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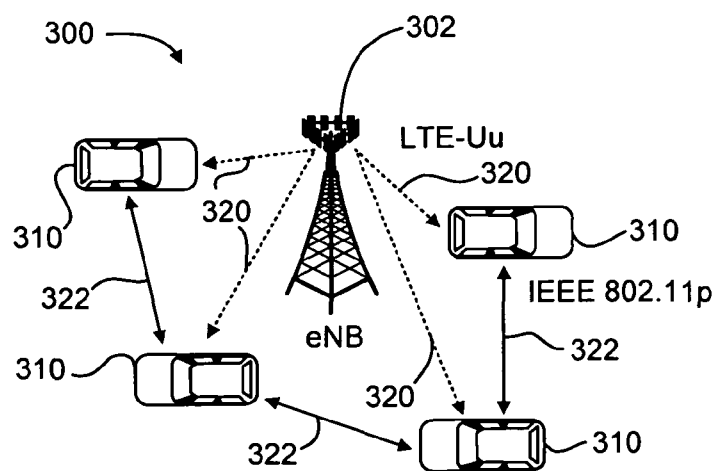
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LTE & Wi-Fi architecture for V2X services

FIG. 3

(57) Abstract: The present disclosure includes systems and methods that provide an alternative approach to providing V2X that is based on hybrid architecture that utilizes two or more radio access technologies (RATs). One described architecture is based on LTE and IEEE 802.11 (IEEE 802.11 p) technologies and allows seamless interworking between LTE and IEEE 802.11 terminals as well as at the network side, providing desired assistance information and ubiquitous connectivity to V2X services in different challenging scenarios. The systems and methods of the present disclosure can provide support for geo-casting based transmission and geo-specific V2X operation applied at different geo-location areas experiencing different radio congestion levels.

DUAL RADIO ARCHITECTURE AND METHODS FOR ENHANCED SUPPORT OF V2X SERVICE WITH NETWORK ASSISTANCE

Related Applications

[0001] This application is an international filing based on U.S. Provisional Patent Application No. 62/232,372, titled DUAL RADIO ARCHITECTURE AND METHODS FOR ENHANCED SUPPORT OF V2X SERVICE WITH NETWORK ASSISTANCE, filed September 24, 2015, which is hereby incorporated herein by reference in its entirety.

Technical Field

[0002] The present disclosure generally relates to vehicular communication services, such as vehicle-to-vehicle (V2V), vehicle-to-pedestrian (V2P), and vehicle-to-infrastructure (V2I), which are sometimes referred to individually and collectively as vehicle-to-everything or vehicular communication (V2X).

Brief Description of the Drawings

[0003] FIG. 1 illustrates a standalone long term evolution (LTE) architecture for providing V2X services.

[0004] FIG. 2 illustrates a standalone Institute of Electrical and Electronics Engineers (IEEE) 802.11p architecture for providing V2X services.

[0005] FIG. 3 illustrates a dual radio architecture, according to one embodiment of the present disclosure, for providing V2X services.

[0006] FIG. 4 illustrates a dual radio architecture, according to another embodiment of the present disclosure, for providing V2X services.

[0007] FIG. 5 illustrates a dual radio architecture, according to another embodiment of the present disclosure, for providing V2X services. The dual radio architecture provides geo-casting.

[0008] FIG. 6 is a block diagram illustrating electronic device circuitry, according to one embodiment

[0009] FIG. 7 is a flow diagram of a method of V2X over a wireless communication system, according to one embodiment.

[0010] FIG. 8 is a flow diagram of a method of V2X over a wireless communication system, according to another embodiment.

[0011] FIG. 9 is a block diagram illustrating, for one embodiment, example components of a user equipment (UE) device 900.

Detailed Description

[0012] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of the claimed invention. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the invention claimed may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

[0013] Wireless mobile communication technology enables communication of mobile user equipment devices, such as smartphones, tablet computing devices, laptop computers, and the like. Mobile communication technology may enable connectivity of various types of devices, supporting the "Internet of things." Vehicles are one example of mobile user equipment that may benefit from connectivity over wireless mobile communication technology.

[0014] Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and a wireless communication device. Wireless wide area network (WWAN) communication system standards and protocols can include, for example, the 3rd Generation Partnership Project (3GPP) long term evolution (LTE), and the IEEE 802.16 standard, which is commonly known to industry groups as worldwide interoperability for microwave access (WiMAX). Wireless local area network (WLAN) can include, for example, the IEEE 802.11 standard, which is commonly known to industry groups as Wi-Fi. Other WWAN and WLAN standards and protocols are also known.

[0015] In 3GPP radio access networks (RANs) in LTE systems, a base station may include Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node Bs (also commonly denoted as evolved Node Bs, enhanced Node Bs, eNodeBs, or eNBs) and/or Radio Network Controllers (RNCs) in an E-UTRAN, which communicate with a wireless communication device, known as user equipment (UE). In LTE networks, an E-UTRAN may include a plurality of eNBs and may communicate with a plurality of UEs. An evolved packet core (EPC) may communicatively couple the E-UTRAN to an external network, such as the Internet. LTE networks include radio access technologies (RATs) and core radio network architecture that can provide high data rate, low latency, packet optimization, and improved system capacity and coverage.

[0016] In homogeneous networks, a node, also called a macro node or macro cell, may provide basic wireless coverage to wireless devices in a cell. The cell may be the area in which the wireless devices can communicate with the macro node. Heterogeneous networks (HetNets) may be used to handle the increased traffic loads on the macro nodes due to increased usage and functionality of wireless devices. HetNets may include a layer of planned high power macro nodes (macro-eNBs or macro cells) overlaid with layers of lower power nodes (small cells, small-eNBs, micro-eNBs, pico-eNBs, femto-eNBs, or home eNBs (HeNBs)) that may be deployed in a less well-planned or even entirely uncoordinated manner within the coverage area (cell) of a macro node. The lower power nodes may generally be referred to as “small cells,” small nodes, or low power nodes. HetNets may also include various types of nodes utilizing varying types of RATs, such as LTE eNBs, 3G NodeBs, Wi-Fi APs, and WiMAX base stations.

[0017] As used herein, the terms “node” and “cell” are both intended to be synonymous and refer to a wireless transmission point operable to communicate with multiple wireless mobile devices, such as a UE, or another base station. Furthermore, cells or nodes may also be Wi-Fi access points (APs), or multi-radio cells with Wi-Fi/cellular or additional RATs. For example, nodes or cells may include various technologies such that cells operating on different RATs are integrated in one unified HetNet.

[0018] Vehicular communication (V2X) is a relatively new and rapidly emerging research and development area opening new market opportunities for wireless

communication systems. There is a quite diverse set of applications that can be enabled by Intelligent Transportation Systems (ITS), if wireless technologies are used for vehicular communication services, such as vehicle-to-vehicle (V2V); vehicle-to-pedestrian (V2P) (e.g., communication between a vehicle and a device carried by an individual, such as a pedestrian, cyclist, driver, or passenger); and vehicle-to-infrastructure (V2I) (e.g., communication between a vehicle and a road side unit (RSU), which is a transportation infrastructure entity, for example, an entity transmitting speed notifications), which are individually and collectively vehicle-to-everything (V2X). The range of applications varies from road safety and vehicular traffic management to applications enabling infotainment, the vision of a “connected car,” and “autonomous driving.” The various sets of applications and use cases are characterized by a very diverse set of communication requirements, which is challenging to satisfy using single wireless communication technology, since vehicular use cases include fundamentally different principles of operation. The broad range of vehicular communication requirements includes multiple technical challenges associated with the real-time packet delivery (latency), reliability of packet delivery, seamless connectivity and ubiquitous coverage. Beside these challenging system requirements, there are additional technical problems associated with the high Doppler, high mobility and operation in dense environments. All these factors demand a combination of different communication principles in order to enable efficient support of the diverse set of V2X services.

[0019] To date, a primary standard for physical layer (PHY) and media access control (MAC) communication between vehicles as well as between vehicles and infrastructure has been the IEEE 802.11p standard. The standardization work on this standard was completed in 2010 and includes multiple changes to address vehicular use cases. The standard is based on the IEEE 802.11a specification and operation principles supporting new ITS spectrum channelization and MAC enhancements to establish short connections and multi-channel operation. The standard was used as the main L1/L2 air-interface protocol for vehicular communication systems in multiple ITS standardization bodies worldwide (Europe, Japan, USA), enabling communication between vehicles as well as between infrastructure and vehicles.

[0020] The developed Wi-Fi technology naturally fits the ad-hoc nature of vehicular networks for inter-vehicular communication. The Wi-Fi technology fits the inter-vehicular communication demands. However, Wi-Fi is difficult to exploit for

connectivity due to limited infrastructure support (lack of worldwide deployment of Wi-Fi based road side units to provide connectivity with a network). This drawback may be naturally resolved by the cellular communication systems deployed worldwide.

[0021] Presently available cellular systems, however, do not traditionally support direct communication between terminals. Therefore, traditional cellular technologies may not be able to efficiently serve V2X applications. Also cellular systems may not be able to meet latency requirements, because communication goes through the network nodes, and may also have capacity issues due to centralized processing. These factors have prevented cellular technologies such as LTE to enter the V2X market.

[0022] Recently, in LTE Rel. 12, the support of sidelink air-interface (device-to-device communication technology) was integrated, which provides an opportunity for single LTE technology to serve different services. However, the time to market for such solutions may be relatively long given that the initial version of sidelink framework is not mature enough and many changes can be made in order to support V2X services. Moreover, there is a resistance to introduce sensing-based mechanisms to LTE based air-interface.

[0023] The present disclosure includes systems and methods that provide an alternative approach to providing V2X that is based on hybrid architecture that utilizes two or more radio access technologies (RATs). One described architecture is based on LTE and IEEE 802.11 (IEEE 802.11p) technologies and allows seamless interworking between LTE and IEEE 802.11 terminals as well as at the network side, providing desired assistance information and ubiquitous connectivity to V2X services in different challenging scenarios.

[0024] The disclosed embodiments may use the hybrid architecture relying on tight interworking of two technologies, such as IEEE 802.11p and LTE. Certain embodiments may use IEEE 802.11p as the main air-interface for communication among vehicles and road side units equipped with the IEEE 802.11p chipsets. In addition, the LTE air-interface can be used to address the seamless connectivity and networking issues of IEEE 802.11p based solutions. The disclosed dual technology approaches based on IEEE 802.11p and LTE can be enabled without additional investments from operators or from UE vendor manufacturers, given that these two technologies are already standardized and mature. For efficient support of V2X,

these two technologies may play different roles and complement each other benefiting the ecosystem of vehicular system/service providers.

[0025] FIG. 1 illustrates a standalone LTE architecture 100 for providing V2X services, which is not presently available in deployed LTE networks. One or more vehicles 110 would receive (and transmit) communications 120 with an eNB 102 via the LTE-Uu interface, with future enhancements. The vehicles 110 would also receive (and transmit) communications 130 with each other over an LTE interface (e.g., air-interface designed for device-to-device communication services (LTE-PC5) interface with additional enhancements to enable V2X services). Presently, LTE technology, such as in the architecture 100 of FIG. 1, may not efficiently support key V2X applications due to the lack of mature air-interface for direct communication between vehicles that can operate effectively in mobile environments and due to limitations of a fully centralized cellular architecture. In other words, the standalone LTE architecture 100 would have various shortcomings that may not be suitable to efficiently support V2X, unless further enhancements are introduced for demodulation, synchronization and resource allocation frameworks.

[0026] FIG. 2 illustrates a standalone IEEE 802.11p architecture 200 for providing V2X services. One or more vehicles 210 receive and transmit communications 222 over IEEE 802.11p with a road side unit 203 (WLAN access point). The vehicles 110 also transmit and receive communications 222 with each other over IEEE 802.11p. However, the standalone IEEE 802.11p based architectures 200 that are presently available have relatively low penetration to the vehicular market given a lack of network infrastructure to enable ubiquitous and seamless connectivity. Road side units are simply lacking from the existing infrastructure, which may limit many V2X services.

[0027] FIG. 3 illustrates a dual technology hybrid architecture 300, according to one embodiment of the present disclosure, for providing V2X services. The hybrid architecture 300 is a simple way to enable efficient support of V2X without significant additional industry efforts and investments across standardization bodies, vehicular ecosystems and network operators. One or more vehicles 310 would receive (and transmit) communications 320 with an eNB 302 via the LTE-Uu interface, with enhancements for V2X services for connectivity with infrastructure, such as described in the present disclosure. The vehicles 310 also transmit and receive

communications 322 with each other over IEEE 802.11p, whether legacy or enhanced for LTE network assistance, such as described in the present disclosure.

[0028] In FIG. 3, the vehicles 310 can be user equipment (UE) to operate in a wireless communication system. The vehicles 310 can include a first radio interface to communicate with a wireless wide area network (WWAN), such as with eNB 302 that is a node on an LTE network. The vehicles 310 can also include a second radio interface to communicate with a wireless local area network (WLAN). The vehicles 310 may form an ad-hoc WLAN (e.g., a V2X network) with each other using the second radio interface. The vehicles 310 may also link to other WLAN nodes such as a pedestrian device, and infrastructure device (e.g., a road side unit providing a WLAN access point), or other device. The vehicles 310 include one or more processing units to communicate over the WLAN with one or more other vehicles via the second radio interface. The vehicles 310 report to the eNB 302 (or other node) of the WWAN, via the first radio interface, at least one of WLAN measurements and WLAN connectivity. The eNB 302 can receive the WLAN measurements and/or provide connectivity to a network and utilize the information to determine V2X services that can be provided to facilitate or otherwise enhance V2X between the vehicles 310. The vehicles 310 receive one or more V2X services from the eNB 302 via the first radio interface. The vehicles 310 then communicate with the one or more other UEs over the WLAN, via the second radio interface, based on the one or more V2X services received.

[0029] The eNB 302 of FIG. 3 provides LTE wireless communications to UEs, such as the vehicles 310 and other devices, such as smartphones, tablet computing devices, and the like. The eNB 302 includes a transceiver (including receive circuitry and transmit circuitry) to wirelessly communicate with the vehicles 310. The eNB also includes one or more processing units to receive, from vehicles, WLAN information (e.g., WLAN measurements and WLAN connectivity). The eNB 302 also, by the one or more processors, determines one or more V2X services to support V2X among the vehicles 310 and then provides the one or more V2X services to the vehicles 310.

[0030] A primary technical benefit from joint utilization of an IEEE 802.11p and LTE air-interface for V2X services is to exploit the key technical advantages of each technology to improve V2X system performance.

[0031] The IEEE 802.11p V2X support of the present disclosure provides the benefits of the ad-hoc distributed communication architecture, reflected in lower latency and high packet reliability characteristics under low and medium system loadings. The IEEE 802.11p V2X support of the present disclosure also provides carrier sense multiple access with collision avoidance (CSMA-CA) mechanism based on listen before talk and backoff principles to efficiently and fairly utilize allocated spectrum resources and avoid collisions within a target communication range. The IEEE 802.11p V2X support of the present disclosure also provides permanent monitoring of medium activity and resource utilization. This information may be collected by vehicles and reported to the network in order to adjust operation settings or parameters to further benefit V2X quality of service. Examples of monitoring and information that may be collected include average amount of transmitters detected and average received power measured over pre-specified time intervals. The IEEE 802.11p V2X support of the present disclosure also resolves regulatory aspects because, compared to pure LTE based architectures, the IEEE 802.11p support in the dual radio architecture is an approved technology in ITS spectrum worldwide, while LTE V2X is yet to be developed and certified for this spectrum (e.g., dedicated short range communication (DSRC)). If LTE V2X is not in a DSRC channel, there will be more technical challenges, such as co-existence with infrastructure operation, that can be further considered.

[0032] The LTE (R.8-R.13) V2X support in a dual radio architecture of the present disclosure provides ubiquitous coverage and connectivity. LTE can provide seamless connectivity with the network when desired and with a controlled quality of service. The LTE V2X support of the present disclosure also provides network assistance information to improve performance of V2X services utilizing the IEEE 802.11p technology (e.g., see FIG. 4). The LTE V2X support also provides synchronization benefits, including availability of a common timing reference across a wide geographical area using a network timing reference or GNSS synchronization aligned with the network timing; a possibility to organize slotted resource allocation and divide spectrum resources on transmission time intervals of predefined duration; common and aligned functional time intervals for transmission of different information types (e.g., control information, data, etc.); and synchronized multi-channel operation across multiple bands (operation over multiple channels in 5.9 GHz band) using a common cellular reference carrier. The LTE V2X support also provides for collection

of measurement reports conducted by means of the IEEE 802.11p air-interface on V2V/V2I links including information relevant to medium utilization indicators (amount of active TXs, received power levels measured at predefined time intervals, or filtered over time, etc.).

[0033] The LTE V2X support in a dual radio architecture of the present disclosure also provides centralized control of the transmission parameters or IEEE 802.11p operation settings through LTE assistance information provided by the network at RAN or application layers to address congestion problems and enable cross-layer optimization for V2X support. Power control settings (e.g., TX power value), for instance, a reduced TX power, can be configured if a highly congested environment is detected on V2V links. A restriction on V2V L1 packet size and a reduction of the maximum V2X L1 packet size that can be used at a lower layer for single transmission can be provided. This restriction may be signaled to accommodate more transmissions from different vehicles under the constraints of the limited number of spectrum resources and high congestion level. In this case of a dual radio architecture, the compressed information may be transferred over the WLAN air-interface. Control of the V2V application layer parameters based on radio-environment (traffic generation rate) can be provided. Radio aware adjustment of the application layer parameters (e.g., packet size and periodicity) based on the information about radio propagation conditions provided by the network to the application layers can be provided. Adjustment of WLAN and RAN thresholds (RSSI/RSRP) to determine whether the V2V medium is busy or idle and trigger congestion control procedures, e.g., switching from/to cellular based V2V service, can be provided. Resource allocation and modulation-and-coding scheme (MCS) control can be provided. Information can be provided on a maximum resource the UE may use on the WLAN air-interface in order to accommodate more capacity in terms of transmissions from multiple vehicles. Alternatively, the network may control the MCS level to ensure a large communication range.

[0034] The LTE V2X support in a dual radio architecture of the present disclosure provides support for geo-casting based transmission and geo-specific V2X operation. Specifically, with the help of tight WLAN-LTE interworking, the network may collect and control the information about resource utilization in different geographical areas within a cell and control IEEE 802.11p transmission parameters or operation settings in order to provide enhanced performance and address

congestion and/or collision issues that may lead to unstable IEEE 802.11p performance in dense vehicle environments. The different parameters may be applied at different geo-location areas experiencing different radio congestion levels (see FIG. 5).

[0035] The LTE V2X support in a dual radio architecture of the present disclosure provides for tight LTE-WLAN interworking. Specifically, a dual radio architecture enables a possibility of tight interworking between LTE and IEEE 802.11p solutions similar to an LTE - IEEE 802.11 aggregation framework (LWA – LTE WLAN Aggregation), such as to be defined in LTE R. 13 specifications.

[0036] The techniques described herein may be applied across different layers of a V2X system, including L1/L2/L3 or application layers.

[0037] FIG. 4 illustrates a dual radio architecture 400, according to another embodiment of the present disclosure, for providing V2X services. The architecture 400 includes one or more eNBs 402, one or more road side units 403 (e.g., a WLAN access point included in transportation infrastructure), and a plurality of vehicles 410. One or more vehicles 410 receive and transmit communications 420 with the eNB 402 via the LTE-Uu interface (uplink and downlink). The vehicles 410 also transmit and receive communications 422 with each other over IEEE 802.11 (e.g., IEEE 802.11p), whether legacy or enhanced for LTE network assistance, to form a WLAN, such as described in the present disclosure. The vehicles 410 can also communicate with other computing devices, such as a pedestrian smart phone 411, over the WLAN. In FIG. 4, the vehicles 410 can be user equipment (UE) to operate in a wireless mobile communication system, such as an LTE network. More specifically, the vehicles 410 can include a first radio interface (e.g., a WWAN radio interface) to communicate with a wireless wide area network (WWAN), such as with an eNB 402 that is a node on the LTE network. The vehicles 410 can also include a second radio interface (e.g., a WLAN radio interface) to communicate with a wireless local area network (WLAN). The vehicles 410 can form an ad-hoc WLAN (e.g., a V2X network) with each other by linking using their second radio interfaces and on a dedicated spectrum used for intelligent transportation systems to enable V2X services. The vehicles 410 may also link to other WLAN nodes such as the pedestrian device 411, and infrastructure devices, such as the road side unit 403 providing a WLAN access point, or other IEEE 802.11 devices. The road side unit 403 may be in communication with the Internet, a node 402 of the WWAN, a V2X

services server 404, a proximity services (ProsSe) server, or other vehicle assistance. In certain embodiments, the vehicles 410 may register with a V2X services server 404 on the WWAN to authorize WLAN for V2X services.

[0038] The vehicles 410 report to one of the eNBs 402 (or other node) of the WWAN, via the first radio interface, at least one of WLAN measurements and WLAN connectivity. The WLAN measurements and/or connectivity may include congestions criteria and indicators, such as received signal strength indicator (RSSI) measurements over predefined time intervals, WLAN resource utilization metrics (e.g., percentage of time when received signal power exceeded predefined threshold over predefined period of time), and an average number of active transmitters detected in a given geographical region distinguished by medium access control (MAC) addresses or any other identities. The eNB 402 can receive the WLAN measurements and/or the WLAN connectivity and utilize the information to determine V2X services that can be provided to facilitate or otherwise enhance V2X between the vehicles 410. The vehicles 410 receive one or more vehicular communication (V2X) services from the eNB 402 via the first radio interface. The vehicles 410 then communicate with the one or more other UEs over the WLAN, via the second radio interface, based on the one or more V2X services received.

[0039] The eNB 402 of FIG. 4 provides LTE wireless communications to UEs, such as the vehicles 410 and other devices, such as smartphones, tablet computing devices, and the like. The eNB 402 includes a transceiver (including receive circuitry and transmit circuitry) to wirelessly communicate with the vehicles 410. The eNB 402 also includes one or more processing units to receive, from vehicles, WLAN information (e.g., WLAN measurements and WLAN connectivity). The eNB 402, also by the one or more processing units, determines one or more V2X services to support V2X among the vehicles 410 and then provides the one or more V2X services to the vehicles 410. In certain embodiments, the V2X services server 404 may receive the WLAN information and determine the V2X services to support V2X among the vehicles 410.

[0040] The V2X services determined by the eNB 402 and/or the V2X services server 404 include one or more of V2X assistance information and V2X operation settings. The V2X assistance information may include information to be used to provide synchronization and common timing reference for the WLAN. The V2X assistance information may include information to be used to provide a control

mechanism to reduce the WLAN congestion and collision. The V2X assistance information may include information to be used to provide V2X services that benefit from network access and wide area coverage. The V2X assistance information can include information to be used to offload V2X traffic from the WLAN to the WWAN.

[0041] The synchronization and common timing reference can include a common timing reference across a wide geographical area using network timing reference or global navigation satellite system (GNSS) synchronization aligned with the network timing. The synchronization and common timing reference can include an enhancement to resource allocation that divides spectrum resources on slotted time intervals for transmission of predefined duration. The synchronization and common timing reference can include an allocation of common and aligned functional time intervals for transmission of different information types (control commands, data, etc.). The synchronization and common timing reference can include synchronized multi-channel operation across multiple bands (operation over multiple channels in 5.9 GHz band) using a common cellular reference carrier.

[0042] The control mechanism to reduce the WLAN congestion and collision can include configuration of congestion criteria and indicators. The congestion criteria may be configured by the WWAN network and provided to the UE through the WWAN radio interface. The one or more congestion indicators for WLAN operation can include one or more of medium monitoring mechanisms, such as received signal strength indicator (RSSI) measurements over predefined time intervals, WLAN resource utilization metrics (e.g., percentage of time when received signal power exceeded predefined threshold over a predefined period of time, and an average number of active transmitters detected in a given geographical region distinguished by medium access control (MAC) addresses or any other identities.

[0043] The control mechanism to reduce the WLAN congestion and collision can also include WLAN measurements corresponding to one or more congestion indicators. The control mechanism to reduce the WLAN congestion and collision can include a congestion function. The control mechanism to reduce the WLAN congestion and collision can include congestion control commands. The congestion control commands are to be provided to the WLAN radio interface from the WWAN radio interface so that WLAN behavior and transmission settings can be adjusted. The congestion control commands can include power control setting commands to adjust transmission power value. The congestion control commands can include

commands setting V2X L1 packet size and/or transmission interval. The congestion control commands can include commands to control V2X application layer parameters based on radio conditions. The congestion control commands can include commands to adjust WLAN thresholds (e.g., received signal strength indicator (RSSI); reference signal received power (RSRP)) to determine whether the V2V medium is busy or idle and trigger congestion control procedures, e.g., switching from/to cellular based V2V service. The congestion control commands can include commands for resource allocation, including information on maximum resources the UE may use on the WLAN radio interface in order to accommodate more capacity in terms of transmissions from multiple UEs. The congestion control commands can include MCS control commands to vary MCS level and control communication range.

[0044] The V2X operation settings can include one or more of: power control; V2X L1 packet size; adjustment of resource allocation configuration; resource selection criteria; contention window settings and parameters affecting WLAN transmission behavior; V2X application layer settings to control V2X traffic parameters such as a message generation rate or payload content; data rate; power save mode; operating channel; latency; and reliability.

[0045] The dual radio architecture 400 of FIG. 4 enables V2X such that the vehicles 410 may communicate with each other (e.g., for purposes of autonomous driving) and with infrastructure (e.g., stoplights, toll booths, parking meters). These communications can improve safety. The architecture 400 also provides connectivity to online resources, such as infotainment, weather, traffic information, or navigation. The data available through V2X can enhance a driving experience and safety.

[0046] FIG. 5 illustrates a dual radio architecture 500, according to another embodiment of the present disclosure, for providing V2X services. The dual radio architecture provides geo-casting, so as to enhance performance in a given geographical area. For example, with the help of a tight WLAN-VWAN architecture, network (e.g., WLAN or V2X network) information may be collected relating to resource utilization in geographical areas within a cell. The network information can be used to control WLAN (e.g., IEEE 802.11p) transmission parameters or operation settings in order to enhance performance and/or address congestion/collision issues that may lead to unstable WLAN performance in dense vehicle environments.

Different parameters may be applied at different geographic location areas experiencing different radio congestion levels.

[0047] The architecture 500 includes a first eNB 502a and a second eNB 502b, both of which may be nodes in a WWAN such as an LTE network. The first eNB 502a and the second eNB 502b are in different geographic locations and are experiencing differing congestion environments. A traffic jam is occurring near the first eNB 502a and a relatively large number of vehicles 510 are present in this first geographic area. As can be appreciated, a larger quantity of V2X may be occurring in this first geographic area during the traffic jam as compared to when a traffic jam is not present. By comparison, a relatively sparse traffic pattern is occurring near the second eNB 502b and a relatively small number of vehicles 510 are present in this second geographic area, particularly relative to the first geographic area. As can be appreciated, fewer V2X may be occurring in this second geographic area, especially compared to the first geographic area.

[0048] The eNBs 502a, 502b (collectively 502) can receive WLAN information from the vehicles. A first WLAN transmission by vehicles 510 in the first geographic area and a second WLAN transmission by vehicles 510 in the second geographic area may experience different congestion levels. The first eNB 502a may detect from the network information a high degree of congestion and may provide V2X services, such as operation settings or control commands to adjust operation settings, to enhance WLAN performance and improve V2X in the first geographic area. For example, the first eNB 502a may communicate 520a a transmission power setting (or command to adjust the transmission power setting) to reduce the transmission power of the WLAN interfaces of the vehicles 510 in the first geographic area. The adjustment of the transmission power level may result in fewer collisions of V2X within the geographic area. The adjustment of the transmission power level may result in the range of transmission of each vehicle 510 being reduced, thereby reaching fewer other vehicles 510 and reducing the number of WLAN collisions.

[0049] The second eNB 502b may detect from the network information a low degree of congestion (sparse population) in the second geographic area and may provide V2X services, such as operation settings or control commands to adjust operation settings, to enhance WLAN performance and improve V2X in the second geographic area. For example, the second eNB 502b may communicate 520b a

transmission power setting (or command to adjust the transmission power setting) to increase the transmission power of the WLAN interfaces of the vehicles 510 in the second geographic area. The adjustment of the transmission power level may result in greater connectivity and improved V2X within the sparsely populated second geographic area. The adjustment of the transmission power level may result in the range of transmission of each vehicle 510 being increased, thereby reaching more vehicles 510 and increasing quality and efficiency of the WLAN.

[0050] As can be appreciated, other V2X services may be provided by geo-casting to set operation settings according to an environment in a geographic area. Examples of operation settings that may be adjusted to enhance a WLAN in a given geographic area include, but are not limited to: V2X L1 packet size; resource allocation configuration; resource selection criteria; contention window settings and parameters affecting WLAN transmission behavior; V2X application layer settings to control V2X traffic parameters such as a message generation rate or payload content; data rate; power save mode; operating channel; latency; and reliability level.

[0051] FIG. 6 is a block diagram illustrating electronic device circuitry 600 that may be eNB circuitry, UE circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments. In some embodiments, the electronic device circuitry 600 may be, or may be incorporated into or otherwise a part of, an eNB, a UE, a network node, or some other type of electronic device. In other embodiments, the electronic device circuitry 600 may include radio transmit circuitry 610 and receive circuitry 612 coupled to control circuitry 614. In yet other embodiments, the transmit circuitry 610 and/or receive circuitry 612 may be elements or modules of transceiver circuitry, as shown. The electronic device circuitry 600 may be coupled with one or more pluralities of antenna elements 616 of one or more antennas. The electronic device circuitry 600 may include or otherwise have access to one or more memory 618 or computer-readable storage media. The electronic device circuitry 600 and/or the components of the electronic device circuitry 600 may be configured to perform operations similar to those described elsewhere in this disclosure.

[0052] In embodiments where the electronic device circuitry 600 is or is incorporated into or otherwise part of a UE, the receive circuitry 612 may include WLAN receive circuitry 612a and WWAN receive circuitry 612b. The receive circuitry 612 may be able to receive, from a node of a WWAN, such as an evolved

NodeB (eNB) of a long term evolution (LTE) network, V2X services, which may include V2X assistance, and/or V2X operation settings. The control circuitry 614 may be able to configure the UE to communicate over a WWAN or a WLAN according to the V2X services received. The transmit circuitry 610 may include WLAN transmit circuitry 610a and WWAN transmit circuitry 610b. The transmit circuitry 610 may be able to transmit, to the eNB, over the WWAN, WLAN measurements and WLAN connectivity. The transmit circuitry 610 may also be able to transmit, to other UEs, over a WLAN, for V2X, according to the V2X services received.

[0053] In embodiments where the electronic device circuitry 600 is an eNB and/or a network node, or is incorporated into or is otherwise part of an eNB and/or a network node, the transmit circuitry 610 may be able to transmit V2X services to a carrier aggregation (CA) enabled UE of an LTE network. The receive circuitry 612 may be able to receive, from the UE, WLAN measurements and WLAN connectivity. The control circuitry 614 may be able to facilitate processing the received WLAN measurements and WLAN connectivity to determine appropriate V2X services to provide to the UE.

[0054] In certain embodiments, the electronic device circuitry 600 shown in FIG. 6 is operable to perform one or more methods, such as the methods shown in FIG. 7. FIG. 7 is a flowchart of a method 700 of V2X over a wireless communication system, according to one embodiment. The method 700 may be performed by a UE, such as a vehicle, and includes communicating 710 over a WLAN with one or more other vehicles via a WLAN radio interface; reporting 712 to a node of a WWAN, via a WWAN radio interface, at least one of WLAN measurements and WLAN connectivity; receiving 714 one or more V2X services from the WWAN via the WWAN radio interface; and communicating 716 with the one or more other vehicles over the WLAN, via the WLAN radio interface, based on the one or more V2X services received.

[0055] In certain embodiments, the electronic device circuitry 600 shown in FIG. 6 is operable to perform one or more methods, such as the methods shown in FIG. 8. FIG. 8 is a flowchart of a method 800 of V2X over a wireless communication system, according to another embodiment. The method 800 may be performed by one or more network nodes, such as an eNB. The method 800 includes receiving 810, via receive circuitry of a transceiver, vehicular communication (V2X) network information

from a plurality of vehicles linked over a WLAN forming a V2X network; determining 812 one or more V2X services to support V2X among the plurality of vehicles over the V2X network; and providing 814 to the plurality of vehicles, via the transmit circuitry, the one or more V2X services to enhance V2X of the plurality of vehicles over the V2X network.

[0056] As used herein, the term “circuitry” may 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 embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0057] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 9 is a block diagram illustrating, for one embodiment, example components of a user equipment (UE) device 900. In some embodiments, the UE device 900 may include application circuitry 902, baseband circuitry 904, Radio Frequency (RF) circuitry 906, front-end module (FEM) circuitry 908, and one or more antennas 910, coupled together at least as shown in FIG. 9.

[0058] The application circuitry 902 may include one or more application processors. By way of non-limiting example, the application circuitry 902 may include one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processor(s) may be operably coupled and/or include memory/storage, and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0059] By way of non-limiting example, the baseband circuitry 904 may include one or more single-core or multi-core processors. The baseband circuitry 904 may include one or more baseband processors and/or control logic. The baseband circuitry 904 may be configured to process baseband signals received from a receive signal path of the RF circuitry 906. The baseband 904 may also be configured to

generate baseband signals for a transmit signal path of the RF circuitry 906. The baseband processing circuitry 904 may interface with the application circuitry 902 for generation and processing of the baseband signals, and for controlling operations of the RF circuitry 906.

[0060] By way of non-limiting example, the baseband circuitry 904 may include at least one of a second generation (2G) baseband processor 904A, a third generation (3G) baseband processor 904B, a fourth generation (4G) baseband processor 904C, a WLAN baseband processor 904D, other baseband processor(s) 904E for other existing generations, and generations in development or to be developed in the future (e.g., fifth generation (5G), sixth generation (6G), etc.). The baseband circuitry 904 (e.g., at least one of baseband processors 904A-904E) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 906. By way of non-limiting example, the radio control functions may include signal modulation/demodulation, encoding/decoding, radio frequency shifting, other functions, and combinations thereof. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 904 may be programmed to perform Fast-Fourier Transform (FFT), precoding, constellation mapping/demapping functions, other functions, and combinations thereof. In some embodiments, encoding/decoding circuitry of the baseband circuitry 904 may be programmed to perform convolutions, tail-biting convolutions, turbo, Viterbi, Low Density Parity Check (LDPC) encoder/decoder functions, other functions, and combinations thereof. Embodiments of modulation/demodulation and encoder/decoder functions are not limited to these examples, and may include other suitable functions.

[0061] In some embodiments, the baseband circuitry 904 may include elements of a protocol stack. By way of non-limiting example, elements of an evolved universal terrestrial radio access network (E-UTRAN) 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) 904F of the baseband circuitry 904 may be programmed to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry 904 may include one or more audio digital signal processor(s) (DSP) 904G. The audio DSP(s) 904G may include elements for compression/decompression and echo

cancellation. The audio DSP(s) 904G may also include other suitable processing elements.

[0062] The baseband circuitry 904 may further include memory/storage 904H. The memory/storage 904H may include data and/or instructions for operations performed by the processors of the baseband circuitry 904 stored thereon. In some embodiments, the memory/storage 904H may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 904H may also include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. In some embodiments, the memory/storage 904H may be shared among the various processors or dedicated to particular processors.

[0063] Components of the baseband circuitry 904 may be suitably combined in a single chip or a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 904 and the application circuitry 902 may be implemented together, such as, for example, on a system on a chip (SOC).

[0064] In some embodiments, the baseband circuitry 904 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 904 may support communication with an E-UTRAN and/or other wireless metropolitan area networks (WMAN), a WLAN, or a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 904 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0065] The RF circuitry 906 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 906 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. The RF circuitry 906 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 908, and provide baseband signals to the baseband circuitry 904. The RF circuitry 906 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 904, and provide RF output signals to the FEM circuitry 908 for transmission.

[0066] In some embodiments, the RF circuitry 906 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 906 may include mixer circuitry 906A, amplifier circuitry 906B, and filter circuitry 906C. The transmit signal path of the RF circuitry 906 may include filter circuitry 906C and mixer circuitry 906A. The RF circuitry 906 may further include synthesizer circuitry 906D configured to synthesize a frequency for use by the mixer circuitry 906A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 906A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 908 based on the synthesized frequency provided by synthesizer circuitry 906D. The amplifier circuitry 906B may be configured to amplify the down-converted signals.

[0067] The filter circuitry 906C may include 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 may be provided to the baseband circuitry 904 for further processing. In some embodiments, the output baseband signals may include zero-frequency baseband signals, although this is not a requirement. In some embodiments, the mixer circuitry 906A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0068] In some embodiments, the mixer circuitry 906A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 906D to generate RF output signals for the FEM circuitry 908. The baseband signals may be provided by the baseband circuitry 904 and may be filtered by filter circuitry 906C. The filter circuitry 906C may include an LPF, although the scope of the embodiments is not limited in this respect.

[0069] In some embodiments, the mixer circuitry 906A of the receive signal path and the mixer circuitry 906A of the transmit signal path may include two or more mixers, and may be arranged for quadrature down-conversion and/or up-conversion, respectively. In some embodiments, the mixer circuitry 906A of the receive signal path and the mixer circuitry 906A of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 906A of the receive signal path and the mixer circuitry 906A of the transmit signal path may be arranged for direct down-conversion and/or direct up-conversion, respectively. In some embodiments, the

mixer circuitry 906A of the receive signal path and the mixer circuitry 906A of the transmit signal path may be configured for super-heterodyne operation.

[0070] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In such embodiments, the RF circuitry 906 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 904 may include a digital baseband interface to communicate with the RF circuitry 906.

[0071] In some dual-mode embodiments, separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0072] In some embodiments, the synthesizer circuitry 906D may include one or more of a fractional-N synthesizer and a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 906D may include a delta-sigma synthesizer, a frequency multiplier, a synthesizer comprising a phase-locked loop with a frequency divider, other synthesizers and combinations thereof.

[0073] The synthesizer circuitry 906D may be configured to synthesize an output frequency for use by the mixer circuitry 906A of the RF circuitry 906 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 906D may be a fractional $N/N+1$ synthesizer.

[0074] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO). Divider control input may be provided by either the baseband circuitry 904 or the applications processor 902 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 902.

[0075] The synthesizer circuitry 906D of the RF circuitry 906 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may include a dual modulus divider (DMD), and the phase accumulator may include a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based

on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In such embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL may provide negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0076] In some embodiments, the synthesizer circuitry 906D may be configured to generate a carrier frequency as the output frequency. In some embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency, etc.) and used in conjunction with a 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 may be a LO frequency (f_{LO}). In some embodiments, the RF circuitry 906 may include an IQ/polar converter.

[0077] The FEM circuitry 908 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 910, amplify the received signals, and provide the amplified versions of the received signals to the RF circuitry 906 for further processing. The FEM circuitry 908 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 906 for transmission by at least one of the one or more antennas 910.

[0078] In some embodiments, the FEM circuitry 908 may include a TX/RX switch configured to switch between a transmit mode and a receive mode operation. The FEM circuitry 908 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 908 may 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 906). The transmit signal path of the FEM circuitry 908 may include a power amplifier (PA) configured to amplify input RF signals (e.g., provided by RF circuitry 906), and one or more filters configured to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 910).

[0079] In some embodiments, the UE device 900 may include additional elements such as, for example, memory/storage, a display, a camera, one or more sensors, an input/output (I/O) interface, other elements, and combinations thereof.

[0080] In some embodiments, the UE device 900 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

[0081] Examples

[0082] The following examples pertain to further embodiments.

[0083] Example 1 is a user equipment (UE) to operate in a wireless communication system. The UE includes a first radio interface to communicate with a wireless wide area network (WWAN), a second radio interface to communicate with a wireless local area network (WLAN), and one or more processing units. The processing units communicate over a WLAN with one or more other UEs via the second radio interface, report to a node of the WWAN, via the first radio interface, at least one of WLAN measurements and WLAN connectivity, receive one or more vehicular communication (V2X) services from the WWAN via the first radio interface, and communicate with one or more UEs over the WLAN, via the second radio interface, based on one or more V2X services received.

[0084] Example 2 includes the UE of Example 1, where one or more processing units register with a V2X service server on the WWAN to authorize WLAN for V2X services.

[0085] Example 3 includes the UE of any of Examples 1-2, where the UE contains a vehicle and second radio interface to be used for wireless communication on the WLAN with other vehicles on a dedicated spectrum used for intelligent transportation systems to enable V2X services.

[0086] Example 4 includes the UE of Example 3, where the second radio interface is further to be used for wireless communication on the WLAN with road side units, that comprise WLAN air-interface and in addition may have WMAN air-interface for communication with network.

[0087] Example 5 includes the UE of any of Examples 1-4, where the first radio interface contains a long term evolution (LTE) radio interface and the WWAN comprises an LTE network.

[0088] Example 6 includes the UE of any of Examples 1-5, where one or more V2X services are received via the first radio interface from a V2X server of the WWAN providing one or more V2X services.

[0089] Example 7 includes the UE of any of Examples 1-6, where the second radio interface operates based on an Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard to communicate with the WLAN providing V2X services.

[0090] Example 8 includes the UE of Example 7, where the WLAN comprises a Wi-Fi network.

[0091] Example 9 includes the UE of any of Examples 1-8, where one or more of the V2X services include one or more of V2X assistance information and V2X operation settings.

[0092] Example 10 includes the UE of Example 9, where the V2X assistance information contains information to be used to provide a synchronization and common timing reference for the WLAN, a control mechanism to reduce the WLAN congestion and collision, and V2X services that benefit network access and wide area coverage.

[0093] Example 11 includes the UE of Example 10, where the synchronization and common timing reference for the second radio interface contains a common timing reference across a wide geographical area using network timing reference or global navigation satellite system (GNSS) synchronization aligned with the network timing, an enhancement to resource allocation that divides spectrum resources on slotted time intervals for transmission of predefined duration, an allocation of common and aligned functional time intervals for transmission of different information types (V2X control commands, V2X service data, etc.), and a synchronized multi-channel operation across multiple bands (e.g., operation over multiple channels in 5.9 GHz band) using common cellular reference carrier.

[0094] Example 12 includes the UE of Example 10, where the control mechanism to reduce the WLAN congestion and collision contain a configuration of congestion criteria and indicators, WLAN measurements corresponding to one or more congestion indicators, a congestion function, and congestion control commands.

[0095] Example 13 includes the UE of Example 12, where the congestion criteria are configured by the WWAN network and provided to the UE through the WWAN radio interface.

[0096] Example 14 includes the UE of Example 12, where one or more congestion indicators for WLAN operation include one or more medium monitoring mechanisms. These medium monitoring mechanisms contain signal strength indicator (RSSI) measurements over predefined time intervals, WLAN resource utilization metric (e.g. percentage of time when received signal power exceeded predefined threshold over predefined period of time, and the average number of active transmitters detected in a given geographical region distinguished by medium access control (MAC) addresses or any other identities.

[0097] Example 15 includes the UE of Example 12, where one or more processing units also collect the WLAN measurements to report to the network entity over the WWAN radio interface to evaluate the congestion function and generate congestion control commands either at the radio resource control (RRC) layer, application layer, or other layers.

[0100] Example 16 includes the UE of any of Examples 1-15, where one or more processing units also collect the WLAN measurements to report to the WWAN network entity providing V2X services.

[0101] Example 17 includes the UE of Example 12, where the congestion control commands are provided to WLAN radio interface from the WWAN radio interface so that WLAN behavior and transmission settings can be adjusted, where the congestion control commands include one or more power control setting commands to adjust transmission power value, commands setting V2X L1 packet size or transmission interval, commands to control V2X application layer parameters based on radio conditions, commands to adjust WLAN thresholds (e.g., received signal strength indicator (RSSI), reference signal received power (RSRP)) to determine whether the V2V medium is busy or idle and trigger congestion control procedures, e.g. switching from/to cellular based V2V service, commands for resource allocation, including information on maximum resource the UE may use on WLAN radio interface in order to accommodate more capacity in terms of transmissions from multiple UEs, and MCS control commands to vary MCS level and control communication range.

[0102] Example 18 includes the UE of Example 9, where the V2X assistance information includes information to be used to offload V2X traffic from the WLAN to the WWAN.

[0103] Example 19 includes the UE of Example 9, where the V2X operation settings include one or more power controls, a V2X L1 packet size, adjustment of resource allocation configuration, resource selection criteria, contention window settings and parameters affecting WLAN transmission behavior, V2X application layer settings to control V2X traffic parameters comprising: message generation rate, payload content, data rate, power saving mode, operating channel, latency, and reliability.

[0104] Example 20 includes the UE of any of Examples 1-19, where one or more processing units also communicate over the WLAN with an access point in communication with the Internet.

[0105] Example 21 includes the UE of Example 20, where the WLAN access point is in communication with the node of the WWAN.

[0106] Example 22 includes the UE of Example 1, where tight interworking of WLAN and WWAN technologies for the benefits of V2X services include offloading V2X traffic from WLAN to WWAN and vice versa.

[0107] Example 23 includes the UE of any of Examples 1-22, together with radio frequency (RF) circuitry to implement one or more of the WLAN and WWAN radio interfaces, and baseband circuitry coupled with the RF circuitry.

[0108] Example 24 includes the UE of any of Examples 1-23, together with an electronic device containing radio frequency (RF) circuitry that includes the WLAN radio interface and the WWAN radio interface, and baseband circuitry paired with the RF circuitry which facilitates transmission of one or more V2X signals to another electronic device by way of the WLAN radio interface.

[0109] Example 25 includes the UE of any of Examples 1-24, where one or more processing units also form the ad-hoc WLAN utilizing proximity services (ProSe) according to a long term evolution (LTE) standard.

[0110] Example 26 includes the UE of any of Examples 1-25, where one or more processors also form the ad-hoc WLAN utilizing V2X services according to a long term evolution (LTE) standard.

[0111] Example 27 includes the UE of any of Examples 1-26, where one or more processing units also form an ad-hoc WLAN with one or more other UEs using proximity services (ProSe).

[0112] Example 28 in an eNodeB for providing wireless communication user equipments (UEs). The eNodeB includes a transceiver, and one or more processing

units. The transceiver receives and transmits circuitry, to wirelessly communicate with a variety of vehicles linked to the eNodeB. The processing units receive from the vehicles, via the receive circuitry, vehicular communication network information, determine one or more vehicular communication services to support vehicular communication among the vehicles, and provide to vehicles, via the transmit circuitry, one or more vehicular communication services; provide geo-specific V2X service or control of V2X service operation by means of geo based transmission to optimize V2X performance characteristics in specific geographical areas, including V2V communication range, congestion level, amount of spectrum resources, capacity or reliability of V2X service.

[0113] Example 29 includes the eNodeB of Example 28, where the variety of vehicles each contain a wireless local area network (WLAN) radio interface to link in an ad-hoc vehicular communication WLAN, and where the vehicular communication network information contains information about a stats of the ad-hoc vehicular communication WLAN.

[0114] Example 30 includes the eNodeB of Example 28, where the vehicular communication network information contains at least one WLAN measurement and WLAN connectivity of the vehicular communication network.

[0115] Example 31 includes the eNodeB of Example 28, where one or more vehicular communication services include one or more of V2X assistance information and V2X operation settings.

[0116] Example 32 includes the eNodeB of Example 31, where the V2X assistance information includes information to be used to provide one or more synchronization and common timing references for the WLAN, a control mechanism to reduce the WLAN congestion and collision, and V2X services that benefit from network access and wide area coverage.

[0117] Example 33 includes the eNodeB of Example 32, where the synchronization and common timing reference for WLAN radio interface contains one or more common timing reference across a wide geographical area using network timing reference or global navigation satellite system (GNSS) synchronization aligned with the network timing, an enhancement to resource allocation by dividing spectrum resources on slotted time intervals for transmission of predefined duration, an allocation of common and aligned functional time intervals for transmission of different information types (control commands, data, etc.), and

synchronized multi-channel operation across multiple bands (operation over multiple channels in 5.9 GHz band) using common cellular reference carrier.

[0118] Example 34 includes the eNodeB of Example 32, where the control mechanism to reduce the WLAN congestion and collision contain one or more congestion criteria, WLAN measurements of one or more congestion indicators, congestion function, and congestion control commands.

[0119] Example 35 includes the eNodeB of Example 31, where the V2X assistance information includes information to be used by the vehicle to offload V2X traffic from WLAN to the WWAN.

[0120] Example 36 is a computer-implemented method of vehicular communication (V2X) over a wireless communication system. The method includes communicating over a wireless local area network (WLAN) with one or more other vehicles via a WLAN radio interface, reporting to a node of a WWAN, via a WWAN radio interface, at least one WLAN measurement and WLAN connectivity, receiving one or more V2X services from the WWAN via the WWAN radio interface, and communicating with one or more other vehicles over the WLAN, via the WLAN radio interface, based on one or more V2X services received.

[0121] Example 37 includes the method of Example 36, together with the method to register with a V2X services server on the WWAN which authorizes WLAN for V2X services.

[0122] Example 38 includes the method of Example 36, where the WLAN radio interface is also used for wireless communication on the WLAN with road side units that comprise WLAN air-interface and in addition may have WMAN air-interface for communication with network.

[0123] Example 39 is a vehicular communication services (V2X) node of a wireless wide area network (WWAN), containing one or more processing units and a computer-readable storage medium with instructions that, when executed by one or processors, cause the apparatus to perform the method of any of Examples 36-38.

[0124] Example 40 is a computer-implemented method of vehicular communication over a wireless communication system. The process receives at a node of a wireless wide area network (WWAN), via receive circuitry of a transceiver, vehicular communication (V2X) network information from a variety of vehicles linked over a wireless local area network (WLAN) forming the V2X network. It then determines one or more V2X services to support V2X among the variety of vehicles

over the V2X network, and provides to the vehicles, via the transmit circuitry, one or more V2X services to enhance V2X the vehicles over the V2X network.

[0125] Example 41 includes the method of Example 40, where one or more V2X services include one or more of V2X assistance information and V2X operation settings.

[0126] Example 42 includes the method of any of Examples 40-41, and also providing proximity services (ProSe) to assist the variety of vehicles in forming an ad-hoc WLAN as part of the V2X network.

[0127] Example 43 includes the method of Examples 40-42, where the V2X network includes a pedestrian device and the V2X network information received includes information concerning connectivity of the plurality of vehicles to the pedestrian device.

[0128] Example 44 includes the method of Examples 40-43, where the V2X network includes a road side infrastructure device and the V2X network information received includes information concerning connectivity of the plurality of vehicles to the road side infrastructure device.

[0129] Example 45 is a vehicular communication services (V2X) node of a wireless wide area network (WWAN), including one or more processing units and a computer-readable storage medium with instructions that, when executed by one or more processors, cause the device to perform the method of any of Examples 40-42.

[0130] Example 46 may include an electronic device comprising: radio frequency (RF) circuitry that includes: a wireless local area network (WLAN) radio interface; and a cellular radio interface; and baseband circuitry coupled with the RF circuitry, the baseband circuitry to facilitate transmission of one or more V2X signals to another electronic device via the WLAN radio interface.

[0131] Example 47 may include the electronic device of example 46 or some other example herein, wherein the WLAN radio interface is based on an institute of electrical and electronics engineers (IEEE) 802.11 specification.

[0132] Example 48 may include the electronic device of example 46 or some other example herein, wherein the cellular radio interface is based on a long term evolution (LTE) standard.

[0133] Example 49 may include the electronic device of example 46 or some other example herein, wherein the transmission of the V2X signals is based on congestion parameters of the WLAN radio interface.

[0134] Example 50 may include the electronic device of example 46 or some other example herein, wherein the RF circuitry is further to receive one or more WLAN power control settings via the LTE radio interface; and the RF circuitry is to transmit, via the WLAN radio interface, the one or more V2X signals in accordance with the one or more WLAN power control settings.

[0135] Example 51 may include a method comprising: identifying, by an electronic device that includes a WLAN radio interface and a cellular radio interface, that the electronic device is to transmit one or more V2X signals; and transmitting, by the electronic device, the one or more V2X signals via the WLAN radio interface.

[0136] Example 52 may include the method of example 51 or some other example herein, wherein the WLAN radio interface is based on an institute of electrical and electronics engineers (IEEE) 802.11 specification.

[0137] Example 53 may include the method of example 51 or some other example herein, wherein the cellular radio interface is based on a long term evolution (LTE) standard.

[0138] Example 54 may include the method of example 51 or some other example herein, wherein the transmission of the V2X signals is based on congestion parameters of the WLAN radio interface.

[0139] Example 55 may include the method of example 51 or some other example herein, further comprising receiving, by the electronic device via the LTE radio interface, one or more WLAN power control settings; and transmitting, by the electronic device, the one or more V2X signals in accordance with the one or more WLAN power control settings.

[0140] Example 56 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 1-21, or any other method or process described herein.

[0141] Example 57 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 46-56, or any other method or process described herein.

[0142] Example 58 may include an apparatus comprising logic, modules, and/or circuitry to perform one or more elements of a method described in or related to any of examples 46-56, or any other method or process described herein.

[0143] Example 59 may include a method, technique, or process as described in or related to any of examples 46-56, or portions or parts thereof.

[0144] Example 60 may include a method of communicating in a wireless network as shown and described herein.

[0145] Example 61 may include a system for providing wireless communication as shown and described herein.

[0146] Example 62 may include a device for providing wireless communication as shown and described herein

[0147] Example 63 may include an apparatus of a user equipment (UE) to operate in a wireless communication system, the apparatus comprising: logic, at least a portion of which includes circuitry, to: communicate over a WLAN with one or more other UEs via a WLAN radio interface; report to a node of the WWAN, via a WWAN radio interface, at least one of WLAN measurements and WLAN connectivity; receive one or more vehicular communication (V2X) services from the WWAN via the WWAN radio interface; and communicate with the one or more other UEs over the WLAN, via the WLAN radio interface, based on the one or more V2X services received.

[0148] Example 64 may include an apparatus of an eNodeB for providing wireless communication to user equipments (UEs), apparatus comprising: logic, at least a portion of which includes circuitry, to: receive from a plurality of vehicles, via receive circuitry, vehicular communication network information; determine one or more vehicular communication services to support vehicular communication among the plurality of vehicles; and provide to the plurality of vehicles, via transmit circuitry, the one or more vehicular communication services.

[0149] Some of the infrastructure that can be used with embodiments disclosed herein is already available, such as general-purpose computers, mobile phones, computer programming tools and techniques, digital storage media, and communications networks. A computing device may include a processor such as a microprocessor, microcontroller, logic circuitry, or the like. The computing device may include a computer-readable storage device such as non-volatile memory, static random access memory (RAM), dynamic RAM, read-only memory (ROM), disk, tape, magnetic, optical, flash memory, or other computer-readable storage medium.

[0150] Various aspects of certain embodiments may be implemented using hardware, software, firmware, or a combination thereof. A component or module

may 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 components that provide the described functionality. As used herein, a software module or component may include any type of computer instruction or computer executable code located within or on a non-transitory computer-readable storage medium. A software module or component may, for instance, comprise one or more physical or logical blocks of computer instructions, which may be organized as a routine, program, object, component, data structure, etc., which performs one or more tasks or implements particular abstract data types.

[0151] In certain embodiments, a particular software module or component may comprise disparate instructions stored in different locations of a computer-readable storage medium, which together implement the described functionality of the module or component. Indeed, a module or component may comprise a single instruction or many instructions, and may be distributed over several different code segments, among different programs, and across several computer-readable storage media. Some embodiments may be practiced in a distributed computing environment where tasks are performed by a remote processing device linked through a communications network.

[0152] Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that certain changes and modifications may be made without departing from the principles thereof. It should be noted that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered illustrative and not restrictive, and the disclosure is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

[0153] Those having skill in the art will appreciate that many changes may be made to the details of the above-described embodiments without departing from the underlying principles of the disclosure. The scope should, therefore, be determined only by the following claims.

Claims

1. A user equipment (UE) to operate in a wireless communication system, the UE comprising:

a first radio interface to communicate with a wireless wide area network (WWAN);

a second radio interface to communicate with a wireless local area network (WLAN); and

one or more processing units to:

communicate over a WLAN with one or more other UEs via the second radio interface;

report to a node of the WWAN, via the first radio interface, at least one of WLAN measurements and WLAN connectivity;

receive one or more vehicular communication (V2X) services from the WWAN via the first radio interface; and

communicate with the one or more other UEs over the WLAN, via the second radio interface, based on the one or more V2X services received.

2. The UE of claim 1, wherein the one or more processing units are further to:

register with a V2X service server on the WWAN and authorize WLAN for V2X services.

3. The UE of any of claims 1-2, wherein the UE comprises a vehicle and the second radio interface is to be used for wireless communication on the WLAN with other vehicles on a dedicated spectrum used for intelligent transportation systems to enable V2X services.

4. The UE of any of claims 1-2, wherein the first radio interface comprises a long term evolution (LTE) radio interface and the WWAN comprises an LTE network.

5. The UE of claim 1, wherein the one or more V2X services are received via the first radio interface from a V2X server of the WWAN providing the one or more V2X services.

6. The UE of claim 1, wherein the second radio interface is to operate based on an Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard to communicate with the WLAN providing V2X services.

7. The UE of any of claims 1-2, wherein the one or more of the V2X services include one or more of V2X assistance information and V2X operation settings.

8. The UE of claim 7, wherein the V2X assistance information includes information to be used to provide one or more of:

- synchronization and common timing reference for the WLAN;
- a control mechanism to reduce the WLAN congestion and collision; and
- V2X services enabled by network access and wide area coverage.

9. The UE of claim 8, wherein the synchronization and common timing reference for second radio interface comprises one or more of:

- a common timing reference across a wide geographical area using network timing reference or global navigation satellite system (GNSS) synchronization aligned with the network timing;

- an enhancement to resource allocation that divides spectrum resources on slotted time intervals for transmission of predefined duration;

- an allocation of common and aligned functional time intervals for transmission of different information types and

- synchronized multi-channel operation across multiple bands using common cellular reference carrier.

10. The UE of claim 8, wherein the control mechanism to reduce the WLAN congestion and collision comprises one or more of:

- configuration of congestion criteria and indicators;

- WLAN measurements corresponding to one or more congestion indicators;

congestion function; and
congestion control commands.

11. The UE of claim 7, wherein the V2X assistance information includes information to be used to offload V2X traffic from the WLAN to the WWAN.

12. The UE of any of claims 1-2, wherein the one or more processing units are further to communicate over the WLAN with an access point in communication with the Internet.

13. The UE of any of claims 1-2, wherein the one or more processing units are further to form an ad-hoc WLAN with one or more other UEs using proximity services (ProSe).

14. An eNodeB for providing wireless communication user equipments (UEs), the eNodeB comprising:

- a transceiver, including receive circuitry and transmit circuitry, to wirelessly communicate with a plurality of vehicles linked to the eNodeB; and
- one or more processing units to:
 - receive from the plurality of vehicles, via the receive circuitry, vehicular communication network information;
 - determine one or more vehicular communication services to support vehicular communication among the plurality of vehicles; and
 - provide to the plurality of vehicles, via the transmit circuitry, the one or more vehicular communication services.

15. The eNodeB of claim 14, wherein the plurality of vehicles each comprise a wireless local area network (WLAN) radio interface to link in an ad-hoc vehicular communication WLAN, and wherein the vehicular communication network information comprises information about a status of the ad-hoc vehicular communication WLAN.

16. The eNodeB of claim 14, wherein the vehicular communication network information comprises at least one of WLAN measurements and WLAN connectivity of the vehicular communication network.

17. The eNodeB of claim 14, wherein the one or more vehicular communication services include one or more of V2X assistance information and V2X operation settings.

18. The eNodeB of claim 17, wherein the V2X assistance information includes information to be used to provide one or more of:

- synchronization and common timing reference for the WLAN;
- a control mechanism to reduce the WLAN congestion and collision; and
- V2X services enabled by network access and wide area coverage.

19. The eNodeB of claim 18, wherein the synchronization and common timing reference for WLAN radio interface comprises one or more of:

a common timing reference across a wide geographical area using network timing reference or global navigation satellite system (GNSS) synchronization aligned with the network timing;

an enhancement to resource allocation by dividing spectrum resources on slotted time intervals for transmission of predefined duration;

an allocation of common and aligned functional time intervals for transmission of different information types (control commands, data, etc.); and

synchronized multi-channel operation across multiple bands (operation over multiple channels in 5.9 GHz band) using common cellular reference carrier.

20. The eNodeB of claim 18, the wherein control mechanism to reduce the WLAN congestion and collision comprises one or more of:

congestion criteria;

WLAN measurements of one or more congestion indicators;

congestion function; and

congestion control commands.

21. The eNodeB of claim 17, wherein the V2X assistance information includes information to be used by the vehicle to offload V2X traffic from WLAN to the WWAN.

22. A vehicular communication services (V2X) node of a wireless wide area network (WWAN), comprising:
- one or more processing units;
 - a computer-readable storage medium having stored thereon instructions that, when executed by the one or processors, cause the apparatus to:
 - communicate over a wireless local area network (WLAN) with one or more other vehicles via a WLAN radio interface;
 - report to a node of a WWAN, via a WWAN radio interface, at least one of WLAN measurements and WLAN connectivity;
 - receive one or more V2X services from the WWAN via the WWAN radio interface; and
 - communicate with the one or more other vehicles over the WLAN, via the WLAN radio interface, based on the one or more V2X services received.
23. The node of claim 22, further to:
- register with a V2X services server on the WWAN to authorize WLAN for V2X services.

24. The node of claim 22, wherein the WLAN radio interface is further to be used for wireless communication on the WLAN with road side units.

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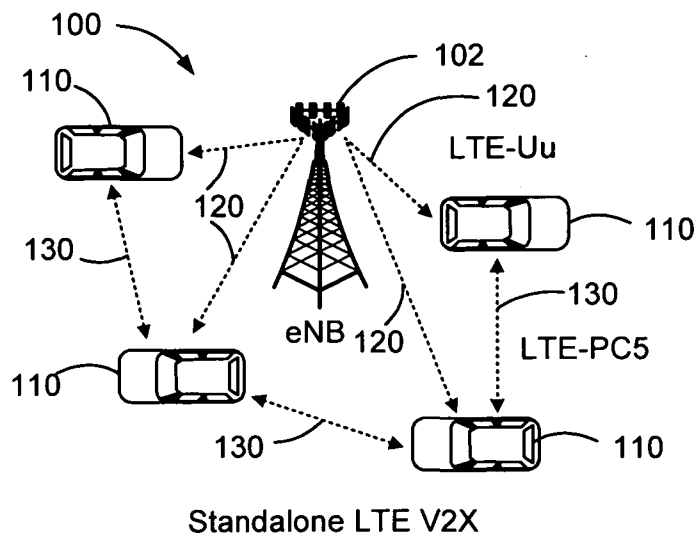


FIG. 1

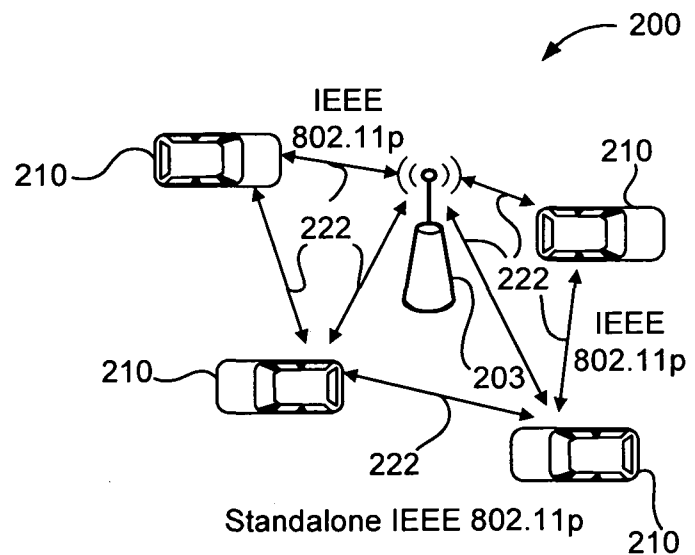
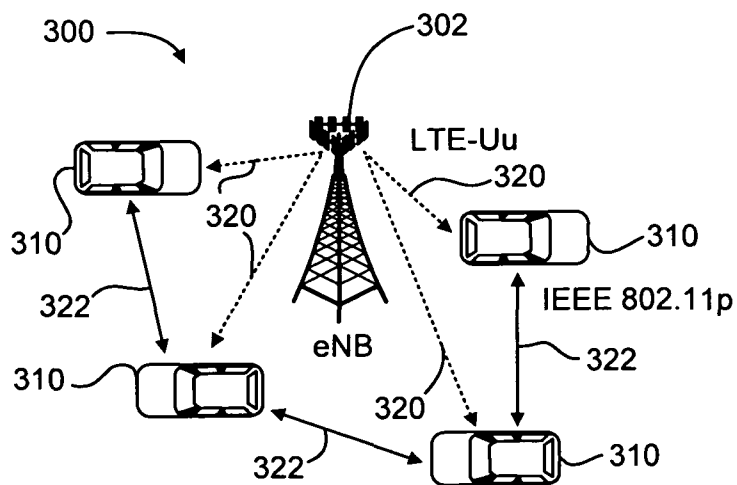


FIG. 2



LTE & Wi-Fi architecture for V2X services

FIG. 3

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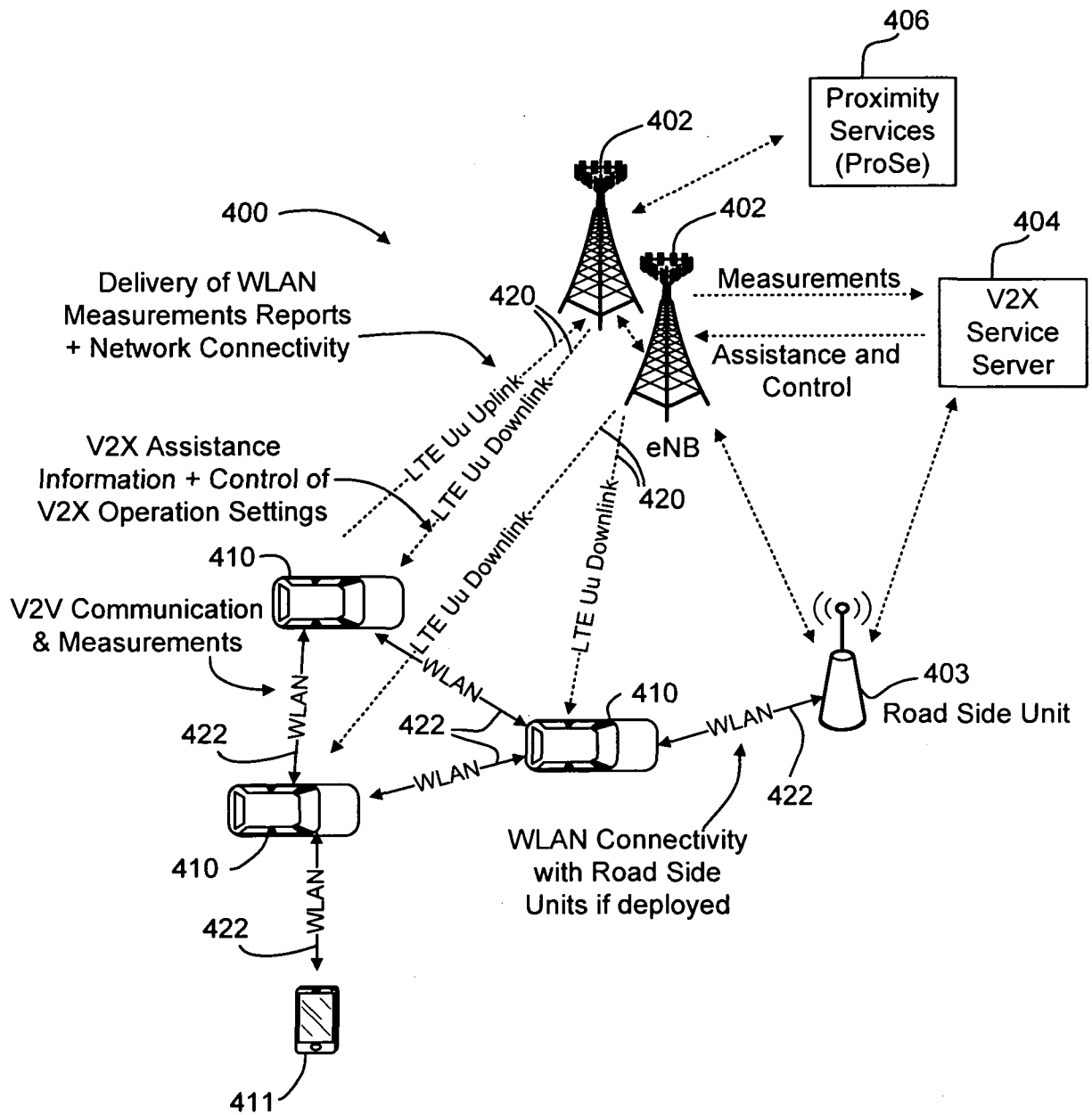


FIG. 4

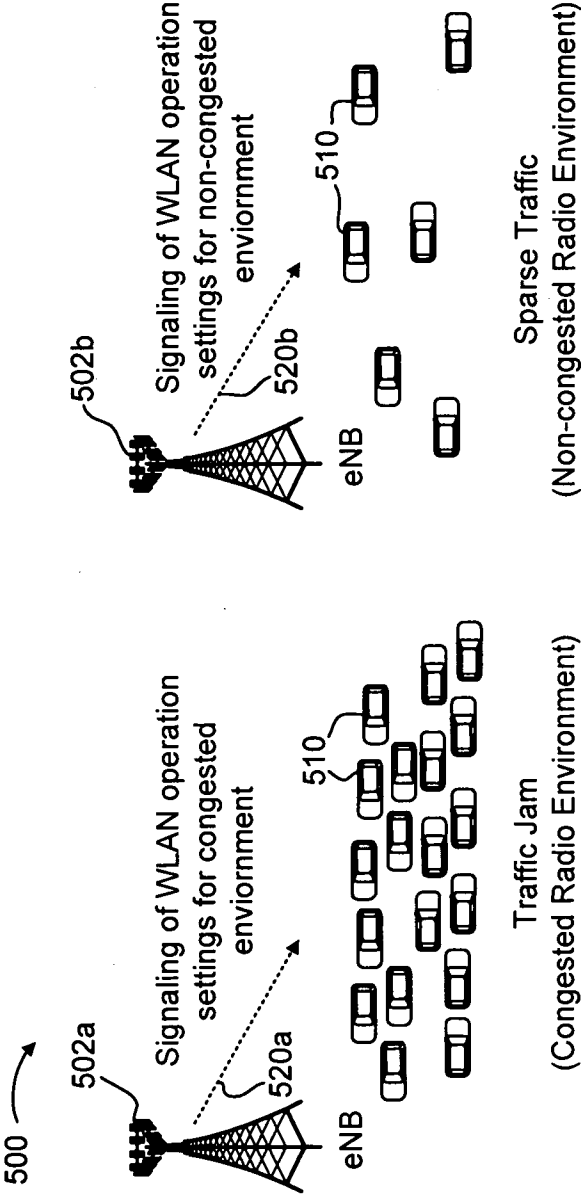


FIG. 5

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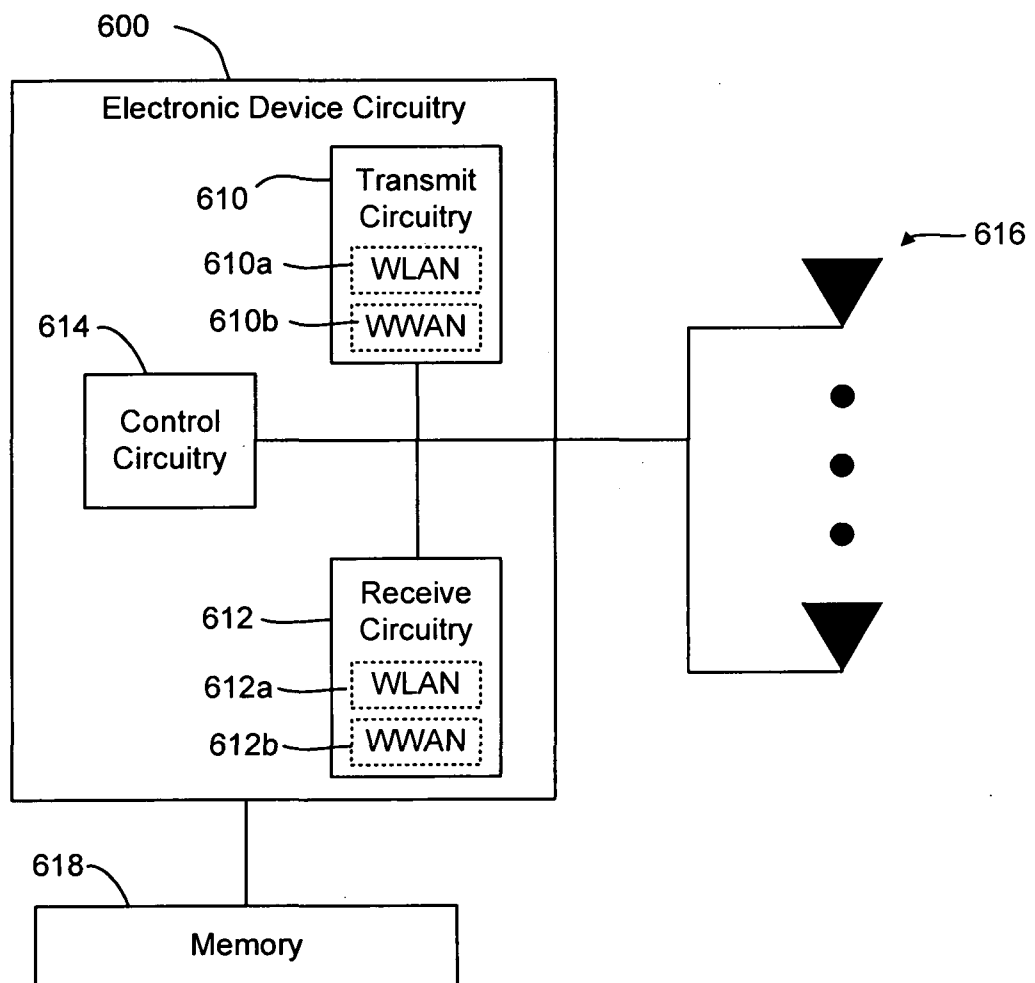


FIG. 6

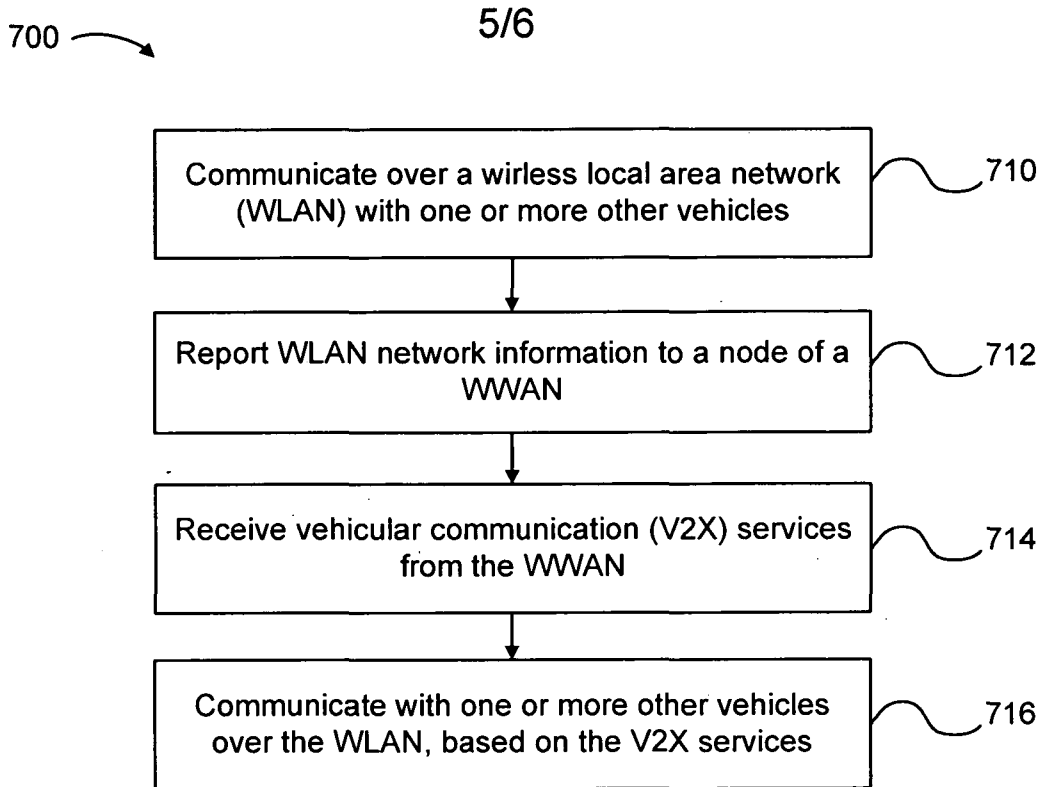


FIG. 7

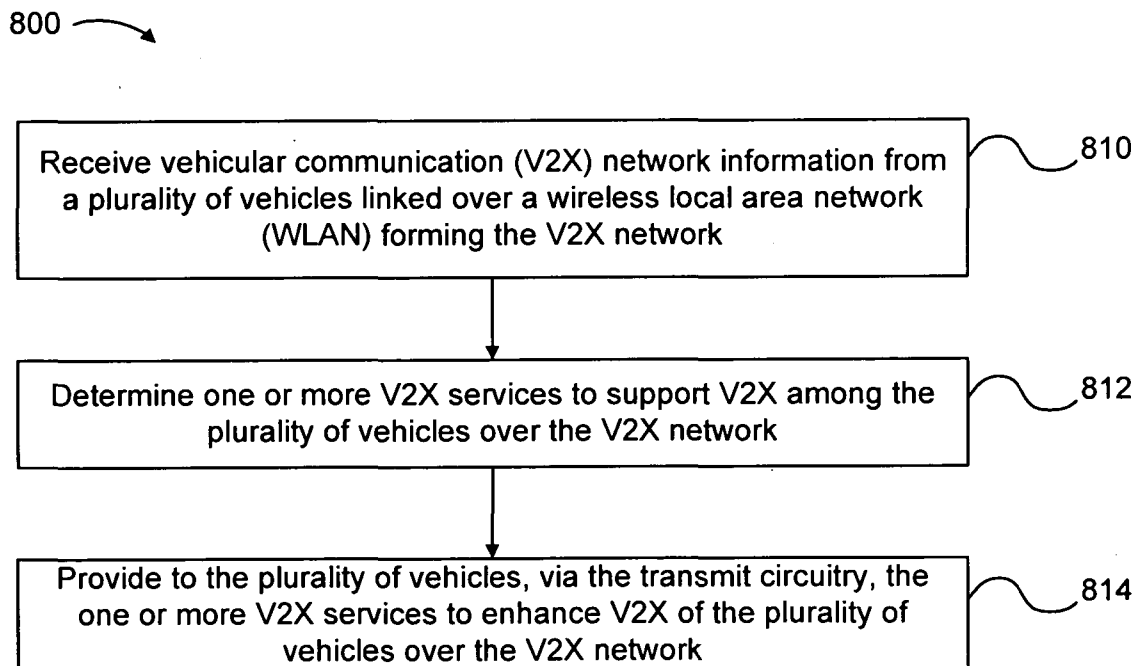


FIG. 8

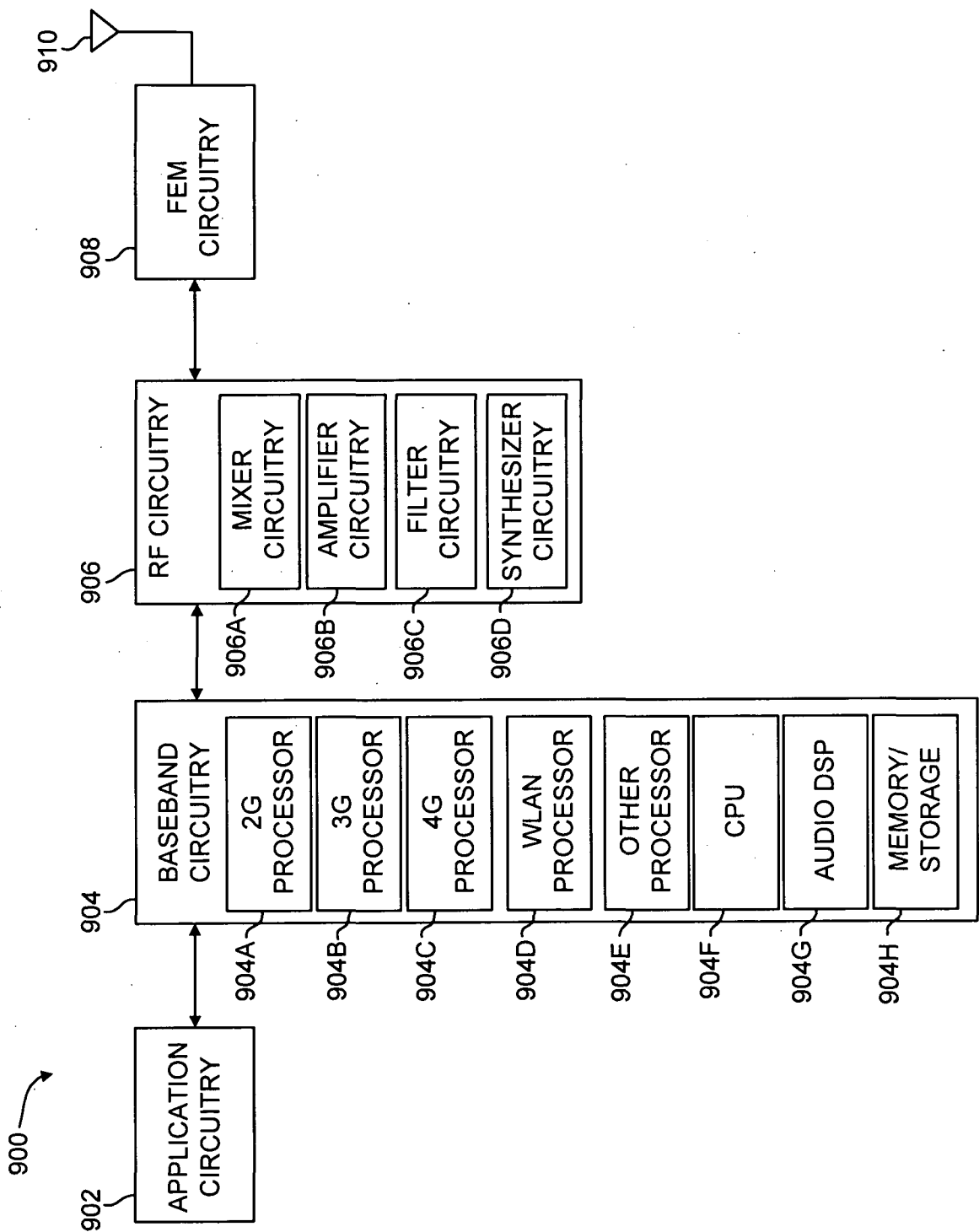


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/000181

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/02 G08G1/01 H04W4/04
ADD. H04W88/06

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 G08G H04L

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/048486 A1 (ERICSSON TELEFON AB L M [SE]) 3 April 2014 (2014-04-03) page 1, line 7, to page 3, line 14; page 3, line 35, to page 16, line 14; figures 1-5	1-24
X	WO 2015/032436 A1 (ERICSSON TELEFON AB L M [SE]) 12 March 2015 (2015-03-12) page 1, line 12, to page 5, line 18; page 6, line 32, to page 18, line 18; page 19, line 7, to page 24, line 8; figures 1-10, 13-16 ----- -/-	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

31 May 2016

Date of mailing of the international search report

06/06/2016

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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/000181

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/173429 A1 (ERICSSON TELEFON AB L M [SE]) 30 October 2014 (2014-10-30) page 1, line 7, to page 3, line 8; page 4, line 4, to page 10, line 21; page 11, line 7, to page 17, line 13; figures 1, 2, 5-9 -----	1-24
X	WO 2014/012244 A1 (RENESAS MOBILE CORP [JP]; FENG XIANJUN [CN]; WANG HAIFENG [CN]; LI ZHE) 23 January 2014 (2014-01-23) page 1, line 6, to page 7, line 4; page 8, line 1, to page 30, line 32; figures 1-9, 11, 13 -----	1-24
X	TUNG LUNG-CHIH ET AL: "A cluster based architecture for intersection collision avoidance using heterogeneous networks", 2013 12TH ANNUAL MEDITERRANEAN AD HOC NETWORKING WORKSHOP (MED-HOC-NET), IEEE, 24 June 2013 (2013-06-24), pages 82-88, XP032579973, DOI: 10.1109/MEDHOCNET.2013.6767414 [retrieved on 2014-03-14] sections Abstract, I.-V. -----	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/000181

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014048486 A1	03-04-2014	EP 2901724 A1 US 2015296411 A1 WO 2014048486 A1	05-08-2015 15-10-2015 03-04-2014
WO 2015032436 A1	12-03-2015	NONE	
WO 2014173429 A1	30-10-2014	CN 105165058 A EP 2989824 A1 US 2016073298 A1 WO 2014173429 A1	16-12-2015 02-03-2016 10-03-2016 30-10-2014
WO 2014012244 A1	23-01-2014	US 2015195827 A1 WO 2014012244 A1	09-07-2015 23-01-2014