window.

[0038] In one aspect, to support priority in autonomous resource selection mode, the priority information can be exchanged between vehicular UEs. For supporting different levels of transmission quality for respective priorities, the priority information collected by a vehicular UE can be used as part of autonomous resource reselection by the vehicular UE.

[0039] In one aspect, Sidelink Control Information (SCI) decoding and energy measurement support can be utilized for sensing and vehicular UE autonomous resource selection. The support of SCI decoding for sensing and resource selection can also be utilized for delivery of priority information. SCI reception may be more robust than a data channel and therefore may be beneficially used to indicate priority. In addition, SCI has a larger communication range which is important for priority handling to ensure transmission quality. Instead of explicit signaling in SCI, it may also be possible to associate some of the SCI resources with priority levels or put priority information into shared channel transmissions. However, in such case, the amount of SCI resources for each priority level may be reduced and additional resources may need to be allocated for each priority level. Therefore, the explicit signaling mechanism may be preferred so that a new field of one to three bits can be added to new SCI format (e.g., SCI format 1) indicating priority level of the transmission. In such instances, 2, 4 or 8 priority levels can be supported.

[0040] In one aspect, the sensing procedure of the vehicular UEs does not depend on priority. The vehicular UEs can perform the sensing procedure independently of priority. However, the conditions for resource selection may be different for different priority levels and configured by higher protocol layers. In another aspect, the vehicular UEs can access the medium irrespective of the resource selection conditions pre-configured for each priority levels for exceptional triggering situations, such as a vehicular crash, where immediate access to resources is desirable. Therefore, the eNBs may configure the vehicular UEs to skip sensing procedures, for high priority transmissions and other exceptional triggering cases, to access the medium with minimal latency.

[0041] In one aspect, high priority transmissions may require better transmission quality conditions in terms of transmission range, interference protection and prioritized access to the medium. Priority and resource selection procedures for V2V communication may take into consideration a number of principles. In one aspect the principles can include priority specific candidate resource set construction based on priority specific conditions. In another aspect, priority specific conditions used to construct priority specific candidate resource sets can be configured by higher protocol layers. The configurations may consider conditions (e.g., metrics and thresholds) to exclude and/or include resources occupied by higher priority transmissions for a candidate resource set. The candidate resource set may include received signal power, reference received signal strength thresholds and other similar metrics. Similarly, the configurations may consider conditions to exclude and/or include resources occupied by lower priority transmissions for a candidate resource set. In another aspect, a priority specific candidate resource set may be based on randomized resource selection. In yet another aspect, the detection of a resource collision with a higher priority transmission can trigger resource reselection procedure at the low or high priority transmitting vehicular UE that detected the collusion on the spectrum resources.

[0042] In one aspect, priority specific candidate resource sets can be determined. In each subframe of a relevant shared channel (PSSCH), the vehicular UE can identify a preferred frequency resource according to one or more predetermined metrics, such as any function of received power on the resource. The subframes of resources can be sorted according to the metric. The metric can also take into account the number of transmitters occupying the resource and their priority. In one instance, each UE can randomly select among M available subframes of candidate resource sets, where M is determined as M = max(MMiN; MTHR). Here, MMIN is the minimum size of the candidate resource set (e.g., MMIN = 8) and MTHR is the number of resources in a resource congestion map that are equal or below the predetermined value of the resource congestion map threshold QMIN. The vehicular UE can randomize its resource selection in the selected candidate set of resources.

[0043] In one aspect, dual threshold operations can be used for V2V communications. From a system perspective it can be advantageous to transmit in high energy subframes on the non-occupied frequency resources in order to reduce near-far and in-band emission problem for receivers. In this case, the dual threshold can be used. The first threshold can be used to identify low energy resources (e.g., "empty resources"), while the second threshold can be used to identify high energy subframes and "empty resources" within high energy subframes. In this case, the priority of resource selection can be given to high energy subframes with empty resources.

[0044] In one aspect, resource selection within priority specific candidate resource sets can be randomized to take into account priority information of other transmitters that occupy resources within identified priority specific candidate resource sets. For instance, a resource occupied by a lower priority transmission may be selected with higher probability while the resource occupied by a higher priority transmission may be selected with lower probability. In another aspect, independently of priority, the resources within a candidate resource set may be selected with equal priority.

[0045] In one aspect, triggers for resource reselection may be priority specific. Detection of high priority transmission on overlapping sets of resources can trigger a resource reselection procedure, so that vehicular UEs transmitting with lower priority do not overlap with resources pre-allocated for high priority transmissions. The vehicular UE can trigger a resource reselection procedure if it detects a collision in its resource allocation with a higher priority transmission. In one instance, the reselection can be triggered for a collision in time, such as colliding on the same subframe but not necessarily the same frequency resource. In another instance, the reselection can be triggered for a collision in time and frequency, such as colliding on a particular time-frequency allocation. In one aspect, the vehicular UE transmitting with a low priority can drop transmissions packets in pre-allocated semi-persistent transmission windows, or just those that collided with the higher priority transmission of another vehicular UE.

[0046] In one aspect, a mechanism for notification of high priority transmission for selected priority levels can be provided. The high priority transmission may require high reliability in terms of reception. In order to improve reliability of high priority transmissions in autonomous resource selection, vehicular UEs can perform notification about detected higher priority transmissions by other UEs. The notification mechanism can indicate the resources utilized by high priority transmissions, so that the transmission environment on the resources become less congested due to sensing and ongoing resource reselection procedures. In one instance, proximate vehicular UEs performing resource reselection procedures in the neighborhood can try and avoid selection of the resources utilized by high priority transmissions and thus reduce interference problems and increase the coverage range of high priority transmissions in interference limited scenarios. The vehicular UE may simply relay (e.g., relay and decode) SCI signals of higher priority vehicular UEs reproducing the content of the original SCI signal of the high priority vehicular UE transmissions. In one aspect, the eNBs can configure conditions under which the notification may happen and for which priority levels. In addition, the eNBs can also configure thresholds of reference signal received power levels in order for the vehicular UEs to signal notification of high priority communications.

[0047] FIG. 5 illustrates signaling in a wireless system supporting resource allocation for prioritized V2V transmission between vehicular UEs. In one aspect, the vehicular UEs 505, 510, 515 can monitor communications by other vehicular UEs 520, 525, 530 to determine information about resources utilized by proximate UEs for different priority levels. In one aspect, the vehicular UEs send 535, 540 the determined information about resources utilized by proximate UEs to respective eNBs 545, 550. The information can indicate the vehicular UE and/or the eNB cell that the information is associated with, or the given eNB can determine the information that is associated with other eNB cells and/or vehicular UE in other eNB cells from those cells and vehicular UEs that do not correspond to the resources allocated by the given eNB.

[0048] In one aspect, the eNBs 545, 550 can take into account the information about resources utilized for different priority level received from the vehicular UEs when allocating 555, 560 resources to vehicular UEs 505, 510. For instance, the eNBs may allocate different resources for sidelink communications for one or more priority level that provide for different characteristics such as transmission reliability, transmission range and medium access. In one aspect, the vehicular UEs 505, 510 can transmit prioritized communications 565 to other vehicular UEs 505, 410 using the resources allocated to the respective vehicular UE. In another aspect, vehicular UEs 515 that are outside the cell coverage area of eNBs can utilize the information about resources utilized for different priority level in selecting resources to transmit prioritized communications to other vehicular UEs.

[0049] FIG. 6 illustrates functionality of coordinating priority handling in V2V transmission for vehicular UEs. The coordination of priority handling can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions that when executed by the one or more processors perform one or more functionalities including the resource allocation. In one aspect, coordinating priority handling in V2V transmission for vehicular UEs, includes a discovery mechanism, a resource allocation mechanism and a prioritized transmission mechanism.

[0050] In one aspect, a discovery mechanism is provided for detection of the proximate vehicle UEs without network assistance for either in-coverage or out-of-coverage scenarios. In one aspect, a vehicular UE can monitor sidelink transmission from proximate vehicular UEs to detect resource utilization of one or more priority levels of communications between other vehicular UEs 610. In one aspect, the vehicular UEs send the information about resource utilization of one or more priority levels used for communications between the proximate vehicular UEs 620, to a corresponding eNB.

[0051] In one aspect, the eNBs receive information about resource utilization of different priority levels used for communications from vehicular UEs within the cell coverage area of the respective eNB 630. In one aspect, each eNB can allocate resources to one or more vehicular UEs within its respective cell coverage area based on the received resource utilization information 640. The resources can be allocated for one or more communication priority levels for sidelink transmission between vehicular UEs. In one instance, related resource and priority parameters can be associated and configured according to the example of Table 1 set forth above.

[0052] In one aspect, a vehicular UE can receive the allocation of resources for communications in one or more priority levels with one or more other vehicular UEs 650. In one aspect, the vehicular UE can determine a priority level for a communication 660. In one aspect, the vehicular UE can communicate using the allocated resource for the determined priority level with one or more other vehicular UEs 670. The communications can be sent at sidelink messages on a physical sideline shared channel (PSSCH) or one or more time slots of the PSSCH.

[0053] FIG. 7 illustrates a diagram of example components of a vehicular UE device in accordance with an example. In some aspects, the vehicular UE device 700 can include application circuitry 702, baseband circuitry 704, Radio Frequency (RF) circuitry 706, front-end module (FEM) circuitry 708 and one or more antennas 710, coupled together at least as shown.

[0054] The application circuitry 702 can include one or more application processors. For example, the application circuitry 702 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors can be coupled with and/or can include memory/storage and can be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0055] The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors can be coupled with and/or can include a storage medium 712, and can be configured to execute instructions stored in the storage medium 712 to enable various applications and/or operating systems to run on the system.

[0056] The baseband circuitry 704 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 704 can include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 706 and to generate baseband signals for a transmit signal path of the RF circuitry 706. Baseband processing circuitry 704 can interface with the application circuitry 702 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 706. For example, in some aspects, the baseband circuitry 704 can include a second generation (2G) baseband processor 704a, third generation (3G) baseband processor 704b, fourth generation (4G) baseband processor 704c, WiFi baseband processor 704d and/or other baseband processor(s) 704e for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 704 (e.g., one or more of baseband processors 704a-d) can handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 706. The radio control functions can include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some aspects, modulation/demodulation circuitry of the baseband circuitry 704 can include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some aspects, encoding/decoding circuitry of the baseband circuitry 704 can include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Aspects of modulation/demodulation and encoder/decoder functionality are not limited to these examples and can include other suitable functionality in other aspects.

[0057] In some aspects, the baseband circuitry 704 can include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 704f of the baseband circuitry 704 can be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some aspects, the baseband circuitry can include one or more audio digital signal processor(s) (DSP) 704g. The audio DSP(s) 704g can be include elements for compression/decompression and echo cancellation and can include other suitable processing elements in other aspects. Components of the baseband circuitry can be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some aspects. In some aspects, some or all of the constituent components of the baseband circuitry 704 and the application circuitry 702 can be implemented together such as, for example, on a system on a chip (SOC).

[0058] In some aspects, the baseband circuitry 704 can provide for communication compatible with one or more radio technologies. For example, in some aspects, the baseband circuitry 704 can support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Aspects in which the baseband circuitry 704 is configured to support radio communications of more than one wireless protocol can be referred to as multi-mode baseband circuitry.

[0059] RF circuitry 706 can enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various aspects, the RF circuitry 706 can include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 706 can include a receive signal path which can include circuitry to down-convert RF signals received from the FEM circuitry 708 and provide baseband signals to the baseband circuitry 704. RF circuitry 706 can also include a transmit signal path which can include circuitry to up-convert baseband signals provided by the baseband circuitry 704 and provide RF output signals to the FEM circuitry 708 for transmission.

[0060] In some aspects, the RF circuitry 706 can include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 706 can include mixer circuitry 706a, amplifier circuitry 706b and filter circuitry 706c. The transmit signal path of the RF circuitry 706 can include filter circuitry 706c and mixer circuitry 706a. RF circuitry 706 can also include synthesizer circuitry 706d for synthesizing a frequency for use by the mixer circuitry 706a of the receive signal path and the transmit signal path. In some aspects, the mixer circuitry 706a of the receive signal path can be configured to down-convert RF signals received from the FEM circuitry 708 based on the synthesized frequency provided by synthesizer circuitry 706d. The amplifier circuitry 706b can be configured to amplify the down-converted signals and the filter circuitry 706c can be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals can be provided to the baseband circuitry 704 for further processing. In some aspects, the output baseband signals can be zero-frequency baseband signals, although the output baseband signals do not have to be zero-frequency baseband signals. In some aspects, mixer circuitry 706a of the receive signal path can comprise passive mixers, although the scope of the aspects is not limited in this respect.

[0061] In some aspects, the mixer circuitry 706a of the transmit signal path can be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 706d to generate RF output signals for the FEM circuitry 708. The baseband signals can be provided by the baseband circuitry 704 and can be filtered by filter circuitry 706c. The filter circuitry 706c can include a low-pass filter (LPF), although the scope of the aspects is not limited in this respect.

[0062] In some aspects, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path can include two or more mixers and can be arranged for quadrature down conversion and/or up conversion respectively. In some aspects, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path can include two or more mixers and can be arranged for image rejection (e.g., Hartley image rejection). In some aspects, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a can be arranged for direct down conversion and/or direct up conversion, respectively. In some aspects, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path can be configured for super-heterodyne operation.

[0063] In some aspects, the output baseband signals and the input baseband signals can be analog baseband signals, although the scope of the aspects is not limited in this respect. In some altemate aspects, the output baseband signals and the input baseband signals can be digital baseband signals. In these alternate aspects, the RF circuitry 706 can include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 704 can include a digital baseband interface to communicate with the RF circuitry 706.

[0064] In some dual-mode embodiments, a separate radio IC circuitry can be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0065] In some embodiments, the synthesizer circuitry 706d can be a fractional-N synthesizer or a fractional N/N+l synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers can be suitable. For example, synthesizer circuitry 706d can be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0066] The synthesizer circuitry 706d can be configured to synthesize an output frequency for use by the mixer circuitry 706a of the RF circuitry 706 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 706d can be a fractional N/N+l synthesizer.

[0067] In some embodiments, frequency input can be provided by a voltage controlled oscillator (VCO), although that is not a constraint. Divider control input can be provided by either the baseband circuitry 704 or the applications processor 702 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) can be determined from a look-up table based on a channel indicated by the applications processor 702.

[0068] Synthesizer circuitry 706d of the RF circuitry 706 can include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider can be a dual modulus divider (DMD) and the phase accumulator can be a digital phase accumulator (DPA). In some embodiments, the DMD can be configured to divide the input signal by either N or N+l (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL can include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements can be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0069] In some embodiments, synthesizer circuitry 706d can be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency can be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency can be a LO frequency (fLO). In some embodiments, the RF circuitry 706 can include an IQ/polar converter.

[0070] FEM circuitry 708 can include a receive signal path which can include circuitry configured to operate on RF signals received from one or more antennas 710, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 706 for further processing. FEM circuitry 708 can also include a transmit signal path which can include circuitry configured to amplify signals for transmission provided by the RF circuitry 706 for transmission by one or more of the one or more antennas 710.

[0071] In some embodiments, the FEM circuitry 708 can include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry can include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry can include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 706). The transmit signal path of the FEM circuitry 708 can include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 706), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 710.

[0072] In some embodiments, the vehicular UE device 700 can include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output **(I/O)** interface.

[0073] FIG. 8 illustrates a diagram 800 of a node 810 (e.g., eNB and/or a base station) and vehicular UE 820 in accordance with an example. The node can include a base station (BS), a Node B (NB), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a remote radio unit (RRU), or a central processing module (CPM). In one aspect, the node can be a Serving GPRS Support Node. The node 810 can include anode device 812. The node device 812 or the node 810 can be configured to communicate with the vehicular UE 820. The node device 812 can be configured to implement the technology described. The node device 812 can include a processing module 814 and a transceiver module 816. In one aspect, the node device 812 can include the transceiver module 816 and the processing module 814 forming a circuitry 818 for the node 810. In one aspect, the transceiver module 816 and the processing module 814 can form a circuitry of the node device 812. The processing module 814 can include one or more processors and memory. In one embodiment, the processing module 814 can include one or more application processors. The transceiver module 816 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 816 can include a baseband processor.

[0074] The vehicular UE 820 can include a transceiver module 824 and a processing module 822. The processing module 822 can include one or more processors and memory. In one embodiment, the processing module 822 can include one or more application processors. The transceiver module 824 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 824 can include a baseband processor. The vehicular UE 820 can be configured to implement the technology described. The node 810 and the vehicular UE 820 can also include one or more storage mediums, such as the transceiver module 816, 824 and/or the processing module 814, 822. In one aspect, the components described herein of the transceiver module 816 can be included in one or more separate devices that can be used in a cloud-RAN (C-RAN) environment.

[0075] FIG. 9 illustrates a diagram of a vehicular UE 900, in accordance with an example. The vehicular UE 900 may be located in autonomous car, in-vehicle infotainment device, in-vehicle navigation system, in-vehicle internet of thing (IOT) device, or similar in-vehicle wireless communication device that is configured to provide communication services. In one instance, the vehicular UE 900 may be integrated into the dashboard instrumentation of vehicles. In one aspect, the vehicular UE 900 can include at least one of an antenna 905, a touch sensitive display screen 910, a speaker 915, a microphone 920, a graphics processor 925, a baseband processor 930, an application processor 935, internal memory 940, a keyboard and/or one or more other keys, buttons, knobs and the like 945, a non-volatile memory port 950, and combinations thereof.

[0076] The vehicular UE 900 can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access point. The one or more antennas of the vehicular UE 900 can also be configured to communicate with one or more other vehicular UEs. The vehicular UE 900 can be configured to communicate using at least one wireless communication standard including 3GPP LTE, WiMAX, High

Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The vehicular UE 900 can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN. The vehicular UE 900 can include a storage medium. In one aspect, the storage medium can be associated with and/or communicate with the application processor, the graphics processor, the display, the non-volatile memory port, and/or internal memory. In one aspect, the application processor and graphics processor are storage mediums.

EXAMPLES

[0077] The following examples pertain to specific technology embodiments and point out specific features, elements, or steps that can be used or otherwise combined in achieving such embodiments.

[0078] Example 1 includes an apparatus of an Evolved NodeB (eNB) operable to coordinate resource allocation for prioritized vehicular User Equipment (UE) to vehicular UE communications, the system comprising one or more processors and memory configured to: process, at an eNB, resource utilization information for a plurality of priority levels, received from one or more neighboring eNBs; and generate, at the eNB, a message including an allocation of one or more resources to a vehicular User Equipment (UE) for communications at one or more priority levels based on the received resource utilization information to permit vehicular UEs to perform vehicular UE to Vehicular UE communication using the one or more resources allocated to the vehicular UE.

[0079] Example 2 includes the apparatus of Example 1 wherein the resource utilization information is received at the eNB from one or more neighboring eNBs through an Evolved Packet Core (EPC).

[0080] Example 3 includes the apparatus of Examples 1 or 2, wherein the resource utilization information is received at the eNB via an X2 interface between the eNB and one or more neighboring eNBs.

[0081] Example 4 includes the apparatus of Example 1, wherein the message including the allocation of one or more resources is encoding for transmission from the eNB to the vehicular UE using a Radio Resource Control (RRC) interface.

[0082] Example 5 includes the apparatus of Example 1, wherein one or more processors and memory are further configured to: process, at the eNB, updated resource utilization information for a plurality of priority levels, received from one or more neighboring eNBs; and generate, at the eNB, a message including an allocation of one or more resources to the vehicular User Equipment (UE) for communications at the one or more priority levels based on the updated resource utilization information to reduce scheduling communications with different priorities for different vehicular UEs on a same or adjacent set of resources.

[0083] Example 6 includes the apparatus of Examples 1 or 5, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

[0084] Example 7 includes an apparatus of a user equipment (UE) operable to prioritize vehicular User Equipment (UE) to vehicular UE communications on allocated resources, the apparatus comprising one or more processors and memory configured to: process, at a vehicular UE, a message received from an eNB including an allocation of one or more resources for communications at one or more priority levels; determine, at the vehicular UE, a priority level for a sidelink message; and process, for transmission from the vehicular UE to a proximate vehicular UE, the sidelink message using a resource allocated to the determined priority level.

[0085] Example 8 includes the apparatus of Example 7, further comprising a transceiver configured to, receive the allocation from the eNB comprising one or more resources for vehicular UE to Vehicular UE communications at the one or more priority levels.

[0086] Example 9 includes the apparatus of Example 7, wherein the one or more processors and memory are further configured to: process, at the vehicular UE, a message received from an eNB including an updated allocation of one or more resources for communications at one or more priority levels; determine, at the vehicular UE, a priority level for a second sidelink message; and process, for transmission from the vehicular UE to a proximate vehicular UE, the second sidelink message for transmission to a proximate vehicular UE using a resource of the updated allocation to the determined priority level.

[0087] Example 10 includes the apparatus of Example **7,** wherein the message including the allocated one or more resources processed by the vehicular UE from the eNB is decoded from a Radio Resource Control (RRC) interface.

[0088] Example 11 includes the apparatus of Examples **7,** 8 or 9, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

[0089] Example 12 includes the apparatus of Example **7,** wherein the sidelink message is transmitted from the vehicular UE to the proximate vehicular UE on a physical sidelink shared channel (PSSCH) or one or more time slots of the PSSCH.

[0090] Example 13 includes the apparatus of Example 12, wherein the one or more sidelink channels support one-to-one, broadcast and relay modes between proximate vehicular UEs.

[0091] Example 14 includes the apparatus of Example **7,** wherein vehicular UE is integrated in one or more of an autonomous car, an in-vehicle infotainment device, an in-vehicle navigation system, or an in-vehicle internet of things **(IOT)** device that are configured to provide communication services.

[0092] Example 15 includes at least one machine readable storage medium having instructions embodied thereon for prioritizing vehicular User Equipment (UE) to vehicular UE communications, the instructions when executed by one or more processors of a vehicular UE perform the following: monitoring, at the vehicular UE, transmission of one or more proximate vehicular UEs to detect resources utilized for at least one priority level of communications; processing, for transmission from the vehicular UE to a corresponding eNB, information about the detected resources utilized for at least one priority level of communications; generating, at the vehicular UE, a message including an allocation received from the corresponding eNB of one or more resources for communications at the one or more priority levels, wherein the allocation of the one or more resources is based on information about resources utilized for one or more priority levels of communications; determining, at the vehicular UE, a priority level of a sidelink message; and processing, for transmission from the vehicular UE to a proximate vehicular UE, the sidelink message using one of the one or more resources allocated to the determined priority level.

[0093] Example 16 includes the at least one machine readable storage medium of Example 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources in response to one or more events.

[0094] Example 17 includes the at least one machine readable storage medium of Example 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources periodically to the corresponding eNB at a predetermined rate.

[0095] Example 18 includes the at least one machine readable storage medium of Example 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources in response to a request from the corresponding eNB.

[0096] Example 19 includes the at least one machine readable storage medium of Example 15, further comprising instructions when executed perform the following: encoding the information about the detected resources for transmission from the vehicular UE to the corresponding eNB using a Radio Resource Control (RRC) interface.

[0097] Example 20 includes the at least one machine readable storage medium of Example 15, further comprising instructions when executed perform the following: generating, at the UE, a message including a re-allocation of one or more resources for communications at the one or more priority levels received from the corresponding eNB; determining, at the vehicular UE, a priority level of a second sidelink message; and processing, for transmission from the vehicular UE to a proximate vehicular UE, the second sidelink message using resources re-allocated to the determined priority level.

[0098] Example 21 includes the at least one machine readable storage medium of Example 15, wherein the sidelink messages are sent from the vehicular UE to the proximate vehicular UE on a physical sidelink shared channel (PSSCH) or one or more time slots of the PSSCH.

[0099] Example 22 includes at least one machine readable storage medium having instructions embodied thereon for allocating resources at an Evolved NodeB for prioritized vehicular User Equipment (UE) to vehicular UE communications, the instructions when executed by one or more processors of an eNB perform the following: processing, at the eNB, information about detected resources utilized for at least one priority level of communications received from one or more vehicular UEs; and generating, for transmission from the eNB to at least one vehicular UE, a message including an allocation of one or more resources for communications at one or more priority levels based on the information about the detected resources.

[00100] Example 23 including the at least one machine readable storage medium of Example 22, wherein the information about the detected resources processed by the eNB from the vehicular UE is decoded from a Radio Resource Control (RRC) interface.

[00101] Example 24 including the at least one machine readable storage medium of Example 22, further comprising instructions when executed perform the following: processing, at the eNB, updated information about a change of the detected resources utilized for at least one priority level of communications received from at least one of the one or more vehicular UEs; and generating, for transmission from the eNB to at the least one vehicular UE, a message including a re-allocation of at least one of the one or more resources for communications at the one or more priority levels based on the updated information about the detected resources.

[00102] Example 25 including the at least one machine readable storage medium of Examples 22 or 24, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

[00103] As used herein, the term "circuitry" can refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other

suitable hardware components that provide the described functionality. In some aspects, the circuitry can be implemented in, or functions associated with the circuitry can be implemented by, one or more software or firmware modules. In some aspects, circuitry can include logic, at least partially operable in hardware.

[00104] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, transitory or non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. Circuitry can include hardware, firmware, program code, executable code, computer instructions, and/or software. A non-transitory computer readable storage medium can be a computer readable storage medium that does not include signal. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

[00105] As used herein, the term processor can include general purpose processors, specialized processors such as VLSI, FPGAs, or other types of specialized processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00106] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00107] Modules may also be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00108] Indeed, a module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The modules may be passive or active, including agents operable to perform desired functions.

[00109] Reference throughout this specification to "an example" or "exemplary" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus, appearances of the phrases "in an example" or the word "exemplary" in various places throughout this specification are not necessarily all referring to the same embodiment.

[00110] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified

as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology.

[00111] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments of the technology. One skilled in the relevant art will recognize, however, that the technology can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the technology.

[00112] While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the technology. Accordingly, it is not intended that the technology be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of an Evolved NodeB (eNB) operable to coordinate resource allocation for prioritized vehicular User Equipment (UE) to vehicular UE communications, the system comprising one or more processors and memory configured to:

process, at an eNB, resource utilization information for a plurality of priority levels, received from one or more neighboring eNBs; and

generate, at the eNB, a message including an allocation of one or more resources to a vehicular User Equipment (UE) for communications at one or more priority levels based on the received resource utilization information to permit vehicular UEs to perform vehicular UE to Vehicular UE communication using the one or more resources allocated to the vehicular UE.

2. The apparatus according to claim 1, wherein the resource utilization information is received at the eNB from one or more neighboring eNBs through an Evolved Packet Core (EPC).

3. The apparatus according to claims 1 or 2, wherein the resource utilization information is received at the eNB via an X2 interface between the eNB and one or more neighboring eNBs.

4. The apparatus according to claim 1, wherein the message including the allocation of one or more resources is encoding for transmission from the eNB to the vehicular UE using a Radio Resource Control (RRC) interface.

5. The apparatus according to claim 1, wherein one or more processors and memory are further configured to:

process, at the eNB, updated resource utilization information for a plurality of priority levels, received from one or more neighboring eNBs; and

generate, at the eNB, a message including an allocation of one or more resources to the vehicular User Equipment (UE) for communications at the one or more priority levels based on the updated resource utilization information to reduce scheduling communications with different priorities for different vehicular UEs on a same or adjacent set of resources.

6. The apparatus according to claims 1 or 5, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

7. An apparatus of a user equipment (UE) operable to prioritize vehicular User Equipment (UE) to vehicular UE communications on allocated resources, the apparatus comprising one or more processors and memory configured to:

process, at a vehicular UE, a message received from an eNB including an allocation of one or more resources for communications at one or more priority levels;

determine, at the vehicular UE, a priority level for a sidelink message; and

process, for transmission from the vehicular UE to a proximate vehicular UE, the sidelink message using a resource allocated to the determined priority level.

8. The apparatus of claim 7, further comprising a transceiver configured to,

receive the allocation from the eNB comprising one or more resources for vehicular UE to Vehicular UE communications at the one or more priority levels.

9. The apparatus according to claim 7, wherein the one or more processors and memory are further configured to:

process, at the vehicular UE, a message received from an eNB including an updated allocation of one or more resources for communications at one or more priority levels;

determine, at the vehicular UE, a priority level for a second sidelink message; and

process, for transmission from the vehicular UE to a proximate vehicular UE, the second sidelink message for transmission to a proximate vehicular UE using a resource of the updated allocation to the determined priority level.

10. The apparatus according to claim 7, wherein the message including the allocated one or more resources processed by the vehicular UE from the eNB is decoded from a Radio Resource Control (RRC) interface.

11. The apparatus according to claims 7, 8 or 9, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

12. The apparatus according to claim 7, wherein the sidelink message is transmitted from the vehicular UE to the proximate vehicular UE on a physical sidelink shared channel (PSSCH) or one or more time slots of the PSSCH.

13. The apparatus according to claim 12, wherein the one or more sidelink channels support one-to-one, broadcast and relay modes between proximate vehicular UEs.

14. The apparatus according to claim 7, wherein vehicular UE is integrated in one or more of an autonomous car, an in-vehicle infotainment device, an in-vehicle navigation system, or an in-vehicle internet of things (IOT) device that are configured to provide communication services.

15. At least one machine readable storage medium having instructions embodied thereon for prioritizing vehicular User Equipment (UE) to vehicular UE communications, the instructions when executed by one or more processors of a vehicular UE perform the following:

monitoring, at the vehicular UE, transmission of one or more proximate vehicular UEs to detect resources utilized for at least one priority level of communications;

processing, for transmission from the vehicular UE to a corresponding eNB, information about the detected resources utilized for at least one priority level of communications;

generating, at the vehicular UE, a message including an allocation received from the corresponding eNB of one or more resources for communications at the one or more priority levels, wherein the allocation of the one or more resources is based on information about resources utilized for one or more priority levels of communications;

determining, at the vehicular UE, a priority level of a sidelink message; and

processing, for transmission from the vehicular UE to a proximate vehicular UE, the sidelink message using one of the one or more resources allocated to the determined priority level.

16. The at least one machine readable storage medium of claim 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources in response to one or more events.

17. The at least one machine readable storage medium of claim 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources periodically to the corresponding eNB at a predetermined rate.

18. The at least one machine readable storage medium of claim 15, further comprising instructions when executed perform the following: transmitting, using a transceiver at the vehicular UE, the information about the detected resources in response to a request from the corresponding eNB.

19. The at least one machine readable storage medium of claim 15, further comprising instructions when executed perform the following: encoding the information about the detected resources for transmission from the vehicular UE to the corresponding eNB using a Radio Resource Control (RRC) interface.

20. The at least one machine readable storage medium of claim 15, further comprising instructions when executed perform the following:

generating, at the UE, a message including a re-allocation of one or more resources for communications at the one or more priority levels received from the corresponding eNB;

determining, at the vehicular UE, a priority level of a second sidelink message; and

processing, for transmission from the vehicular UE to a proximate vehicular UE, the second sidelink message using resources re-allocated to the determined priority level.

21. The at least one machine readable storage medium of claim 15, wherein the sidelink messages are sent from the vehicular UE to the proximate vehicular UE on a physical sidelink shared channel (PSSCH) or one or more time slots of the PSSCH.

22. At least one machine readable storage medium having instructions embodied thereon for allocating resources at an Evolved NodeB for prioritized vehicular User Equipment (UE) to vehicular UE communications, the instructions when executed by one or more processors of an eNB perform the following:

processing, at the eNB, information about detected resources utilized for at least one priority level of communications received from one or more vehicular UEs; and generating, for transmission from the eNB to at least one vehicular UE, a message including an allocation of one or more resources for communications at one or more priority levels based on the information about the detected resources.

23. The at least one machine readable storage medium of claim 22, wherein the information about the detected resources processed by the eNB from the vehicular UE is decoded from a Radio Resource Control (RRC) interface.

24. The at least one machine readable storage medium of claim 22, further comprising instructions when executed perform the following:

processing, at the eNB, updated information about a change of the detected resources utilized for at least one priority level of communications received from at least one of the one or more vehicular UEs; and

generating, for transmission from the eNB to at the least one vehicular UE, a message including a re-allocation of at least one of the one or more resources for communications at the one or more priority levels based on the updated information about the detected resources.

25. The at least one machine readable storage medium of claims 22 or 24, wherein the one or more resources include one or more communication spectrum characteristics selected from the group consisting of communication reliability, communication range, medium access, and communication latency.

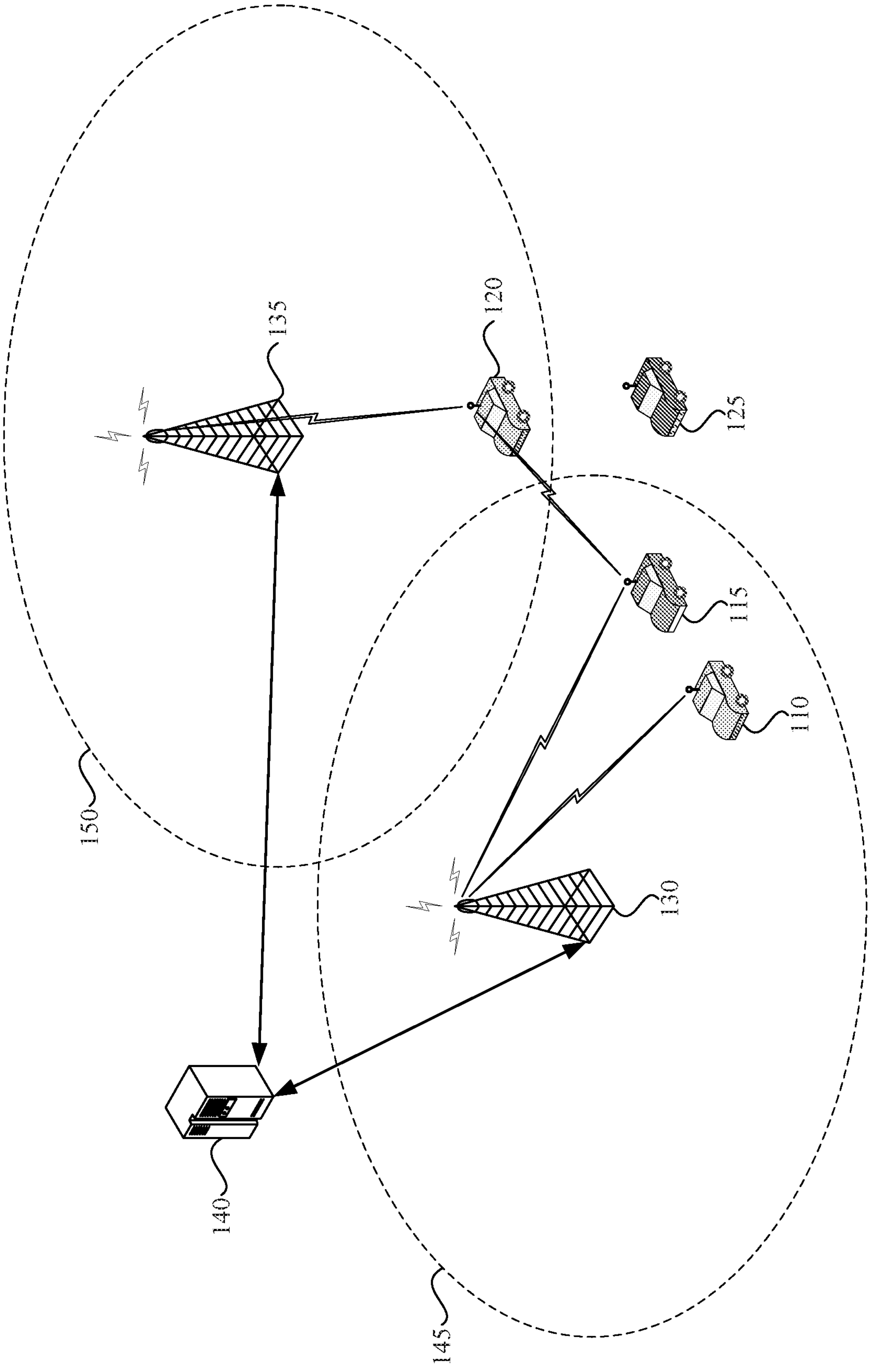

FIG. 1

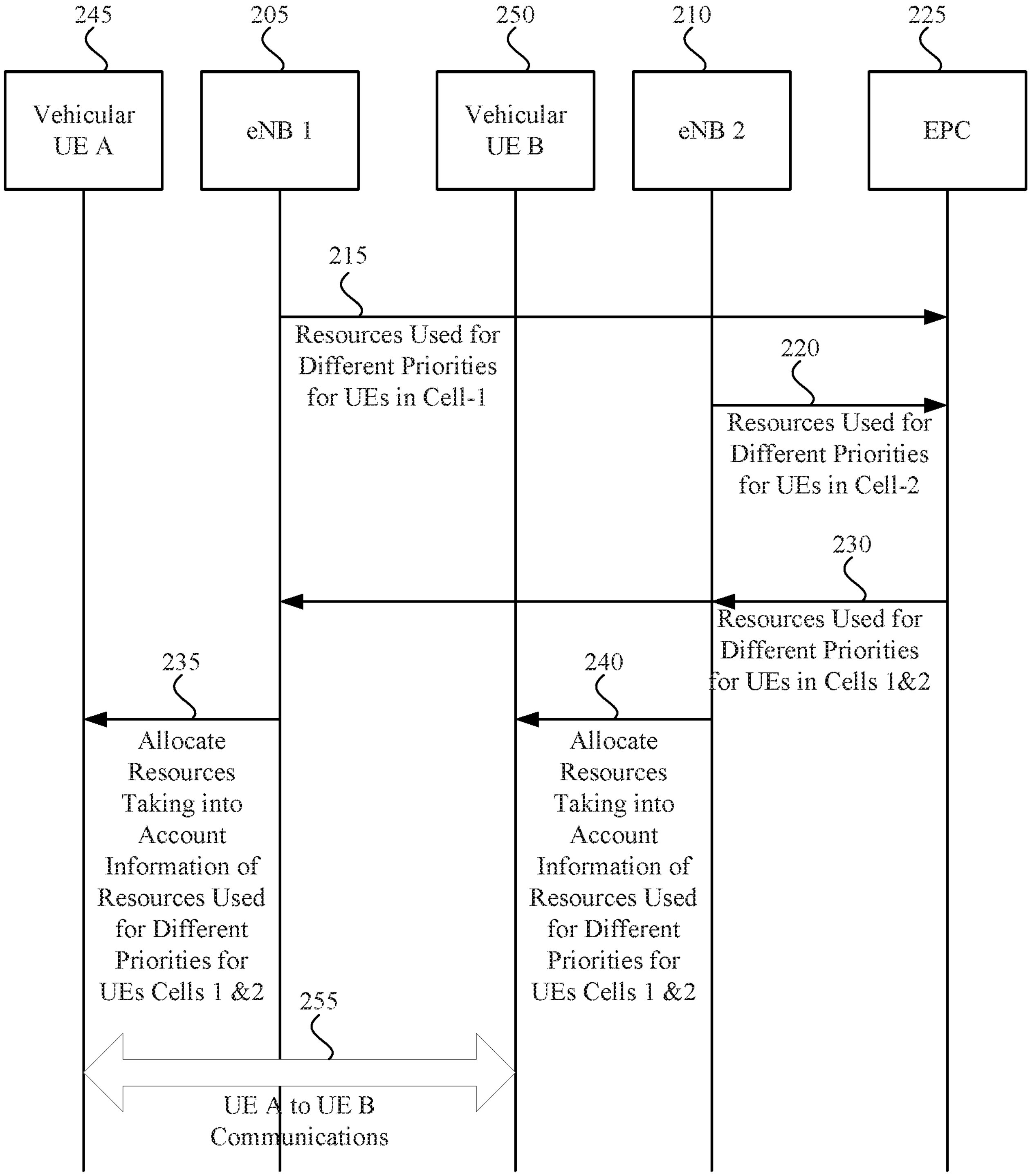
245
205
250
210
225
Vehicular UE A
eNB 1
Vehicular UE B
eNB 2
EPC
215
Resources Used for Different Priorities for UEs in Cell-1
220
Resources Used for Different Priorities for UEs in Cell-2
230
Resources Used for Different Priorities for UEs in Cells 1&2
235
Allocate Resources Taking into Account Information of Resources Used for Different Priorities for UEs Cells 1 &2
240
Allocate Resources Taking into Account Information of Resources Used for Different Priorities for UEs Cells 1 &2
255
UE A to UE B Communications

FIG. 2

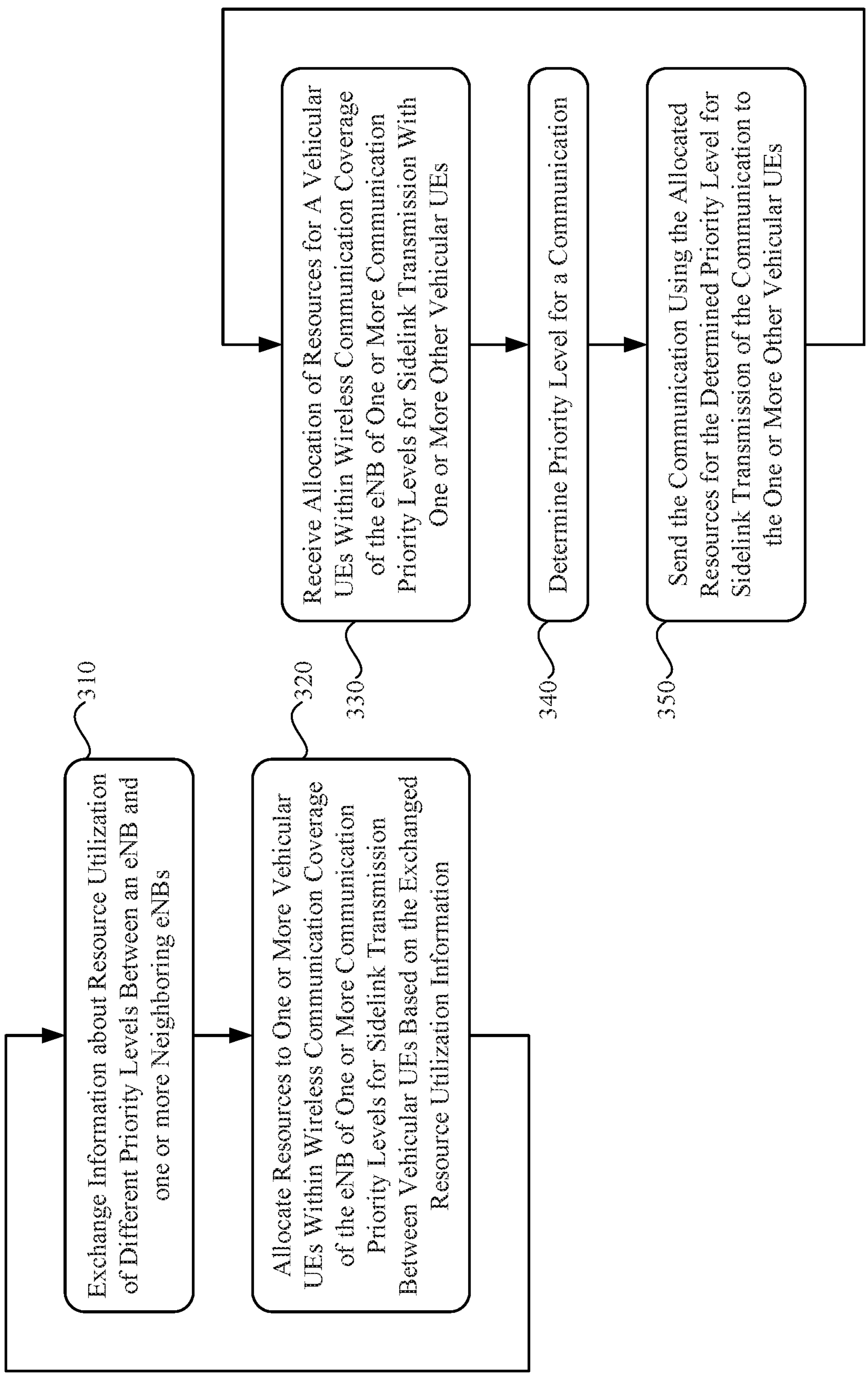
Exchange Information about Resource Utilization of Different Priority Levels Between an eNB and one or more Neighboring eNBs
310
Allocate Resources to One or More Vehicular UEs Within Wireless Communication Coverage of the eNB of One or More Communication Priority Levels for Sidelink Transmission Between Vehicular UEs Based on the Exchanged Resource Utilization Information
320
Receive Allocation of Resources for A Vehicular UEs Within Wireless Communication Coverage of the eNB of One or More Communication Priority Levels for Sidelink Transmission With One or More Other Vehicular UEs
330
Determine Priority Level for a Communication
340
Send the Communication Using the Allocated Resources for the Determined Priority Level for Sidelink Transmission of the Communication to the One or More Other Vehicular UEs
350

FIG. 3

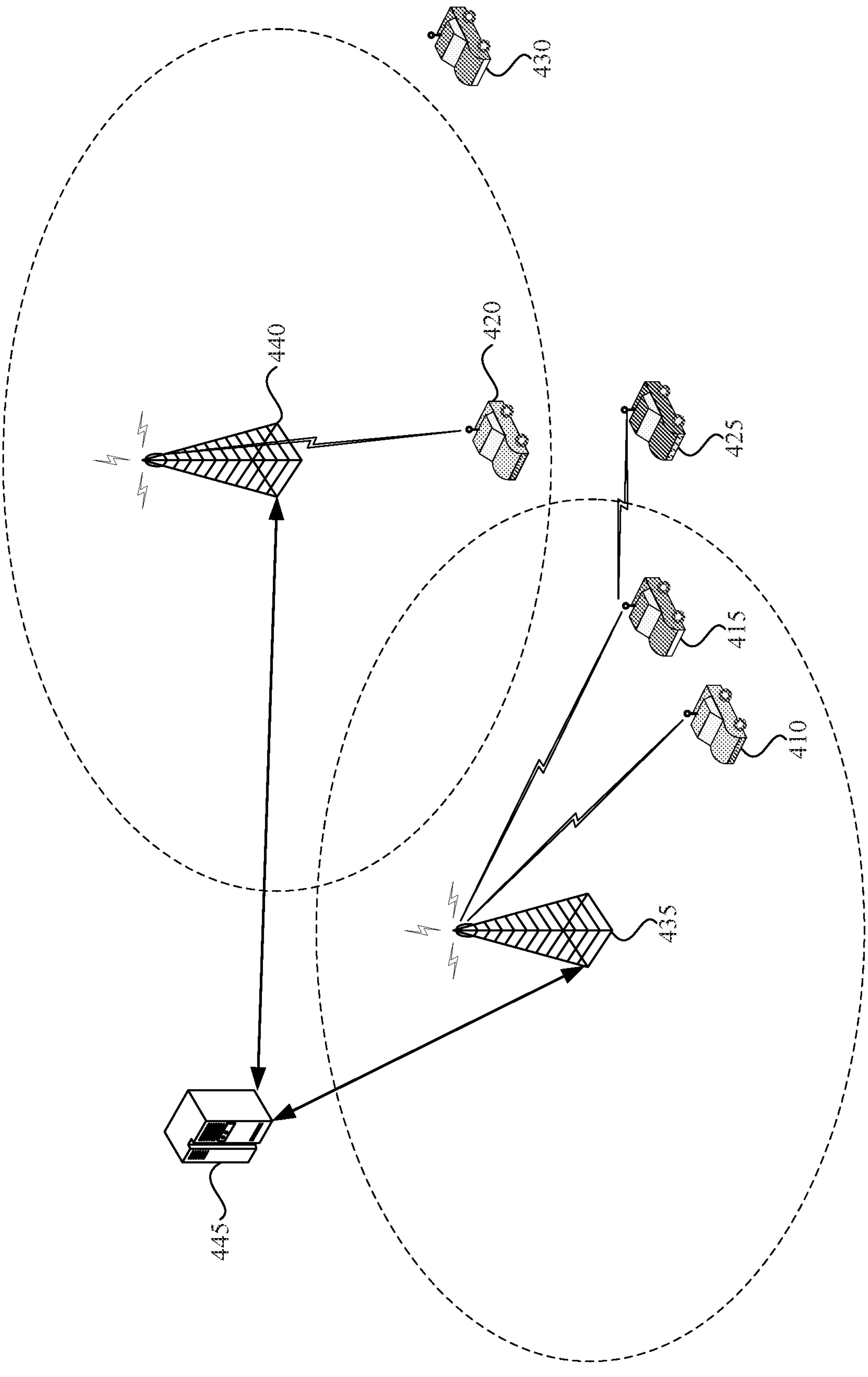

FIG. 4

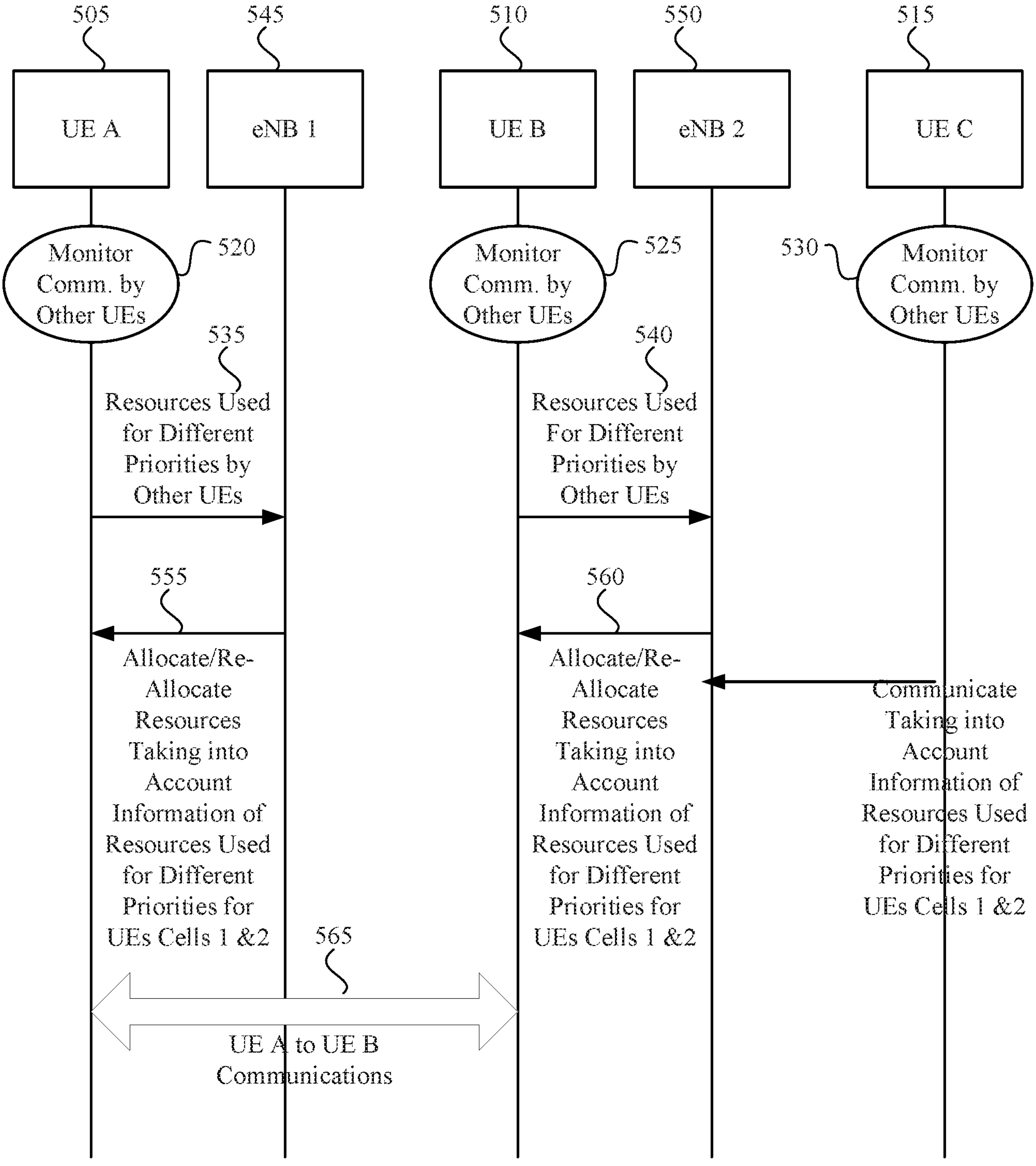
505
545
510
550
515
UE A
eNB 1
UE B
eNB 2
UE C
Monitor Comm. by Other UEs
520
Monitor Comm. by Other UEs
525
530
Monitor Comm. by Other UEs
535
Resources Used for Different Priorities by Other UEs
540
Resources Used For Different Priorities by Other UEs
555
Allocate/Re-Allocate Resources Taking into Account Information of Resources Used for Different Priorities for UEs Cells 1 &2
560
Allocate/Re-Allocate Resources Taking into Account Information of Resources Used for Different Priorities for UEs Cells 1 &2
Communicate Taking into Account Information of Resources Used for Different Priorities for UEs Cells 1 &2
565
UE A to UE B Communications

FIG. 5

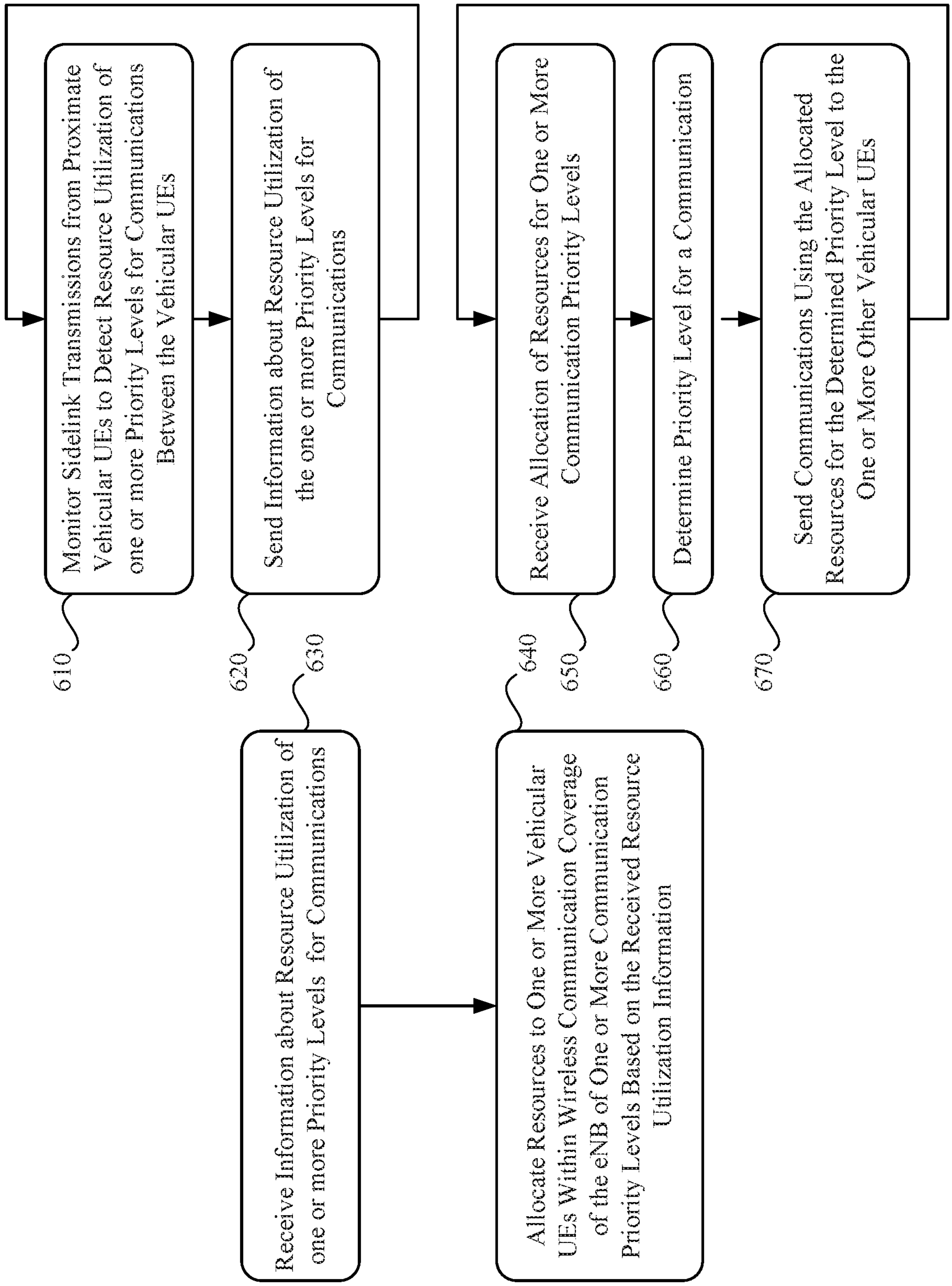
Monitor Sidelink Transmissions from Proximate Vehicular UEs to Detect Resource Utilization of one or more Priority Levels for Communications Between the Vehicular UEs
610
Send Information about Resource Utilization of the one or more Priority Levels for Communications
620
Receive Information about Resource Utilization of one or more Priority Levels for Communications
630
Allocate Resources to One or More Vehicular UEs Within Wireless Communication Coverage of the eNB of One or More Communication Priority Levels Based on the Received Resource Utilization Information
640
Receive Allocation of Resources for One or More Communication Priority Levels
650
Determine Priority Level for a Communication
660
Send Communications Using the Allocated Resources for the Determined Priority Level to the One or More Other Vehicular UEs
670

FIG. 6

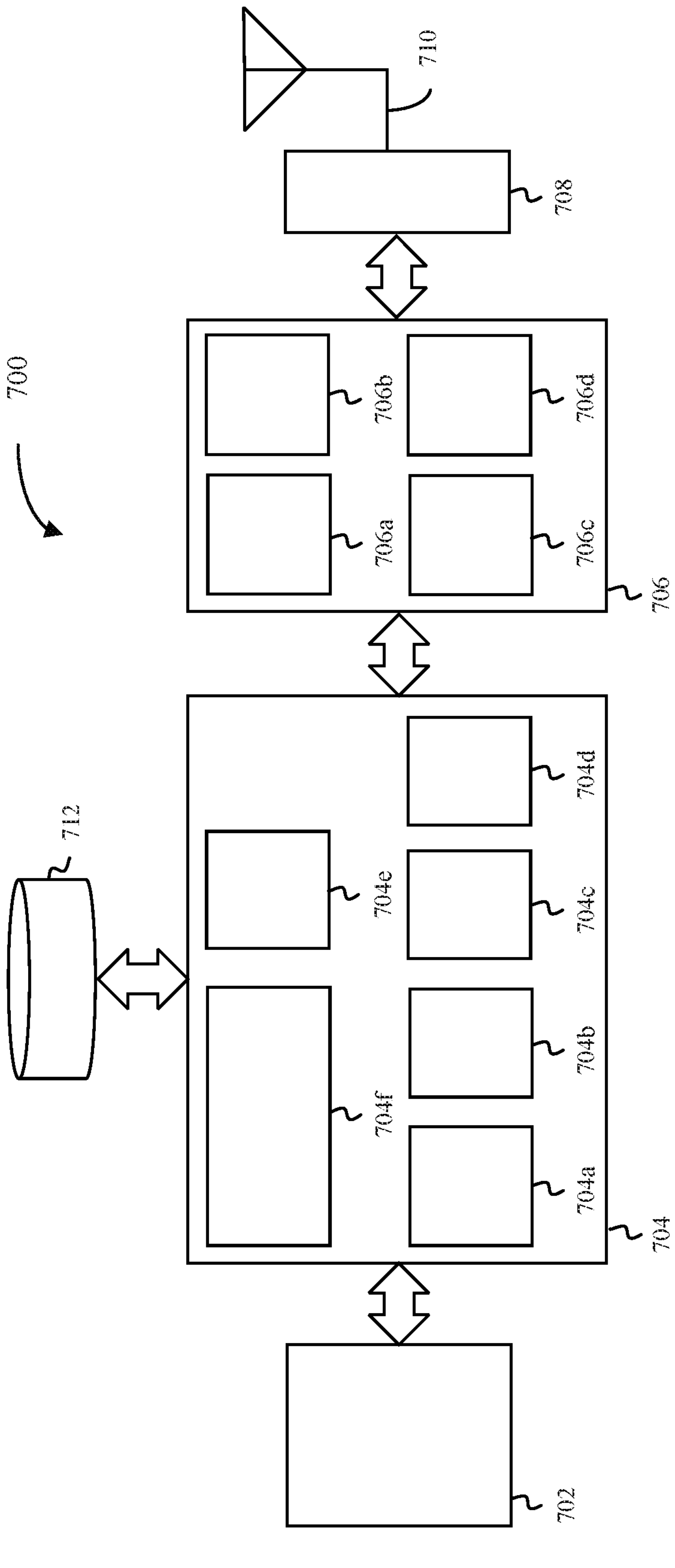
710
708
700
706b
706d
706a
706c
706
712
704e
704d
704c
704b
704f
704a
704
702

FIG. 7

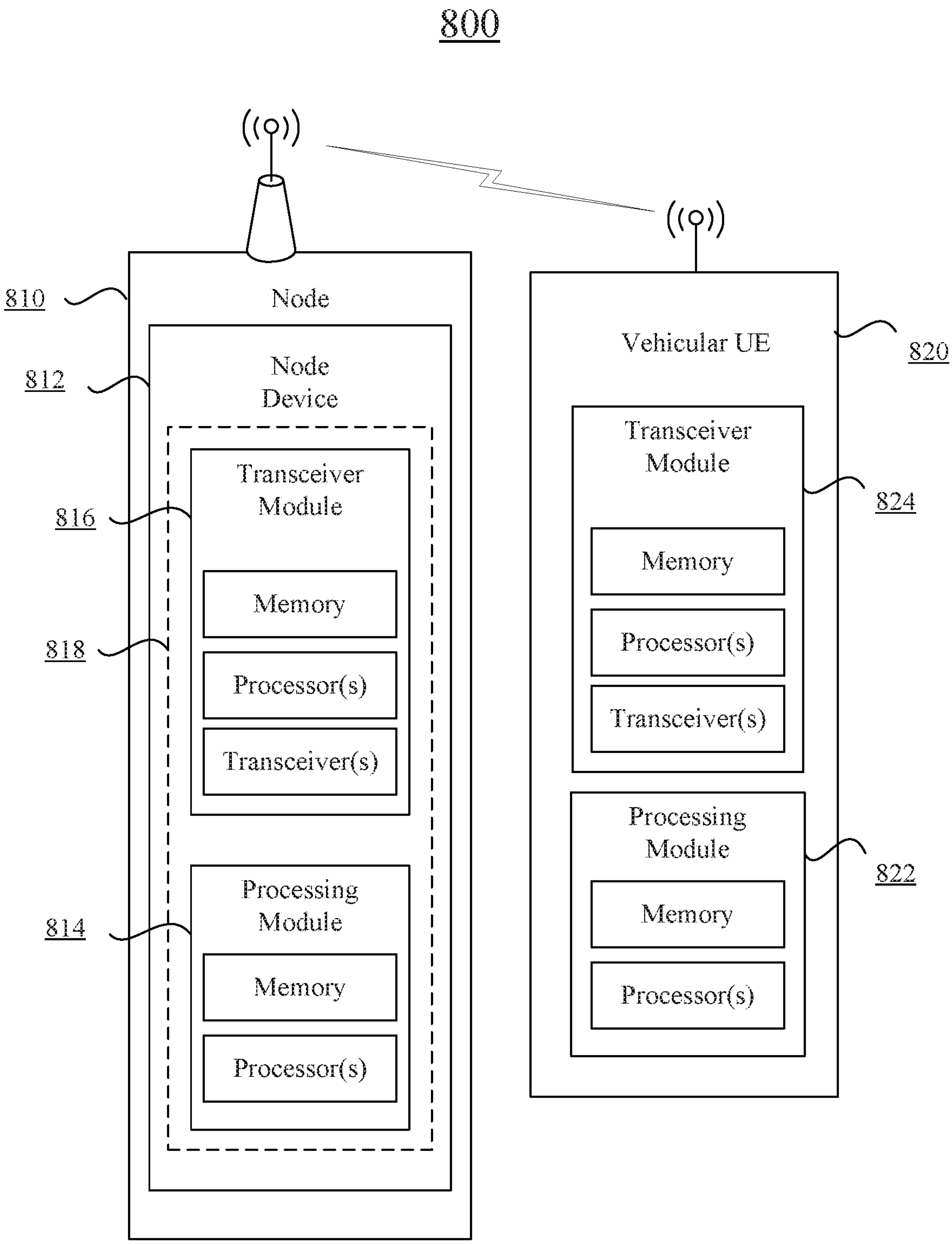
800
810
Node
812
Node
Device
816
Transceiver
Module
Memory
818
Processor(s)
Transceiver(s)
814
Processing
Module
Memory
Processor(s)
Vehicular UE
820
Transceiver
Module
824
Memory
Processor(s)
Transceiver(s)
Processing
Module
822
Memory
Processor(s)

FIG. 8

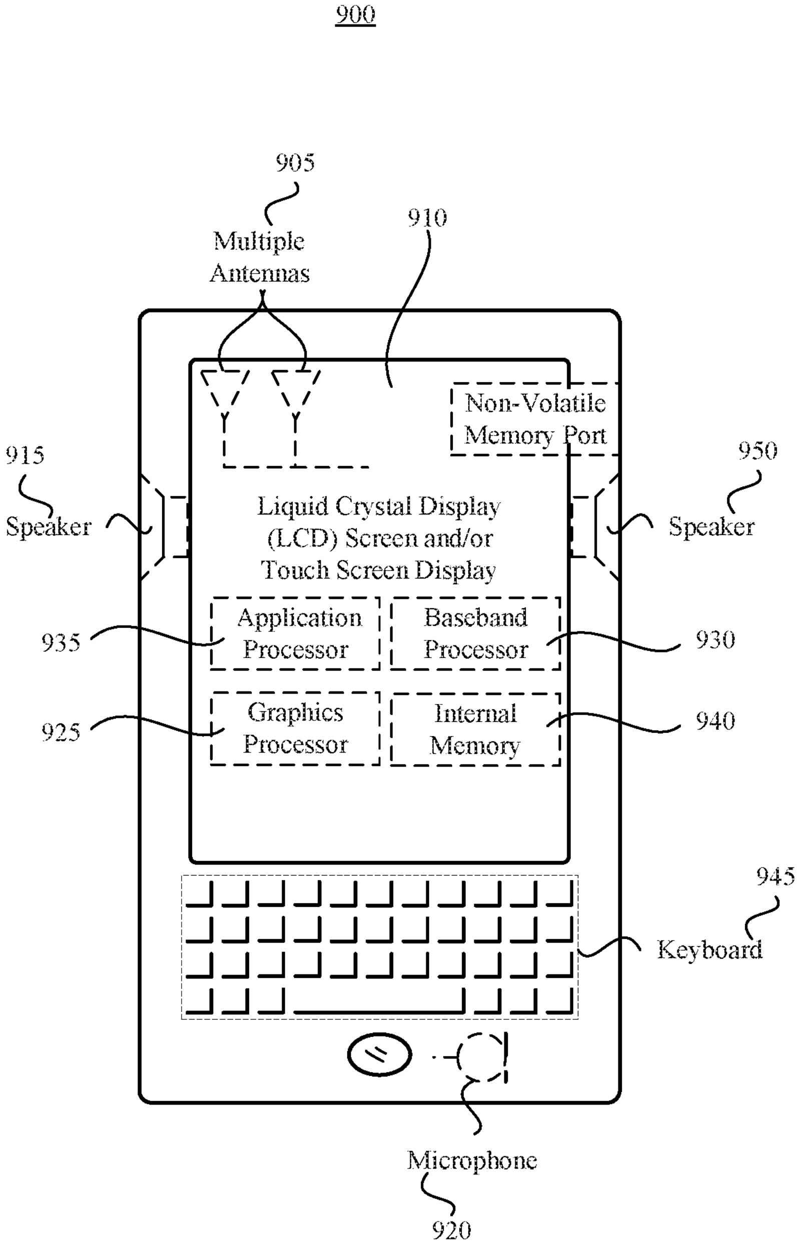
900
905
Multiple Antennas
910
Non-Volatile Memory Port
915
Speaker
950
Speaker
Liquid Crystal Display (LCD) Screen and/or Touch Screen Display
935
Application Processor
Baseband Processor
930
925
Graphics Processor
Internal Memory
940
945
Keyboard
Microphone
920

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/067610

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/04
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 A	WO 2015/096845 Al (HUAWEI TECHNOLOGIES DUESSELDORF GMBH [DE]) 2 July 2015 (2015-07-02) page 19, lines 28-30 page 21, lines 33-36 page 23, lines 21-36; figures 7, 10, 11, 12 page 24, lines 25-32 page 29, lines 7-35 ----- -/-	1-6 7-25

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2017	22/03/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stefan , Andrei

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/067610

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FUJITSU: "Prioritization-based resource allocation for sidelink-based V2V communication", 3GPP DRAFT; Rl-162393 FINAL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Busan, Korea; 20160411 - 20160415 1 April 2016 (2016-04-01), XP051079561, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WGl_RL1/TSGRl_84b/Docs/ [retrieved on 2016-04-01]	7-14, 22-25
Y	the whole document	15-21
A		1-6
Y	INTEL CORPORATION: "On Sensing Design Details for Sidelink V2V Communication", 3GPP DRAFT; Rl-162363 INTEL - V2V SENSING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Busan, Korea; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051080142, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WGl_RL1/TSGRl_84b/Docs/ [retrieved on 2016-04-02]	15-21
A	Section 1 "Introduction", Section 2.2 "Resource Allocation Configuration", Section 2.3 "Collision Avoidance Scheme"	1-14, 22-25
X	US 2009/161644 Al (SUZUKI YUSUKE [JP] ET AL) 25 June 2009 (2009-06-25)	22-25
A	paragraphs [0009], [0010], [0034] - [0037], [0059] - [0064]; figures 1, 11	1-21

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Form PCT/ISA/210 (continuation of second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CATT: "Considerations on V2V traffic priority and relative resource allocation", 3GPP DRAFT; Rl-162273, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Busan, Korea; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051080078, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WGl_RLl/TSGRl_84b/Docs/ [retrieved on 2016-04-02] the whole document -----	1-25

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/067610

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			US 2009161644	A1	25-06-2009