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(72) Inventors:
• **LE HOUEROU, Brice**
35690 ACIGNE (FR)
• **MORVAN, Isabelle**
35135 CHANTEPIE (FR)
• **NASSOR, Eric**
35235 THORIGNE-FOUILLARD (FR)
• **RUELLAN, Hervé**
35700 RENNES (FR)

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(74) Representative: **Casalonga**
31 Rue de Fleurus
75006 Paris (FR)

(71) Applicant: **CANON KABUSHIKI KAISHA**
Tokyo 146-8501 (JP)

(54) **METHOD, DEVICE, AND COMPUTER PROGRAM FOR ANNOUNCING ROAD USAGE IN AN INTELLIGENT TRANSPORT SYSTEM**

(57) According to some embodiments of the disclosure, it is provided a method of communication in an intelligent transport system, ITS. After determining at least one road usage area that the transmitting ITS station, an

object, or a person associated with the transmitting ITS station may possibly use, an ITS message comprising an item of information indicating the at least one road usage area is transmitted.

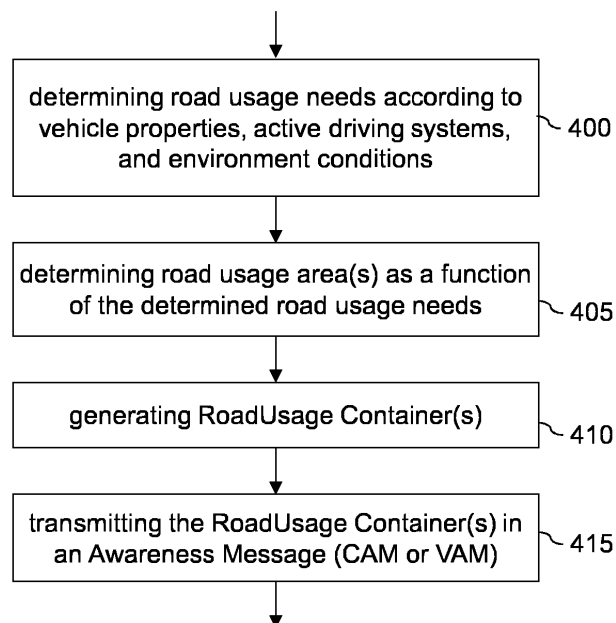


Fig. 4

DescriptionFIELD OF THE DISCLOSURE

5 **[0001]** The present disclosure relates generally to Intelligent Transport Systems (ITSs) and more specifically to Co-operative Intelligent Transport Systems (C-ITSs).

BACKGROUND OF THE DISCLOSURE

10 **[0002]** Cooperative Intelligent Transport Systems (C-ITSs) is an emerging technology for future transportation management that aims at improving road safety, traffic efficiency and driver experience.

[0003] Intelligent Transport Systems (ITS), as defined by the European Telecommunications Standards Institute (ETSI), include various types of communication such as:

- 15 - communications between vehicles (e.g., car-to-car), and
 - communications between vehicles and stationary stations (e.g., car-to-infrastructure).

[0004] C-ITSs are not restricted to road transport as such. More generally, C-ITS may be defined as the use of information and communication technologies (ICT) for rail, water, and air transport, including navigation systems. Such various types of C-ITS generally rely on radio services for communication and use dedicated technologies.

[0005] Such C-ITSs are subject to standards, specified for each country and/or territory where C-ITSs are implemented. Today, in Europe, the European Telecommunications Standards Institute is in charge of the elaboration of the specifications forming the standards to which C-ITSs are subjected.

25 **[0006]** Cooperation within C-ITSs is achieved by exchange of messages, referred as to ITS messages, between ITS stations (denoted ITS-Ss). The ITS-Ss may be vehicles, Road Side Units (RSUs), Vulnerable Road Users (VRUs) carrying an ITS equipment (for instance included in a smartphone, a GPS device, a smart watch, or in a cyclist equipment), or any other entities or infrastructure equipped with an ITS equipment, as well as central subsystems (back-end systems and traffic management centers).

30 **[0007]** As observed above, C-ITSs may support various types of communications, for instance between vehicles (vehicle-to-vehicle or "V2V"), referring to all kinds of road users, e.g., car-to-car, or between vehicles and stationary stations such as vehicle-to-infrastructure or "V2I", and infrastructure-to-vehicle or "I2V", e.g., car-to-infrastructure.

[0008] Such exchanges of messages may be performed via a wireless network, referred to as "V2X" (for "vehicle" to any kind of devices) networks, examples of which may include 3GPP LTE-Advanced Pro, 3GPP 5G, or IEEE 802.11p technology (3GPP, LTE, and IEEE are Registered Trade Marks).

35 **[0009]** Exemplary ITS messages include Cooperative Awareness Messages (CAMs), Vulnerable Road Users Awareness Messages (VAMs), and Decentralized Environmental Notification Messages (DENMs). An ITS-S sending an ITS message is referred to as an "originating" ITS-S and an ITS-S receiving an ITS message is referred to as a "receiving" ITS-S. VAMs and CAMs are generally periodically sent with a period varying depending, for example, on the speed of the originating ITS-S.

40 **[0010]** It is recalled here that EN 302 637-2 (V1.4.1 of April 2019) standard defines the Cooperative Awareness Basic Service, that may be used by an ITS-S to transmit, using broadcast CAMs, its ego-vehicle dynamics (e.g., its position and speed). The CAMs are generally periodically sent with a period varying from 100 milliseconds to one second depending, for example, on the speed of the originating ITS-S.

45 **[0011]** It is also to be noted that ETSI TS 103 300-3 (December 2022) standard defines the Vulnerable Road User (VRU) Awareness basic Service (VBS), that may be used by an originating ITS-S to send, using broadcast VAMs, notifications to other ITS-Ss, such as dynamic properties of the VRU (motion, acceleration, etc.).

[0012] It is also to be noted that EN 302 637-3 (V1.3.1 of April 2019) standard defines the Decentralized Environmental Notification Basic Service, that may be used by an originating ITS-S to send, using broadcast DENMs, notifications to other ITS-Ss, such as warnings or alerts. Such a message notifies an event (e.g., a road hazard, driving environment information, traffic condition information, etc.) detected by the originating ITS-S.

50 **[0013]** Each ITS station has an environment model called a Local Dynamic Map (LDM) that is regularly updated with highly dynamic data to locate vehicles, pedestrians, bicycles, etc., in the vicinity of the ITS station. The LDM is updated using information from on-board sensors and completed with information from received ITS messages such as awareness messages containing the ego-position and the speed of connected vehicles (CAM) and/or of connected Vulnerable Road Users (VAM).

55 **[0014]** By exchanging items of information regarding their dynamics, each ITS station enables an overall improvement in safety of the ITS users. However, it should be kept in mind that exchanging data between ITS stations and processing received data in each ITS station require significant resources (e.g., bandwidth, processing, etc.). Therefore, there is a

constant need to improve the selection of transmitted data to increase the overall safety of the system.

SUMMARY OF THE DISCLOSURE

[0015] The present disclosure has been devised to address one or more of the foregoing concerns.

[0016] In this context, there is provided a solution for improving the selection of data to be exchanged in an ITS to increase the overall safety of the system.

[0017] According to a first aspect of the disclosure, there is provided a method of communication in an Intelligent Transport System, ITS, the method comprising, at a transmitting ITS station:

determining at least one road usage area that the transmitting ITS station, an object, or a person associated with the transmitting ITS station may possibly use; and
transmitting an ITS message comprising an item of information indicating the at least one road usage area.

[0018] Accordingly, the method of the disclosure makes it possible for an ITS-S to signal its usage intention regarding a road area, which increases the overall ITS safety.

[0019] According to some embodiments, the road usage area is an area to be traversed by the transmitting ITS station within a given time period.

[0020] Still according to some embodiments, the method further comprises determining a road usage type associated with the at least one road usage area and transmitting an item of information indicating the road usage type.

[0021] Still according to some embodiments, the method further comprises determining a road usage safety indication associated with the at least one road usage area and transmitting an item of information indicating the road usage safety indication.

[0022] Still according to some embodiments, the at least one road usage area is defined with a distance, a vector, a polygon, and/or an ellipse.

[0023] Still according to some embodiments, the at least one road usage area extends over at least two adjacent lane sections of a road.

[0024] Still according to some embodiments, the at least one road usage area extends over two lane sections belonging to two intersected roads.

[0025] Still according to some embodiments, the method further comprises obtaining road usage needs, the at least one road usage area being determined as a function of the obtained road usage needs.

[0026] Still according to some embodiments, the item of information indicating the at least one road usage area is transmitted in at least one RoadUsage Container of a Cooperative Awareness Message, CAM, or of a Vulnerable Road Users Awareness Message, VAM.

[0027] Still according to some embodiments, the method further comprises generating the at least one RoadUsage Container, the generated at least one RoadUsage Container belonging to a High-Frequency Container or to a Low-Frequency Container.

[0028] According to a second aspect of the disclosure there is provided a method of communication in an Intelligent Transport System, ITS, the method comprising, at a receiving ITS station:

receiving, from a transmitting ITS station, an ITS message comprising an item of information indicating at least one road usage area; and

determining, from the received ITS message, at least one road usage area that the transmitting ITS station, an object, or a person associated with the transmitting ITS station may possibly use.

[0029] Accordingly, the method of the disclosure makes it possible for a receiving ITS-S to take into account the usage intention of a transmitting ITS-S regarding a road area, which increases the overall ITS safety.

[0030] According to some embodiments, the road usage area is an area to be traversed by the transmitting ITS station within a given time period.

[0031] Still according to some embodiments, the method further comprises determining, from the received ITS message, a road usage type associated with the at least one road usage area.

[0032] Still according to some embodiments, the method further comprises determining, from the received ITS message, a road usage safety indication associated with the at least one road usage area.

[0033] Still according to some embodiments, the method further comprises determining whether the at least one road usage area overlaps a predicted path of the receiving ITS station.

[0034] Still according to some embodiments, the method further comprises, in case the at least one road usage area overlaps the predicted path of the receiving ITS station, evaluating effects of the overlap.

[0035] Still according to some embodiments, the method further comprises adapting parameters of the receiving ITS

station as a function of the evaluated effects.

[0036] Still according to some embodiments, the received ITS message is a Cooperative Awareness Message, CAM, or a Vulnerable Road Users Awareness Message, VAM.

[0037] Still according to some embodiments, the received ITS message comprises at least one RoadUsage Container, the at least one RoadUsage Container comprising at least one High-Frequency Container and/or at least one Low-Frequency Container, the at least one High-Frequency Container and/or the at least one Low-Frequency Container comprising a RoadUsage Container comprising the item of information indicating the at least one road usage area.

[0038] According to another aspect of the disclosure there is provided a device comprising a processing unit configured for carrying out each of the steps of the method described above.

[0039] This aspect of the disclosure has advantages similar to those mentioned above.

[0040] At least parts of the methods according to the disclosure may be computer implemented. Accordingly, the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit", "module" or "system". Furthermore, the present disclosure may take the form of a computer program product embodied in any tangible medium of expression having computer usable program code embodied in the medium.

[0041] Since the solutions of the present disclosure can be implemented in software, the solutions of the present disclosure can be embodied as computer readable code for provision to a programmable apparatus on any suitable carrier medium. A tangible carrier medium may comprise a storage medium such as a floppy disk, a CD-ROM, a hard disk drive, a magnetic tape device or a solid-state memory device and the like. A transient carrier medium may include a signal such as an electrical signal, an electronic signal, an optical signal, an acoustic signal, a magnetic signal or an electromagnetic signal, e.g., a microwave or RF signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] Further advantages of the present disclosure will become apparent to those skilled in the art upon examination of the drawings and detailed description. Embodiments of the disclosure will now be described, by way of example only, and with reference to the following drawings, in which:

Figure 1 illustrates an example of an ITS in which some embodiments of the present disclosure may be implemented; **Figure 2** illustrates an example of a structure of a cooperative awareness message, CAM, according to some embodiments of the disclosure;

Figure 3 illustrates an example of a structure of a vulnerable road user awareness message, VAM, according to some embodiments of the disclosure;

Figures 4 and 5 illustrate, using flowcharts, examples of general steps of methods according to embodiments of the present disclosure, respectively at an originating ITS-S sending a CAM or VAM containing information about road usage needs and at a corresponding receiving ITS-S;

Figure 6 illustrates a use case according to some embodiments of the present disclosure, according to which a vehicle is using an adaptive cruise control system and disseminates a Road Usage Container to indicate, in CAMs, to other ITS-Ss, the set distance;

Figure 7 illustrates a use case according to some embodiments of the present disclosure, according to which a VRU disseminates a RoadUsage Container to indicate, in VAMs, to other ITS-Ss, a safety area;

Figure 8 illustrates a use case according to some embodiments of the present disclosure, according to which a vehicle is using an assist parking system and disseminates a RoadUsage Container to indicate, in CAMs, to other ITS-Ss, the required area for its maneuver;

Figure 9 illustrates examples of road usage areas defined either by using distances, vectors, rectangles, polygons, or ellipses, according to some embodiments of the present disclosure;

Figure 10 illustrates a use case according to some embodiments of the present disclosure, according to which an ITS-S disseminates a RoadUsage Container to indicate, in CAMs, to other ITS-Ss, the road usage areas based on road sections;

Figures 11 and 12 illustrate a use case of some embodiments of the present disclosure, according to which an ITS-S disseminates a RoadUsage Container to indicate, in CAMs, to other ITS-Ss, the different safety distances according to its braking system;

Figure 13 is a schematic representation of an example of a communication ITS-S device configured to implement some embodiments of the present disclosure; and

Figure 14 illustrates an example of a structure of a cooperative awareness message, CAM, according to some embodiments of the disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0043] The names of the lists and elements (such as data elements) provided in the following description are only illustrative. Embodiments are not limited thereto and other names could be used.

[0044] The embodiments of the present disclosure are intended to be implemented in Intelligent Transportation Systems (ITS).

[0045] Exemplary ITS messages include Cooperative Awareness Messages (CAMs), Vulnerable Road Users Awareness Messages (VAMs), and Decentralized Environmental Notification Messages (DENMs). As described above, an ITS-S sending an ITS message is referred to as an "originating" ITS-S and an ITS-S receiving an ITS message is referred to as a "receiving" ITS-S. The VAMs are generally periodically sent with a period varying depending, for example, on the speed of the originating ITS-S.

[0046] It is recalled here that EN 302 637-2 (V1.4.1 of April 2019) standard defines the Cooperative Awareness Basic Service, that may be used by an ITS-S to transmit, using broadcast CAMs, its ego-vehicle dynamics (e.g., its position and speed). The CAMs are generally periodically sent with a period varying from 100 milliseconds to one second depending, for example, on the speed of the originating ITS-S.

[0047] The inventors have noted that if an ITS-S may anticipate or predict the behavior of another ITS-S, for example using its position, drive direction, speed, and acceleration transmitted either using Cooperative Awareness Messages (CAM) or VRU awareness messages (VAM), such prediction is extremely limited and only covers a few cases. Indeed, this prediction is limited by the lack of knowledge of vehicle properties and intention, activated adaptive systems or safety systems and driving conditions.

[0048] For example, a vehicle may use an adaptive cruise control system which properties change according to the road conditions (e.g., weather, light conditions, road type and traffic, vehicle speed, user preferences, etc.) or use a safety system such as an emergency brake system which may be triggered according to some parameters which are specific to each vehicle and road conditions. These properties are unknown by other vehicles. Therefore, if a first vehicle is using such a feature, a second vehicle may trigger an emergency automatic brake by entering in the road area monitored by sensors involved in the safety system of the first vehicle, being noted that the braking distance depends on multiple parameters which are unknown by other vehicles (e.g., the vehicle weight, the road slope, a requirement of gently braking, etc.). Consequently, a first vehicle may not be able to estimate if its trajectory will interfere with the road area required by a second vehicle to maintain its optimal and safe driving conditions.

[0049] Still for the sake of example, it is not possible for a vehicle to predict whether a passenger is likely to get out of another vehicle or to predict a change of direction of another vehicle, for example for parking purpose.

[0050] According to the present disclosure, road usage information is provided to inform other ITS-Ss about the required road usage areas associated with an ITS-S (e.g., a vehicle or a VRU), for example required road usage areas associated with an active system, driving operations, driving conditions, intentions, etc. A road usage area is therefore an area of a road that may be possibly used, penetrated, driven on, walked on, etc. by an originating ITS-S, a portion of the originating ITS-S, or an object or a person associated with the originating ITS-S, for example transported by the originating ITS-S, or an area of the road that the originating ITS-S, a portion of the originating ITS-S, or an object or a person associated with the originating ITS-S, for example transported by the originating ITS-S, may move in, so as to maintain nominal driving conditions. For the sake of illustration, a road usage area may be an area to be traversed by the transmitting ITS station within a given time period.

[0051] Accordingly, an originating ITS-S may share, with other ITS-Ss, one or more road usage areas required to maintain its nominal driving conditions, by determining and providing road usage area information in one or more 'Road-Usage Container' of a CAM or VAM. The road usage areas may be determined by taking into account any specific parameters derived from originating ITS-S characteristics such as adaptive system characteristics, driver or occupant comfort requirements and current dynamics, or any instantaneous decision taken by the driver. The road usage areas may be composed of different areas around the originating ITS-S and derived from the distance of emergency braking (such as a protective/warning fields for automatic mobile robots), an area to maintain its speed using an adaptive system, or a driver's choice to reserve a free space for its maneuver. The road usage area information provided in a CAM or VAM may be valid until next CAM or VAM or may be associated with a time duration.

[0052] Using the content of the 'RoadUsage Container', any receiving ITS-S may determine if its trajectory may impact the originating ITS-S.

[0053] For example, a receiving ITS-S may determine an overlap between its trajectory and a road usage area associated with the originating ITS-S. In case of overlap, the impact may be estimated and the receiving ITS-S may adapt its dynamics and/or trajectory.

[0054] The 'RoadUsage Container' may comprise a 'RoadUsage type' associated with a road usage area so that a receiving ITS-S is able to determine which system is impacted and whether it is involving a safety system of the originating ITS-S.

[0055] The 'RoadUsage Container' may also comprise an item of information referred to as 'DangerLevel', associated

with a road usage area, so that in case of overlap, the receiving ITS-S may assess a danger level.

[0056] The 'RoadUsage Container' may also comprise an item of information referred to as 'ControllabilityClass', associated with a road usage area, so that in case of overlap, a receiving ITS-S may assess the risk of loss of driving control of the originating ITS-S.

[0057] Accordingly, the present disclosure makes it possible to improve the traffic flow and the safety by sharing road usage of vehicles and VRUs with each other.

[0058] Figure 1 illustrates an example of an ITS 100 in which some embodiments of the present disclosure may be implemented.

[0059] According to this example, an ITS station, that may generate and transmit CAMs such as CAMs 131, is embedded within a vehicle at position 130.

[0060] As illustrated, ITS 100 is implemented at an intersection 110 and comprises several entities that may carry or embed an ITS station (ITS-S) each, for transmitting and/or receiving ITS messages within the ITS. The several entities may be for example, vehicles located at positions 130 and 140, a motorcyclist located at position 150, and a pedestrian located at position 160.

[0061] A VRU may be considered as an ITS-S when carrying an ITS equipment, for example a ITS equipment included in a smartphone, a satnav system, a smart watch, or in a cyclist equipment.

[0062] More generally, any ITS-S in ITS 100 may share information on itself, by sending Cooperative Awareness Messages, CAMs, for example as defined in document ETSI EN 302 637-2. CAMs may include a position, a kinematic (or dynamics), a unique station identifier, temporal information, behavioral or object type classification information, etc. Similarly, VRU Awareness Messages, VAMs, for example as defined in document ETSI TS 103 300-3, can be sent by VRU ITS-Ss to share their own position and kinematic.

[0063] The ITS messages are usually broadcast by their originating ITS-S, so that any other ITS-S can receive and exploit them.

[0064] All the messages exchanged over ITS 100 may help each ITS-S to have a good level of knowledge of its environment in terms of which objects are present, where, and how they behave.

[0065] For the sake of illustration, the pedestrian located at position 160 holds an originating ITS-S 170, for example a mobile phone supporting connection with ITS 100 and having sensors for determining kinematics of the pedestrian. The originating ITS-S 170 periodically disseminates VAMs 161 to share its kinematic references to ITS epoch time base, including different containers with a position and a speed for example. As illustrated, pedestrian at position 160 is attending to cross the street using the crosswalk 120.

[0066] Still for the sake of illustration, the bicycle at position 150 carries an ITS equipment disseminating VAMs 151. According to the disclosure, VAMs 151 comprise road usage information as described by reference to Figure 3. Accordingly, using VAMs 151, bicycle at position 150 shares with other receiving ITS-Ss (e.g., receiving ITS-Ss 170, 130, and 140) a road usage area denoted 152, using a RoadUsage Container. RoadUsage area 152 is used to alert other ITS-Ss (e.g., receiving ITS-Ss 170, 130, and 140) that the bicycle at position 150 requests to respect a safety area 152 around it. For example, the RoadUsage area 152 can be described as longitudinal and lateral distances which may vary according to countries, VRU size, VRU speed, and VRU preferences. Additionally, the RoadUsage Container may include a RoadUsage type to explain to other receiving ITS-Ss, such as vehicles at positions 130 and 140, the purpose of this RoadUsage area. For the sake of illustration, the RoadUsage type of RoadUsage area 150 may be set to 'safety'.

[0067] Still for the sake of illustration, the vehicle at position 130 embeds an ITS equipment disseminating CAMs 131. According to the disclosure, CAMs 131 comprise road usage information as described by reference to Figure 2. Accordingly, using CAMs 131, the vehicle at position 130 shares with other receiving ITS-Ss (e.g., receiving ITS-Ss 170, 150, and 140) a road usage area denoted 132, using a RoadUsage Container. The RoadUsage area 132 is used to alert other ITS-Ss (e.g., receiving ITS-Ss 170, 150, and 140) that the vehicle at position 130 needs a RoadUsage area 132 in front of it to be able to gently brake if needed. For example, The RoadUsage area 132 can be specified as a rectangle using CAM the *ReferencePosition* data element as a reference point (as described with reference to Figures 2 and 14).

[0068] As another example, the RoadUsage area 132 may be described as a distance value using the CAM *ReferencePosition* data element and the *heading* data element (as described with reference to Figure 14). The RoadUsage area 132 may vary over time as a function of the vehicle dynamics such as the speed, the acceleration, the road conditions, the occupancy, the vehicle weight, the braking system performance, or user comfort preferences. In addition, the RoadUsage Container may include a RoadUsage type to explain to other receiving ITS-Ss (e.g., ITS-Ss located at position 140, 150, 160) the purpose of this RoadUsage area. For the sake of illustration, the RoadUsage type of RoadUsage area 132 may be set to 'braking distance'. The vehicle located at position 130 may use the algorithm described by reference to Figure 4 to disseminate CAMs 131 comprising the Road Usage Container.

[0069] Using ITS 100, the vehicle located at position 140 is informed of the 'braking distance' needs of the approaching vehicle located at position 130. Using an algorithm such as the one described by reference to Figure 5 and CAMs 131 and VAMs 151, the vehicle located at position 140 may decide to enter in the intersection 110 or to stay at the position 140 to prevent to cut-in the RoadUsage areas 132 and/or 152. Alternately, the vehicle located at position 140 may decide

to adapt its trajectory.

[0070] As described in reference to Figure 9, the RoadUsage areas may be defined using different means.

Structure of a CAM according to some embodiments of the disclosure

[0071] Figure 2 illustrates an example of a structure of a cooperative awareness message, CAM, according to some embodiments of the disclosure.

[0072] The illustrated CAM structure, referenced 200, is based on specification ETSI TS 103 900 V0.0.4_2.1.1 (2023-03) and is extended with one or more RoadUsage Containers.

[0073] As illustrated, it comprises an ITS PDU header referenced 210, a Basic Container 220, a High-Frequency Container 230, a Low-Frequency Container 240, and a special vehicle Container 250.

[0074] ITS PDU header 210 may be a common header including information about the protocol version, a message type (set to 2 for CAM), and an ITS-S identifier (ID) of the originating ITS-S.

[0075] Each container includes some data elements (DE) and/or data frames (DF). ETSI TS 102 894-2 Specification defines conventional data elements and data frames used in ITS messages.

[0076] ITS PDU header 210 comprises *generationDeltaTime* 211. It is a value expressed in milliseconds indicating the amount of time spent since ITS epoch to generate CAM 200.

[0077] Basic Container 220 comprises *stationType* and *ReferencePosition* 221. *stationType* is used to indicate the type of station (vehicle category/class or Road side unit) and *ReferencePosition* is the position of the ITS at ITS epoch + *generationDeltaTime*. It is expressed as WGS84 coordinates with a confidence level.

[0078] *High-Frequency Container* 230 is used to transmit any dynamics of a vehicle. It is transmitted in each CAM 200 and comprises

- a *Heading* that includes orientation of the VRU, for example according to WGS84 north,
- a *Speed* that includes the speed value, for example in centimeters per second,
- a *Lane position* that includes a lane on the road (same as for a vehicle), a lane off the road, or an island between two lanes to allow the correlation to a map, and
- an *Acceleration*, that includes the acceleration value, for example in centimeters per second squared.

[0079] *Low-Frequency Container* 240 is used to transmit additional information, not having place in High-Frequency Container 230 as it is static or slow-changing according to dynamics. *Low-Frequency Container* 240 is conditionally transmitted in CAM 200.

[0080] *GenerationDeltaTime*, *ReferencePosition*, *Heading*, *Speed*, *Lane position*, and *Acceleration* information can be used by an algorithm such as the one described by reference to Figure 5 to predict the originating ITS-S path trajectory.

[0081] As illustrated, High-Frequency Container 230 and/or Low-frequency Container 240 may comprise one or more RoadUsage Containers 231. In turn, each RoadUsage Container comprises one or more RoadUsage areas (denoted *RoadUsageArea*[]) and optional characteristics associated with the RoadUsage areas.

[0082] Figure 14 illustrates another example of a structure of a cooperative awareness message, CAM, according to some embodiments of the disclosure. As illustrated, CAM 200 comprises one or more RoadUsage Containers 231.

[0083] According to some embodiments, a RoadUsageArea may be:

- an area as defined in a Common Data Dictionary (CDD),
- a distance (e.g., in meter, with centimeter precision) between a first point and a second point, considering *ReferencePosition* from Basic Container 221 as the first point and the *heading* from High-Frequency Container 230 as the direction to join the second point at the given distance;
- a distance (e.g., in meter, with centimeter precision), referenced from a previous RoadUsage area, defined as a distance, considering the same *heading* from High-Frequency Container 230 and the second point of the previous RoadUsage as first point,
- a vector from *ReferencePosition* 221 as defined in Basic Container 220, or
- a vector referenced from a previous RoadUsage area defined as a vector.

[0084] Different possibilities to describe RoadUsage areas are described by reference to Figure 9.

[0085] As described above, a RoadUsage type (denoted *RoadUsageType*[]) may be associated with each defined RoadUsage area. It makes it possible to provide information regarding the usage of the corresponding RoadUsage area. According to some embodiments of the disclosure, the following types may be used as values for the RoadUsage type:

- collision,

- auto-braking,
- assist braking,
- safety distance,
- protective or warning field,
- 5 - comfort or economic mode (smooth drive),
- maneuver on-going,
- emergency requirements,
- parking,
- pedestrian exits from a vehicle, and
- 10 - others.

[0086] In addition, a RoadUsage safety indication (denoted *RoadUsageSafety[]*) may be associated with each defined RoadUsageArea. The RoadUsage safety indication may be used to inform an ITS-S that the corresponding RoadUsage area is directed to a safety issue. It may be used to indicate a danger level and/or a controllability class as defined by the originating ITS-S. It may be used by an ITS receiving the corresponding RoadUsage Container to assess the risk in case of presence in the road usage area. For the sake of illustration, the RoadUsage safety indication may comprise:

- a *ControllabilityClass* that can be used to define the controllability class (ASIL) of the vehicle if a hazardous event occurs in the RoadUsageArea. These classes may be the following:
 - o C0: controllable in general,
 - o C1: simply controllable,
 - o C2: normally controllable (most drivers could act to prevent injury), and
 - o C3: difficult to control or uncontrollable,
- a *DangerLevel* that can be used to define the danger level for the vehicle occupants and/or for the occupants of any other vehicle in case of collision in the RoadUsage area. These levels may be the following:
 - o Level 4: high danger,
 - o Level 3: considerable danger,
 - o Level 2: moderate danger, and
 - o Level 1: no or minor danger.

[0087] In addition also, a RoadUsage validity indication (denoted *RoadUsageValidity[]*) may provide information about the period of time during which the items of information regarding the RoadUsage area are valid. For the sake of illustration, it may comprise a start time and an end time or only an end time if it is considered that the start time corresponds to the time at which the CAM or VAM is sent. For example, the time at which the CAM or VAM is sent may be determined by the receiving ITS-S by adding generationDeltaTime 211 to ITS epoch. ITS epoch is known and common reference between every ITS-S.

Structure of a CAM according to some embodiments of the disclosure

[0088] **Figure 3** illustrates an example of a structure of a cooperative awareness message, VAM, according to some embodiments of the disclosure.

[0089] The illustrated VAM structure, referenced 300, is based on specification ETSI TS 103 300-3 and is extended with one or more RoadUsage Containers.

[0090] As illustrated, VAM 300 comprises:

- a common ITS PDU header referenced 305,
- a generation delta time referenced 310,
- a basic container referenced 315,
- a VRU high frequency container referenced 320 with dynamic properties of the VRU (motion, acceleration, etc.),
- an optional VRU low frequency container referenced 325, with physical properties of the VRU and static or slow-changing vehicle state (such as exterior lights),
- an optional cluster information container referenced 330,
- an optional cluster operation container referenced 335, and
- an optional motion prediction container referenced 340.

[0091] ITS PDU header 305 may be a common header including information about the protocol version, a message type (set to 16 for VAM), and an ITS-S identifier (ID) of the originating ITS-S.

[0092] Each container includes some data elements (DE) and/or data frames (DF). ETSI TS 102 894-2 Specification defines conventional data elements and data frames used in ITS messages.

[0093] Basic container 315 provides basic information of the originating ITS-S, in particular:

- a *stationType* that represents the station type of the originating ITS-S. This data element may take one of the following values: 1 for a pedestrian, 2 for a bicyclist, 3 for a moped, 4 for a motorcycle, 12 for a lightVRUvehicle, or 13 for an animal, and
- a *Position* or *referencePosition* that is the latest geographic position of the originating ITS-S as obtained by the VBS at the VAM generation. It provides the position and position confidence measured at the reference point of the originating ITS-S. The measurement time corresponds to *generationDeltaTime* that is similar to the *generationDeltaTime* of a CAM, as described previously.

[0094] VRU High-Frequency container 320 of the VAM may contain potentially fast-changing status information of the VRU ITS-S such as:

- a *Heading* that includes an orientation of the VRU, for example according to WGS84 north,
- a *Speed* that includes the speed value, for example in centimeters per second,
- a *Lane position* that includes a lane on the road (same as for a vehicle), a lane off the road, or an island between two lanes to allow the correlation to a map, and
- an *Acceleration* the includes the acceleration value, for example in centimeters per second squared.

[0095] *GenerationDeltaTime*, *ReferencePosition*, *Heading*, *Speed*, *Lane position*, and *Acceleration* information may be used by an algorithm such as the one described by reference to Figure 5 to predict the originating ITS-S path trajectory.

[0096] VRU Low-Frequency container 325 of the VAM may contain potentially slow-changing status information of the VRU ITS-S such as:

- *Lights* that indicate the profile or the status of the exterior lights,
- a *Sub-Profile* that provides a status of the VRU lights, and
- a *Size class* that provides the range of dimensions of the VRU. Cluster information container 330 provides information when a VRU is a VRU cluster leader. When effective, a VRU cluster leader reports VAMs on behalf of the other devices located inside the cluster, and
- cluster operation container 335 provides information and/or parameters relevant to a VRU cluster to which the originating ITS-S belongs according to Cluster information container 330

[0097] VRU motion prediction container 340 provides dynamic VRU motion prediction information as well as explicit path prediction, when such information is available in the VRU ITS-S. The path prediction can be used as an alternative method to determine the originating ITS-S path trajectory in an algorithm such as the one described by reference to Figure 4. In addition, and when such information is available, VRU motion prediction container 340 may provide safe distance indicating that one or more new vehicles or other VRUs (e.g. VRU Profile 3 - Motorcyclist) have come closer than a minimum safe lateral distance (MSLaD) laterally, closer than a minimum safe longitudinal distance (MSLoD) longitudinally, and closer than a minimum safe vertical distance (MSVD) vertically.

[0098] As illustrated, VAM structure 400 further comprises RoadUsage Containers referenced 321, that may be part of High-Frequency Container 320 and/or of Low-frequency Container 325. RoadUsage Containers 321 are similar to RoadUsage Containers 231 described in reference to Figure 2.

Generation, transmission, and processing of CAMs or VAMs and decision

[0099] Figures 4 and 5 illustrate, using flowcharts, examples of general steps of methods according to embodiments of the present disclosure respectively at an originating ITS-S sending a CPM containing information about road usage needs and at a corresponding receiving ITS-S.

[0100] As illustrated in **Figure 4**, a method of communication in an ITS according to some embodiments of the present disclosure aims at transmitting, from an originating ITS-S (for example the vehicle located in position 130 or the VRU located in position 150 in Figure 1), one or more RoadUsage Containers in a CAM or in a VAM (e.g., in CAM 131 or in VAM 151 in Figure 1).

[0101] In step 400, the originating ITS-S determines a required road usage or road usage needs according to needs or recommendations from an active system, an automatic or assist braking system, vehicle characteristics, a vehicle

type, vehicle driver settings, or vulnerable user settings. Environment conditions such as the road slope, the road quality, and/or the weather conditions may also be taken into account.

[0102] Next, in step 405, the originating ITS-S determines one or more road usage areas according to the previously determined road usage needs. The road usage areas define particular areas on the road, that may be referenced from the *referencePosition* of the origination ITS-S. The road usage areas may be used to inform other ITS-Ss of a specific usage of these road areas, in order to maintain driving in nominal conditions if these areas remain free from other ITS-Ss and obstacles.

[0103] Next, in step 410, the originating ITS-S generates one or more RoadUsage Containers (e.g., RoadUsage Containers 231 in Figure 2 or RoadUsage Containers 321 in Figure 3), for example by concatenating the RoadUsageArea, RoadUsageType, RoadUsageSafety, and/or RoadUsageValidity as described by reference to Figure 2.

[0104] Next, in step 415, the originating ITS-S transmits the generated RoadUsage Containers in an Awareness message (i.e., a CAM if the originating ITS-S is a vehicle or a VAM if the originating ITS-S is a VRU).

[0105] As illustrated in **Figure 5**, a method of communication in an ITS according to some embodiments of the present disclosure aims at processing, in a receiving ITS-S (e.g., the vehicle located at position 130 or 140 or the VRU located at position 150 or 160 in Figure 1), one or more RoadUsage Containers received in a CAM or in a VAM (e.g., CAM 131 or VAM 151 in Figure 1) to increase the overall safety of the ITS.

[0106] In step 500, the receiving ITS-S receives an Awareness Message comprising at least one RoadUsage Container.

[0107] Next, in step 505, the receiving ITS-S obtains one or more road usage areas from the one or more RoadUsage Containers comprised in the received Awareness Message.

[0108] Next, in step 510, the receiving ITS-S determines whether there exists one or more overlapping portions between the road usage areas and next ego vehicle dynamics. The receiving ITS-S may determine such overlapping portions by determining if its trajectory will overlap the road usage areas in a near future.

[0109] For the sake of illustration, the trajectory of a receiving ITS-S may be defined by a mathematical relation representing positions as a function of time (e.g., a list of 2D points). A Cartesian coordinate system (S) may be defined with a center C, using the metric convention according to which the abscissa axis is aligned with the East axis and the ordinate axis is aligned with the North axis, such relation may be expressed as follows:

$$Pr(t) = x(t) + y(t) \text{ in } (S)$$

with $x(t)$ being abscissa coordinate of the receiving ITS-S and $y(t)$ being ordinate coordinate of the receiving ITS-S.

[0110] $Pr(0)$ is equal to (0,0) in (S). $Pr(0)$ corresponds to the position of the receiving ITS-S at the time T_0 . Time T_0 is determined using the ITS epoch and *generationDeltaTime* received from the originating ITS-S, as follows:

$$T_0 = \text{ITS epoch} + \text{generationDeltaTime}$$

[0111] $Pr(t)$ may also be defined as a road usage area, as illustrated in Figure 9 being constant or changing as a function of time.

[0112] It is noted here that a receiving ITS-S may predict the trajectory of an originating ITS-S by using path prediction from the Motion Prediction container (if present).

[0113] Alternatively, a receiving ITS-S may predict the trajectory of an originating ITS-S by extrapolating its position as a function of time, using received information from the Basic Container comprising the *ReferencePosition* and/or *heading*, *DriveDirection*, Speed from the High Frequency Container:

$$Po(t) = T(RPoT_0, RPrT_0) + Mo(t) \text{ in } (S)$$

wherein $RPoT_0$ is the *ReferencePosition* of the originating ITS-S from the Basic Container at time T_0 and $RPrT_0$ is the *ReferencePosition* of the originating ITS-S at the previously determined time T_0 . $T(RPoT_0, RPrT_0)$ is the translation from point $RPoT_0$ to $RPrT_0$ in (S).

[0114] For example, $Mo(t)$ can be determined using *heading*, *DriveDirection* and Speed from the High Frequency Container, wherein:

- *heading* is indicating the orientation of the originating ITS-S using reference to the WGS84 North axis. The following value can be set: wgs84North(0), wgs84East(900), wgs84South(1800), wgs84West(2700) or any value from 0 to 3601 corresponding 1/10 of degrees according to WGS84 North axis,
- *DriveDirection* is indicating forward or backward movement, and

- *Speed* is indicating the velocity of the originating ITS-S with *SpeedValue* expressed in centimeters per seconds (0cm/s for standstill, up to 16383).

[0115] According to the *Speed* and *heading*, the coordinates offsets can be defined as a function of time in meters according to (S):

$$dx(t) = \text{SpeedValue}/10 \times \cos (2 \times \text{PI} \times \text{heading} / 3600) \times t \text{ in (S)}$$

$$dy(t) = \text{SpeedValue}/10 \times \sin (2 \times \text{PI} \times \text{heading} / 3600) \times t \text{ in (S)}$$

$$\text{Mo}(t) = (dx(t), dy(t)) \text{ in (S)}$$

PI being the constant number 'pi' that is the ratio of a circle's circumference to its diameter.

[0116] The translation from point RPoT0 to RPrT0, T(RPoT0 , RPrT0), in (S), may be determined by converting it as a translation in meter:

$$\text{DY} = \text{PI}/180 \times \text{R} \times (\text{Lat_RPrT0} - \text{Lat_RPoT0})$$

$$\text{DX} = \text{PI}/180 \times \text{R} \times (\text{long_RPrT0} \times \cos (\text{lat_RPrT0} \times \text{PI} / 180) - \text{long_RPoT0} \times \cos (\text{lat_RPoT0} \times \text{PI}/180))$$

where R is the Earth's radius in meter (R = 6378137m), Lat_RPrT0 is the latitude of RPrT0, Long_RPrT0 is the longitude of RPrT0, Lat_RPoT0 is the latitude of RPoT0, and long_RPoT0 is the longitude of RPoT0. All longitude and latitude are referring to WGS84 system.

$$\text{Po}(t) \text{ can be defined as } \text{Po}(t) = (\text{DX}, \text{DY}) + (dx(t), dy(y))$$

[0117] Po(t) function can be refined by the receiving ITS-S when a new CAM from the originating ITS-S is received.

[0118] The function to determine the successive geometry of the Road usage area, denoted *AreaPrediction*, may be defined by using the geometry definition used by the Road usage area added with the predicted trajectory of the Originating ITS-S:

$$\text{AreaPrediction}(t) = \text{Po}(t) + \text{RoadUsageArea}$$

[0119] The overlapping function can be defined as a function in time for a given duration of prediction, denoted *prediction_time*, with a resolution denoted *prediction_resolution*, as follows:

$$\text{Overlap}(t) = \text{Po}(t) \cap \text{Pr}(t) \text{ with } t \in [0 \text{ to } \text{prediction_time}] \text{ in step } [\text{prediction_resolution}] \text{ in (S)}$$

[0120] For the sake of illustration, the value of *prediction_resolution* may be set to 25ms. Still for the sake of illustration, the value of *prediction_time* may be estimated at 5 seconds.

[0121] The overlapping function should be reevaluated at every received CAM or VAM messages by the receiving ITS-S.

[0122] Using the overlapping function previously defined or any other overlapping function, the receiving ITS-S is able to determine the various overlapping points between the road usage area of the originating ITS-S and the trajectory of the receiving ITS-S.

[0123] Turning back to Figure 5, the receiving ITS-S evaluates the consequences of the next ego vehicle movement on the originating ITS-S transmitting the Road usage Container(s) (step 515), for example in terms of comfort, disabling adaptive system, emergency braking, and/or safety risk.

[0124] For each previously determined overlapping portion, the receiving ITS-S may obtain, from the RoadUsageArea,

the associated RoadUsageType information as described with reference to Figure 2. According to the RoadUsageType, the receiving ITS-S may determine the impact on the driving conditions of the originating ITS-S if it is present in the associated RoadUsageArea. For example, if the RoadUsageType is indicating 'collision', 'auto-braking', 'assist braking', 'safety distance', 'protective field', or 'warning field' and any value indicating a system in relationship with the safety, the receiving ITS-S determines that its trajectory will create a safety risk.

[0125] In addition, for each previously determined overlapping portion, the receiving ITS-S may obtain, from the RoadUsage area, the associated RoadUsageSafety information as described with reference to Figure 2. Using this field, the receiving ITS-S may determine a danger level if a *DangerLevel* information is present. From the danger level, the receiving ITS-S determines that its trajectory will create a safety risk if DangerLevel is greater than 0.

[0126] Using the RoadUsageSafety information field, the receiving ITS-S may determine the ControllabilityClass associated with the RoadUsage area, if ControllabilityClass information is present. From the controllability class, if DangerLevel is different than C0, the receiving ITS-S may determine that its trajectory will create a safety risk.

[0127] Accordingly, the receiving ITS-S may, in step 520,

- adapt its trajectory to reduce the overlapping portions previously determined,
- adapt its trajectory if there is a safety risk,
- take into account multiple RoadUsage Containers containing multiple RoadUsageArea, and/or
- adapt its trajectory by reducing its speed, by accelerating or stopping.

[0128] Figure 6 illustrates a use case according to some embodiments of the present disclosure, according to which a vehicle is using an adaptive cruise control system and disseminates a RoadUsage Container to indicate, in CAMs, to other ITS-Ss, the set distance.

[0129] Considering the road situation 600, the vehicle located at position 605, being an originating ITS-S, and the vehicle located at position 610, being a receiving ITS-S, are able to receive and transmit CAMs as described with reference to Figure 1. According to some embodiments of the disclosure, the vehicle located at position 605 executes an algorithm such as the one described with reference to Figure 5 and the vehicle located at position 610 executes an algorithm such as the one described with reference to Figure 5. Accordingly, the vehicle located at position 605 disseminates CAMs comprising a RoadUsage Container having a single RoadUsage area associated with a RoadUsage type. According to the illustrated example, the RoadUsage area 620 is the rectangle aligned with the heading of the vehicle located at position 605. For the sake of illustration, the rectangle width is equal to the vehicle width and the rectangle length corresponds to the setting programmed by the driver 'set distance', for example 100 meters.

[0130] RoadUsage type is equal 'adaptive cruise control'.

[0131] By receiving, the previous RoadUsage Container, the vehicle located at position 610 can adapt its trajectory 615 without cut-in RoadUsage area 620.

[0132] Figure 7 illustrates a use case according to some embodiments of the present disclosure, according to which a VRU disseminates a RoadUsage Container to indicate, in VAMs, to other ITS, a safety area.

[0133] Considering the road situation 700, the vehicle located at position 705, being an originating ITS-S, and the VRU located at position 710, being a receiving ITS-S, are able respectively to receive and transmit VAM, as described with reference to Figure 1. According to some embodiments of the disclosure, the VRU located at position 710 executes an algorithm such as the one described with reference to Figure 4 and the vehicle located at position 705 executes an algorithm such as the one described with reference to Figure 5. Therefore, the VRU located at position 710 disseminates VAMs including a RoadUsage Container with a single RoadUsage area 720 associated with a RoadUsage type. The RoadUsage area can be defined as distances referenced from a bounding box of the VRU located at position 710. For example, the distances can be the recommend values defined as the minimum safe lateral distance (MSLaD) laterally, and the minimum safe longitudinal distance (MSLoD) longitudinally and the minimum safe vertical distance (MSVD) vertically as specified with the minimum safe distance condition in clause 6.5.10.5 of ETSI TS 103 300-2.

[0134] The RoadUsageType is equal to 'safety distance'.

[0135] Additionally, the RoadUsageSafety can be defined as ControllabilityClass equals to C5 or DangerLevel equals to 5 because it concerns a Vulnerable Road User.

[0136] By receiving the previous RoadUsage Container, the vehicle located at position 705 can adapt its trajectory 715 without cut-in RoadUsage area 720.

[0137] Figure 8 illustrates a use case according to some embodiments of the present disclosure, according to which a vehicle is using an assist parking system and disseminates a Road Usage Container to indicate, in CAMs, to other ITS, the required area for its maneuver.

[0138] Considering the road situation 800, the vehicle 801, at time T0, T1, T2, and T3, being an originating ITS-S, and the vehicle 802, at time T0, T1, T2, T3, and T4 being a receiving ITS-S, are able to receive and transmit CAMs as described by reference to Figure 1. Likewise, the vehicle 806, at time T4, being a receiving ITS-S, is able to receive and transmit CAMs as described by reference to Figure 1.

[0139] According to some embodiments of the disclosure, vehicle 802 executes an algorithm like the one described by reference to Figure 4 and vehicles 801 and 806 execute an algorithm like the one described by reference to Figure 5.

[0140] It is assumed that at time T₀, vehicle 802 is using an assisted system to perform a parking maneuver targeting the free place referenced 810. The other neighboring places are occupied by different vehicles generically referenced 820.

[0141] At time T₀, vehicle 802 generates a CAM message including a RoadUsage Container with a RoadUsage area corresponding to the overall area required to execute the parking maneuver until reaching the situation at T₃ where vehicle 802 is over the previous free place 810 at T₀. The RoadUsage Container with this RoadUsage area contains a RoadUsage type set to 'parking'.

[0142] At time T₀, the RoadUsage area is defined with polygon 803a referenced from the ReferencePosition of vehicle 802 (at time T₀). Therefore, at time T₀, vehicle 802 generates a CAM including a RoadUsage Container with the RoadUsage area 803a and an associated RoadUsage type set to 'parking'.

[0143] Next, at time T₁, the RoadUsage area is modified. It is defined with polygon 803b referenced from the ReferencePosition of vehicle 802 (at time T₁). Accordingly, at time T₁, vehicle 802 generates a CAM including a RoadUsage Container with the updated RoadUsage area 803b and an associated RoadUsage type set to 'parking'.

[0144] Next, at time T₂, the RoadUsage area is modified again. It is defined with polygon 803c referenced from the ReferencePosition of vehicle 802 (at time T₂). Accordingly, at time T₂, vehicle 802 generates a CAM including a RoadUsage Container with the updated RoadUsage area 803c and an associated RoadUsage type set to 'parking'.

[0145] Next, at time T₃, vehicle 802 has completed its maneuver using the assisted system. There is no longer need for a RoadUsage area. Therefore, vehicle 802 does not include any including RoadUsage Container in the CAMs it generates.

[0146] Next, at time T₄, an occupant opens a door of vehicle 802 on the street side. Accordingly, vehicle 802 determines a new RoadUsage area, referenced 804, that is required to protect the appearing pedestrian referenced 805. RoadUsage area 804 may be defined with a rectangle around the vehicle 802. The associated RoadUsage type may be set to 'safety'. Accordingly, at time T₄, vehicle 802 generates a CAM including a RoadUsage Container with the updated RoadUsage area 804 and an associated RoadUsage type set to 'safety'. This CAM may be used, in particular, by vehicle 806.

[0147] According to some embodiments, vehicle 802 transmits the corresponding RoadUsage Container in VAMs as long as pedestrian 805 is near vehicle 802.

[0148] Alternately, pedestrian 805 may generate VAMs including a RoadUsage Container with the previous RoadUsage area 804 being defined as a rectangle around pedestrian 805. The associated RoadUsage type may still be set to 'safety'.

[0149] Vehicle 801 may use an algorithm like the one described by reference to Figure 5 in order to prevent itself for overlapping the different RoadUsage areas 803a, 803b, and 803c from time T₀ to time T₂. Vehicle 801 stops itself so that vehicle 802 may execute safely its assisted maneuver, without conflicting with vehicle 801. At time T₃, vehicle 801 may restart since it is no longer stopped by the previous RoadUsage areas.

[0150] Similarly, vehicle 806 may use an algorithm like the one described by reference to Figure 5 to be aware of the RoadUsage areas transmitted by other ITS-Ss, in particular of RoadUsage area 804 of the 'safety' type (that may be transmitted either from vehicle 802 in CAMs or from pedestrian 805 in VAMs). Accordingly, vehicle 806 stops itself until pedestrian 805 left the RoadUsage area 804.

[0151] Figure 9 illustrates examples of Road Usage areas defined either by using distances, vectors, rectangles, polygons, ellipses, or road sections according to some embodiments of the present disclosure.

[0152] As illustrated, vehicle 901 may define a RoadUsage area 911 in a RoadUsage Container using a rectangle defined by 4 points having coordinates that are relative to the ReferencePosition of vehicle 901.

[0153] Similarly, vehicle 902 may define successive RoadUsage areas 912, 922, and 932 in a same RoadUsage Container using different rectangles defined by 4 points having coordinates that are relative to the ReferencePosition of vehicle 902. Each of the RoadUsage areas 912, 922, and 932 may correspond to different safety levels.

[0154] Still for the sake of illustration, vehicle 903 defines a RoadUsage area 913 in a RoadUsage Container using a single distance from the ReferencePosition of vehicle 903, that is aligned with the heading of the vehicle.

[0155] Likewise, vehicle 904 defines successive RoadUsage areas 912, 922, and 932 in the same RoadUsage Container, using successive distances, starting from the ReferencePosition of vehicle 904.

[0156] Still for the sake of illustration, vehicle 905 defines a RoadUsage area 915 in a RoadUsage Container, using a single polar vector starting from the ReferencePosition of vehicle 903, that is referenced from the heading of vehicle 903.

[0157] Likewise, vehicle 906 defines successive RoadUsage areas 1016, 1026, and 1036 in the same RoadUsage Container, using successive polar vectors starting from the ReferencePosition of vehicle 906, that is referenced from the heading of vehicle 906.

[0158] Still for the sake of illustration, vehicle 907 defines a RoadUsage area 907 in a RoadUsage Container, using a polygon having coordinates relative to the ReferencePosition of vehicle 907, and vehicle 908 defines a RoadUsage area 913 in a RoadUsage Container, using an ellipsoid having coordinate relative to the ReferencePosition of vehicle 908.

[0159] Figure 10 illustrates examples of RoadUsage areas defined using road sections.

[0160] According to some embodiments of the disclosure, RoadUsage areas are defined as a function of successive

road sections determined according to a road representation and as a function of lanes per road section.

[0161] Therefore, a RoadUsage area may be defined using a list of one or more successive road sections and a list of one or more lanes per section, according to a road representation, with preferably a first distance indicating the start of the RoadUsage area according to the first section in the list and/or a second distance indicating the end of the RoadUsage area according to the last section of the list.

[0162] Considering the road situation referenced 1000 in Figure 10, vehicle 1001 is present in lane 1 of section 1 (this item of information may be disseminated in CAMs using *LanePosition* using the High-Frequency Container).

[0163] For the sake of illustration, vehicle 1001 may define RoadUsage area 1002 in a RoadUsage Container, using a list containing (Section1, lane1, distance D1), (Sections, lane1), (Section 4, lane 2, distance D2).

[0164] As specified in 'ETSI TS 103 900 V0.0.4_2.1.1 (2023-03)', Cooperative Awareness Messages (CAMs) are messages exchanged in the ITS network between ITS-Ss to create and maintain awareness of each other and to support cooperative performance of vehicles using the road network. A CAM contains status and attribute information of the originating ITS-S. The content varies depending on the type of the ITS-S. For vehicle ITS-Ss the status information includes time, position, motion state, activated systems, etc. and the attribute information includes data about the dimensions, vehicle type and role in the road traffic. On reception of a CAM, the receiving ITS-S becomes aware of the presence, type, and status of the originating ITS-S. The received information can be used by the receiving ITS-S to support several ITS applications. For example, by comparing the status of the originating ITS-S with its own status, a receiving ITS-S is able to estimate the collision risk with the originating ITS-S and if necessary, may inform the driver of the vehicle via the in-vehicle system.

[0165] Even if a connected vehicle is able to determine and predict the near future movement of other vehicles by receiving CAMs, this prediction is limited by the lack of knowledge on vehicle properties such as braking distance, active adaptive control system or safety systems and driving conditions. For example, a connected vehicle may use an adaptive cruise control system which properties are changing according to the road conditions (weather, light conditions, road type and traffic, vehicle speed, user preferences). For example, a connected vehicle may use an automatic driving mode relying on monitored fields (warning, protective) in its surroundings to maintain its safety conditions. Those properties are unknown by other connected vehicles and difficult to estimate by their nature. Consequently, another connected vehicle is not able to determine how its driving may impact the previous vehicle driving. It may result in various effects such as triggering an adaptive system, gently braking or entering in safety issue (collision, automatic braking, non-respect of safety distance).

[0166] According to the disclosure, it is proposed to solve this issue by adding information in the CAMs to make it possible to disseminate the road usage area required by the vehicle to maintain its driving in nominal conditions.

[0167] In the example illustrated in Figure 11, the car is having the priority and would like to turn on its right. According to the road rule 'Priority on the right', the bus shall stop and let the car turns. Even by knowing the bus dynamics by receiving CAMs from the bus, the car is not able to determine if the bus is able to safely brake.

[0168] To solve this issue, the bus can disseminate its braking distance using CAMs. By receiving this status information over CAMs, the car is able to determine if it can safely turn and adapt its dynamics to maintain a safe distance with the bus, as illustrated in Figure 12. As illustrated, several road usage areas may be defined, for example a first area corresponding to a distance from the bus wherein a collision cannot be avoided, a second area corresponding to the distance needed for stopping the bus using an auto-braking system, and a third area corresponding to the distance for stopping the bus in case of a normal braking. As can be seen, since it exists a margin between the stop position of the bus (while considering a normal braking) and the position of the car, the latter may decide to turn, without letting the bus pass.

[0169] In the example illustrated in Figure 6, an adaptive cruise control is used by a car. The adaptive cruise control permits to maintain a safe distance with other cars. This kind of system has some limitations in close cut-in scenario and it may not assist.

[0170] This car disseminates using CAMs the area corresponding to the distance set for the adaptive cruise control to maintain a safe distance with other cars.

[0171] By receiving CAMs, the other car is informed of the road usage by the other car and prevents itself from cut-in it before it overtakes the area.

[0172] It permits to keep safe distance, to prevent other vehicle to enter in this area, and to get a fluent road traffic.

[0173] Accordingly, it is proposed to add a container named 'RoadUsageContainer' containing a set of RoadUsage data frames including:

- RoadUsageArea:
A distance, an area, a polygon or a vector. It's Referred to the ReferencePosition.
- RoadUsageType

◦ it is used to define the corresponding road usage of the area

- braking distance
 - collision
 - auto-braking
 - assist braking
 - 5 ▪ safety distance
 - Adaptive Cruise control
 - Advanced driver Assistance System
 - protective or warning field
 - 10 ▪ comfort or economic mode (smooth drive)
 - maneuver on-going
 - emergency requirement
 - parking
 - pedestrian exits from vehicle
 - 15 ▪ other
- RoadUsageSafety: It's used to indicate the danger level and/or the controllability class. It may be used by an ITS to assess the risk in case of presence in the road usage area. It may include:
- o ControllabilityClassification: it is used to define the controllability class (ASIL) of the vehicle if a hazardous event occurs in the RoadUsageArea:
 - 20 ▪ C0 Controllable in general
 - C1 Simply controllable
 - 25 ▪ C2 Normally controllable (most drivers could act to prevent injury)
 - C3 Difficult to control or uncontrollable
 - o DangerLevel: it is used to define the danger level for the car occupancy and/or any other vehicle in case of collision in Road UsageArea
 - 30 ▪ Level 4 High danger
 - Level 3 Considerable danger
 - Level 2 Moderate danger
 - Level 1 No or minor danger
- 35 **[0174]** It is observed that disclosing erroneous braking distance may create legal dispute in case of accident. Therefore, it is necessary to make sure that this information cannot be misunderstood or wrongly interpreted by receiving ITS stations.
- 40 **[0175]** In some embodiments, the transmitting ITS vehicle disseminates the braking distances of the vehicle class required by the approval of the concerned vehicle, as defined by UNECE Regulation Acts. These values are used as criteria for the concerned vehicle approval and periodic technical inspection.
- 40 **[0176]** Only legal information on braking distance is disclosed. This item of information is already part of the approval certificate being approved or extended.
- 45 **[0177]** The receiving ITS vehicle is informed without ambiguity of the braking distance of the transmitting ITS vehicle as defined. The receiving ITS vehicle should extrapolate the stopping distance taking into account environmental conditions. For example, the receiving ITS vehicle should take into account weather conditions (e.g., rain), the road slope, etc., and should add reaction distance due to the driver (for example a reaction time less than 1.5s).
- 45 **[0178]** The following UNECE acts are relevant to determine braking distances per vehicle class:
- Regulation No 13 of the Economic Commission for Europe of the United Nations (UN/ECE)- Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking,
 - 50 • Regulation No 13-H of the Economic Commission for Europe of the United Nations (UN/ECE) - Uniform provisions concerning the approval of passenger cars with regard to braking, and
 - Regulation No 78 of the Economic Commission for Europe of the United Nations (UNECE)- Uniform provisions concerning the approval of vehicles of categories L1, L2, L3, L4 and L5 with regard to braking
- 55 **[0179]** The braking distance may be the distance covered by the vehicle from the moment when the driver begins to actuate the control of the braking system until the moment when the vehicle stops.
- 55 **[0180]** It is observed that estimating a braking distance is complex and that such an estimation depends on multiple parameters including road adhesion, braking effectiveness, weather conditions, road slope and others. Therefore, it is

necessary to make sure that this information cannot be misunderstood or wrongly interpreted by receiving ITS stations.

[0181] In some embodiments, the transmitting ITS vehicle disseminates braking distance(s) of the vehicle class as required by the approval test of the concerned vehicle in well-defined conditions which may include weather conditions, road friction surface, laden/unladen criteria, as a second braking distance value associated with the prescribed test conditions.

[0182] Still according to some embodiments, the road usage area may be defined as the area required by the transmitting ITS station, an object, or a person associated with the transmitting ITS station to conduct or carry out an action or a maneuver. For example, the action or maneuver may not be predicted, such as an emergency brake activation. In some embodiments, a road usage area comprises a predicted or predictable path and an additional set of paths that may be used to conduct or carry out an action or a maneuver that depends on the context and the environment, on traffic regulations, etc. The road usage area may be of any shape and may be defined as a set of one or more distances (it being noted that some dimension parameters of the road usage area may be implicit e.g., the width of a vehicle, or may be considered as useless).

[0183] In some embodiments, a road usage area is a surrounding region of a vehicle considered by a driver or a driving system to manage the vehicle taking into account different driving need or traffic rules (e.g. safe driving distance), considering the occurrence of unpredictable events triggering a driving action (e.g. braking area), or considering any assistance system monitoring proximity with other vehicles (e.g. adaptive cruise control).

[0184] For different vehicle classes, UNECE Regulation acts define performance criteria according to the driving conditions and vehicle characteristics such as laden / unladen, dry / rain, high friction surface / low friction surface, continuous braking, cold brake / hot brake / wet brake, and trailer with or without braking system.

[0185] For the sake of illustration and regarding motorcycles, approval tests are performed considering UE - ECE Regulation No. 78 Annex 3.1.1 Test surfaces (low/high friction), same approach in US and Japan. (FMVSS 122 Motorcycle Brake systems, Japanese Safety Standard 12-61)

[0186] The receiving vehicle is informed without ambiguity of the braking distance of the transmitting ITS vehicle as defined in particular environmental conditions as defined in the regulation or standard. The receiving ITS vehicle should adapt the stopping distance taking into account current environmental conditions.

[0187] It is observed that such a minimum braking performance of the transmitting ITS vehicle does not include the additional distance covered by the vehicle due to the driver reaction delay before he/she begins to actuate the control, the stopping distance being expressed as follows:

$$\text{stopping distance} = \text{reaction distance} + \text{braking distance}$$

[0188] It is noted here that the reaction time value is generally about one second, but it can be greater due to the driving conditions or the driver (accordingly, a reaction time of 1.5 seconds is a recommended value considering rainy weather conditions). A receiving ITS station may thus extrapolate the braking distance to determine the stopping distance.

[0189] According to a particular embodiment, a first braking distance value to disseminate in CAMs is the braking distance value obtained during the type-0 test with non-connected engine.

[0190] For Example, the UNECE Regulation No13 (1.6.2) conformity M3 class vehicle test Type-0 connected engine (1.6.3) defines the braking distance as follows:

$$\text{braking distance} < 0.15v + 1,33 v^2/130$$

wherein v is the vehicle speed in km/h.

[0191] The two following performance values are described for braking approval test in UNECE Regulation acts:

- the mean fully developed deceleration (MFDD) and
- the stopping distance (without reaction time of the driver).

[0192] The braking distance may be determined using the following equations (motion equation):

- equation (1): braking distance d determined using MFDD disseminated using CAM message: $d = 0,15v + v^2 / (25.92 \times \text{MFDD})$
- equation (2): braking distance d determined using polynomial coefficient in CAM message $d = (C0/C1) \times v + (C2/C3) \times v^2$

wherein C0, C1, C2, and C3 are coefficients of the motion equation. The coefficient values can be the ones required by

the homologation of the vehicle class (UNECE Regulation No.13, No. 13-H, No. 78) when the braking distance is expressed using the motion equation. C0 and C1 may be coefficients depending on the initial speed of the vehicle while C2 and C3 may be the coefficients depending on MFDD.

[0193] One or both can be used for braking performance approval of a vehicle.

[0194] The required performance values (i.e., the maximum of both values if both values are used for vehicle approval) may be used to determine the 'Braking UNECE Type-0 non connected engine' distance value.

[0195] Using this approach,

- the ITS transmitting vehicle may efficiently share to other ITS stations its braking distance as an intrinsic minimum performance that is certified using non-ambiguous information and applicable in well know conditions (as specified in UNECE. Regulation acts),
- legal responsibility is limited as it is already part of vehicle approval information. In case of legal dispute, this item of information is anyway part of the approval tests description and performances criteria,
- the receiving vehicle is informed without ambiguity of the braking distance of the transmitting ITS vehicle, as it is defined. The receiving vehicle should extrapolate the stopping distance by taking into account environmental conditions (e.g., rains and/or slope road) and adding a reacting thinking distance due to the driver reaction (for example 1.5 s), and
- an ITS vehicle can indicate a road usage area for safety reason to other ITS stations.

[0196] Indicating a road usage area for safety reason can be used in many situations, in particular in the following use cases:

- for maintaining a safety distance between vehicles, which is useful, for example, for lane merging, lane change, (for example, $d=v \times 2$ seconds between cars, $l_{cy} = v \times 4$ seconds)
- for maintaining a safety distance with or between heavy vehicles (e.g., truck),
- when driving near buses stopped from which passengers exit (example: Danger zones for school bus, protecting children exit),
- for managing an exceptional convoy (for example: distance > 150 meters in front),
- when driving behind a military convoy,
- for managing a Police escort, and
- when driving behind a fire engine, a police vehicle, an ambulance, or other emergency vehicle.

[0197] Indicating a road usage area may also be useful regarding applicable safe driving distance rules, such as the following;

- convoy of vehicles
- truck / cars under a tunnel,
- large vehicles / motorcycles,
- funeral procession,
- tramway crossing shared road under priority,
- accident area,
- maneuver for parking, and
- any applicable safe driving distance rule.

[0198] Still according to some embodiments, an ITS vehicle may indicate an area used by an Advanced Driver Assistance System of the vehicle. Any-cut in the specified area interferes with the concerned active system;

- Adaptative cruise control,
- Emergency Braking system, and
- other ADAS.

[0199] All CAMs generated by a vehicle ITS-S shall include at least a high frequency vehicle (Vehicle HF) container, and optionally a low frequency vehicle (Vehicle LF) container.

[0200] The Vehicle HF container contains all fast-changing (dynamic) status information of the vehicle ITS-S such as heading or speed while the Vehicle LF container contains static or slow-changing vehicle data like the status of the exterior lights.

[0201] Considering backward compatibility, BasicVehicleContainerHighFrequency is a non-extensible type.

[0202] RoadUsageContainer dissemination rule is similar to highFrequencyContainer.

[0203] RoadUsageContainer can be added in CamParameters SEQUENCE.

[0204] In some embodiments, the following ASN.1 specification can be used to define the RoadUsageContainer.

```

5      CamParameters ::= SEQUENCE {
          basicContainer          BasicContainer,
          highFrequencyContainer  HighFrequencyContainer,
10         lowFrequencyContainer  LowFrequencyContainer OPTIONAL,
          specialVehicleContainer SpecialVehicleContainer OPTIONAL,
          ...,
15         roadUsageContainer     RoadUsageContainer OPTIONAL,
          ...
20     }

```

[0205] For the sake of illustration, the following data frame (DF) represents a Road Usage container as a list of road usage information:

RoadUsageContainer ::= SEQUENCE SIZE(1..16) OF RoadUsage

[0206] Still for the sake of illustration, the following data frame (DF) represents information on how a vehicle is using an area over the road for a given purpose denoted usage type, wherein the road UsageType indicates the usage type for the concerned area and the roadUsageArea provides a specification of the area over the road:

```

          RoadUsage ::= SEQUENCE {
30             roadUsageType  RoadUsageType,
             roadUsageArea    RoadUsageArea,
             ...,
35         }

```

[0207] Still for the sake of illustration, the following data element (DE) indicates the road usage type for concerned area:

```

RoadUsageType ::= ENUMERATED {
    Braking-UNECE-Type-0-disconnected-engine    (0),
5      Braking-UNECE-complementary                (1),
      BrakingEstimated                          (2),
      Safety                                    (3),
10     AdaptiveCruiseControl                    (4),
      AdvancedEmergencyBraking                 (5),
      AdvancedDriverAssistance                 (6),
15     WarningField                             (7),
      ProtectiveField                          (8),
      Collision                               (9),
20     Braking_Type-0-connected-engine          (10),
      Braking_hot                             (11),
      Braking_continuous                      (12),
25     Braking_downslope                       (13),
      Braking_wet                             (14),
      Braking_Low-adhesion                    (15),
30     Braking_rainy                           (16),

      Braking_Laden                           (17),
      etc.
35 }

```

or as

40

45

50

55

```

RoadUsageType ::= INTEGER {
    Braking-UNECE-Type-0-disconnected-engine    (0),
    Braking-UNECE-complementary                 (1),
    BrakingEstimated                             (2),
    Safety                                        (3),
    AdaptiveCruiseControl                       (4),
    AdvancedEmergencyBraking                    (5),
    AdvancedDriverAssistance                    (6),
    WarningField                                (7),
    ProtectiveField                              (8),
    Collision                                    (9),
    Braking_Type-0-connected-engine              (10),
    Braking_hot                                 (11),
    Braking_continuous                           (12),
    Braking_downslope                           (13),
    Braking_wet                                 (14),
    Braking_Low-adhesion                        (15),
    Braking_rainy                               (16),
    Braking_Laden                               (17),
} (18..255)

```

[0208] According to some embodiments, the value may be set as follows:

0 - 'Braking-UNECE-Type-0-disconnected-engine' indicates a braking area corresponding to a braking distance as prescribed during the homologation of the vehicle according to its vehicle class (known from StationType field value as specified in ETSI TS 102 894) and described in UNECE Regulation No.13, No.13H or No.78 as Type-0 disconnected engine,

1 - 'Braking-UNECE-complementary' indicates a braking area corresponding to a braking distance as prescribed during the homologation of the vehicle according to its vehicle class (known from StationType field value as specified in ETSI TS 102 894) and described in UNECE Regulation act as complementary to Type-0 disconnected engine,

2 - 'BrakingEstimated' indicates a braking area corresponding to a braking area estimated by the vehicle,

3 - 'Safety' indicates a safety area corresponding to a safety distance required by the vehicle in front/back and/or side (for example Speed x 2 seconds in front of the vehicle), but it can be extended on other purpose (e.g., exceptional convoy: 150m safety distance, convoy in column area, vehicle pilot, vehicle protection, emergency vehicle safe driving distance, school bus danger zone, bus stopped with exit for passengers, etc.),

4 - 'AdaptiveCruiseControl' indicates an area used by Adaptive Cruise control system of the vehicle. Any-cut in the specified area interferes with the active system,

5 - 'AdvancedEmergencyBraking' indicates an area used by an Advanced Emergency Braking System of the vehicle. Any-cut in the specified area interferes with the active system and may trigger the system,

6 - 'AdvancedDriverAssistance' indicates an area used by Advanced Driver Assistance system of the vehicle. Any-cut in the specified area interferes with the active system,

7 - 'Warning Field' indicates an area used by the (autonomous) vehicle as a warning field. Any-cut in the specified area will change the autonomous vehicle behavior,

8 - 'ProtectiveField' indicates an area used by the (autonomous) vehicle as a protective field. Any-cut in the specified area will trigger an emergency stop of vehicle,

9 - 'Collision' indicates an area considered by the (autonomous) vehicle as a high probability of collision in case of object presence, and

10 - 'Braking-UNECE-Type-0-connected-engine' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class M, M1, M2 and described in UNECE Regulation act as Type-0 connected vehicle,

11 - 'Braking-hot' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when braking system is hot,

12 - 'Braking-continuous' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when braking system is continuously used,

13 - 'Braking-downslope' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when braking system is used when the road in a downslope direction,

14 - 'Braking-wet' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when braking system is wet,

15 - 'Braking-low-adhesion' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when the adhesion is low,

16 - 'Braking-rainy' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when the weather is rainy,

17 - 'Braking-laden' indicates a braking area corresponding to a braking distance as prescribed by the homologation of the vehicle class and described in UNECE Regulation act as complementary to Type-0 non-connected vehicle when the vehicle is laden, and

18 - 255 - reserved for future use.

[0209] Still for the sake of illustration, the following data frame (DF) represents an area of road used by a vehicle specified as a distance, vectors or a polygonal shape, or deceleration value to determine the area:

```

RoadUsageArea ::= CHOICE {
    distance      StandardLength2B,
    vectors       DeltaReferencePosition (SIZE (0..16)),
    shape         PolygonalShape,
    acceleration  AccelerationValue,
    motionCoeffs  INTEGER (SIZE (4)),
    ...
}

```

wherein:

the distance field indicates the offset position to specify the area as a distance from the reference point of the vehicle and using heading as direction. The value can also be 'unavailable(65534)' or 'outofRange(65535)'. 'outofRange(65535)' value indicates that the vehicle is not able to determine the value due to abnormal conditions or vehicle problem. 'unavailable(65534)' value indicates that the vehicle doesn't provide the value,

the vector field provides a specification of the area over the road defined as one or more relative position,

the shape field provides a specification of the area over the road defined as a polygonal shape, and

the acceleration field provides a specification of the value of an acceleration used to determine a distance using the vehicle speed. Considering a road usage area for braking, the acceleration can be equal to MFDD (mean fully developed deceleration) expressed in m/s² as required by the homologation of the vehicle class and according to UNECE Regulation No.13 (Type-0 *non-connected vehicle or equivalent). The distance may then be determined as follows, considering d the distance in meter, v the speed in m/s, and a the acceleration in m/s²:

$$d = 0,15v + v^2/(2*a)$$

or considering UNECE Regulation No.13:

$$d = 0,15v + v^2/(2*a)$$

[0210] With v in km/h and considering MFDD UNECE Regulation No.13 or 13-H), the distance is expressed as follows:

$$d = 0,15*v + v^2/(2*(3,6)^2*MFDD) = 0,15*v + v^2/(25,92 * MFDD)$$

[0211] The motionCoeffs field provides a specification of the value(s) of a second order polygon used to determine a distance using the vehicle speed value and using a basic equation of motion. Considering a road usage area for braking, the coefficients value can be the ones required by the homologation of the vehicle class (UNECE Regulation No.13, No. 13-H, No. 78) or equivalent. In such a case, the distance d may be expressed as follows:

$$d = (\text{motionCoeffs}[0] / \text{motionCoeffs}[1]) \times v + (\text{motionCoeffs}[2] / \text{motionCoeffs}[3]) \times v^2$$

wherein the speed value v may be the 'SpeedValue' contained in the Speed DF in BasicVehicleContainerHighFrequency.

[0212] In other words, a road usage area may be a surrounding region of a vehicle considered by a driver or a driving system to control it taking into account different driving need or traffic rules (e.g. safe driving distance), considering the occurrence of unpredictable events triggering a driving action (e.g. braking area), or considering any assistance system monitoring proximity with other vehicles (e.g. adaptive cruise control).

[0213] There are multiple manners to determine a road usage area.

[0214] A first manner is to use to a geometric representation which may be based on a polygon shape. A second manner is to use a relative distance to a point in the heading of the vehicle from a reference point of the vehicle, the road usage area being defined as the road area delimited by these two points, and by the width of the vehicle. A third manner is to use a relative vector from a reference point of the vehicle, the road usage area being defined as the road area delimited by the vector and by the width of the vehicle.

[0215] Another manner is to use an acceleration value. In such a case, the corresponding road usage area is the road area delimited by the distance covered by the vehicle until it stops, by applying the acceleration value as a deceleration, and by the width of the vehicle. For example, this distance can be determined using the following motion equation: $d = 0,15v + v^2/(2*a)$ wherein d is the distance, v is the speed, and a is the acceleration.

[0216] Still another manner is to use second order polynomial coefficients describing the motion equation. In such a case, the corresponding road usage area is the road area delimited by the distance determined using the polynomial coefficients and by the width of the vehicle. For example, this distance can be determined using the coefficients (A and B) of the following motion equation: $d = A*v + B*v^2/$ wherein d is the distance, v is the speed, and a is the acceleration.

Example of a hardware to carry out steps of the method of embodiments of the present disclosure

[0217] **Figure 9** is a schematic representation of an example of a communication ITS-S device configured to implement some embodiments of the present disclosure. It may be either an ITS-S embedded in a vehicle or in a unit such as a mobile phone of a Vulnerable Road User, for example unit in vehicles 130,140 or held by Vulnerable Road Users 150,160 in Figure 1.

[0218] The communication device 1300 may preferably be a device such as a microcomputer, a workstation or a light portable device embedded in a vehicle. The communication device 1300 comprises a communication bus 1313 to which there are preferably connected:

- a central processing unit 1311, such as a microprocessor, denoted CPU or a GPU (for graphical processing unit);
- a read-only memory 1307, denoted ROM, for storing computer programs for implementing some embodiments of the disclosure;
- a random access memory 1312, denoted RAM, for storing the executable code of methods according to embodiments of the disclosure as well as the registers adapted to record variables and parameters necessary for implementing methods according to embodiments of the disclosure; and
- at least one communication interface 1302 connected to the radio communication network over which ITS messages are transmitted. The ITS messages are written from a FIFO sending memory in RAM 1312 to the network interface

for transmission or are read from the network interface for reception and writing into a FIFO receiving memory in RAM 1312 under the control of a software application running in the CPU 1311.

[0219] Optionally, the communication device 1300 may also include the following components:

- a data storage means 1304 such as a hard disk, for storing computer programs for implementing methods according to one or more embodiments of the disclosure;
- a disk drive 1305 for a disk 1306, the disk drive being adapted to read data from the disk 1306 or to write data onto said disk;
- a screen 1309 for serving as a graphical interface with the user, by means of a keyboard 1310 or any other pointing means.

[0220] The communication device 1300 may be optionally connected to various peripherals including perception sensors 1308, such as for example a digital camera, each being connected to an input/output card (not shown) so as to supply data to the communication device 1300.

[0221] Preferably the communication bus provides communication and interoperability between the various elements included in the communication device 1300 or connected to it. The representation of the bus is not limiting and in particular the central processing unit is operable to communicate instructions to any element of the communication device 1300 directly or by means of another element of the communication device 1300.

[0222] The disk 1306 may optionally be replaced by any information medium such as for example a compact disk (CD-ROM), rewritable or not, a ZIP disk, a USB key or a memory card and, in general terms, by an information storage means that can be read by a microcomputer or by a microprocessor, integrated or not into the apparatus, possibly removable and adapted to store one or more programs whose execution enables a method according to the disclosure to be implemented.

[0223] The executable code may optionally be stored either in read-only memory 1307, on the hard disk 1304 or on a removable digital medium such as for example a disk 1306 as described previously. According to an optional variant, the executable code of the programs can be received by means of the communication network, via the interface 1302, in order to be stored in one of the storage means of the communication device 1300, such as the hard disk 1304, before being executed.

[0224] The central processing unit 1311 is preferably adapted to control and direct the execution of the instructions or portions of software code of the program or programs according to the disclosure, which instructions are stored in one of the aforementioned storage means. On powering up, the program or programs that are stored in a nonvolatile memory, for example on the hard disk 1304 or in the read-only memory 1307, are transferred into the random access memory 1312, which then contains the executable code of the program or programs, as well as registers for storing the variables and parameters necessary for implementing the disclosure.

[0225] In a preferred embodiment, the apparatus is a programmable apparatus which uses software to implement the disclosure. However, alternatively, the present disclosure may be implemented in hardware (for example, in the form of an Application Specific Integrated Circuit or ASIC).

[0226] Although the present disclosure has been described herein above with reference to specific embodiments, the present disclosure is not limited to the specific embodiments, and modifications will be apparent to a skilled person in the art which lie within the scope of the present disclosure.

[0227] Many further modifications and variations will suggest themselves to those versed in the art upon referring to the foregoing illustrative embodiments, which are given by way of example only and which are not intended to limit the scope of the disclosure, that being determined solely by the appended claims. In particular, the different features from different embodiments may be interchanged, where appropriate.

[0228] Each of the embodiments of the disclosure described above can be implemented solely or as a combination of a plurality of the embodiments. Also, features from different embodiments can be combined where necessary or where the combination of elements or features from individual embodiments in a single embodiment is beneficial.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that different features are recited in mutually different dependent claims does not indicate that a combination of these features cannot be advantageously used.

Claims

1. A method of communication in an Intelligent Transport System, ITS, the method comprising, at a transmitting ITS station:

determining at least one road usage area that the transmitting ITS station, an object, or a person associated with the transmitting ITS station may possibly use; and
transmitting an ITS message comprising an item of information indicating the at least one road usage area.

- 5 **2.** The method of claim 1, wherein the road usage area is an area to be traversed by the transmitting ITS station within a given time period.
- 10 **3.** The method of claim 1 or claim 2, further comprising determining a road usage type associated with the at least one road usage area and transmitting an item of information indicating the road usage type.
- 15 **4.** The method of any one of claims 1 to 3, further comprising determining a road usage safety indication associated with the at least one road usage area and transmitting an item of information indicating the road usage safety indication.
- 20 **5.** The method of any one of claims 1 to 4, wherein the at least one road usage area is defined with a distance, a vector, a polygon, and/or an ellipse.
- 25 **6.** The method of any one of claims 1 to 4, wherein the at least one road usage area extends over at least two adjacent lane sections of a road.
- 30 **7.** The method of any one of claims 1 to 4, wherein the at least one road usage area extends over two lane sections belonging to two intersected roads.
- 35 **8.** The method of any one of claims 1 to 7, further comprising obtaining road usage needs, the at least one road usage area being determined as a function of the obtained road usage needs.
- 40 **9.** The method of any one of claims 1 to 8, wherein the item of information indicating the at least one road usage area is transmitted in at least one RoadUsage Container of a Cooperative Awareness Message, CAM, or of a Vulnerable Road Users Awareness Message, VAM.
- 45 **10.** The method of claim 9, further comprising generating the at least one RoadUsage Container, the generated at least one RoadUsage Container belonging to a High-Frequency Container or to a Low-Frequency Container.
- 50 **11.** A method of communication in an Intelligent Transport System, ITS, the method comprising, at a receiving ITS station:
receiving, from a transmitting ITS station, an ITS message comprising an item of information indicating at least one road usage area; and
determining, from the received ITS message, at least one road usage area that the transmitting ITS station, an object, or a person associated with the transmitting ITS station may possibly use.
- 55 **12.** The method of claim 11, wherein the road usage area is an area to be traversed by the transmitting ITS station within a given time period.
- 60 **13.** The method of claim 11 or claim 12, further comprising determining, from the received ITS message, a road usage type associated with the at least one road usage area.
- 65 **14.** The method of any one of claims 11 to 13, further comprising determining, from the received ITS message, a road usage safety indication associated with the at least one road usage area.
- 70 **15.** The method of any one of claims 11 to 14, further comprising determining whether the at least one road usage area overlaps a predicted path of the receiving ITS station.
- 75 **16.** The method of claim 15, depending on claim 14, further comprising, in case the at least one road usage area overlaps the predicted path of the receiving ITS station, evaluating effects of the overlap.
- 80 **17.** The method of claim 16, further comprising adapting parameters of the receiving ITS station as a function of the evaluated effects.

18. The method of any one of claims 11 to 17, wherein the received ITS message is a Cooperative Awareness Message, CAM, or a Vulnerable Road Users Awareness Message, VAM.

19. The method of claim 18, wherein the received ITS message comprises at least one RoadUsage Container, the at least one RoadUsage Container comprising at least one High-Frequency Container and/or at least one Low-Frequency Container, the at least one High-Frequency Container and/or the at least one Low-Frequency Container comprising a RoadUsage Container comprising the item of information indicating the at least one road usage area.

20. A computer program product for a programmable apparatus, the computer program product comprising a sequence of instructions for implementing each of the steps of the method according to any one of claims 1 to 19 when loaded into and executed by the programmable apparatus.

21. A non-transitory computer-readable storage medium storing instructions of a computer program for implementing each of the steps of the method according to any one of claims 1 to 19.

22. A device for an Intelligent Transport System, ITS, station, the device comprising a processing unit configured for carrying out each of the steps of the method according to any one of claims 1 to 19.

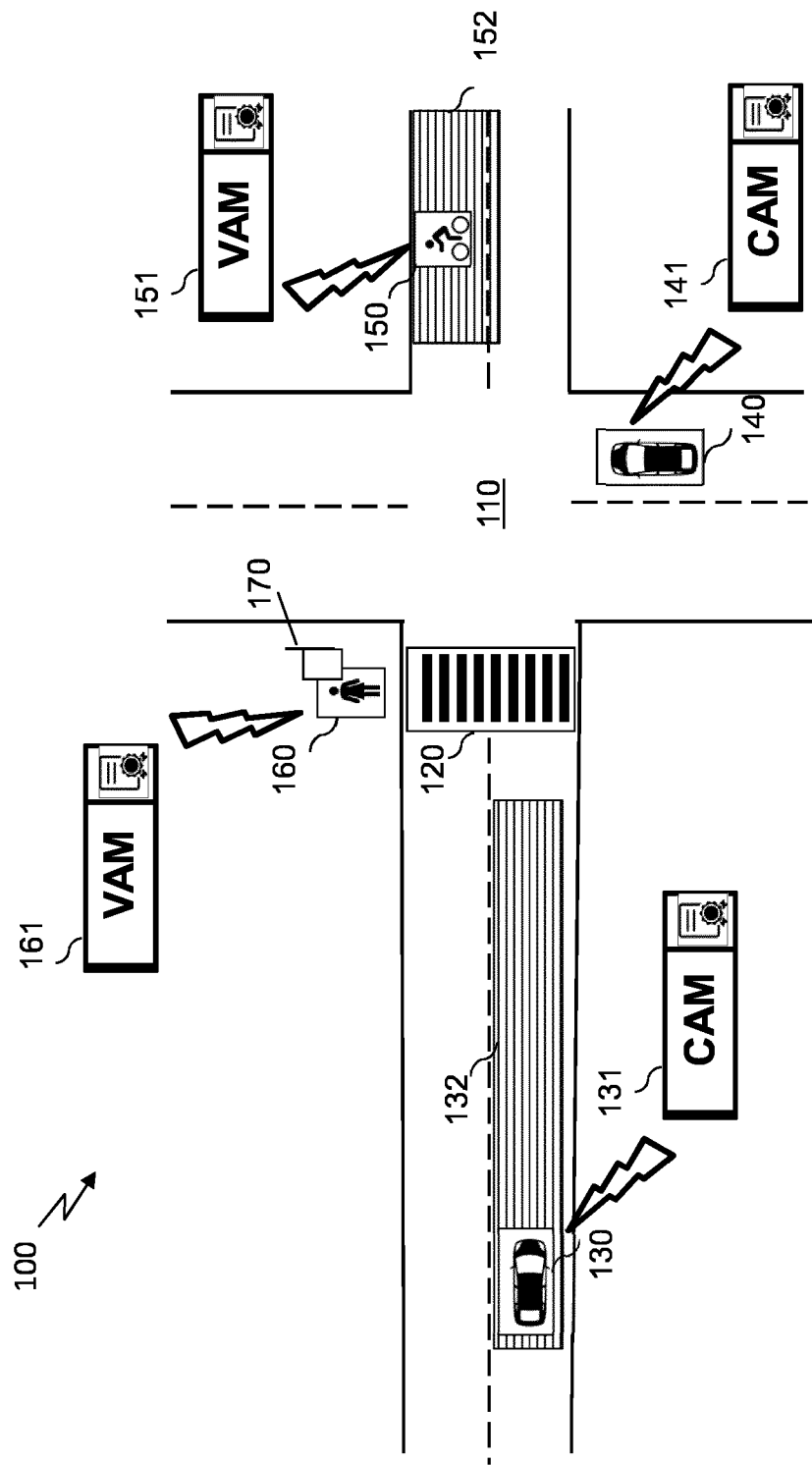
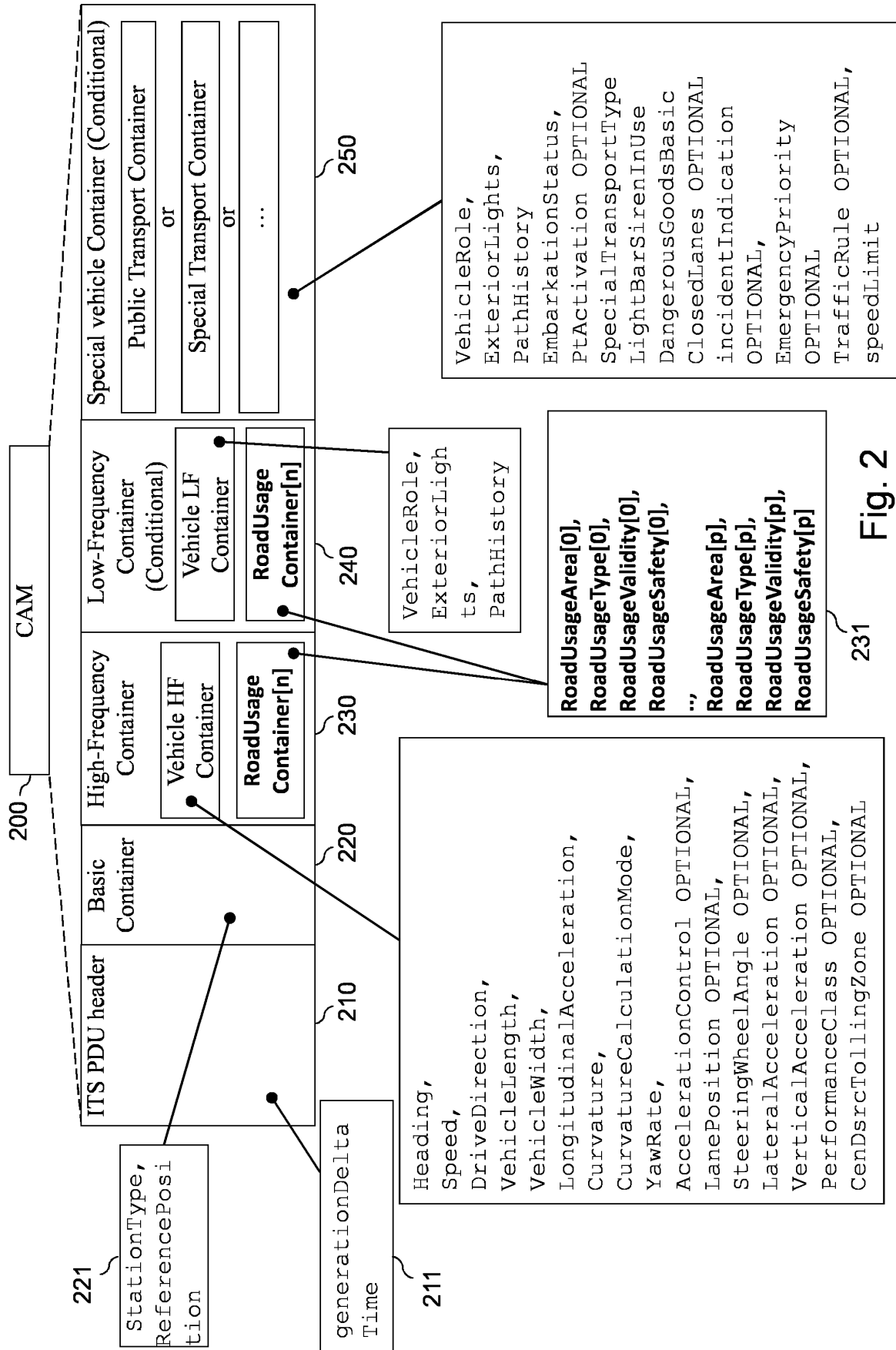


Fig. 1



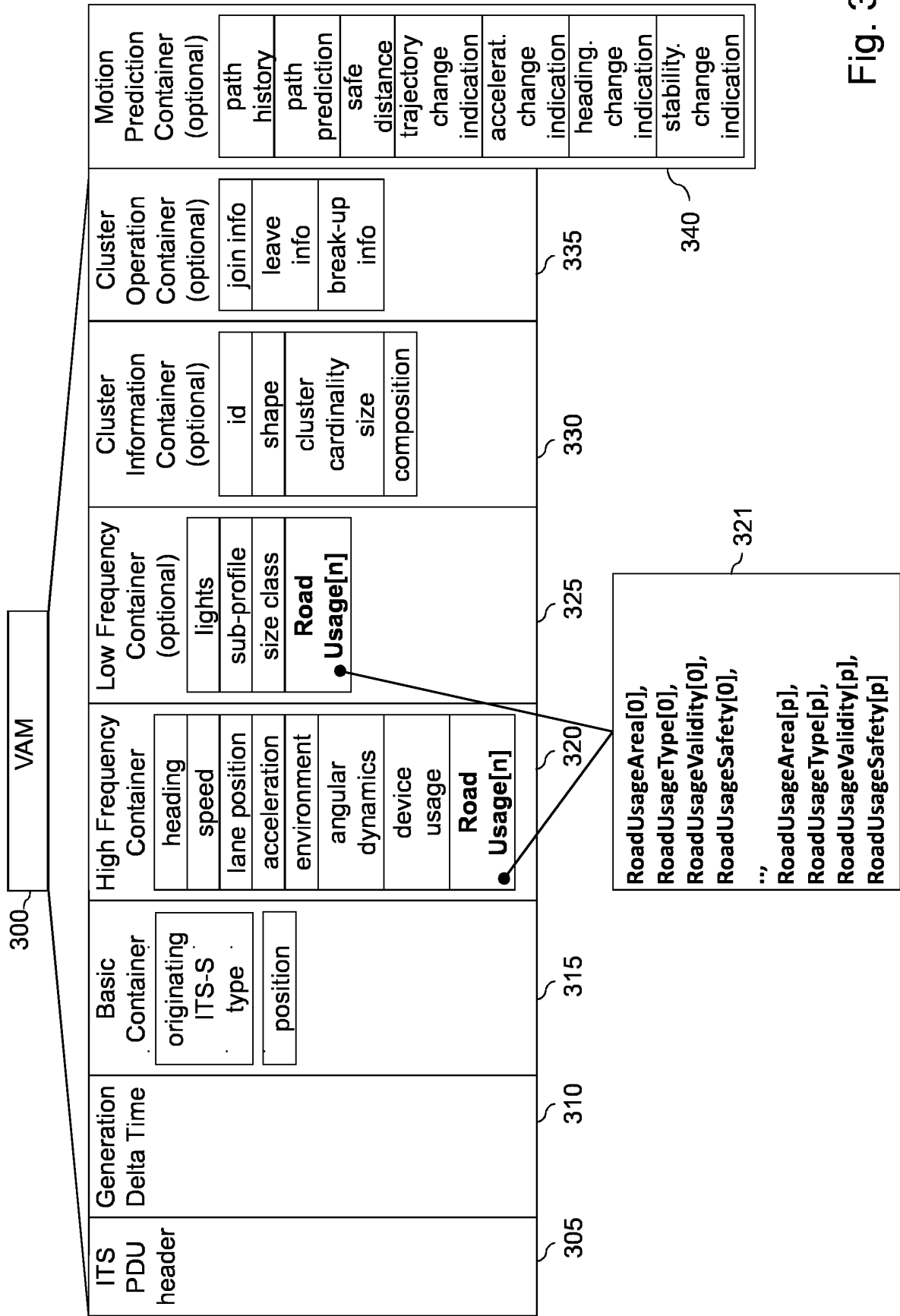


Fig. 3

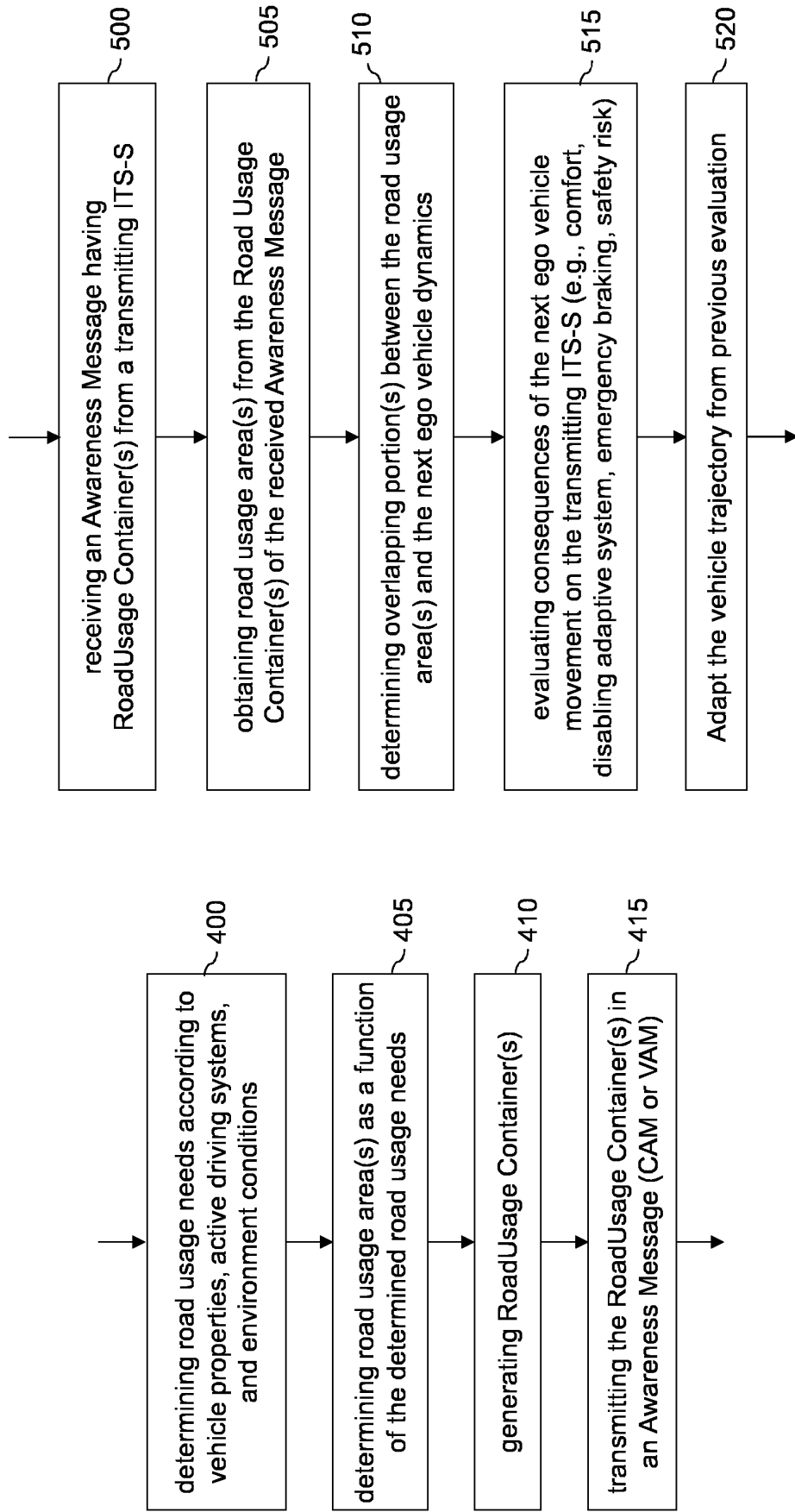


Fig. 4

Fig. 5

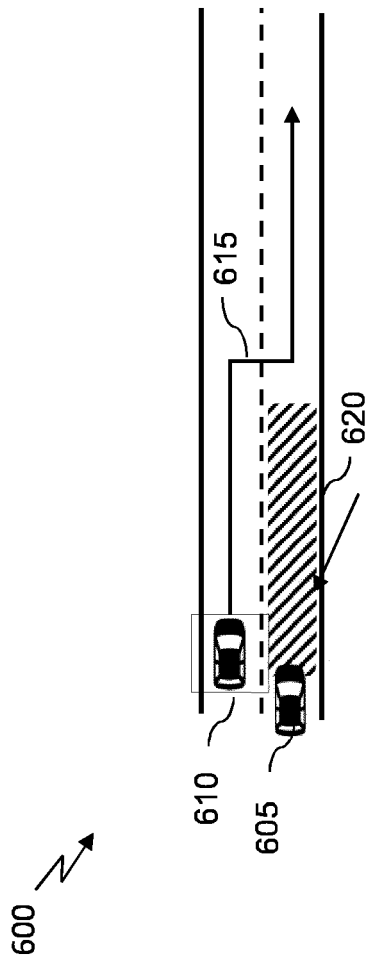


Fig. 6

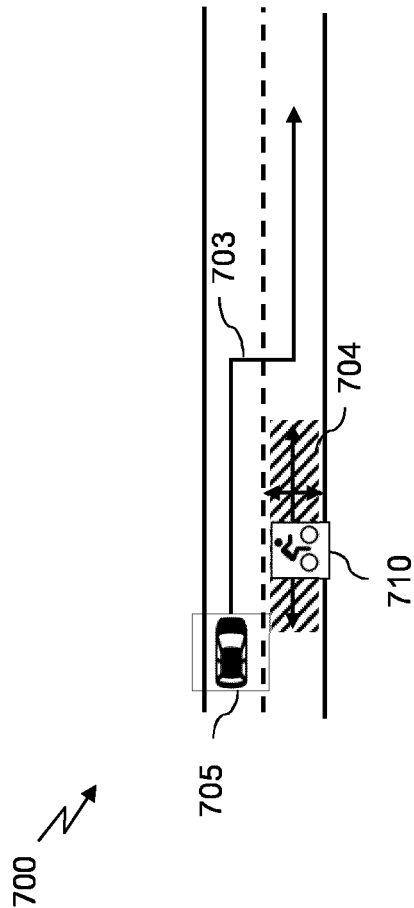


Fig. 7

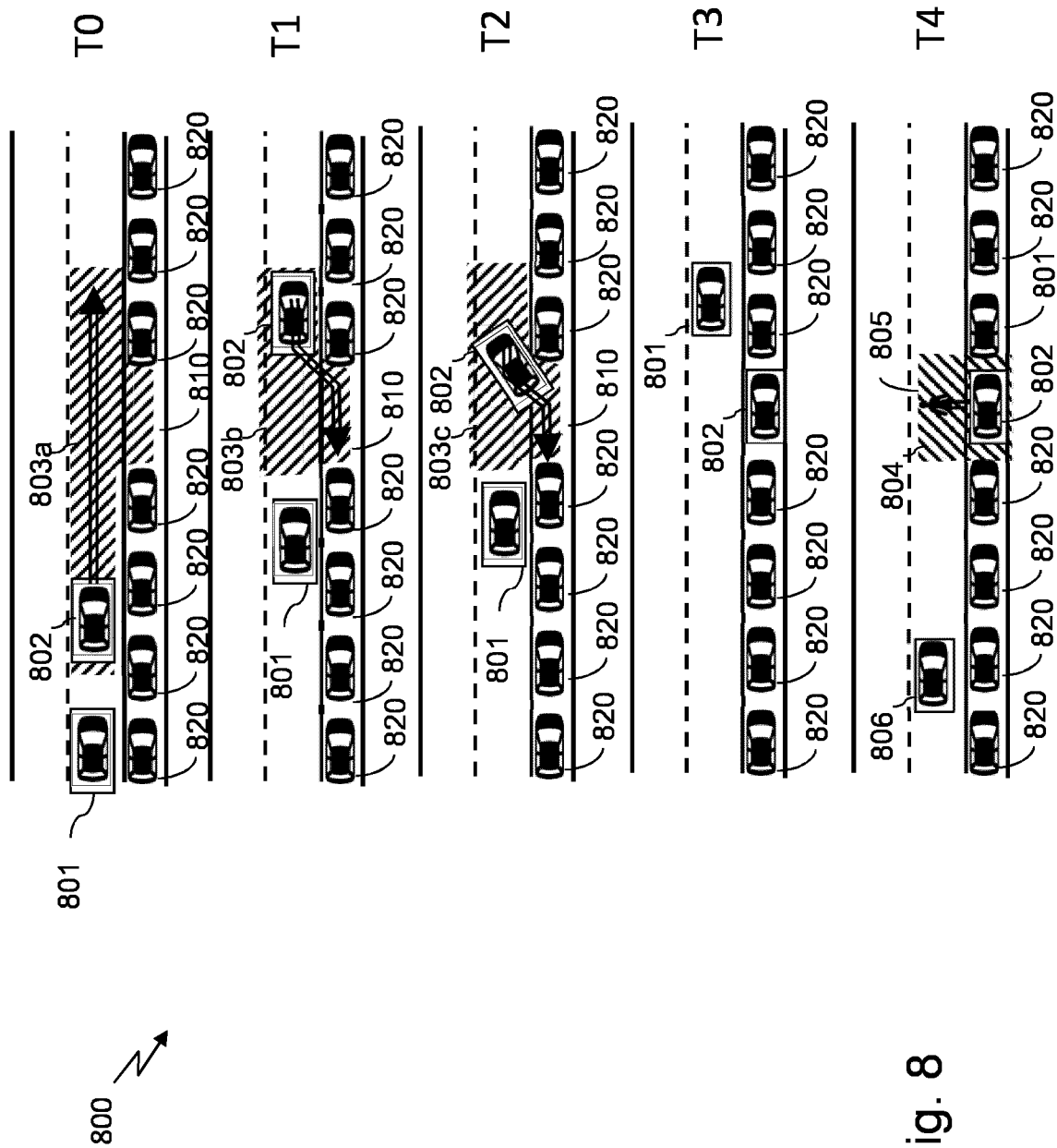


Fig. 8

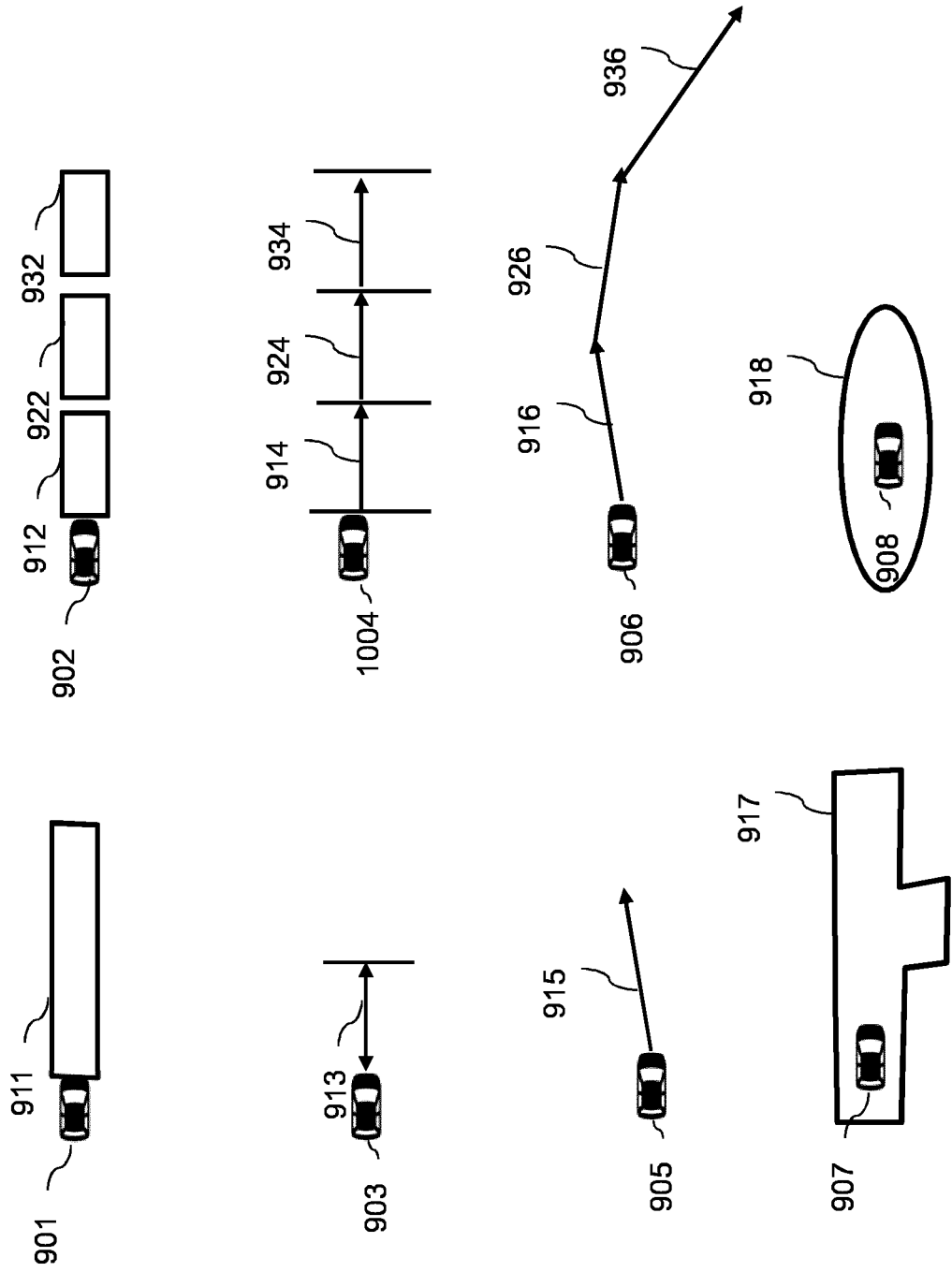


Fig. 9

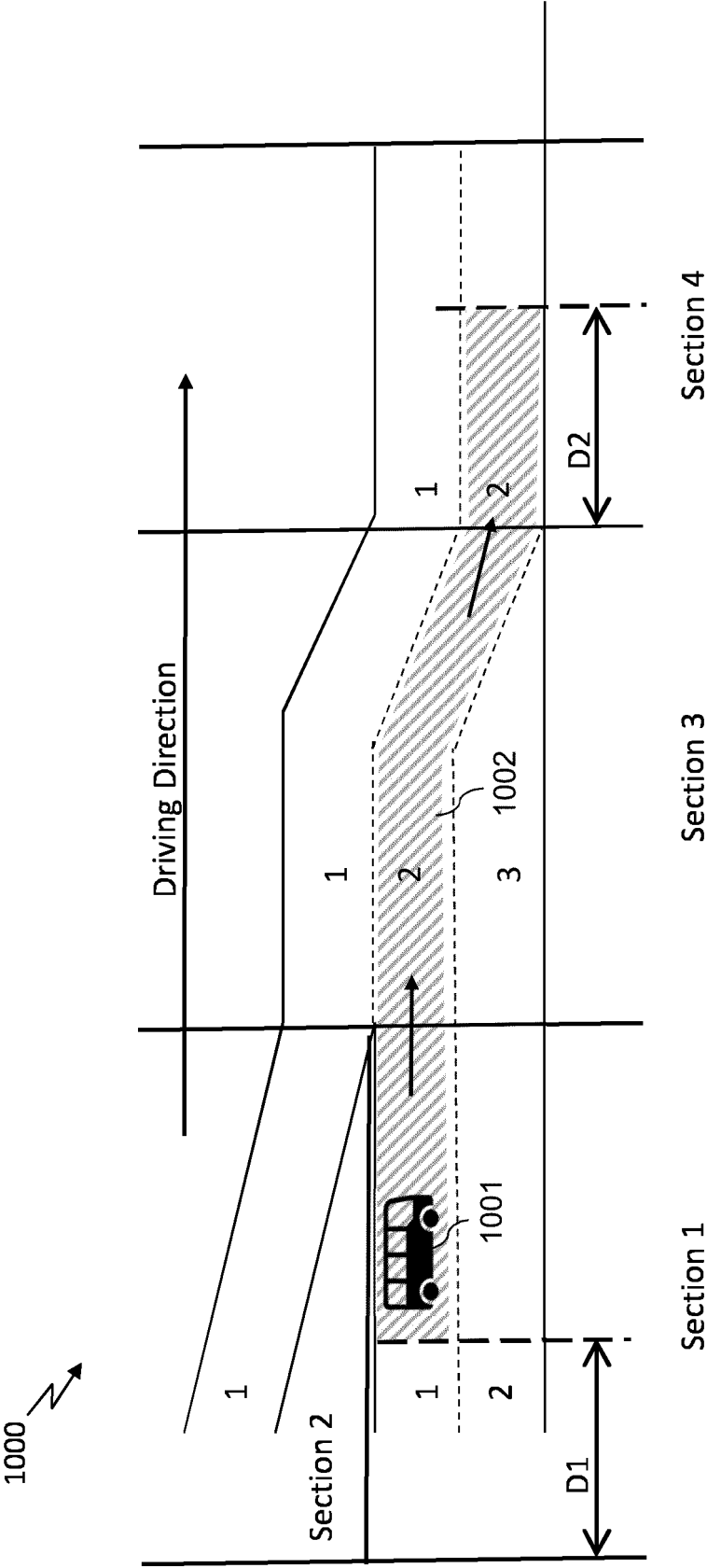


Figure 10

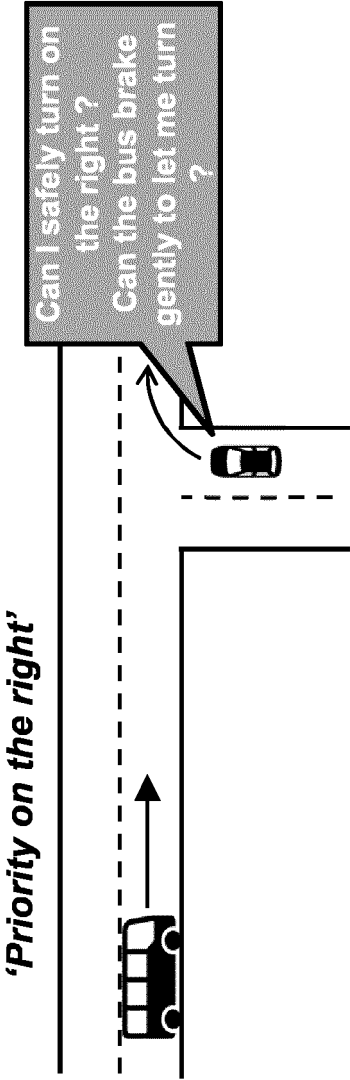


Fig. 11

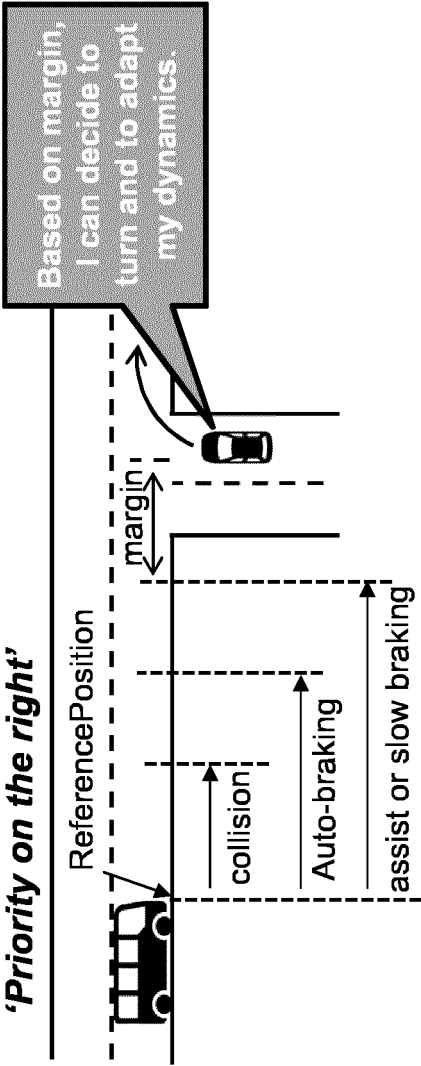


Fig. 12

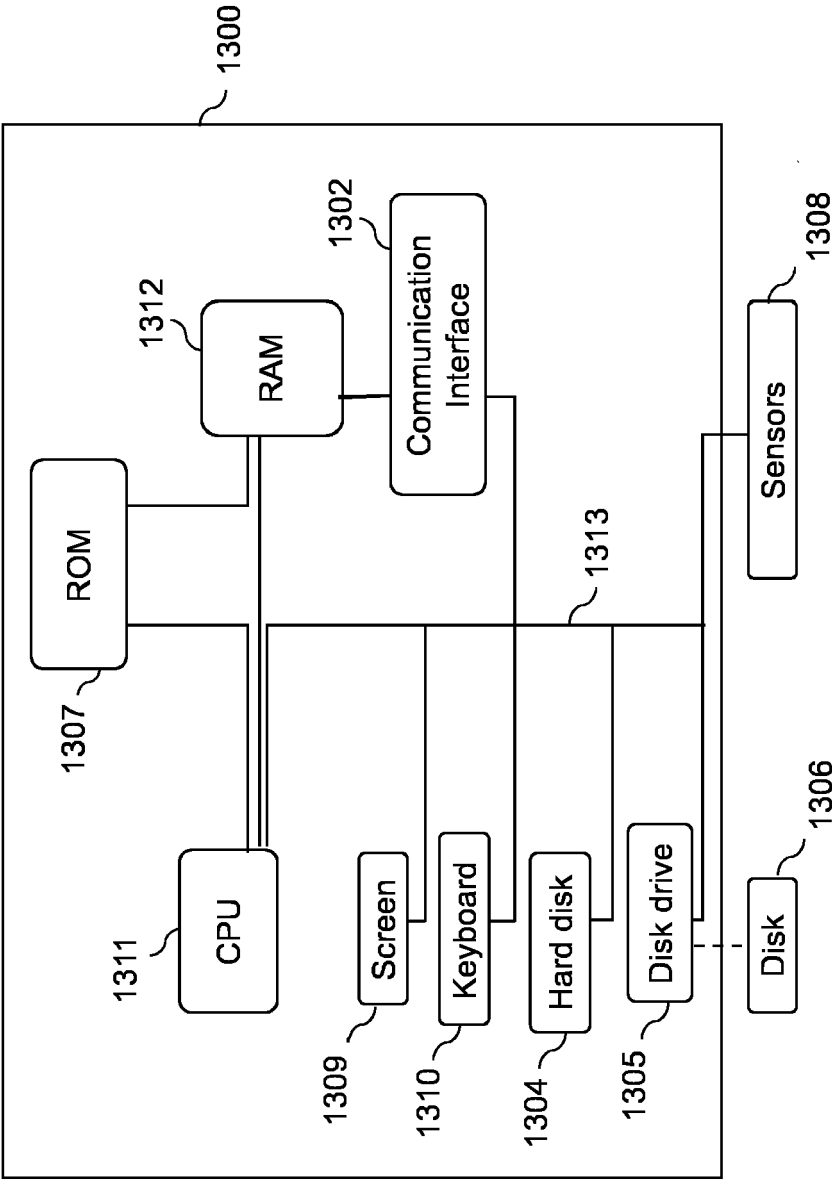


Fig. 13

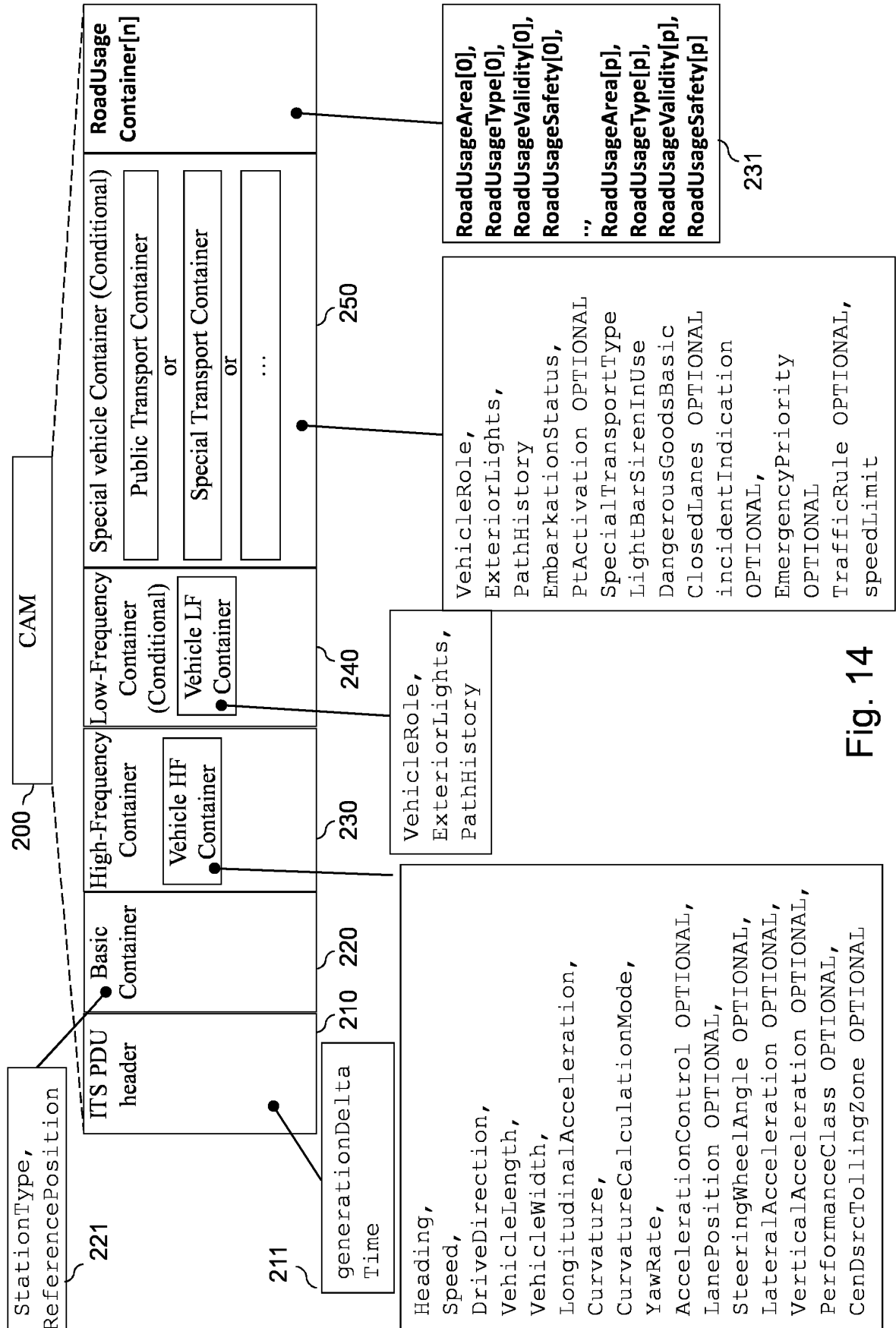


Fig. 14



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Application Number

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The Hague		27 September 2024	Simigliani, V
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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