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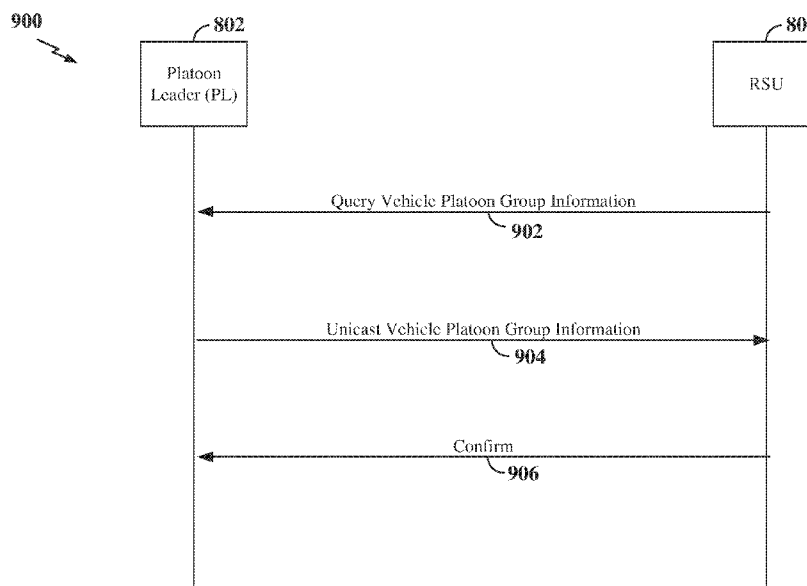


FIG. 9

(57) Abstract: Aspects of the disclosure relate to mechanisms for a roadside unit (RSU) in a vehicle-to-everything (V2X) wireless communication network to query vehicle platoon group information from one or more vehicle platoon groups. The vehicle platoon group information may then be utilized by the RSU to assist one or more vehicles in subsequently joining vehicle platoon groups. For example, the RSU may receive a request for the vehicle platoon group information of nearby vehicle platoon groups from a V2X device within a vehicle and provide the vehicle platoon group information to the V2X device for use in selecting a vehicle platoon group to join.



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RSU-ASSISTED JOINDER OF VEHICLE PLATOONING GROUPS

TECHNICAL FIELD

[0001] The technology discussed below relates generally to wireless communication networks, and more particularly, to vehicle-to-everything (V2X) wireless communication.

INTRODUCTION

[0002] Vehicle-to-Everything (V2X) communication involves the wireless exchange of information between not only vehicles themselves, but also between vehicles and external systems, such as streetlights, buildings, pedestrians, and wireless communication networks. V2X systems enable vehicles to obtain information related to the weather, nearby accidents, road conditions, activities of nearby vehicles and pedestrians, objects nearby the vehicle, and other pertinent information that may be utilized to improve the vehicle driving experience and increase vehicle safety.

[0003] Enhanced V2X (eV2X) wireless communication extends V2X to support advanced driving (semi-automated or fully-automated driving), extended sensors, remote driving, and vehicle platooning. Vehicle platooning refers to the ability of a vehicle to join a group of vehicles traveling together. One of the vehicles operates as the platoon leader (head vehicle) to manage vehicles joining and leaving the vehicle platoon group. The vehicles within the vehicle platoon group may exchange information related to, for example, speed, direction, braking, and acceleration, to facilitate automated cooperative driving. For example, the exchanged information may be utilized to enable vehicles moving in the same lane to maintain a nearly constant inter-vehicle distance and to synchronize their motion.

[0004] As the demand for eV2X communication increases, research and development continue to advance eV2X technologies not only to meet the growing demand for eV2X, but also to advance and enhance the automated vehicle driving experience.

BRIEF SUMMARY OF SOME EXAMPLES

[0005] The following presents a summary of one or more aspects of the present disclosure, in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated features of the disclosure, and is intended neither to identify key or critical elements of all aspects of the disclosure nor to

delineate the scope of any or all aspects of the disclosure. Its sole purpose is to present some concepts of one or more aspects of the disclosure in a form as a prelude to the more detailed description that is presented later.

[0006] Various aspects of the disclosure relate to mechanisms for a roadside unit (RSU) to query vehicle platoon group information from one or more vehicle platoon groups. The vehicle platoon group information may then be utilized by the RSU to assist one or more vehicles in subsequently joining vehicle platoon groups. For example, the RSU may receive a request for the vehicle platoon group information of nearby vehicle platoon groups from a vehicle-to-everything (V2X) device within a vehicle and provide the vehicle platoon group information to the V2X device for use by the V2X device in selecting a vehicle platoon group to join.

[0007] In some examples, the vehicle platoon group information may include private platoon group information, such as the number and/or a list of vehicles in a vehicle platoon group, intended route of the vehicle platoon group, the inter-vehicle distance, the relative position of each vehicle in the vehicle platoon group, or individual vehicle information indicating, for example, a recommended speed and recommended transmit power of each of the vehicles in the vehicle platoon group. In addition to the private platoon group information, the vehicle platoon group information may further include public platoon group information, such as the platoon group identifier, speed of a platoon leader of the vehicle platoon group, direction of the platoon leader, location of the platoon leader, or an event message indicating braking, accelerating, and/or steering to be performed by the vehicles in the vehicle platoon group.

[0008] The RSU may utilize the private and public platoon group information to identify nearby vehicle platoon groups that the V2X device may join and transmit at least part of the public and/or private platoon group information to the V2X device. For example, the RSU may transmit a route, speed, direction (trajectory), platoon group identifier, and wireless resources for the V2X device to transmit a join request for each of the nearby vehicle platoon groups.

[0009] These and other aspects of the invention will become more fully understood upon a review of the detailed description, which follows. Other aspects, features, and embodiments of the present invention will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, exemplary embodiments of the present invention in conjunction with the accompanying figures. While features of the present invention may be discussed relative to certain embodiments and figures

below, all embodiments of the present invention can include one or more of the advantageous features discussed herein. In other words, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various embodiments of the invention discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments it should be understood that such exemplary embodiments can be implemented in various devices, systems, and methods.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0010] FIG. 1 is a diagram illustrating an example of a wireless radio access network.
- [0011] FIG. 2 is a diagram illustrating an example of a vehicle-to-everything (V2X) wireless communication network.
- [0012] FIG. 3 is a diagram illustrating an example of vehicle platooning in a V2X wireless communication network.
- [0013] FIG. 4 is a schematic diagram illustrating organization of wireless resources in an air interface utilizing orthogonal frequency divisional multiplexing (OFDM).
- [0014] FIG. 5 illustrates an example of a slot that may be utilized to communicate over a V2X channel.
- [0015] FIG. 6 is a block diagram illustrating an example of a hardware implementation for a roadside unit (RSU) employing a processing system according to some aspects of the present disclosure.
- [0016] FIG. 7 is a block diagram illustrating an example of a hardware implementation for a V2X device employing a processing system according to some aspects of the present disclosure.
- [0017] FIG. 8 is a diagram illustrating exemplary signaling between an RSU and a platoon leader (PL) of a vehicle platoon group to obtain vehicle platoon group information according to some aspects of the present disclosure.
- [0018] FIG. 9 is a diagram illustrating other exemplary signaling between an RSU and a platoon leader (PL) of a vehicle platoon group to obtain vehicle platoon group information according to some aspects of the present disclosure.
- [0019] FIG. 10 is a diagram illustrating exemplary signaling between a V2X device, RSU, and a platoon leader (PL) of a vehicle platoon group for the V2X device to join the vehicle platoon group according to some aspects of the present disclosure.

[0020] FIG. 11 is a flow chart of an exemplary method for V2X wireless communication at an RSU according to some aspects of the present disclosure.

[0021] FIG. 12 is a flow chart of an exemplary method for V2X wireless communication at a V2X device according to some aspects of the present disclosure.

[0022] FIG. 13 is a diagram illustrating an example of control information and data transmitted by platoon members (PMs) and platoon leaders (PLs) in a vehicle platoon group.

[0023] FIG. 14 is a diagram illustrating another example of control information and data transmitted by platoon members (PMs) and platoon leaders (PLs) in a vehicle platoon group.

DETAILED DESCRIPTION

[0024] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0025] While aspects and embodiments are described in this application by illustration to some examples, those skilled in the art will understand that additional implementations and use cases may come about in many different arrangements and scenarios. Innovations described herein may be implemented across many differing platform types, devices, systems, shapes, sizes, packaging arrangements. For example, embodiments and/or uses may come about via integrated chip embodiments and other non-module-component based devices (e.g., end-user devices, vehicles, communication devices, computing devices, industrial equipment, retail/purchasing devices, medical devices, AI-enabled devices, etc.). While some examples may or may not be specifically directed to use cases or applications, a wide assortment of applicability of described innovations may occur. Implementations may range a spectrum from chip-level or modular components to non-modular, non-chip-level implementations and further to aggregate, distributed, or OEM devices or systems incorporating one or more aspects of the described innovations. In some practical settings, devices incorporating described

aspects and features may also necessarily include additional components and features for implementation and practice of claimed and described embodiments. For example, transmission and reception of wireless signals necessarily includes a number of components for analog and digital purposes (e.g., hardware components including antenna, RF-chains, power amplifiers, modulators, buffer, processor(s), interleaver, adders/summers, etc.). It is intended that innovations described herein may be practiced in a wide variety of devices, chip-level components, systems, distributed arrangements, end-user devices, etc. of varying sizes, shapes and constitution.

[0026] The various concepts presented throughout this disclosure may be implemented across a broad variety of telecommunication systems, network architectures, and communication standards. Referring now to FIG. 1, as an illustrative example without limitation, a schematic illustration of a radio access network 100 is provided. The RAN 100 may implement any suitable wireless communication technology or technologies to provide radio access. As one example, the RAN 100 may operate according to 3rd Generation Partnership Project (3GPP) New Radio (NR) specifications, often referred to as 5G. As another example, the RAN 100 may operate under a hybrid of 5G NR and Evolved Universal Terrestrial Radio Access Network (eUTRAN) standards, often referred to as LTE. The 3GPP refers to this hybrid RAN as a next-generation RAN, or NG-RAN. Of course, many other examples may be utilized within the scope of the present disclosure.

[0027] The geographic region covered by the radio access network 100 may be divided into a number of cellular regions (cells) that can be uniquely identified by a user equipment (UE) based on an identification broadcasted over a geographical area from one access point or base station. FIG. 1 illustrates macrocells 102, 104, and 106, and a small cell 108, each of which may include one or more sectors (not shown). A sector is a sub-area of a cell. All sectors within one cell are served by the same base station. A radio link within a sector can be identified by a single logical identification belonging to that sector. In a cell that is divided into sectors, the multiple sectors within a cell can be formed by groups of antennas with each antenna responsible for communication with UEs in a portion of the cell.

[0028] In general, a respective base station (BS) serves each cell. Broadly, a base station is a network element in a radio access network responsible for radio transmission and reception in one or more cells to or from a UE. A BS may also be referred to by those skilled in the art as a base transceiver station (BTS), a radio base station, a radio

transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), an access point (AP), a Node B (NB), an eNode B (eNB), a gNode B (gNB) or some other suitable terminology.

[0029] In FIG. 1, two base stations 110 and 112 are shown in cells 102 and 104; and a third base station 114 is shown controlling a remote radio head (RRH) 116 in cell 106. That is, a base station can have an integrated antenna or can be connected to an antenna or RRH by feeder cables. In the illustrated example, the cells 102, 104, and 106 may be referred to as macrocells, as the base stations 110, 112, and 114 support cells having a large size. Further, a base station 118 is shown in the small cell 108 (e.g., a microcell, picocell, femtocell, home base station, home Node B, home eNode B, etc.) which may overlap with one or more macrocells. In this example, the cell 108 may be referred to as a small cell, as the base station 118 supports a cell having a relatively small size. Cell sizing can be done according to system design as well as component constraints. It is to be understood that the radio access network 100 may include any number of wireless base stations and cells. Further, a relay node may be deployed to extend the size or coverage area of a given cell. The base stations 110, 112, 114, 118 provide wireless access points to a core network for any number of mobile apparatuses.

[0030] FIG. 1 further includes a quadcopter or drone 120, which may be configured to function as a base station. That is, in some examples, a cell may not necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile base station such as the quadcopter 120.

[0031] In general, base stations may include a backhaul interface for communication with a backhaul portion (not shown) of the network. The backhaul may provide a link between a base station and a core network (not shown), and in some examples, the backhaul may provide interconnection between the respective base stations. The core network may be a part of a wireless communication system and may be independent of the radio access technology used in the radio access network. Various types of backhaul interfaces may be employed, such as a direct physical connection, a virtual network, or the like using any suitable transport network.

[0032] The RAN 100 is illustrated supporting wireless communication for multiple mobile apparatuses. A mobile apparatus is commonly referred to as user equipment (UE) in standards and specifications promulgated by the 3rd Generation Partnership Project (3GPP), but may also be referred to by those skilled in the art as a mobile station (MS), a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote

unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal (AT), a mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology. A UE may be an apparatus that provides a user with access to network services.

[0033] Within the present document, a “mobile” apparatus need not necessarily have a capability to move, and may be stationary. The term mobile apparatus or mobile device broadly refers to a diverse array of devices and technologies. For example, some non-limiting examples of a mobile apparatus include a mobile, a cellular (cell) phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal computer (PC), a notebook, a netbook, a smartbook, a tablet, a personal digital assistant (PDA), and a broad array of embedded systems, e.g., corresponding to an “Internet of things” (IoT). A mobile apparatus may additionally be an automotive or other transportation vehicle, a remote sensor or actuator, a robot or robotics device, a satellite radio, a global positioning system (GPS) device, an object tracking device, a drone, a multi-copter, a quad-copter, a remote control device, a consumer and/or wearable device, such as eyewear, a wearable camera, a virtual reality device, a smart watch, a health or fitness tracker, a digital audio player (e.g., MP3 player), a camera, a game console, etc. A mobile apparatus may additionally be a digital home or smart home device such as a home audio, video, and/or multimedia device, an appliance, a vending machine, intelligent lighting, a home security system, a smart meter, etc. A mobile apparatus may additionally be a smart energy device, a security device, a solar panel or solar array, a municipal infrastructure device controlling electric power (e.g., a smart grid), lighting, water, etc.; an industrial automation and enterprise device; a logistics controller; agricultural equipment; military defense equipment, vehicles, aircraft, ships, and weaponry, etc. Still further, a mobile apparatus may provide for connected medicine or telemedicine support, i.e., health care at a distance. Telehealth devices may include telehealth monitoring devices and telehealth administration devices, whose communication may be given preferential treatment or prioritized access over other types of information, e.g., in terms of prioritized access for transport of critical service data, and/or relevant QoS for transport of critical service data.

[0034] Within the RAN 100, the cells may include UEs that may be in communication with one or more sectors of each cell. For example, UEs 122 and 124 may be in communication with base station 110; UEs 126 and 128 may be in communication with

base station 112; UEs 130 and 132 may be in communication with base station 114 by way of RRH 116; UE 134 may be in communication with base station 118; and UE 136 may be in communication with mobile base station 120. Here, each base station 110, 112, 114, 118, and 120 may be configured to provide an access point to a core network (not shown) for all the UEs in the respective cells.

[0035] In another example, a mobile network node (e.g., quadcopter 120) may be configured to function as a UE. For example, the quadcopter 120 may operate within cell 102 by communicating with base station 110. In some aspects of the present disclosure, two or more UE (e.g., UEs 126 and 128) may communicate with each other using peer to peer (P2P) or sidelink signals 127 without relaying that communication through a base station (e.g., base station 112).

[0036] Unicast or broadcast transmissions of control information and/or traffic information (e.g., user data traffic) from a base station (e.g., base station 110) to one or more UEs (e.g., UEs 122 and 124) may be referred to as downlink (DL) transmission, while transmissions of control information and/or traffic information originating at a UE (e.g., UE 122) may be referred to as uplink (UL) transmissions. In addition, the uplink and/or downlink control information and/or traffic information may be time-divided into frames, subframes, slots, and/or symbols. As used herein, a symbol may refer to a unit of time that, in an orthogonal frequency division multiplexed (OFDM) waveform, carries one resource element (RE) per sub-carrier. A slot may carry 7 or 14 OFDM symbols. A subframe may refer to a duration of 1ms. Multiple subframes or slots may be grouped together to form a single frame or radio frame. Of course, these definitions are not required, and any suitable scheme for organizing waveforms may be utilized, and various time divisions of the waveform may have any suitable duration.

[0037] The air interface in the RAN 100 may utilize one or more multiplexing and multiple access algorithms to enable simultaneous communication of the various devices. For example, multiple access for uplink (UL) or reverse link transmissions from UEs 122 and 124 to base station 110 may be provided utilizing time division multiple access (TDMA), code division multiple access (CDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), sparse code multiple access (SCMA), single-carrier frequency division multiple access (SC-FDMA), resource spread multiple access (RSMA), or other suitable multiple access schemes. Further, multiplexing downlink (DL) or forward link transmissions from the base station 110 to UEs 122 and 124 may be provided utilizing time division

multiplexing (TDM), code division multiplexing (CDM), frequency division multiplexing (FDM), orthogonal frequency division multiplexing (OFDM), sparse code multiplexing (SCM), single-carrier frequency division multiplexing (SC-FDM) or other suitable multiplexing schemes.

[0038] Further, the air interface in the RAN 100 may utilize one or more duplexing algorithms. Duplex refers to a point-to-point communication link where both endpoints can communicate with one another in both directions. Full duplex means both endpoints can simultaneously communicate with one another. Half duplex means only one endpoint can send information to the other at a time. In a wireless link, a full duplex channel generally relies on physical isolation of a transmitter and receiver, and suitable interference cancellation technologies. Full duplex emulation is frequently implemented for wireless links by utilizing frequency division duplex (FDD) or time division duplex (TDD). In FDD, transmissions in different directions operate at different carrier frequencies. In TDD, transmissions in different directions on a given channel are separated from one another using time division multiplexing. That is, at some times the channel is dedicated for transmissions in one direction, while at other times the channel is dedicated for transmissions in the other direction, where the direction may change very rapidly, e.g., several times per subframe.

[0039] In various implementations, the air interface in the radio access network 100 may utilize licensed spectrum, unlicensed spectrum, or shared spectrum. Licensed spectrum provides for exclusive use of a portion of the spectrum, generally by virtue of a mobile network operator purchasing a license from a government regulatory body. Unlicensed spectrum provides for shared use of a portion of the spectrum without need for a government-granted license. While compliance with some technical rules is generally still required to access unlicensed spectrum, generally, any operator or device may gain access. Shared spectrum may fall between licensed and unlicensed spectrum, wherein technical rules or limitations may be required to access the spectrum, but the spectrum may still be shared by multiple operators and/or multiple RATs. For example, the holder of a license for a portion of licensed spectrum may provide licensed shared access (LSA) to share that spectrum with other parties, e.g., with suitable licensee-determined conditions to gain access.

[0040] In order for transmissions over the RAN 100 to obtain a low block error rate (BLER) while still achieving very high data rates, channel coding may be used. That is, wireless communication may generally utilize a suitable error correcting block code. In

a typical block code, an information message or sequence is split up into code blocks (CBs), and an encoder (e.g., a CODEC) at the transmitting device then mathematically adds redundancy to the information message. Exploitation of this redundancy in the encoded information message can improve the reliability of the message, enabling correction for any bit errors that may occur due to the noise.

[0041] In some examples, access to the air interface may be scheduled, wherein a scheduling entity (e.g., a base station) allocates resources (e.g., time-frequency resources) for communication among some or all devices and equipment within its service area or cell. Within the present disclosure, as discussed further below, the scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more scheduled entities. That is, for scheduled communication, UEs or scheduled entities utilize resources allocated by the scheduling entity.

[0042] Base stations are not the only entities that may function as a scheduling entity. That is, in some examples, a UE may function as a scheduling entity, scheduling resources for one or more scheduled entities (e.g., one or more other UEs). In other examples, sidelink signals may be used between UEs without necessarily relying on scheduling or control information from a base station. For example, UE 138 is illustrated communicating with UEs 140 and 142. In some examples, the UE 138 is functioning as a scheduling entity or a primary sidelink device, and UEs 140 and 142 may function as a scheduled entity or a non-primary (e.g., secondary) sidelink device. In still another example, a UE, which may be stationary, may function as a scheduling entity in a device-to-device (D2D), peer-to-peer (P2P), or vehicle-to-vehicle (V2V) network, a vehicle-to-everything (V2X), enhanced V2X (eV2X) and/or in a mesh network. In a mesh network example, UEs 140 and 142 may optionally communicate directly with one another in addition to communicating with the scheduling entity 138.

[0043] Two primary technologies that may be used by V2X networks include dedicated short range communication (DSRC) based on IEEE 802.11p standards and cellular V2X based on LTE and/or 5G (New Radio) standards. Various aspects of the present disclosure may relate to New Radio (NR) cellular V2X or eV2X networks, referred to herein as V2X networks, for simplicity. In some examples, V2X communications may be enabled by sidelink communications scheduled by a roadside unit (RSU), which may be, for example, a stationary UE operating as a scheduling entity for V2X

communication. However, it should be understood that the concepts disclosed herein may not be limited to a particular V2X standard.

[0044] FIG. 2 illustrates an example of a vehicle-to-everything (V2X) wireless communication network 200. A V2X network can connect vehicles 202a and 202b to each other (vehicle-to-vehicle (V2V)), to roadway infrastructure 204/205 (vehicle-to-infrastructure (V2I)), to pedestrians/cyclists 206 (vehicle-to-pedestrian (V2P)), and/or to the network 208 (vehicle-to-network (V2N)).

[0045] A V2I transmission may be between a vehicle (e.g., vehicle 202a) and a roadside unit (RSU) 204, which may be coupled to various infrastructure 205, such as a traffic light, building, streetlight, traffic camera, tollbooth, or other stationary object. The RSU 204 may act as a base station enabling communication between vehicles 202a and 202b, between vehicles 202a/202b and the RSU 204 and between vehicles 202a/202b and mobile devices 206 of pedestrians/cyclists. The RSU 204 may further exchange V2X data gathered from the surrounding environment, such as a connected traffic camera or traffic light controller, V2X connected vehicles 202a/202b, and mobile devices 206 of pedestrians/cyclists, with other RSUs 204 and distribute that V2X data to V2X connected vehicles 202a/202b and pedestrians 206. Examples of V2X data may include status information (e.g., position, speed, acceleration, trajectory, etc.) or event information (e.g., traffic jam, icy road, fog, pedestrian crossing the road, collision, etc.), and may also include video data captured by a camera on a vehicle or coupled to an RSU 204.

[0046] Such V2X data may enable autonomous driving and improve road safety and traffic efficiency. For example, the exchanged V2X data may be utilized by a V2X connected vehicle 202a/202b to provide in-vehicle collision warnings, road hazard warnings, approaching emergency vehicle warnings, pre-/post-crash warnings and information, emergency brake warnings, traffic jam ahead warnings, lane change warnings, intelligent navigation services, and other similar information. In addition, V2X data received by a V2X connected mobile device 206 of a pedestrian/cyclist may be utilized to trigger a warning sound, vibration, flashing light, etc., in case of imminent danger.

[0047] V2N communication may utilize traditional cellular links to provide cloud services to a V2X device (e.g., within a vehicle 202a/202b or RSU 204, or on a pedestrian 206) for latency-tolerant use cases. For example, V2N may enable a V2X network server to broadcast messages (e.g., weather, traffic, or other information) to

V2X devices over a wide area network and may enable V2X devices to send unicast messages to the V2X network server. In addition, V2N communication may provide backhaul services for RSUs 204.

[0048] FIG. 3 is a diagram illustrating an example of vehicle platooning in a V2X wireless communication network 200. Vehicle platooning refers to the ability of autonomous or semi-autonomous vehicles to organize into vehicle platoon groups to engage in automated cooperative driving. Each vehicle platoon group includes two or more vehicles traveling in the same lane at substantially the same speed in a train-like manner to maintain a small, nearly constant inter-vehicle distance therebetween. In the example shown in FIG. 3, two vehicle platoons groups 302a and 302b are illustrated, each including two vehicles, for simplicity. For example, vehicle platoon group 302a includes vehicles 202a and 202b, while vehicle platoon group 302b includes vehicles 202c and 202d.

[0049] One of the vehicles in each of the vehicle platoon groups 302a and 302b operates as the platoon leader (PL) of the vehicle platoon group and is responsible for setting the route, inter-vehicle distance, and speed of the vehicle platoon group. The remaining vehicles may be referred to herein as platoon members (PMs), which implement the route, inter-vehicle distance, and speed set by the PL. The PL is further responsible for joining and removing PMs to and from the vehicle platoon group. For example, a vehicle, such as vehicle 202e, desiring to join a particular vehicle platoon group (e.g., vehicle platoon group 302b) may transmit a join request to the PL (e.g., vehicle 202c) of the vehicle platoon group 302b. The PL 202c may then transmit a join response to the vehicle 202e that confirms or denies the joinder of the vehicle 202e to the vehicle platoon group 302b.

[0050] All of the vehicles in a vehicle platoon group 302a or 302b communicate with each other to exchange vehicle platoon group information related to, for example, their speed, direction, and data obtained from on-board sensors (e.g., cameras, LiDARS, radars, etc.). In addition, the PL communicates additional vehicle platoon group information, such as the vehicle platoon group identifier (ID), geographical location of the PL, inter-vehicle distance, planned route of the vehicle platoon group, number and/or list of PMs in the vehicle platoon group, recommended/known individual PM information (e.g., speed, relative position in the vehicle platoon group, and transmit power of PMs in the group), and event messages indicating braking, accelerating, and/or steering to be performed by the vehicles in the vehicle platoon group. For example, the

event message may instruct the vehicles in the group to change lanes, may include a crash warning, or other event that may indicate that the vehicle should perform braking, accelerating, or steering.

[0051] In some examples, such vehicle platoon group information may be exchanged using cooperative awareness messages (CAMs). Each PM in a vehicle platoon group may utilize CAMs from the PL and from the immediately preceding vehicle, along with on-board sensor information, to adjust its speed (e.g., by braking or accelerating) and position (e.g., by performing steering).

[0052] The CAMs may be transmitted over wireless resources allocated to each vehicle platoon group 302a and 302 by the RSU 204. In some examples, the RSU 204 may allocate dedicated V2X resources to vehicle platoon groups 302a and 302b dynamically according to requests from PMs/PLs or semi-persistently by reserving resources for periodic transmissions by each PM/PL in each vehicle platoon group 302a and 302b. In some examples, the resources may be allocated to support half-duplex V2X communication.

[0053] Each vehicle platoon group 302a and 302b may be either a public vehicle platoon group or a private vehicle platoon group. A private vehicle platoon group may be, for example, a tour group, public safety group, or other group that is only open to vehicles that meet certain criteria or require a certain clearance to join. For private vehicle platoon groups, at least some of the vehicle platoon group information transmitted by the PL may be private in order to protect the security of the vehicle platoon group. Examples of private platoon group information may include, for example, the inter-vehicle distance, planned route of the vehicle platoon group, number and/or list of PMs in the vehicle platoon group, and the recommended individual PM information (e.g., speed, relative position in the vehicle platoon group, and wireless transmit power utilized by PMs in the group). Other vehicle platoon group information transmitted by the PL or by other PMs may be public platoon group information that may be known to the RSU 204 and other vehicles outside of the vehicle platoon group.

[0054] In some examples, the private platoon group information may be scrambled with a private key known only to the PMs in the vehicle platoon group. Thus, the private platoon group information may not be able to be decoded by the RSU 204 or other vehicles in other vehicle platoon groups. As such, a vehicle (e.g., vehicle 202e) seeking to join a vehicle platoon group may not have the requisite information needed to determine whether to request to join the private vehicle platoon group. In addition, the

half duplex nature of V2X communication may cause the vehicle 202e to miss some of the public platoon group information transmitted by one or more vehicle platoon groups, which may further prevent the vehicle 202e from identifying a vehicle platoon group to join.

[0055] Therefore, in various aspects of the present disclosure, the vehicle platoon group information (both public and private) of each nearby vehicle platoon group may be collected by the RSU 204. Vehicles desiring to join a vehicle platoon group may then query the RSU 204 for the vehicle platoon group information of nearby vehicle platoon groups to determine whether to transmit a join request to a particular vehicle platoon group. The PL of the vehicle platoon group receiving the join request may then decide to accept or deny the vehicle admission to the vehicle platoon group. In some examples, the vehicle wishing to join a vehicle platoon group may transmit the vehicle's speed, direction, desired route, and other similar vehicle information to the RSU 204. The RSU may then utilize the vehicle information to identify one or more nearby vehicle platoon groups that the vehicle may join.

[0056] Various aspects of the present disclosure will be described with reference to an OFDM waveform, schematically illustrated in FIG. 4. It should be understood by those of ordinary skill in the art that the various aspects of the present disclosure may be applied to an SC-FDMA waveform in substantially the same way as described herein below. That is, while some examples of the present disclosure may focus on an OFDM link for clarity, it should be understood that the same principles may be applied as well to SC-FDMA waveforms.

[0057] Referring now to FIG. 4, an expanded view of an exemplary slot 402 is illustrated, showing an OFDM resource grid 404. However, as those skilled in the art will readily appreciate, the PHY transmission structure for any particular application may vary from the example described here, depending on any number of factors. Here, time is in the horizontal direction with units of OFDM symbols 410; and frequency is in the vertical direction with units of subcarriers 412.

[0058] The resource grid 404 may be used to schematically represent time–frequency resources for a given antenna port. That is, in a MIMO implementation with multiple antenna ports available, a corresponding multiple number of resource grids 404 may be available for communication. The resource grid 404 is divided into multiple resource elements (REs) 306. An RE, which is 1 subcarrier $\times$ 1 symbol, is the smallest discrete part of the time–frequency grid, and contains a single complex value representing data

from a physical channel or signal. Depending on the modulation utilized in a particular implementation, each RE may represent one or more bits of information. In some examples, a block of REs may be referred to as a physical resource block (PRB) or more simply a resource block (RB) 408, which contains any suitable number of consecutive subcarriers 412 in the frequency domain. In one example, an RB may include twelve subcarriers, a number independent of the numerology used. In some examples, depending on the numerology, an RB may include any suitable number of consecutive OFDM symbols 410 in the time domain.

[0059] A UE or V2X device generally utilizes only a subset of the resource grid 404. An RB may be the smallest unit of resources that can be allocated to or reserved by a UE or V2X device. Thus, the more RBs scheduled for or reserved by a UE or V2X device, and the higher the modulation scheme chosen for the air interface, the higher the data rate for the UE or V2X device.

[0060] In this illustration, the RB 408 is shown as occupying less than the entire bandwidth of the slot 402, with some subcarriers 412 illustrated above and below the RB 408. In a given implementation, the slot 402 may have a bandwidth corresponding to any number of one or more RBs 408. Further, in this illustration, the RB 408 is shown as occupying less than the entire duration of the slot 402, although this is merely one possible example.

[0061] In various aspects of the disclosure, V2X wireless communications may be transmitted over a V2X channel including spectrum that is divided into a plurality of slots. FIG. 5 illustrates an example of a slot 500 that may be utilized to communicate over such a V2X channel. In the example shown in FIG. 5, time is illustrated along a horizontal axis, while frequency is illustrated along a vertical axis.

[0062] In some examples, the slot 500 may be utilized for broadcast or unicast communication. A broadcast communication may refer to a point-to-multipoint transmission by one V2X device (e.g., a vehicle, roadside unit (RSU), UE of a pedestrian/cyclist, or other V2X device) to other V2X devices. A unicast communication may refer to a point-to-point transmission by one V2X device (e.g., a vehicle, roadside unit (RSU), UE of a pedestrian/cyclist, or other V2X device) to a single other V2X device.

[0063] In this example, the slot 500 may include a downlink (DL) burst 502, which may include a physical downlink control channel (PDCCH), in the initial of beginning portion of the slot 500. The DL burst 502 may include control information related to the

slot 500 that may be transmitted by an RSU (base station) towards one or more of a set of V2X devices nearby the RSU. In some examples, the control information may include synchronization information to synchronize communication by a plurality of V2X devices on the V2X channel. In addition, the control information may include scheduling information indicating one or more resource blocks allocated to V2X devices (e.g., platoon leaders (PLs) and/or platoon members (PMs) of one or more vehicle platoon groups) for device-to-device (D2D) or sidelink communication between the PL and PM's.

[0064] The slot 500 may further include a control portion 504 and a data portion 506 frequency-division multiplexed with the control portion 504 that collectively form a transmit section 510 of the slot 500. Based on the scheduling information, the V2X devices (PLs/PMs) may transmit control information within the control portion 504 and data within the data portion 506 of the transmit section 510. In some examples, the control information may be transmitted within a physical sidelink control channel (PSCCH), while the data may be transmitted within a physical sidelink shared channel (PSSCH).

[0065] In some examples, the control information transmitted by an individual vehicle (e.g., a PM) may include, for example, an indication that a new vehicle platoon group is being formed, an indication that the PM is assuming the role of PL within a new or existing vehicle platoon group, a join request to join a vehicle platoon group, or information related to the data to be transmitted by the individual vehicle, such as an indication of the allocated wireless resources for the data, a modulation and coding scheme utilized for the data, an indication of whether the data relates to an initial data transmission or a retransmission, etc. The data transmitted by an individual vehicle (e.g., a PM) may include, for example, vehicle information (e.g., the position, speed, trajectory, etc. of the vehicle), acknowledgement information (e.g., an ACK/NACK to the PL) and/or join request data, such as a platoon group identifier of the vehicle platoon group that the vehicle is requesting to join.

[0066] In some examples, the control information transmitted by a PL within a vehicle platoon group may include, for example, a platoon group identifier or information related to the data to be transmitted by the PL, such as an indication of the allocated wireless resources for the data, a modulation and coding scheme utilized for the data, an indication of whether the data relates to an initial data transmission or a retransmission, etc. The data transmitted by a PL may include, for example, both public platoon group

information and private platoon group information. For example, the public platoon group information may include the vehicle platoon group identifier (ID), geographical location of the PL, speed and trajectory (direction) of the PL, an indication of whether the vehicle platoon group is a private group (e.g., a one bit private group indicator), and event messages indicating braking, accelerating, or steering to be performed by the vehicles in the vehicle platoon group. The private platoon group information may include, for example, the inter-vehicle distance, planned route of the vehicle platoon group, number and/or list of PMs in the vehicle platoon group, recommended/known individual PM information (e.g., speed, relative position in the vehicle platoon group, and transmit power of PMs in the group).

[0067] In some examples, the slot 500 may further include a common uplink (UL) burst 508, which may include a physical uplink control channel (PUCCH), in the end of the slot 500. The PUCCH may include control information, such as a request for resources transmitted from V2X devices (e.g., PLs/PMs) to the RSU. As illustrated in FIG. 5, the end of the DL burst 502 may be separated in time from the beginning of the control portion 504 and the end of the transmit section 510 may be separated in time from the beginning of the UL burst 508. This time separation may sometimes be referred to as a gap, a guard period, a guard interval, and/or various other suitable terms. This separation may provide time for the various V2X devices to perform a switch-over between transmitting and receiving, or vice-versa.

[0068] FIG. 6 is a block diagram illustrating an example of a hardware implementation for a roadside unit (RSU) 600 employing a processing system 614. For example, the RSU 600 may correspond to the RSU shown and described above in reference to FIGs. 2 or 3.

[0069] The RSU 600 may be implemented with a processing system 614 that includes one or more processors 604. Examples of processors 604 include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. In various examples, the RSU 600 may be configured to perform any one or more of the functions described herein. That is, the processor 604, as utilized in the RSU 600, may be used to implement any one or more of the processes and procedures described below.

[0070] In this example, the processing system 614 may be implemented with a bus architecture, represented generally by the bus 602. The bus 602 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 614 and the overall design constraints. The bus 602 links together various circuits including one or more processors (represented generally by the processor 604), a memory 605, and computer-readable media (represented generally by the computer-readable medium 606). The bus 602 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[0071] A bus interface 608 provides an interface between the bus 602 and a transceiver 610. The transceiver 610 provides a means for communicating with various other apparatus over a transmission medium (e.g., air interface). Depending upon the nature of the apparatus, a user interface 612 (e.g., keypad, display, touch screen, speaker, microphone, control knobs, etc.) may also be provided. Of course, such a user interface 612 is optional, and may be omitted in some examples. The bus interface 608 further provides an interface between the bus 602 and one or more peripherals. For example, peripherals may include an optional camera 625. In some examples, the camera 625 may include a traffic camera attached to a traffic light or tollbooth.

[0072] The processor 604 is responsible for managing the bus 602 and general processing, including the execution of software stored on the computer-readable medium 606. The software, when executed by the processor 604, causes the processing system 614 to perform the various functions described below for any particular apparatus. The computer-readable medium 606 and the memory 605 may also be used for storing data that is manipulated by the processor 604 when executing software.

[0073] One or more processors 604 in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0074] The computer-readable medium 606 may be a non-transitory computer-readable medium. A non-transitory computer-readable medium includes, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., a compact disc (CD) or a digital versatile disc (DVD)), a smart card, a flash

memory device (e.g., a card, a stick, or a key drive), a random access memory (RAM), a read only memory (ROM), a programmable ROM (PROM), an erasable PROM (EPROM), an electrically erasable PROM (EEPROM), a register, a removable disk, and any other suitable medium for storing software and/or instructions that may be accessed and read by a computer. The computer-readable medium 606 may reside in the processing system 614, external to the processing system 614, or distributed across multiple entities including the processing system 614. The computer-readable medium 606 may be embodied in a computer program product. By way of example, a computer program product may include a computer-readable medium in packaging materials. In some examples, the computer-readable medium 606 may be part of the memory 605. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0075] In some aspects of the disclosure, the processor 604 may include circuitry configured for various functions. For example, the processor 604 may include V2X communication and processing circuitry 641 configured to communicate over a V2X channel to exchange V2X information 618 with V2X devices and with the network. In some examples, the communication and processing circuitry 641 may be configured to generate and transmit a PDCCH containing scheduling information for one or more V2X devices (e.g., PLs/PMs within one or more vehicle platoon groups). The communication and processing circuitry 641 may further receive V2X information 618 from the network (e.g., a V2X server) or other V2X devices via the transceiver 610 and transmit the V2X information 618 to other V2X devices via the transceiver 610. For example, the V2X information 618 may include traffic information, weather information, road hazard information, map data, the location of one or more pedestrians or cyclists, and/or vehicle platoon group information (VPGI) 615. The VPGI 615 and other V2X information 618 may be maintained, for example, within memory 605. The communication and processing circuitry 641 may operate in coordination with communication and processing software 651.

[0076] The processor 604 may further include vehicle platoon group management circuitry 642 configured to manage one or more vehicle platoon groups near the RSU 600. In some examples, the vehicle platoon group management circuitry 642 may be configured to receive VPGI 615, including public platoon group information and private platoon group information, from one or more vehicle platoon groups. To obtain the

private platoon group information, the vehicle platoon group management circuitry 642 may be configured to operate together with the V2X communication and processing circuitry 641 to generate and transmit a query requesting VPGI 615 from one or more vehicle platoon groups. In some examples, the query requests both the public and private platoon group information. In other examples, the query requests only the private platoon group information.

[0077] The query may further identify wireless resources allocated to the vehicle platoon groups to transmit the VPGI 615 to the RSU 600. In some examples, the query is a unicast message transmitted to a PL of a particular vehicle platoon group. In this example, the PL may utilize the wireless resources to transmit a unicast message to the RSU 600 including the requested VPGI 615. In other examples, the query is a broadcast message transmitted to two or more vehicle platoon groups. In this example, the allocated wireless resources may be shared by the PLs of each vehicle platoon group. For example, the PLs may utilize a listen-before-talk (LBT) mechanism to gain access to the V2X channel. LBT enables fair sharing of the spectrum between the PLs. LBT is a contention-based protocol used in wireless communication that allows several wireless devices to utilize the same spectrum or channel. For example, before a PL can transmit a signal over the V2X channel, the PL may first check (listen) to determine that the V2X channel is not currently in use. If the channel is not being used (e.g., the channel is idle or silent), the PL can transmit the signal over the V2X channel.

[0078] In some examples, the vehicle platoon group management circuitry 642 may operate together with the V2X communication and processing circuitry 641 to receive and process the CAMs broadcast from nearby PLs to identify the nearby vehicle platoon groups in order to generate and transmit unicast queries to each PL. In other examples, the vehicle platoon group management circuitry 642 does not listen to any broadcast CAMs, and therefore, generates and transmits a broadcast query to all nearby vehicle platoon groups. In examples in which the vehicle platoon group management circuitry 642 listens to (e.g., receives and processes) broadcast CAMs, the vehicle platoon group management circuitry 642 may further store the public platoon group information as VPGI 615 within the memory 605 and then query for the private platoon group information from the vehicle platoon groups. In some examples, the query may further include a query for the private key utilized to scramble the private platoon group information. In other examples, the vehicle platoon group management circuitry 642 may utilize the platoon group ID to generate the query for both the public and private

platoon group information without storing the remaining public platoon group information. Upon receiving the VPGI 615 from a PL, the vehicle platoon group management circuitry 642 may further operate together with the V2X communication and processing circuitry 641 to generate and transmit a confirmation message confirming receipt of the VPGI 615.

[0079] The vehicle platoon group management circuitry 642 may further be configured to assist one or more vehicles (e.g., V2X devices within vehicles) in joining vehicle platoon groups. For example, the vehicle platoon group management circuitry 642 may receive a query from a vehicle for the VPGI 615 of nearby vehicle platoon groups. The query may include, for example, an identifier of the vehicle (e.g., V2X device within the vehicle), the speed of the vehicle, the trajectory (direction of travel) of the vehicle, the current geographical location of the vehicle, an intended or desired route of the vehicle and/or other vehicle information.

[0080] The vehicle platoon group management circuitry 642 may further be configured to utilize the vehicle information to identify one or more nearby vehicle platoon groups that the vehicle may be able to join. For example, the vehicle platoon group management circuitry 642 may compare one or more components of the vehicle information to the stored VPGI 615 of vehicle platoon groups to identify one or more vehicle platoon groups that the vehicle may join. In some examples, the identified vehicle platoon groups may have a similar geographical location, trajectory, speed, and intended route to the vehicle, and may indicate that they are able to accept new PMs. In other examples, the identified vehicle platoon groups may merely be geographically close to the vehicle and traveling along the same trajectory to provide a broader list of potential vehicle platoon groups.

[0081] The vehicle platoon group management circuitry 642 may further be configured to operate in coordination with the V2X communication and processing circuitry 641 to generate and transmit a query response to the vehicle including at least a portion of the VPGI 615 of each of the identified vehicle platoon groups. For example, the VPGI 615 for each identified vehicle platoon group included in the query response may include the route, speed, direction of travel, and group identifier of each of the vehicle platoon groups. In addition, the query response may indicate wireless resources for the vehicle to transmit a join request to each of the vehicle platoon groups. In some examples, the vehicle platoon group management circuitry 642 may determine that there are no nearby vehicle platoon groups that the vehicle may join, and as such, the vehicle platoon group

management circuitry 642 may generate and transmit a query response that indicates that no vehicle platoon groups were found. The vehicle platoon group management circuitry 642 may further operate in coordination with vehicle platoon group management software 652.

[0082] FIG. 7 is a block diagram illustrating an example of a hardware implementation for a V2X device 700 within a vehicle employing a processing system 714. For example, the V2X device 700 may be included within one of the vehicles shown and described above in reference to FIGs. 2 or 3.

[0083] The V2X device 700 may be implemented with a processing system 714 that includes one or more processors 704. The processing system 714 may be substantially the same as the processing system 614 illustrated in FIG. 6, including a bus interface 708, a bus 702, memory 705, a processor 704, and a computer-readable medium 706. The bus interface 708 may further provide an interface between the bus 702 and one or more peripherals. For example, peripherals may include a navigation system 722, a global positioning system (GPS) receiver 724, one or more sensors 726, and/or a camera 725. Furthermore, the V2X device 700 may include or be coupled to a user interface 712 and a transceiver 710 substantially similar to those described above in FIG. 6. In addition, the processor 704, as utilized in a V2X device 700, may be used to implement any one or more of the processes described below.

[0084] The navigation system 722 provides a means for mapping or planning a route to one or more destinations for the V2X device 700. In the illustrated example, the navigation system 722 is illustrated external to the processing system 714; however, in another example, the navigation system 722 may be internal to the processing system 714, e.g., operational by the processor 704 utilizing software stored on the computer-readable medium 706. The GPS receiver 724 provides a means for communicating with a plurality of GPS satellites and determining position, speed, and trajectory (direction) information of the V2X device 700. The one or more sensors 726 may include any suitable set of one or more sensors, including, for example, sensors for determining whether the V2X device 700 is braking or accelerating. The set of sensors 726 may further include other types of gauges, such as a speedometer. The camera 725 may include a back-up camera or other camera within the vehicle.

[0085] In some aspects of the disclosure, the processor 704 may include V2X communication and processing circuitry 741 configured to communicate over a V2X channel to exchange V2X information 718 with other V2X devices and with the RSU.

In some examples, the communication and processing circuitry 741 may be configured to receive a PDCCH containing scheduling information for communicating over a sidelink with other V2X devices within a vehicle platoon group. The communication and processing circuitry 741 may further receive V2X information 718 from the RSU or other V2X devices via the transceiver 710 and transmit V2X information 718 to other V2X devices via the transceiver 710. In some examples, the V2X information 718 may include traffic information, weather information, road hazard information, map data, the location of one or more pedestrians or cyclists, control information (e.g., the control information transmitted by PLs and/or PMs described above in connection to FIG. 5) and/or vehicle platoon group information (VPGI) 715. The VPGI 715 and other V2X information 718 may be maintained, for example, within memory 705. The V2X communication and processing circuitry 741 may operate in coordination with communication and processing software 751.

[0086] The processor 704 may further include vehicle platoon group operating circuitry 742 configured to enable the V2X device 700 to create a vehicle platoon group, lead a vehicle platoon group, join a vehicle platoon group, operate within the vehicle platoon group, and/or leave a vehicle platoon group. In some examples, the vehicle platoon group operating circuitry 742 may be configured to obtain V2X information 718 from the navigation system 722, GPS receiver 724, sensors 726, and/or camera 725. In addition, the vehicle platoon group operating circuitry 742 may be configured to receive V2X information 718 from one or more neighbor V2X devices (e.g., vehicles, mobile devices of pedestrians, RSU's, etc.) or from a V2X server via the transceiver 710. The vehicle platoon group operating circuitry 742 may further be configured to utilize the V2X information 718 to derive VPGI 715 for the vehicle and to operate together with the V2X communication and processing circuitry 741 to transmit the VPGI 715 to other V2X devices within the vehicle platoon group.

[0087] In examples in which the V2X device 700 is a platoon member (PM) of a vehicle platoon group, the vehicle platoon group operating circuitry 742 may be configured to receive VPGI 715 from the platoon leader (PL) and at least the immediately preceding V2X device in the vehicle platoon group and to transmit the VPGI 715 of the V2X device 700 (e.g., the speed and direction of the vehicle, along with data obtained from various peripherals (e.g., navigation system 722, GPS receiver 724, camera 725, and sensors 726)) to the immediately following V2X device. In addition, the V2X device 700 may be configured to utilize the VPGI of the PL and the

immediately preceding vehicle, together with data from the peripherals to adjust the speed of the vehicle associated with the V2X device (e.g., by providing instructions to the vehicle to perform braking or accelerating) and/or position of the vehicle associated with the V2X device (e.g., by providing instructions to the vehicle to perform steering).

[0088] In examples in which the V2X device 700 is a PL of a vehicle platoon group, the vehicle platoon group operating circuitry 742 may further be configured to operate together with the V2X communication and processing circuitry 741 to generate and transmit broadcast VPGI 715, together with other V2X information 718 (e.g., traffic information, weather information, road hazard information, map data, the location of one or more pedestrians or cyclists, etc.) to PMs within the vehicle platoon group. The VPGI 715 may include, for example, public platoon group information and private platoon group information. The private platoon group information may be scrambled with a private key maintained by PMs to prevent unauthorized access to the private platoon group information.

[0089] In some examples, the private platoon group information may be transmitted together with the public platoon group information on the same wireless resources (same resource blocks), with the private platoon group information being scrambled with the private key. In other examples, the private platoon group information may be transmitted on different, non-overlapping wireless resources (resource blocks) than the public platoon group information. In this example, the private platoon group information may further be scrambled with the private key.

[0090] The vehicle platoon group operating circuitry 742 may further be configured to receive a query from an RSU requesting the VPGI 715 of the vehicle platoon group to which the V2X device belongs. The query may include an indication of the wireless resources (resource blocks) that the V2X device should utilize to transmit the VPGI 715 to the RSU.

[0091] In examples in which the V2X device is the PL of a vehicle platoon group, in response to receiving the query, the vehicle platoon group operating circuitry 742 may operate together with the V2X communication and processing circuitry 741 to generate and transmit a query response to the RSU that includes at least a portion of the VPGI 715 of the vehicle platoon group. The VPGI 715 transmitted within the query response may include, for example, information to enable the RSU to assist other vehicles in joining the vehicle platoon group. In some examples, the query response may include both the public platoon group information and the private platoon group

information. In other examples, the query response may include only the private platoon group information or the private key utilized to scramble the private platoon group information. The query response may further include only a portion of the public and/or private VPGI 715. For example, the query may include an indication of the type of VPGI 715 to include in the query response, or may request all VPGI 715. In some examples, the vehicle platoon group operating circuitry 742 may decide to not respond to the query, for example, when the vehicle platoon group is full.

[0092] In examples in which the V2X device 700 is seeking to join a vehicle platoon group, the vehicle platoon group operating circuitry 742 may further be configured to operate together with the V2X communication and processing circuitry 741 to generate and transmit a query to the RSU requesting VPGI 715 of nearby vehicle platoon groups. The query may include, for example, an identifier of the vehicle (e.g., V2X device within the vehicle), the speed of the vehicle, the trajectory (direction of travel) of the vehicle, the current geographical location of the vehicle, an intended or desired route of the vehicle and/or other vehicle information.

[0093] The vehicle platoon group operating circuitry 742 may further be configured to receive a query response from the RSU containing at least a portion of the VPGI 715 of one or more surrounding vehicle platoon groups. For example, the VPGI 615 for each vehicle platoon group included in the query response may include the route, speed, direction of travel, and group identifier of each of the vehicle platoon groups. In addition, the query response may indicate wireless resources for the V2X communication and processing circuitry 741 to transmit a join request to each of the vehicle platoon groups. The wireless resources may be dedicated to join requests to reduce blind decoding by the PL.

[0094] Based on the received VPGI 715, the vehicle platoon group operating circuitry 742 may select one of the vehicle platoon groups and transmit a join request to the PL of the selected vehicle platoon group utilizing the indicated wireless resources for the join request. The join request may include, for example, the vehicle identifier of the vehicle associated with the V2X device 700 and the vehicle information of the V2X device 700.

[0095] In response to the join request, the vehicle platoon group operating circuitry 742 may receive a join response carrying an acceptance (confirmation) message or a denial message. In some examples, when the join response includes a denial message, the vehicle platoon group operating circuitry 742 may select another vehicle platoon group

to join and may transmit another join request to the other vehicle platoon group. In other examples, the vehicle platoon group operating circuitry 742 may decide to delay joining any of the other nearby vehicle platoon groups when the join response includes a denial message.

[0096] In examples in which the V2X device 700 is a PL of a vehicle platoon group, the vehicle platoon group operating circuitry 742 may receive the join request from a vehicle requesting to join the vehicle platoon group. The join request may be generated, for example, based on VPGI provided to the vehicle from the RSU and/or the V2X device 700 of the PL. The vehicle platoon group operating circuitry 742 may then determine whether to allow the vehicle to join the vehicle platoon group based on one or more factors, including, for example, the number of vehicles currently in the vehicle platoon group, the maximum number of vehicles allowed in the vehicle platoon group, whether the vehicle platoon group is private, the vehicle identifier of the vehicle, and other vehicle information of the vehicle. The vehicle platoon group operating circuitry 742 may then operate together with the V2X communication and processing circuitry 741 to generate and transmit the join response including the confirmation message or the denial message to the vehicle requesting to join. The vehicle platoon group operating circuitry 742 may further be configured to operate in coordination with vehicle platoon group operating software 752.

[0097] FIG. 8 is a diagram illustrating exemplary signaling 800 between an RSU 804 and a platoon leader (PL) 802 of a vehicle platoon group to obtain vehicle platoon group information according to some aspects of the present disclosure. In some examples, the PL 802 corresponds to the V2X device 700 shown in FIG. 7, and the RSU 804 corresponds to the RSU 600 shown in FIG. 6.

[0098] At 806, the PL broadcasts vehicle platoon group information (VPGI) to the platoon members (PMs) in the vehicle platoon group. The VPGI may be transmitted, for example, within CAMs. The RSU 804 further receives and processes the broadcast CAMs transmitted from the PL 802 containing the VPGI to identify the vehicle platoon group associated with the PL 802 (e.g., ascertain the platoon group ID of the vehicle platoon group). The VPGI may include, for example, public platoon group information and private platoon group information. The private platoon group information may be scrambled with a private key maintained by PMs to prevent unauthorized access to the private platoon group information. In some examples, the private platoon group information may be transmitted together with the public platoon group information on

the same wireless resources (same resource blocks), with the private platoon group information being scrambled with the private key. In other examples, the private platoon group information may be transmitted on different, non-overlapping wireless resources (resource blocks) than the public platoon group information, with the private platoon group information being scrambled with the private key.

[0099] Since the private platoon group information is scrambled with a private key, the RSU 804 is unable to decode the private platoon group information. Therefore, at 808, the RSU utilizes the platoon group ID to transmit a query to the PL 802 requesting that the PL 802 transmit the VPGI of the vehicle platoon group to the RSU. In some examples, the query requests both the public and private platoon group information. In other examples, the query requests only the private platoon group information. The query may further identify wireless resources allocated to the PL 802 to transmit the VPGI to the RSU 804. In some examples, the query is a unicast message transmitted to the PL 802.

[0100] At 810, the PL 802 may transmit a query response including the requested VPGI to the RSU 804. The query response may be a unicast message transmitted on the wireless resources indicated in the query. In some examples, the query response may include both the public platoon group information and the private platoon group information. In other examples, the query response may include only the private platoon group information or the private key utilized to scramble the private platoon group information. The query response may further include only a portion of the public and/or private VPGI, based on the type of VPGI requested in the query. Upon receiving the VPGI, at 812, the RSU 804 may transmit a confirmation message confirming receipt of the VPGI to the PL 802. The confirmation message may include, for example, the platoon group ID and a one-bit confirmation indicator.

[0101] FIG. 9 is a diagram illustrating other exemplary signaling 900 between an RSU 804 and a platoon leader (PL) 802 of a vehicle platoon group to obtain vehicle platoon group information according to some aspects of the present disclosure. In FIG. 9, the RSU 804 does not process any broadcast information from the PL 802 or other PLs, and therefore, does not have knowledge of the platoon group identities of any nearby vehicle platoon groups.

[0102] Thus, at 902, the RSU 804 broadcasts a query requesting that the PL 802 and any other nearby PLs transmit their respective VPGI to the RSU 804. The query may request that the PLs transmit all VPGI (public and private) to the RSU 804 and may

further identify shared wireless resources allocated for the transmission of the VPGI by the various PLs to the RSU 804. For example, the PLs may utilize a listen-before-talk (LBT) mechanism to gain access to the V2X channel.

[0103] At 904, the PL 802 may transmit a query response including the requested VPGI to the RSU 804. The query response may be a unicast message transmitted on the wireless resources indicated in the query. In some examples, the query response may include both the public platoon group information and the private platoon group information. Upon receiving the VPGI, at 906, the RSU 804 may transmit a confirmation message confirming receipt of the VPGI to the PL 802. The confirmation message may include, for example, the platoon group ID and a one-bit confirmation indicator.

[0104] FIG. 10 is a diagram illustrating exemplary signaling 1000 between a V2X device 1002, RSU 804, and a platoon leader (PL) 802 of a vehicle platoon group for the V2X device to join the vehicle platoon group according to some aspects of the present disclosure. In some examples, the V2X device 1002 may correspond to the V2X device 700 shown in FIG. 7 operating as a non-member of any vehicle platoon groups.

[0105] At 1004, the V2X device 1002 may transmit a query for nearby vehicle platoon groups to the RSU 804. The query may include, for example, an identifier of the vehicle (e.g., V2X device 1002 within the vehicle), the speed of the vehicle, the trajectory (direction of travel) of the vehicle, the current geographical location of the vehicle, an intended or desired route of the vehicle and/or other vehicle information.

[0106] At 1006, the RSU 804 may utilize the vehicle information to identify one or more nearby vehicle platoon groups that the vehicle may be able to join and transmit a query response to the V2X device 1002 including at least a portion of the VPGI of each of the identified vehicle platoon groups. For example, the RSU 804 may compare one or more components of the vehicle information to the stored VPGI of vehicle platoon groups to identify one or more vehicle platoon groups that the V2X device 1002 may join. The VPGI for each identified vehicle platoon group included in the query response may include, for example, the route, speed, direction of travel, and group identifier of each of the vehicle platoon groups. In addition, the query response may indicate wireless resources for the V2X device 1002 to transmit a join request to each of the vehicle platoon groups.

[0107] At 1008, the V2X device 1002 may select one of the vehicle platoon groups (VPG) to join based on the received VPGI. In some examples, the V2X device 1002

may compare the VPGI of each of the vehicle platoon groups identified by the RSU 804 to the current vehicle speed, direction, geographical location, desired route, and other vehicle information to select the VPG that most closely matches the vehicle information.

[0108] At 1010, the V2X device 1002 may transmit a join request to the PL 802 of the selected VPG. The join request may be transmitted over the wireless resources indicated in the query response from the RSU 804. In some examples, the wireless resources may be dedicated to join requests to reduce blind decoding by the PL 802. The join request may include, for example, the vehicle identifier of the vehicle associated with the V2X device 1002 and the vehicle information of the V2X device 1002.

[0109] In response to the join request, at 1012, the PL 802 may transmit a join response carrying an acceptance (confirmation) message or a denial message. The PL 802 may determine whether to allow the V2X device 1002 to join the vehicle platoon group based on one or more factors, including, for example, the number of vehicles currently in the vehicle platoon group, the maximum number of vehicles allowed in the vehicle platoon group, whether the vehicle platoon group is private, the vehicle identifier of the vehicle, and other vehicle information associated with the V2X device 1002. At 1014, the V2X device 1002 may transmit an optional confirmation message to the PL 802 confirming receipt of the join response.

[0110] FIG. 11 is a flow chart 1100 of a method for V2X wireless communication at an RSU. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all embodiments. In some examples, the method may be performed by the RSU 600, as described above and illustrated in FIG. 6, by a processor or processing system, or by any suitable means for carrying out the described functions.

[0111] At block 1102, the RSU may transmit a query requesting vehicle platoon group information (VPGI) from platoon leaders of one or more vehicle platoon groups. In some examples, the query requests both the public and private platoon group information. In other examples, the query requests only the private platoon group information or the private key utilized to scramble the private platoon group information. The query may further identify wireless resources allocated to the vehicle platoon groups to transmit the VPGI to the RSU. In some examples, the query is a unicast message transmitted to a PL of a particular vehicle platoon group. In other

examples, the query is a broadcast message transmitted to two or more vehicle platoon groups. For example, the V2X communication and processing circuitry 641 together with the vehicle platoon group management circuitry 642 shown and described above in connection with FIG. 6 may transmit the query to the platoon leader(s) of one or more vehicle platoon groups via the transceiver 610.

[0112] At block 1104, the RSU may receive the VPGI from the platoon leader(s) of one or more vehicle platoon groups over the allocated wireless resources. In some examples, one or more of the PLs may utilize the wireless resources to transmit a unicast message to the RSU including the requested VPGI. In other examples, the allocated wireless resources may be shared by the PLs of each vehicle platoon group. For example, the V2X communication and processing circuitry 641 together with the vehicle platoon group management circuitry 642 shown and described above in connection with FIG. 6 may receive the VPGI from each of the vehicle platoon groups via the transceiver 610.

[0113] FIG. 12 is a flow chart 1200 of a method for V2X wireless communication at a V2X device within a vehicle. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all embodiments. In some examples, the method may be performed by the V2X device 700, as described above and illustrated in FIG. 7, by a processor or processing system, or by any suitable means for carrying out the described functions.

[0114] At block 1202, the V2X device may transmit a query to the RSU requesting vehicle platoon group information (VPGI) of nearby vehicle platoon groups. The query may include, for example, an identifier of the V2X device and other vehicle information, such as the speed, direction, current geographical location, and desired route of the vehicle. For example, the V2X communication and processing circuitry 741 together with the vehicle platoon group operating circuitry 742 shown and described above in connection with FIG. 7 may transmit the query to the RSU via the transceiver 710.

[0115] At block 1204, the V2X device may receive VPGI of one or more nearby vehicle platoon groups from the RSU. For example, the VPGI for each vehicle platoon group included in the query response may include the route, speed, direction of travel, and group identifier of each of the vehicle platoon groups. In addition to the VPGI, the RSU may further indicate wireless resources for the V2X device to transmit a join request to each of the vehicle platoon groups. For example, the V2X communication and

processing circuitry 741 together with the vehicle platoon group operating circuitry 742 shown and described above in connection with FIG. 7 may receive the VPGI of the nearby vehicle platoon groups.

[0116] At block 1206, the V2X device may select a vehicle platoon group to join based on the received VPGI of the nearby vehicle platoon groups. For example, the vehicle platoon group operating circuitry 742 shown and described above in connection with FIG. 7 may select the vehicle platoon group to join.

[0117] At block 1208, the V2X device may transmit a join request to the platoon leader (PL) of the selected vehicle platoon group. The join request may be transmitted over the wireless resources indicated by the RSU. The join request may include, for example, the vehicle identifier of the vehicle associated with the V2X device and the vehicle information of the V2X device. For example, the V2X communication and processing circuitry 741 together with the vehicle platoon group operating circuitry 742 shown and described above in connection with FIG. 7 may transmit the join request to the PL via the transceiver 710.

[0118] At block 1210, the V2X device may receive a join response from the PL of the selected vehicle platoon group. The join response may include, for example, a confirmation message or a denial message. For example, the V2X communication and processing circuitry 741 together with the vehicle platoon group operating circuitry 742 shown and described above in connection with FIG. 7 may receive the join response from the PL via the transceiver 710.

[0119] FIG. 13 is a diagram illustrating an example of control information and data transmitted by platoon members (PMs) and platoon leaders (PLs) in a vehicle platoon group. The control information and data may be transmitted, for example, in a slot, such as the slot 500 illustrated in FIG. 5. Thus, as in FIG. 5, in the example shown in FIG. 13, time is illustrated along the horizontal axis, while frequency is illustrated along the vertical axis. In addition, as in FIG. 5, the slot 500 may be frequency-divided into a control portion 504 and a data portion 506.

[0120] Within the slot 500, both PMs and PLs may transmit control information (e.g., PSSCH) and data (e.g., PSSCH). The control information may be transmitted in sub-channels using specific resource blocks (RBs) across time. In addition, data associated with the control information may be transmitted in RBs that are adjacent or non-adjacent to the control information (the latter being illustrated in FIG. 13) across the same time as the control information.

[0121] In the example shown in FIG. 13, a PM may transmit control information (Control-1) 1302, which may include a scheduling assignment for data (Data-1) 1306 to be transmitted by the PM. For example, the scheduling assignment may indicate the allocated wireless resources for the Data-1 1306, a modulation and coding scheme utilized for the data, an indication of whether the data relates to an initial data transmission or a retransmission, etc. The control information of Control-1 1302 may further include, for example, an indication that a new vehicle platoon group is being formed, an indication that the PM is assuming the role of PL within a new or existing vehicle platoon group, or a join request to join a vehicle platoon group. The data transmitted by the PM within the Data-1 1306 may include, for example, vehicle information (e.g., the position, speed, trajectory, etc. of the vehicle), acknowledgement information (e.g., an ACK/NACK to the PL) and/or join request data, such as a platoon group identifier of the vehicle platoon group that the vehicle is requesting to join.

[0122] A PL may further transmit control information (Control-2) 1304, which may include a scheduling assignment for data (Data-2) 1308 to be transmitted by the PL within the slot 500. For example, the scheduling assignment may indicate allocated wireless resources for the Data-2 1308, a modulation and coding scheme utilized for the data, an indication of whether the data relates to an initial data transmission or a retransmission, etc. The control information of Control-2 1304 may further include, for example, a platoon group identifier.

[0123] The data transmitted by the PL within the Data-2 1308 may include, for example, both public platoon group information and private platoon group information. For example, the public platoon group information may include the vehicle platoon group identifier (ID), geographical location of the PL, speed and trajectory (direction) of the PL, an indication of whether the vehicle platoon group is a private group (e.g., a one bit private group indicator), and event messages indicating braking, accelerating, or steering to be performed by the vehicles in the vehicle platoon group. The private platoon group information may include, for example, the inter-vehicle distance, planned route of the vehicle platoon group, number and/or list of PMs in the vehicle platoon group, recommended/known individual PM information (e.g., speed, relative position in the vehicle platoon group, and transmit power of PMs in the group). The private platoon group information may further be scrambled with a private key to prevent unauthorized access to the private platoon group information. In this example, both the public and

private platoon group information is transmitted within the same RBs (e.g., within Data-2 1308).

[0124] FIG. 14 is a diagram illustrating another example of control information and data transmitted by platoon members (PMs) and platoon leaders (PLs) in a vehicle platoon group within a slot 500. As in FIG. 13, a PM may transmit control information (Control-1) 1402 in the control portion 504 of the slot 500, which may include a scheduling assignment for data (Data-1) 1406 to be transmitted by the PM within the data portion 506 of the slot 500. In addition, a PL may transmit control information (Control-2) 1404 in the control portion 504 of the slot 500, which may include a scheduling assignment for data to be transmitted by the PL within the data portion 506 of the slot 500. In the example shown in FIG. 14, the control information (Control-2) 1404 may include two scheduling assignments, one for public platoon group information (Data-2) 1408, and another for private platoon group information (Data-3) 1410. The private platoon group information may be scrambled with a private key.

[0125] In some examples, the public and private platoon group information (Data-2 and Data-3) may be transmitted on adjacent RBs (as illustrated in FIG. 14) or non-adjacent RBs across the same time as the control information (Control-2) 1404. In other examples, separate control information (scheduling assignments) may be transmitted for each of the public and private platoon group information (Data-2 1408 and Data-3 1410).

[0126] Several aspects of a wireless communication network have been presented with reference to an exemplary implementation. As those skilled in the art will readily appreciate, various aspects described throughout this disclosure may be extended to other telecommunication systems, network architectures and communication standards.

[0127] By way of example, various aspects may be implemented within other systems defined by 3GPP, such as Long-Term Evolution (LTE), the Evolved Packet System (EPS), the Universal Mobile Telecommunication System (UMTS), and/or the Global System for Mobile (GSM). Various aspects may also be extended to systems defined by the 3rd Generation Partnership Project 2 (3GPP2), such as CDMA2000 and/or Evolution-Data Optimized (EV-DO). Other examples may be implemented within systems employing IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Ultra-Wideband (UWB), Bluetooth, and/or other suitable systems. The actual telecommunication standard, network architecture, and/or communication standard

employed will depend on the specific application and the overall design constraints imposed on the system.

[0128] Within the present disclosure, the word “exemplary” is used to mean “serving as an example, instance, or illustration.” Any implementation or aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects of the disclosure. Likewise, the term “aspects” does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation. The term “coupled” is used herein to refer to the direct or indirect coupling between two objects. For example, if object A physically touches object B, and object B touches object C, then objects A and C may still be considered coupled to one another—even if they do not directly physically touch each other. For instance, a first object may be coupled to a second object even though the first object is never directly physically in contact with the second object. The terms “circuit” and “circuitry” are used broadly, and intended to include both hardware implementations of electrical devices and conductors that, when connected and configured, enable the performance of the functions described in the present disclosure, without limitation as to the type of electronic circuits, as well as software implementations of information and instructions that, when executed by a processor, enable the performance of the functions described in the present disclosure.

[0129] One or more of the components, steps, features and/or functions illustrated in FIGs. 1–14 may be rearranged and/or combined into a single component, step, feature or function or embodied in several components, steps, or functions. Additional elements, components, steps, and/or functions may also be added without departing from novel features disclosed herein. The apparatus, devices, and/or components illustrated in FIGs. 1–3 and/or 6–10 may be configured to perform one or more of the methods, features, or steps described herein. The novel algorithms described herein may also be efficiently implemented in software and/or embedded in hardware.

[0130] It is to be understood that the specific order or hierarchy of steps in the methods disclosed is an illustration of exemplary processes. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the methods may be rearranged. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented unless specifically recited therein.

[0131] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects

will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but are to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” Unless specifically stated otherwise, the term “some” refers to one or more. A phrase referring to “at least one of” a list of items refers to any combination of those items, including single members. As an example, “at least one of: a, b, or c” is intended to cover: a; b; c; a and b; a and c; b and c; and a, b and c. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112(f) unless the element is expressly recited using the phrase “means for” or, in the case of a method claim, the element is recited using the phrase “step for.”

CLAIMS

What is claimed is:

1. A method for vehicle-to-everything (V2X) wireless communication at a roadside unit (RSU), comprising:

transmitting a query requesting vehicle platoon group information from a platoon leader of a vehicle platoon group, wherein the query identifies wireless resources for use by the platoon leader in transmitting the vehicle platoon group information to the RSU; and

receiving the vehicle platoon group information from the platoon leader of the vehicle platoon group over the wireless resources;

wherein the vehicle platoon group information comprises at least a number of vehicles within the vehicle platoon group and route information indicating an intended route of the vehicle platoon group.

2. The method of claim 1, wherein the query comprises a unicast message transmitted to the platoon leader of the vehicle platoon group.

3. The method of claim 1, wherein the query comprises a broadcast message transmitted to the vehicle platoon group and at least one additional vehicle platoon group.

4. The method of claim 3, wherein the wireless resources are shared by the vehicle platoon group and the at least one additional vehicle platoon group utilizing listen-before-talk.

5. The method of claim 1, wherein the vehicle platoon group information comprises public platoon group information and private platoon group information, wherein the private platoon group information is scrambled with a private key associated with the vehicle platoon group, and further comprising:

receiving the public platoon group information and the private platoon group information from the platoon leader of the vehicle platoon group over additional wireless resources; and

determining to transmit the query for at least the private platoon group information of the vehicle platoon group information or the private key when the public platoon group information comprises a private indicator indicating the RSU is unable to decipher the private platoon group information.

6. The method of claim 5, wherein the private platoon group information comprises one or more of the number of vehicles within the vehicle platoon group, the route information indicating an intended route of the vehicle platoon group, a list of the vehicles in the vehicle platoon group, a respective relative position of each of the vehicles in the vehicle platoon group, an inter-vehicle distance and individual vehicle information indicating a recommended speed, or a recommended transmit power of each of the vehicles in the vehicle platoon group.

7. The method of claim 5, wherein the public platoon group information further comprises at least one of a platoon group identifier, speed of the platoon leader, direction of the platoon leader, location of the platoon leader, or an event message indicating braking, accelerating, or steering to be performed by the vehicles in the vehicle platoon group.

8. The method of claim 5, wherein:
the additional wireless resources comprise a first set of wireless resources over which the public platoon group information is transmitted and a second set of wireless resources over which the private platoon group information is transmitted; and
the first set of wireless resources and the second set of wireless resources are non-overlapping.

9. A roadside unit (RSU) for vehicle-to-everything (V2X) wireless communication, comprising:

- a processor;
- a transceiver communicatively coupled to the processor; and
- a memory communicatively coupled to the processor, wherein the processor is configured to:

- transmit a query requesting vehicle platoon group information from a platoon leader of a vehicle platoon group via the transceiver, wherein the query

identifies wireless resources for use by the platoon leader in transmitting the vehicle platoon group information to the RSU; and

receive the vehicle platoon group information from the platoon leader of the vehicle platoon group over the wireless resources via the transceiver;

wherein the vehicle platoon group information comprises at least a number of vehicles within the vehicle platoon group and route information indicating an intended route of the vehicle platoon group.

10. The RSU of claim 9, wherein the query comprises a unicast message transmitted to the platoon leader of the vehicle platoon group.

11. The RSU of claim 9, wherein the query comprises a broadcast message transmitted to the vehicle platoon group and at least one additional vehicle platoon group.

12. The RSU of claim 11, wherein the wireless resources are shared by the vehicle platoon group and the at least one additional vehicle platoon group utilizing listen-before-talk.

13. The RSU of claim 9, wherein the vehicle platoon group information comprises public platoon group information and private platoon group information, wherein the private platoon group information is scrambled with a private key associated with the vehicle platoon group, and wherein the processor is further configured to:

receive the public platoon group information and the private platoon group information from the platoon leader of the vehicle platoon group over additional wireless resources; and

determine to transmit the query for at least the private platoon group information of the vehicle platoon group information or the private key when the public platoon group information comprises a private indicator indicating the RSU is unable to decipher the private platoon group information.

14. The RSU of claim 13, wherein the private platoon group information comprises one or more of the number of vehicles within the vehicle platoon group, the route information indicating an intended route of the vehicle platoon group, a list of the

vehicles in the vehicle platoon group, a respective relative position of each of the vehicles in the vehicle platoon group, an inter-vehicle distance and individual vehicle information indicating a recommended speed, or a recommended transmit power of each of the vehicles in the vehicle platoon group.

15. The RSU of claim 13, wherein the public platoon group information further comprises at least one of a platoon group identifier, speed of the platoon leader, direction of the platoon leader, location of the platoon leader, or an event message indicating braking, accelerating, or steering to be performed by the vehicles in the vehicle platoon group.

16. The RSU of claim 13, wherein:

the additional wireless resources comprise a first set of wireless resources over which the public platoon group information is transmitted and a second set of wireless resources over which the private platoon group information is transmitted; and

the first set of wireless resources and the second set of wireless resources are non-overlapping.

17. A roadside unit (RSU) for vehicle-to-everything (V2X) wireless communication, comprising:

means for transmitting a query requesting vehicle platoon group information from a platoon leader of a vehicle platoon group, wherein the query identifies wireless resources for use by the platoon leader in transmitting the vehicle platoon group information to the RSU; and

means for receiving the vehicle platoon group information from the platoon leader of the vehicle platoon group over the wireless resources;

wherein the vehicle platoon group information comprises at least a number of vehicles within the vehicle platoon group and route information indicating an intended route of the vehicle platoon group.

18. The RSU of claim 17, wherein the query comprises a unicast message transmitted to the platoon leader of the vehicle platoon group.

19. The RSU of claim 17, wherein the query comprises a broadcast message transmitted to the vehicle platoon group and at least one additional vehicle platoon group.

20. The RSU of claim 19, wherein the wireless resources are shared by the vehicle platoon group and the at least one additional vehicle platoon group utilizing listen-before-talk.

21. The RSU of claim 17, wherein the vehicle platoon group information comprises public platoon group information and private platoon group information, wherein the private platoon group information is scrambled with a private key associated with the vehicle platoon group, and further comprising:

means for receiving the public platoon group information and the private platoon group information from the platoon leader of the vehicle platoon group over additional wireless resources; and

means for determining to transmit the query for at least the private platoon group information of the vehicle platoon group information or the private key when the public platoon group information comprises a private indicator indicating the RSU is unable to decipher the private platoon group information.

22. The RSU of claim 21, wherein the private platoon group information comprises one or more of the number of vehicles within the vehicle platoon group, the route information indicating an intended route of the vehicle platoon group, a list of the vehicles in the vehicle platoon group, a respective relative position of each of the vehicles in the vehicle platoon group, an inter-vehicle distance and individual vehicle information indicating a recommended speed, or a recommended transmit power of each of the vehicles in the vehicle platoon group.

23. The RSU of claim 21, wherein the public platoon group information further comprises at least one of a platoon group identifier, speed of the platoon leader, direction of the platoon leader, location of the platoon leader, or an event message indicating braking, accelerating, or steering to be performed by the vehicles in the vehicle platoon group.

24. The RSU of claim 21, wherein:
the additional wireless resources comprise a first set of wireless resources over which the public platoon group information is transmitted and a second set of wireless resources over which the private platoon group information is transmitted; and
the first set of wireless resources and the second set of wireless resources are non-overlapping.
25. A method for vehicle-to-everything (V2X) wireless communication at a vehicle, the method comprising:
transmitting a query to a roadside unit (RSU) requesting vehicle platoon group information of nearby vehicle platoon groups;
receiving the vehicle platoon group information of the nearby vehicle platoon groups from the RSU;
selecting a first vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information;
transmitting a join request to the first vehicle platoon group requesting to join the first vehicle platoon group; and
receiving a join response from a platoon leader of the first vehicle platoon group.
26. The method of claim 25, wherein the query comprises a vehicle identifier and vehicle information indicating at least one of a speed, direction, or route of the vehicle.
27. The method of claim 26, wherein the join request comprises the vehicle identifier and the vehicle information.
28. The method of claim 25, wherein the vehicle platoon group information comprises a route, speed, direction, group identifier, and wireless resources for the join request for each of the nearby vehicle platoon groups.
29. The method of claim 25, wherein the join response comprises a join confirmation message or a denial message.
30. The method of claim 29, further comprising:

selecting a second vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information when the join response comprises the denial message;

transmitting an additional join request to the second vehicle platoon group requesting to join the second vehicle platoon group; and

receiving an additional join response from the second vehicle platoon group.

31. The method of claim 29, further comprising:

delaying joining any of the nearby vehicle platoon groups when the join response comprises the denial message.

32. A vehicle-to-everything (V2X) device within a vehicle, comprising:

a processor;

a wireless transceiver communicatively coupled to the processor; and

a memory communicatively coupled to the processor, wherein the processor is configured to:

transmit a query to a roadside unit (RSU) requesting vehicle platoon group information of nearby vehicle platoon groups;

receive the vehicle platoon group information of the nearby vehicle platoon groups from the RSU;

select a first vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information;

transmit a join request to the first vehicle platoon group requesting to join the first vehicle platoon group; and

receive a join response from a platoon leader of the first vehicle platoon group.

33. The V2X device of claim 32, wherein the query comprises a vehicle identifier and vehicle information indicating at least one of a speed, direction, or route of the vehicle.

34. The V2X device of claim 33, wherein the join request comprises the vehicle identifier and the vehicle information.

35. The V2X device of claim 32, wherein the vehicle platoon group information comprises a route, speed, direction, group identifier, and wireless resources for the join request for each of the nearby vehicle platoon groups.

36. The V2X device of claim 32, wherein the join response comprises a join confirmation message or a denial message.

37. The V2X device of claim 36, further comprising:
selecting a second vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information when the join response comprises the denial message;
transmitting an additional join request to the second vehicle platoon group requesting to join the second vehicle platoon group; and
receiving an additional join response from the second vehicle platoon group.

38. The V2X device of claim 36, further comprising:
delaying joining any of the nearby vehicle platoon groups when the join response comprises the denial message.

39. A vehicle-to-everything (V2X) device within a vehicle, comprising:
means for transmitting a query to a road side unit (RSU) requesting vehicle platoon group information of nearby vehicle platoon groups;
means for receiving the vehicle platoon group information of the nearby vehicle platoon groups from the RSU;
means for selecting a first vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information;
means for transmitting a join request to the first vehicle platoon group requesting to join the first vehicle platoon group; and
means for receiving a join response from a platoon leader of the first vehicle platoon group.

40. The V2X device of claim 39, wherein the query comprises a vehicle identifier and vehicle information indicating at least one of a speed, direction, or route of the vehicle.

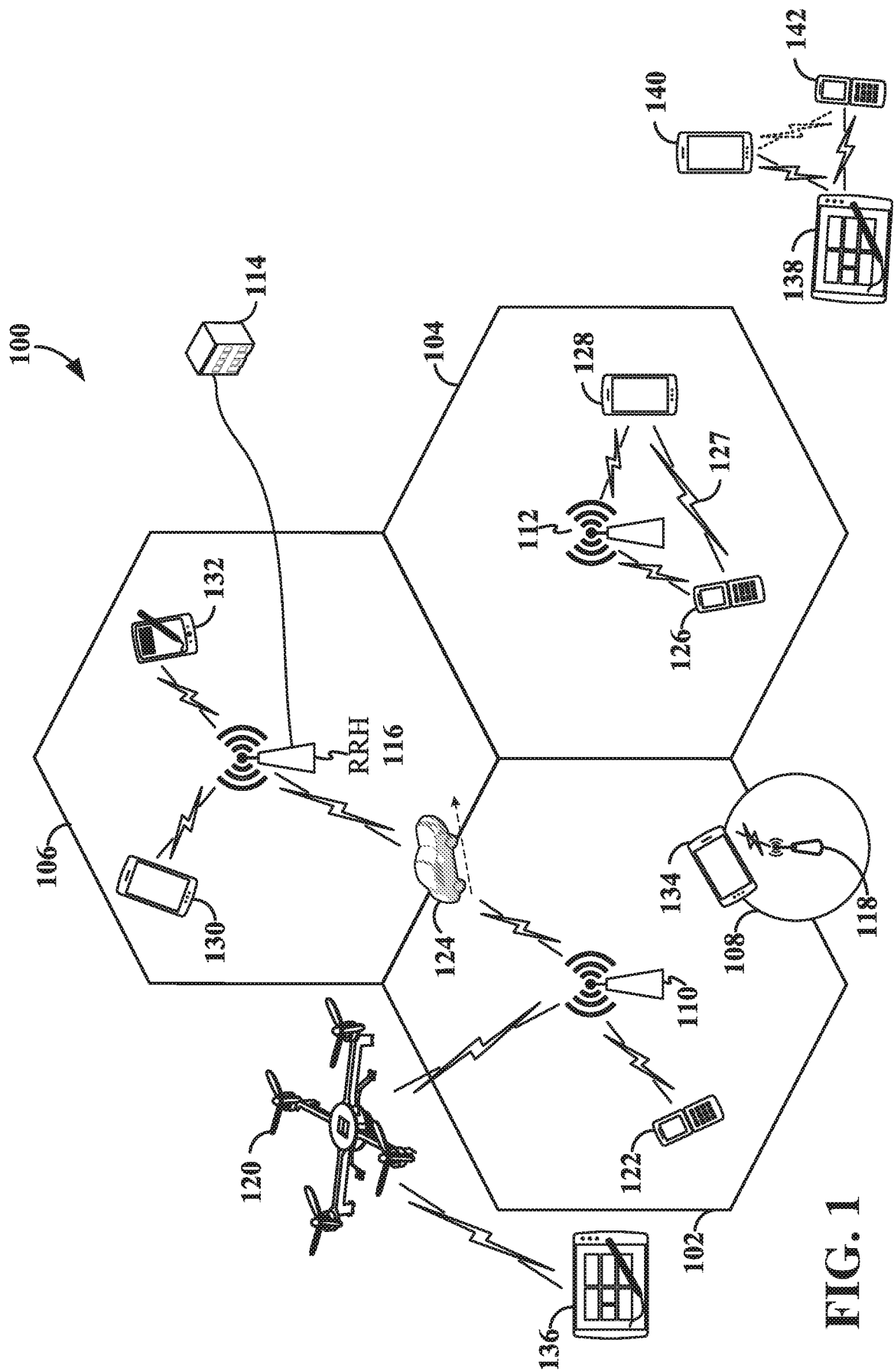
41. The V2X device of claim 40, wherein the join request comprises the vehicle identifier and the vehicle information.

42. The V2X device of claim 39, wherein the vehicle platoon group information comprises a route, speed, direction, group identifier, and wireless resources for the join request for each of the nearby vehicle platoon groups.

43. The V2X device of claim 39, wherein the join response comprises a join confirmation message or a denial message.

44. The V2X device of claim 43, further comprising:
means for selecting a second vehicle platoon group from the nearby vehicle platoon groups to join based on the vehicle platoon group information when the join response comprises the denial message;
means for transmitting an additional join request to the second vehicle platoon group requesting to join the second vehicle platoon group; and
means for receiving an additional join response from the second vehicle platoon group.

45. The V2X device of claim 43, further comprising:
means for delaying joining any of the nearby vehicle platoon groups when the join response comprises the denial message.



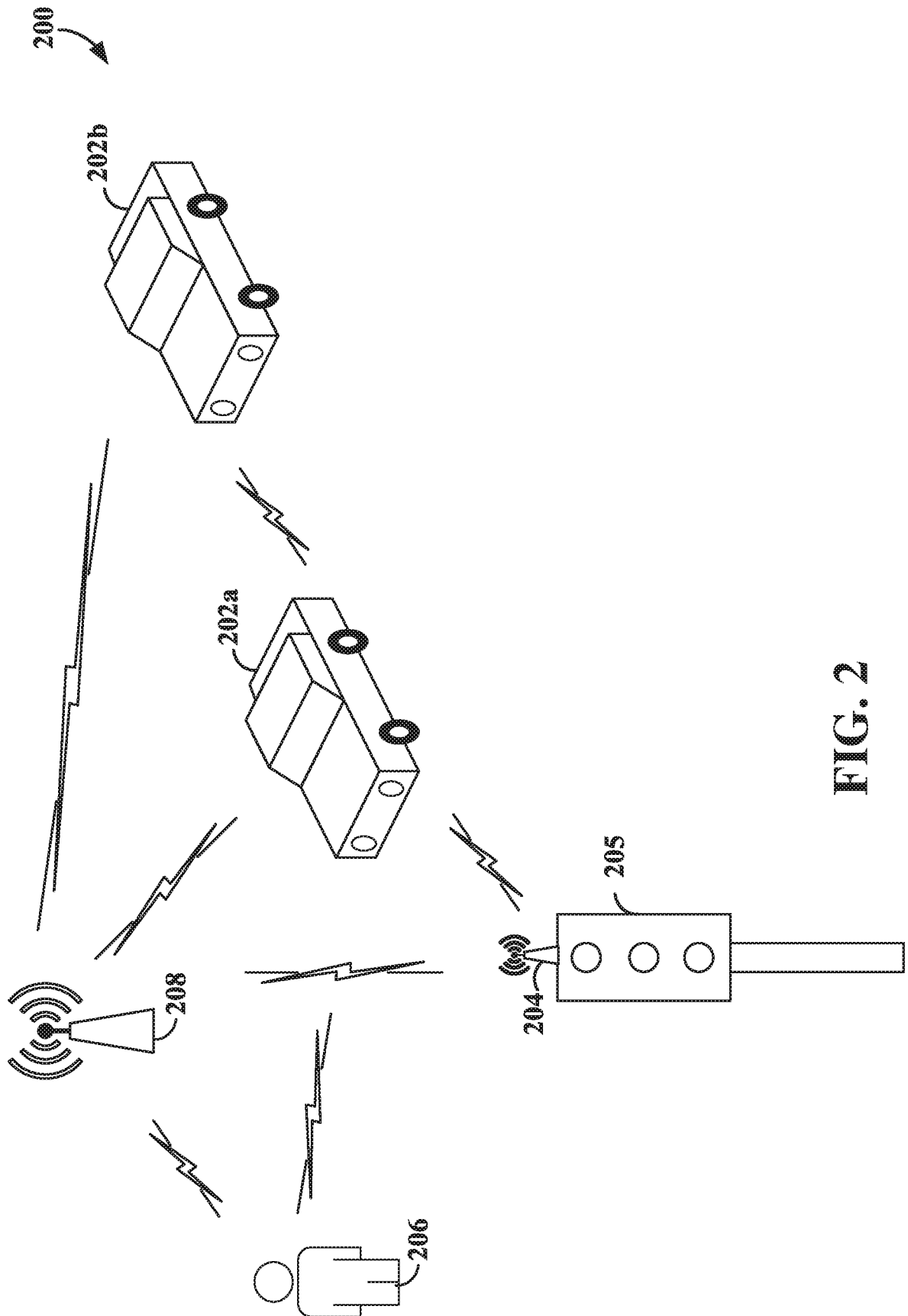


FIG. 2

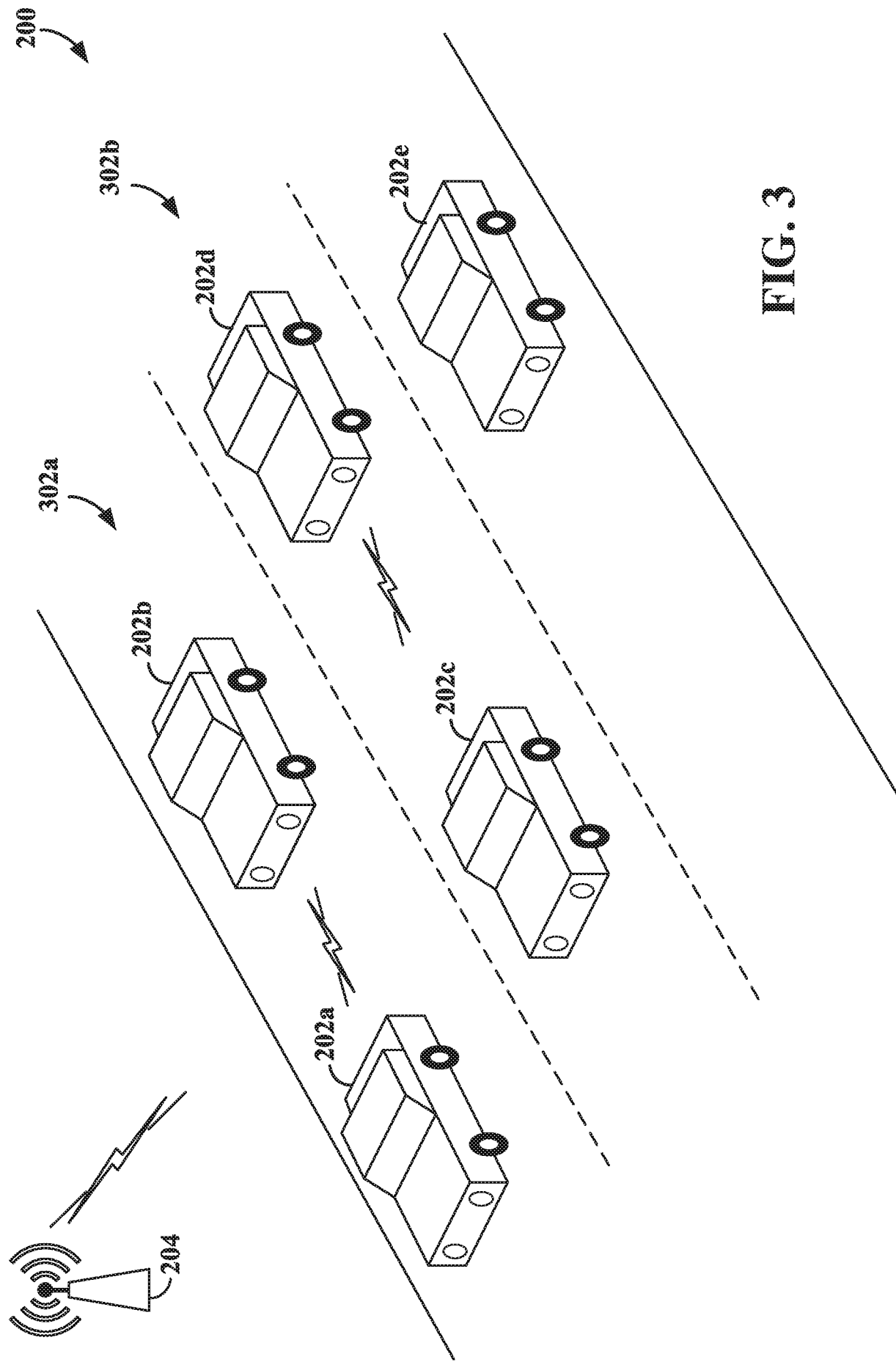
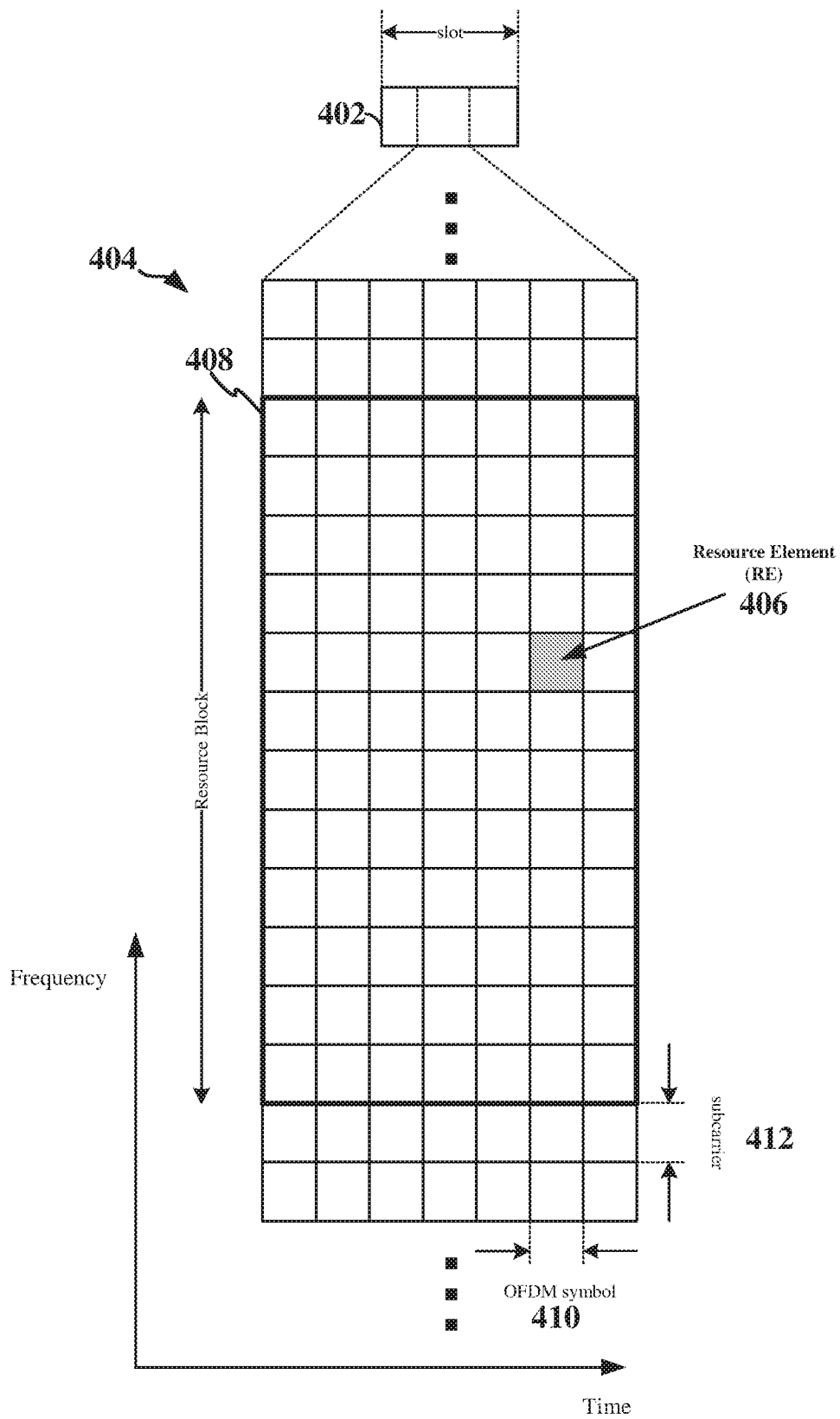


FIG. 3

**FIG. 4**

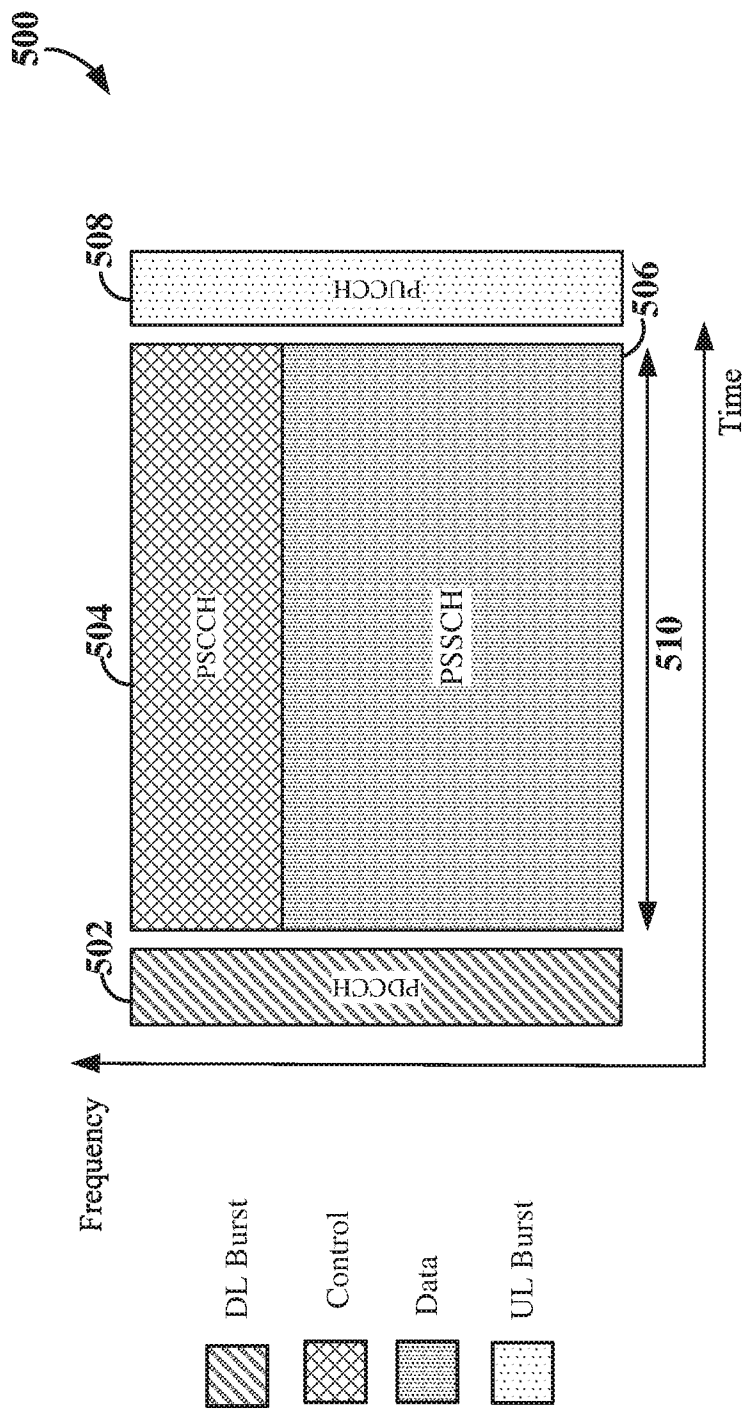


FIG. 5

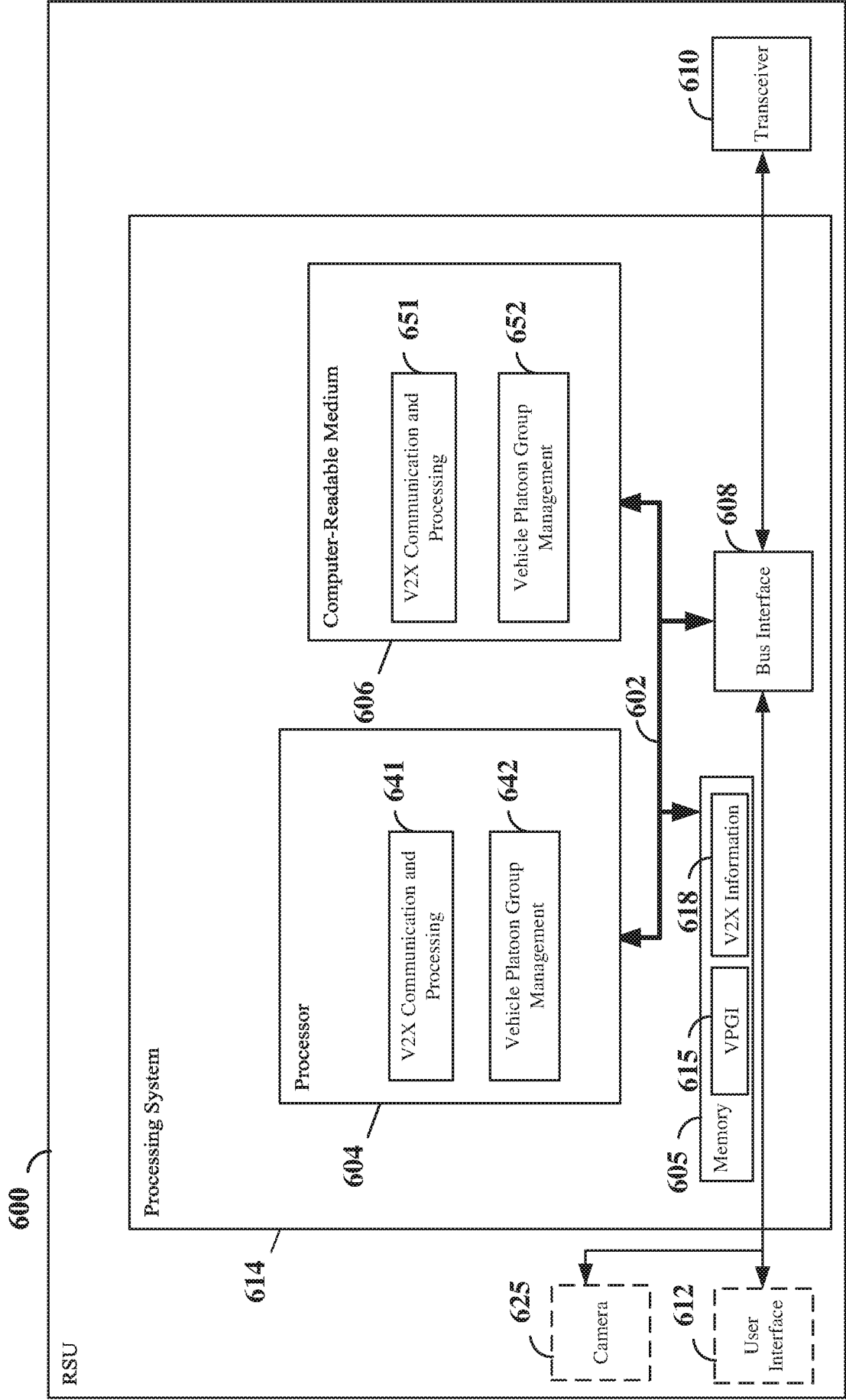


FIG. 6

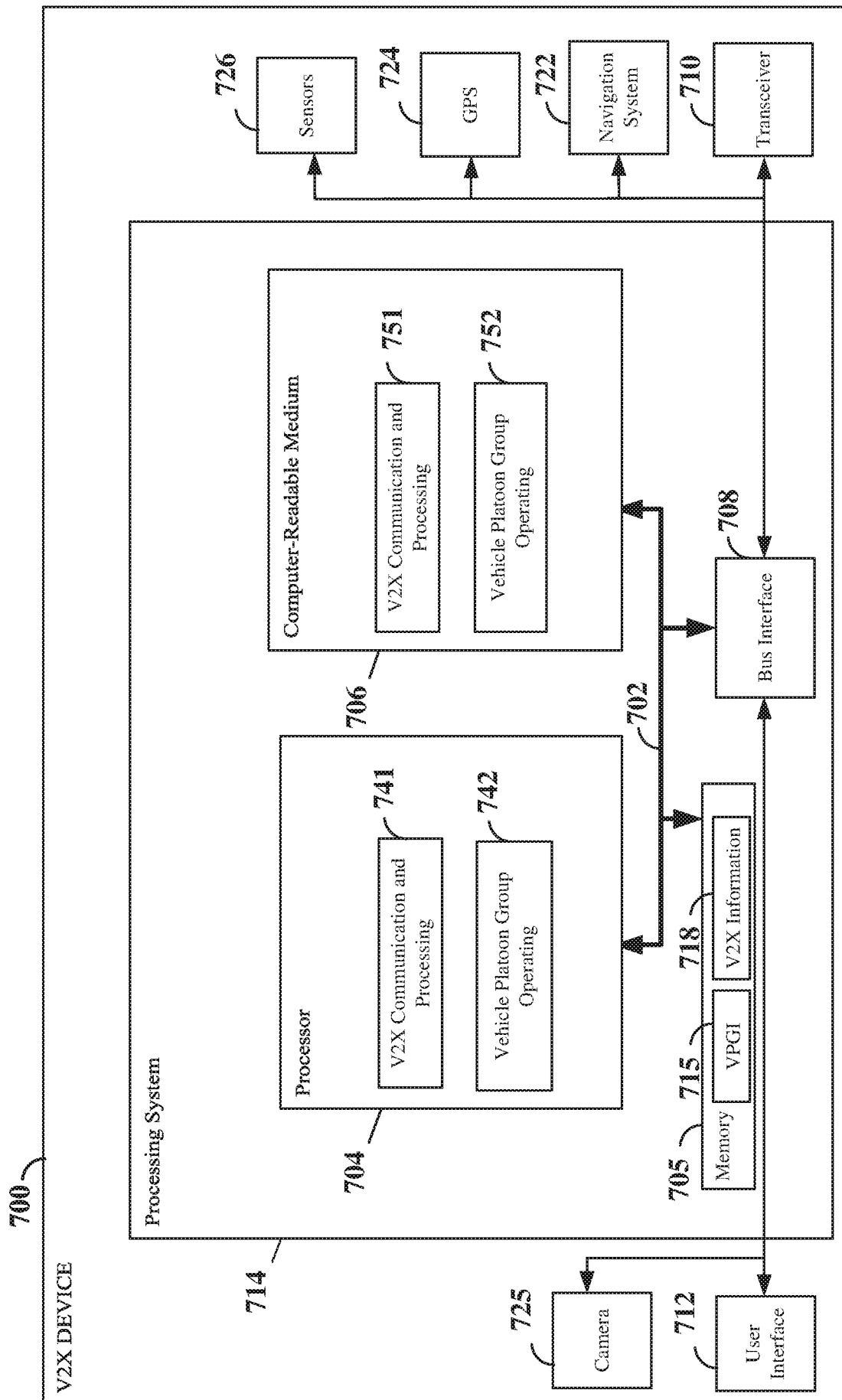


FIG. 7

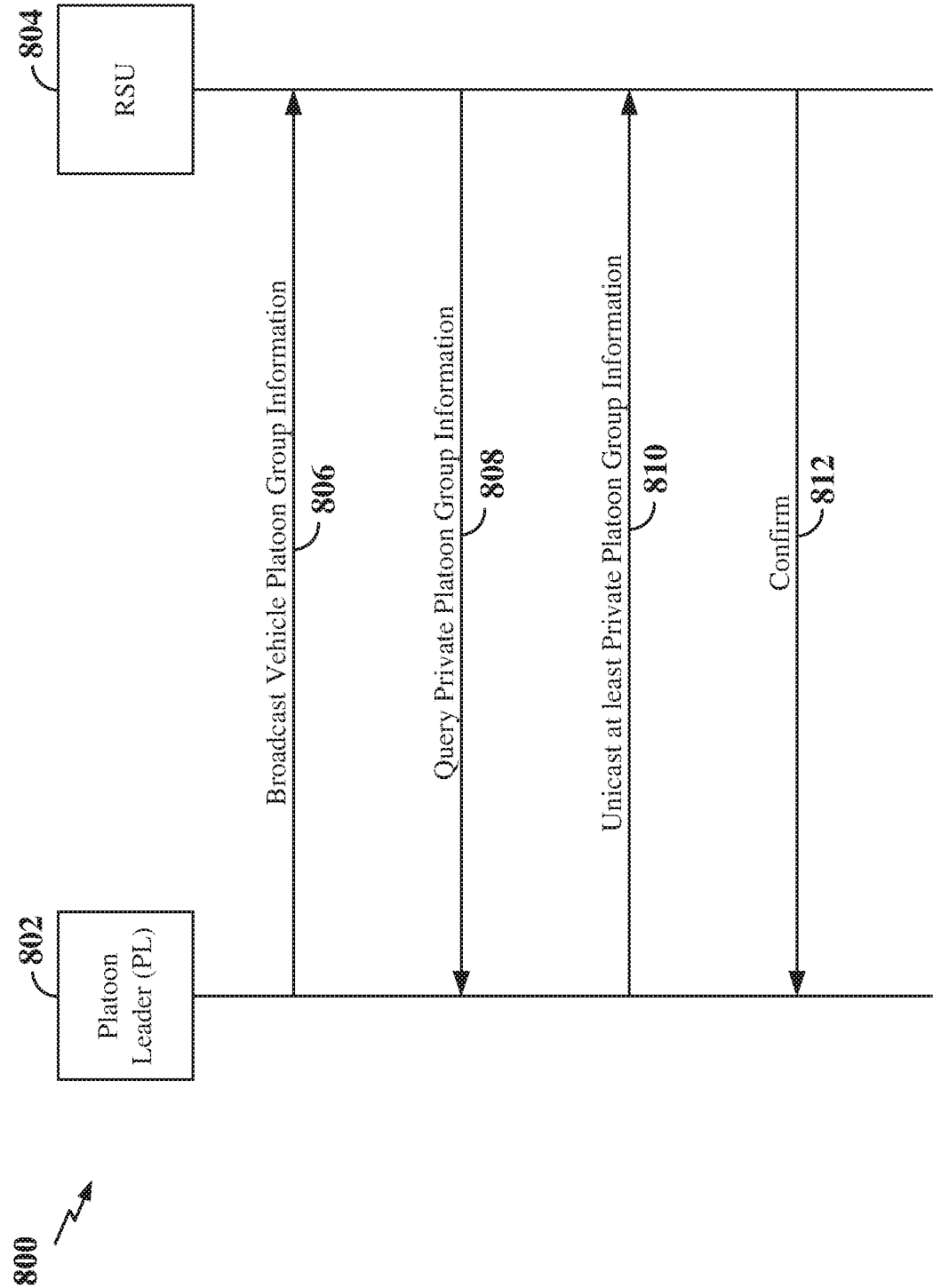


FIG. 8

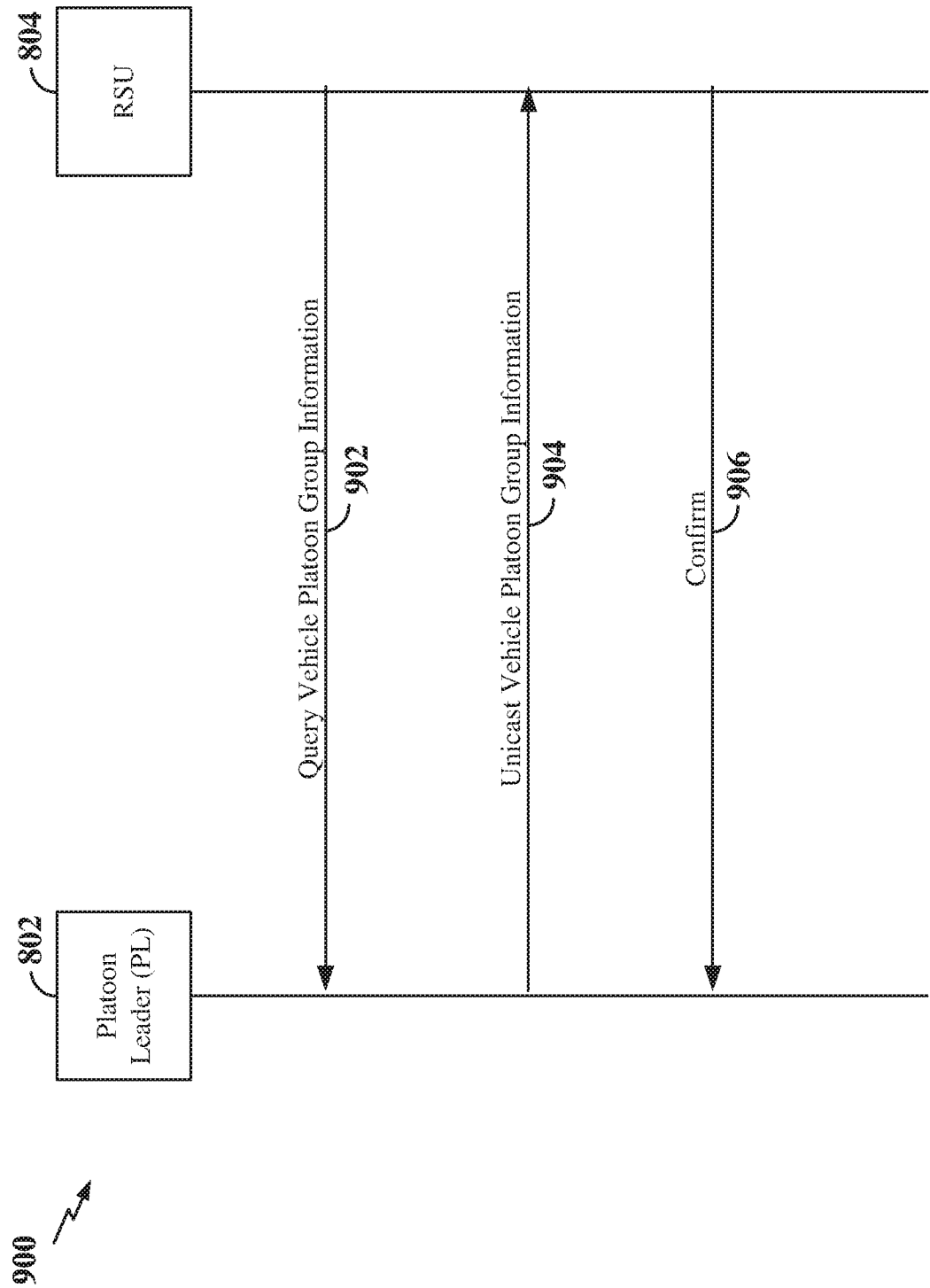


FIG. 9

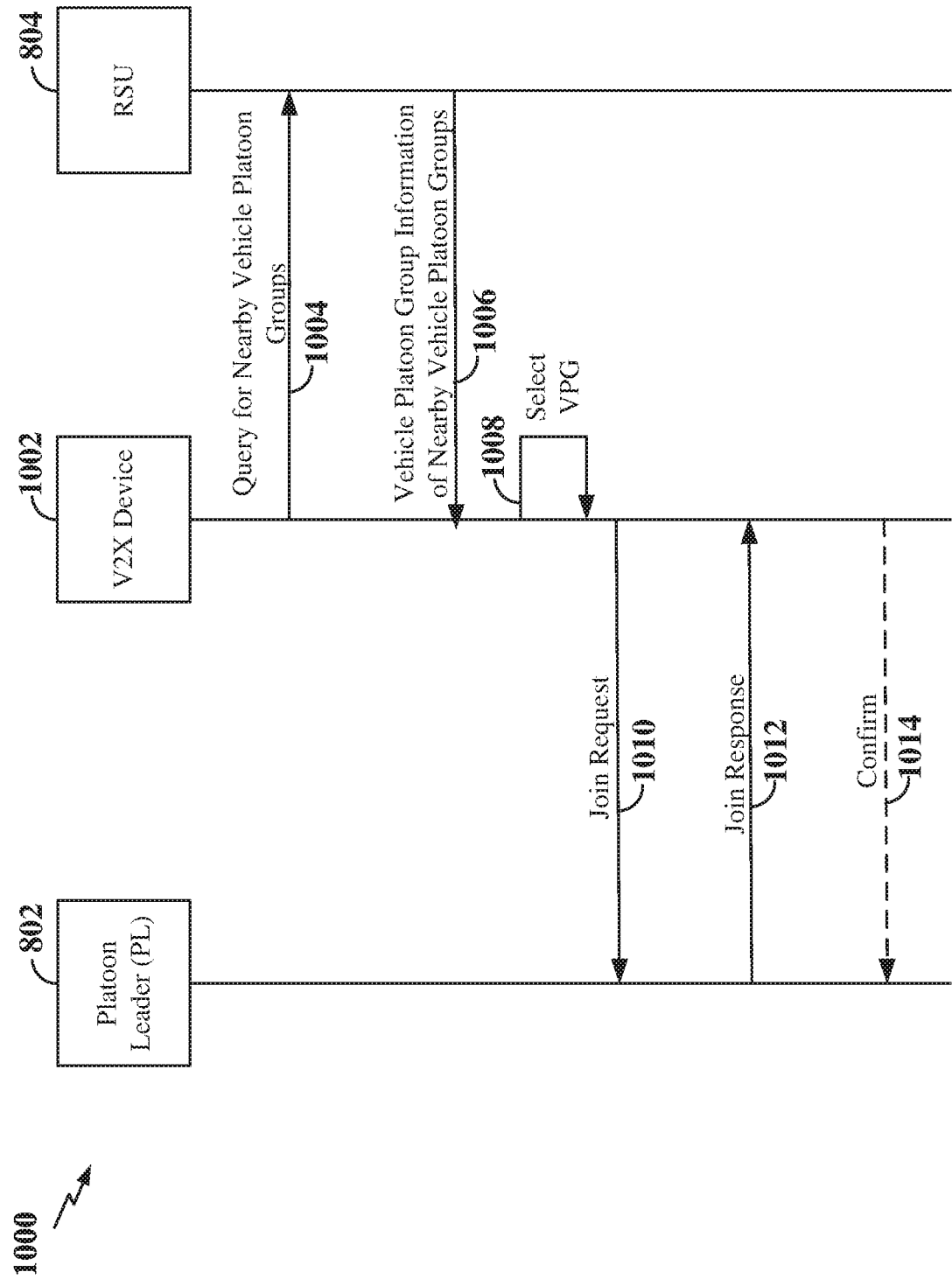


FIG. 10

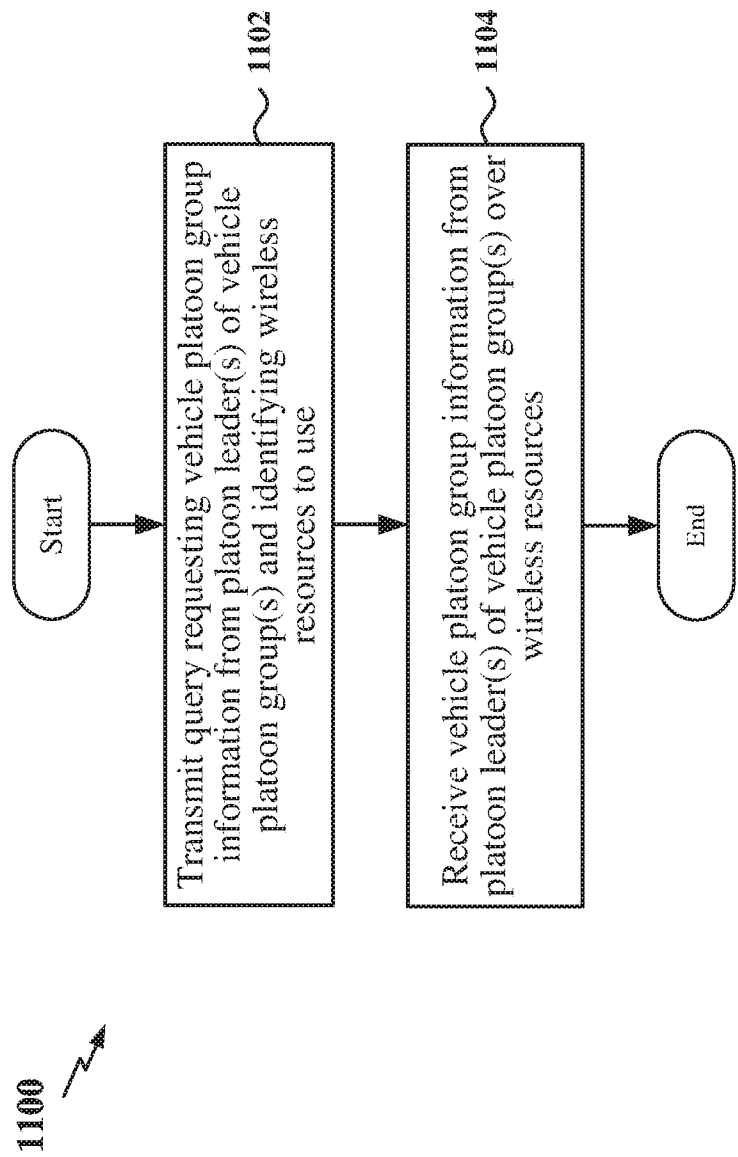
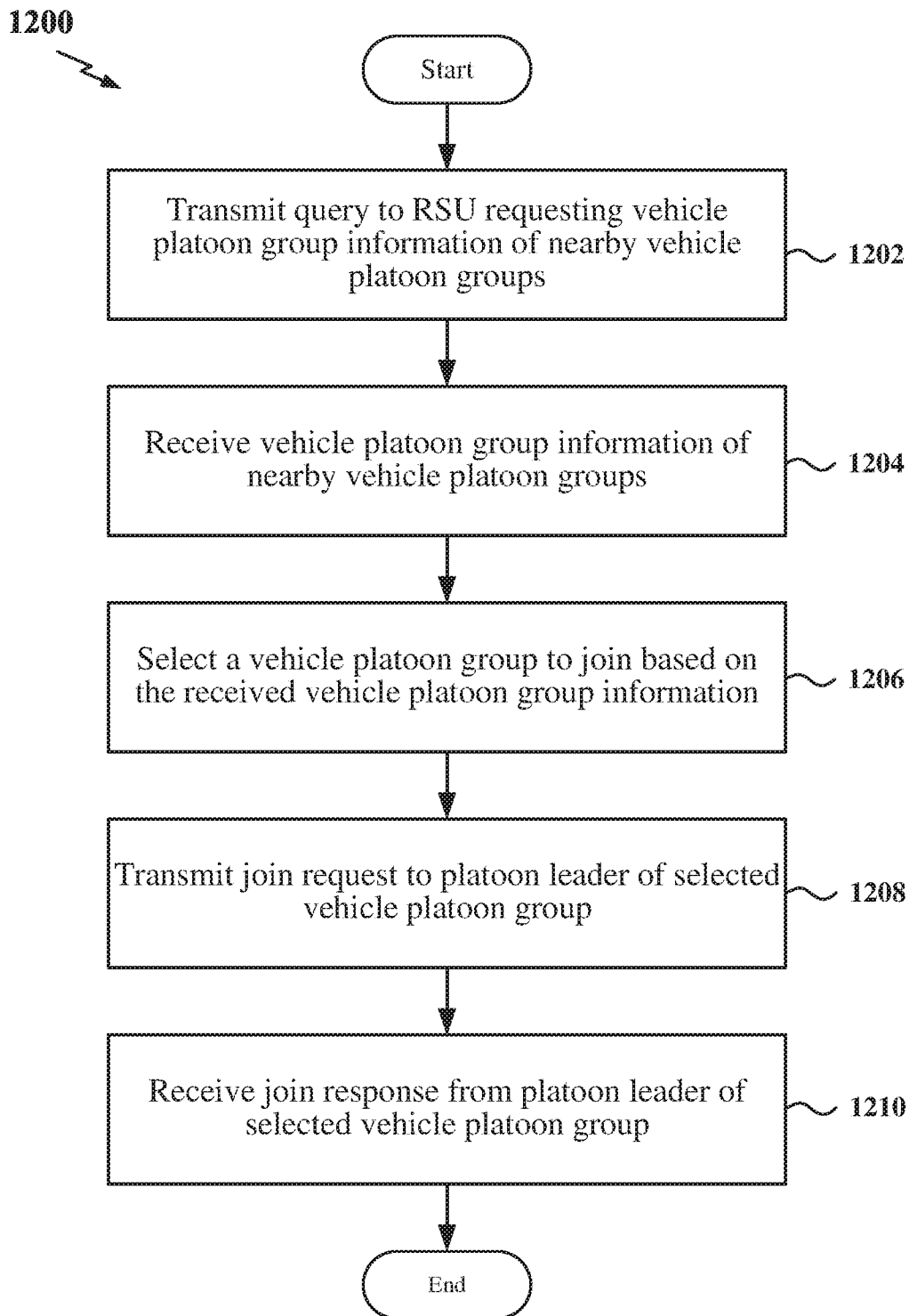


FIG. 11

**FIG. 12**

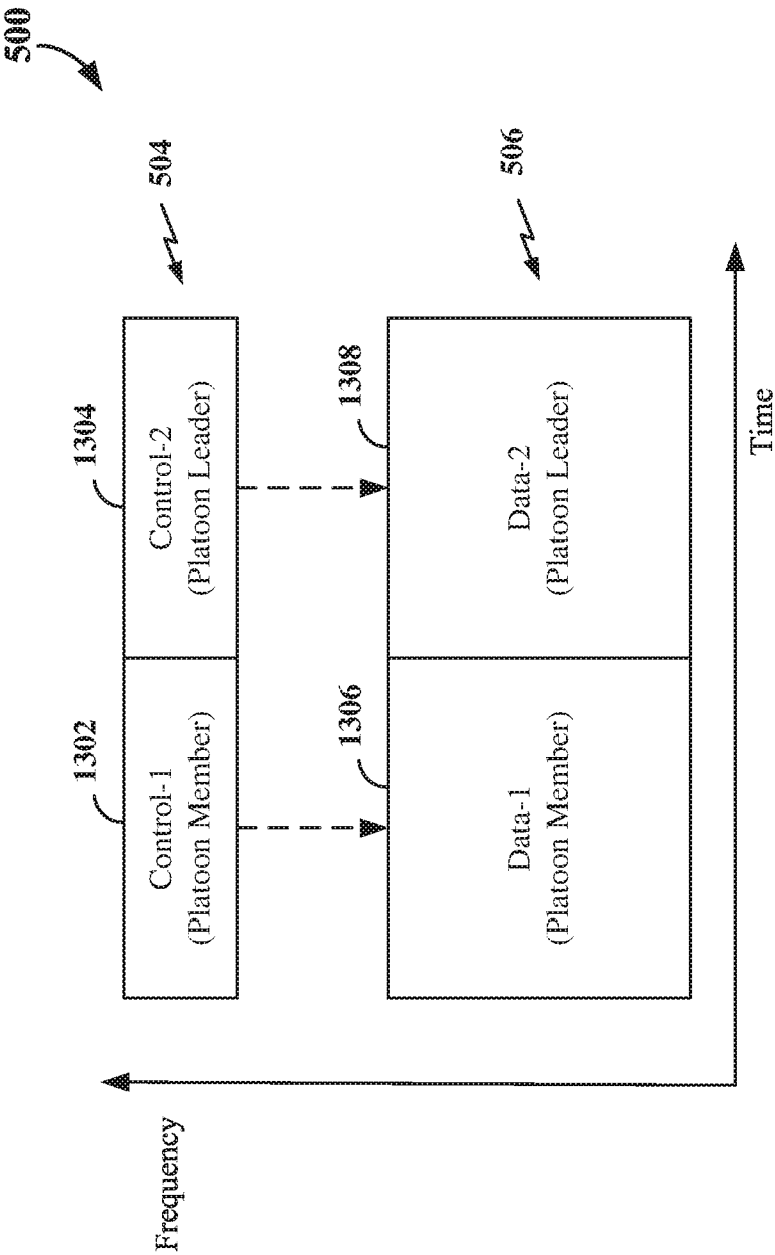


FIG. 13

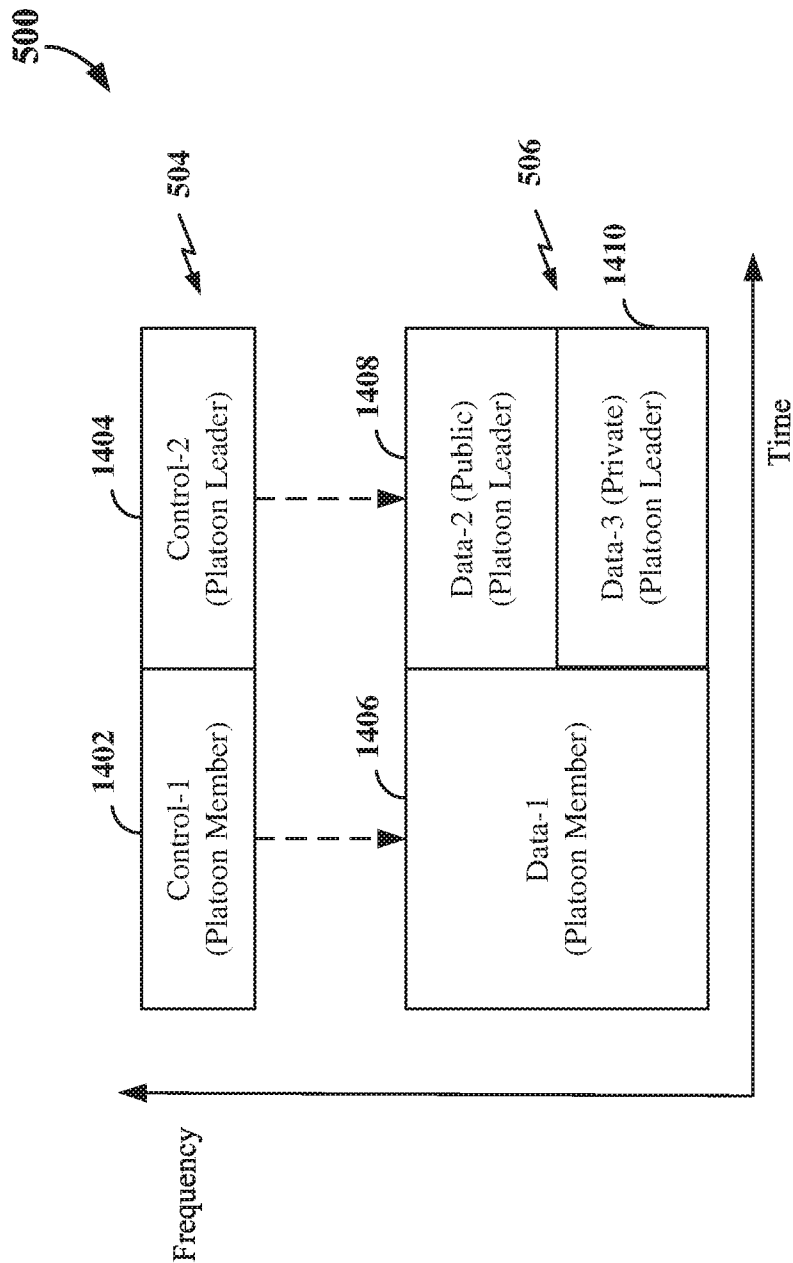


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/100118

A. CLASSIFICATION OF SUBJECT MATTER

H04W 4/00(2018.01)i; G08G 1/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; G08G

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)

CNABS;CNTXT;CNKI;VEN;WOTXT;USTXT;EPTXT: V2X, vehicle, RSU, team, group, head, leader, resource, request, response, query, join, route

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 105702018 A (CHONGQING YUNTU TRAFFIC TECHNOLOGY CO., LTD.) 22 June 2016 (2016-06-22) description paragraphs [0007]-[0015]	25-45
X	CN 107941233 A (BEIJING CHINA TSP TECHNOLOGY CO., LTD.) 20 April 2018 (2018-04-20) description paragraphs [0045]-[0047]	25-45
A	CN 106559877 A (ZTE CORP.) 05 April 2017 (2017-04-05) description paragraphs [0017]-[0046]	1-24
A	CN 107798861 A (UNIV HUBEI AUTOMOTIVE TECHNOLOGY) 13 March 2018 (2018-03-13) the whole document	1-45
A	EP 3316658 A1 (ZTE CORP.) 02 May 2018 (2018-05-02) the whole document	1-45

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

28 March 2019

Date of mailing of the international search report

17 April 2019

Name and mailing address of the ISA/CN

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LIANG, Na

Facsimile No. (86-10)62019451

Telephone No. 86-(010)-62089560

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/100118

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	105702018	A	22 June 2016	CN	105702018	B	29 January 2019
CN	107941233	A	20 April 2018	None			
CN	106559877	A	05 April 2017	WO	2017049976	A1	30 March 2017
				EP	3355636	A1	01 August 2018
				US	2018263052	A1	13 September 2018
CN	107798861	A	13 March 2018	None			
EP	3316658	A1	02 May 2018	EP	3316658	A4	02 January 2019
				WO	2016206290	A1	29 December 2016
				CN	106303986	A	04 January 2017