



Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR). **YUN, SeYoung** [KR/KR]; Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR). **PYUN, SungYeop** [KR/KR]; Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR). **KIM, WooChan** [KR/KR]; Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR). **MOON, Jung-Min** [KR/KR]; Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR). **LEE, Kisong** [KR/KR]; Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon 305-701 (KR).

(74) **Agent: JANG, Seong Ku**; 19th Fl., Trust Tower, 275-7, Yangjae-dong, Seocho-gu, Seoul 137-130 (KR).

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Description

Title of Invention: SYSTEM AND METHOD FOR CONTROLLING A PLURALITY OF GROUP DRIVINGS

Technical Field

- [1] The present invention relates to a system and method for controlling multiple groups of electric vehicles each of the groups engaged in a respective group driving while travelling on a road.

Background Art

- [2] By group driving, it is meant a mode of driving performed by a group of vehicles travelling in tandem on a road section, each of the vehicles maintaining a safety distance determined based on, e.g., travelling and road conditions. A variety of systems and methods have been proposed for controlling the driving of vehicles engaged in a group driving wherein the operations of the vehicles following a leading vehicle in the group are automatically controlled based on data transmitted from the leading vehicle relating to the driving operations of the leading vehicle. For example, United States Patent No. 6,301,530 ("530 patent") discloses an automatic cruise control system which allows a group driving led by a leading vehicle which is followed by a plurality of succeeding vehicles. Figs. 1 and 8 of the 530 patent disclose an exemplary structure of an electric vehicle that may be engaged in a group driving incorporating a power train electronic control unit ("ECU"), a brake ECU, a steering ECU and an automatic driving ECU for driving the electric vehicle with an automatic cruise control wherein switching between automatic cruise and manual driving is easily performed based on a signal indicating the presence/absence of an IC card.
- [3] United States Patent No. 6,169,940 ("940 patent") also discloses an automatic driving system which is capable of achieving an appropriate automatic driving for a group of vehicles in a manner that a target running trajectory suitable for each vehicle can be calculated based on a received running course, thereby enabling each vehicle in the group to travel in accordance with the resultant target running trajectories. The 940 patent further discloses a structure of a vehicle used for such automatic driving system, including a navigation unit (e.g., GPS) and a total plan ECU which executes running instructions, such as maintaining/changing a lane, based on information on obstacles in front of the vehicle, road information (e.g., road surface conditions) or traffic information (e.g., traffic congestion information).
- [4] However, these prior art methods have focused on managing a single group of queued vehicles, without providing a group management plan dealing with multiple groups of vehicles engaged in their respective group drivings. Therefore, an efficient

plan for group formation, dissolution and participation, etc. is in need for an effective management of multiple groups of vehicles engaged in their respective group drivings.

- [5] Further, the automatic driving systems proposed by the prior art methods fail to take into account communications interferences stemming from, e.g., neighboring groups of vehicles travelling on multiple lanes of a road. Further, a more complicated situation arising from, e.g., a plurality of vehicles engaged in a group driving being intermingled with those individual vehicles which are not involved in the group driving is not considered at all in these prior art methods.

Disclosure of Invention

Technical Problem

- [6] It is, therefore, a primary object of the present invention to provide a method for efficiently controlling multiple groups of electric vehicles, each of the groups engaged in a respective group driving on a road, wherein each of the electric vehicles communicates with a road infrastructure to thereby overcome the various problems discussed above.
- [7] It is another object of the present invention to provide, by using a road infrastructure, a method for controlling multiple groups of electric vehicles engaged in their respective group drivings and a communications resource management method for efficient communications among the vehicles.

Solution to Problem

- [8] In accordance with an embodiment of the present invention, there is provided a system for controlling multiple groups of electric vehicles each of the groups engaged in a respective group driving on a road, comprising: an under-road communications unit for providing each of the electric vehicles with location information from which a position of said each electric vehicle is estimated; a road-periphery communications unit, installed in a vicinity of the road section, for providing group driving information to said each electric vehicle, the group driving information including the position of said each electric vehicle and information required to maintain the respective group driving in which said each electric vehicle is engaged; and an automatic driving unit, installed in or attached to said each electric vehicle, for enabling said each electric vehicle to maintain the group driving based on the group driving information.
- [9] In accordance with another embodiment of the present invention, there is provided a method for controlling multiple groups of electric vehicles, each of the groups engaged in a respective group driving on a road, comprising the steps of: providing each of the electric vehicles with location information from which a position of said each electric vehicle is estimated; receiving a group registration request message for requesting the registration of a new group from one of the electric vehicles, the request message

including a vehicle ID, a destination and the position of said one of the electric vehicles; and transmitting a group registration acceptance message to said one of the electric vehicles.

Brief Description of Drawings

- [10] The above and other objects and features of the present invention will become apparent from the following description of embodiments given in conjunction with the accompanying drawings, in which:
- [11] Fig. 1 shows a configuration of a group-driving control system in accordance with an embodiment of the present invention.
- [12] Fig. 2 is a diagram that depicts multiple groups of electric vehicles engaged in their respective group drivings on a road section where the group-driving control system is installed.
- [13] Fig. 3 presents a conceptional structure of a road-periphery communications unit in accordance with an embodiment of the present invention.
- [14] Fig. 4 depicts a diagram that shows a database stored in a storage unit of the road-periphery communications unit in accordance with an embodiment of the present invention.
- [15] Fig. 5 is a diagram that offers an initial process of forming a group via registration on the road-periphery communications unit.
- [16] Fig. 6 is a diagram that shows how a particular electric vehicle participates in a registered group.
- [17] Fig. 7 is a diagram that illustrates how a particular electric vehicle in a registered group breaks away from it.
- [18] Figs. 8 and 9 are diagrams showing how a particular electric vehicle breaks away from a registered group and participates in another group.
- [19] Figs. 10 and 11 are diagrams offering processes of dissolution of a registered group.
- [20] Figs. 12 and 13 are diagrams depicting a process of re-formation of a group when a non-participating vehicle enters the group.
- [21] Fig. 14 is a diagram that shows a process of confirming the maintenance of a group driving among the electric vehicles engaged in the group driving.
- [22] Fig. 15 and 16 are examples illustrating how a group is re-formed when a non-participating vehicle enters the group and when some of the electric vehicles in a group are caught at a traffic light.
- [23] Fig. 17 is a diagram showing how separate lanes are assigned depending on speeds of multiple groups of electric vehicles engaged in their respective group drivings.
- [24] Fig. 18 is a diagram showing how communications resources are allocated in order to avoid communications interferences among multiple groups of vehicles travelling on

neighboring lanes.

Mode for the Invention

- [25] Hereinafter, certain preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. Fig. 1 shows a configuration of a group-driving control system 100 in accordance with an embodiment of the present invention.
- [26] The group-driving control system 100 includes an under-road communications unit 101, a road-periphery communications unit 102 and a traffic signal communications unit 103, an automatic driving system 105, all of which are discussed in detail below.
- [27] The system in accordance with the present invention is integrated into an electro-magnetic induction-powered vehicle system, the electromagnetic induction-powered vehicle system including a road provided with an electric power supply unit and an electric vehicle designed to travel with electric power supplied therefrom.
- [28] Further, for the purpose of the present invention, a road section, as a basic unit, may be chosen to have a length of, e.g., 1 kilometer (km) section, 2 km section or 4 km section, etc. However, the present invention is not limited to such definitions; the road section 110 may be defined in a variety of different lengths.
- [29] Next, descriptions will be made on the automatic driving system 105. The automatic driving system 105 is installed on or attached to the electric vehicle 106. Basically, the automatic driving system 105 of the electric vehicle 106 appropriately selects and performs automatic driving on the electric vehicle 106 with minimum intervention from a driver. Specifically, the automatic driving system 105 includes a communications unit, a graphical user interface (GUI), a detection unit, a switching unit, an electronic control unit (ECU), and a direction control unit.
- [30] The communications unit may include, for example, an inter-vehicle communications unit and a road-vehicle communications unit (infrastructure communications unit). It is possible to have the inter-vehicle communications unit of a vehicle communicate with inter-vehicle communications units of other electric vehicles through, for example, ad-hoc communications. Also, the road-vehicle communications unit may communicate with under-road communications units, road-periphery communications units and traffic signal communications units for receiving information necessary for a group driving. The communications unit may employ any of the common communications techniques such as radio-frequency, magnetic-field or visible-ray communications technique.
- [31] The GUI displays information received from other elements or another electric vehicle on the road section 110. The driver of an electric vehicle may input specific information (e.g., a destination of the electric vehicle, initial formation of a group, par-

icipation in a particular group, or withdrawal from a group in which the electric vehicle was participating) or select any of the displayed information on the GUI. For example, the driver may choose to participate in one of the groups displayed on the GUI based on the received information.

- [32] The detection unit may detect a distance between two successive electric vehicles or the presence of an obstacle in a vicinity of the electric vehicle 106. The detection unit is of, for example, a millimeter wave radar-type, laser radar-type distance detector, or 2D laser scanner. Also, the detection unit may be provided, for example, at a front of the electric vehicle, and may be able to transmit millimeter wave or laser to a preceding vehicle. Further, the 2D laser scanner may detect the whole of an obstacle located in a vicinity of the electric vehicle 106.
- [33] The switching unit may perform a switching between an automatic mode and a manual mode. For example, the manual mode is automatically transformed into the automatic mode when the vehicle 106 forms a group or joins a group on the road section 110.
- [34] The ECU controls the overall automatic driving system 105. The ECU is, for example, mainly formed of a computer that includes a central processing unit (CPU), a read only memory (ROM) and a random access memory (RAM). The ECU functions as a cruise control unit. For example, the cruise control unit may adjust the speed and direction of the electric vehicle 106 and perform the cruise control on the electric vehicle 106 based on group driving information received from the road-periphery communications unit.
- [35] The direction control unit may control the direction of the electric vehicle 106 driving on the electric power supply rail embedded in the road section 110 by sequentially detecting the magnitude of magnetic inductance of the electric power supply rail. The electric power supply rail may be a center line under each lane in the road section 110. Thus, the direction control unit may adjust the direction of the electric vehicle 106 based on a minimum deviation from the maximum magnitude of the magnetic inductance measurable from the center line, such that the electric vehicle 106 stays on each lane in a proper straight direction. Further, the direction control unit can be controlled by instructions from the ECU.
- [36] A plurality of under-road communications units, as shown in Fig. 1, may be installed along the road section 110 for providing vehicles travelling on the road section 110 with location information from which a location of each of the vehicles may be estimated. Specifically, the under-road communications unit 101 may include a transmitter for transmitting information concerning a current location of each of the vehicles on the road section 110 to each of the vehicles and a lane ID for notifying a lane on which each of the vehicles is travelling. The under-road communications unit

101 may be installed, as shown in Fig. 1, along the center-line of each lane on the road section 110 although other arrangements of the under-road communications units may be made. Furthermore, it may not be necessary to install the under-road communications unit 101 in all sections of a road. Where the under-road communications unit is absent, therefore, each of the vehicles may obtain the current location thereof by using, e.g., GPS.

[37] Next, description will be made on how the under-road communications unit 101 transmits the location information to a vehicle. First of all, the under-road communications unit 101 may transmit the location information by periodically emitting the location information without checking whether the vehicle passes thereover or not. In this case, the reach of the under-road communications unit 101 may be limited to a certain range to avoid possible interferences with other under-road communications units. Alternatively, the under-road communications unit 101 may include a measuring means operatively connected to the electric power supply rail for measuring a change in the magnetic inductance of the power supply rail to determine whether the vehicle is passing over the under-road communications unit 101 based on the change, and transmit to the vehicle the information including location information and the lane ID. In any event, the under-road communications unit 101 can transmit the information to the vehicle without a special equipment for requesting the information to the under-road communications unit 101 in the vehicle.

[38] Fig. 2 is a diagram that depicts multiple groups of vehicles engaged in their respective group drivings on a road section where the group-driving control system is installed.

[39] The road-periphery communications unit 102, as depicted therein, is installed in a vicinity of the road section 110 for controlling multiple groups of vehicles engaged in their respective group drivings on the road section 110 by providing with each of the vehicles the group driving information including the location information thereof and information required to maintain the group driving to which said each electric vehicle belongs. The road-periphery communications unit can be installed even in a place where no under-road communications unit 101 is installed.

[40] Specifically, the road-periphery communications unit 102 may include, as shown in Fig. 3, a transmitter-receiver 201 for providing the group driving information to a vehicle, and for broadcasting group information to vehicles located on the road section 110 in which the road-periphery communications unit 102 is installed, a storage unit 203 including a database for storing the group information (e.g., information for groups 205 and 206, shown in Fig. 4) and an ID of the road section 110, and a control device 202 for controlling the transmitter-receiver 201 and the storage unit 203 and assigning communications resources to each of the groups travelling on the road

section 110.

- [41] The road-periphery communications unit 102 is a node that communicates with vehicles, other road-periphery communications units (e.g., a road-periphery communications unit 108) and traffic signal communications unit 103, which will be described below, by using a conventional method such as radio-frequency, visible-ray or magnetic-field communications technique.
- [42] In order to obtain and maintain the group information related to the vehicles running on the road section 110, the road-periphery communications unit 102 can communicate with other road-periphery communications units 108 installed within a same road section 110 and also with other road-periphery communications units which may be installed in neighboring road sections.
- [43] Specifically, the road-periphery communications unit 102 and the road-periphery communications unit 108 installed in the same road section 110 may communicate with each other the group information stored in their respective databases so as to update them based on the group driving information received from the vehicles on the road section 110. Thus, the road-periphery communications units located in a same road section may share, on a real-time basis, the information concerning groups of vehicles travelling on the same road section.
- [44] Further, since a group of vehicles will have to move from a road section to a different road section as they travel along the road, it will be difficult for the road-periphery communications unit 102 to maintain the group information on the group of vehicles already moved to a different road section. Accordingly, the road-periphery communications unit 102 may communicate with neighboring road-periphery communications unit installed in another road section to obtain group information that is not stored in the database of the road-periphery communications unit 102 thereof but relates to a group travelling on the road section 110 (e.g., group information regarding a group which has just entered the road section 110). For example, referring to Fig. 1, a leading vehicle 132 of a group 131 may transmit to the road-periphery communications unit 102 group driving information including an ID of an earlier road section received previously from another road-periphery communications unit. The road-periphery communications unit 102 compares the received ID of the earlier road section with an ID stored in the database thereof, and if the received ID is identical to the stored ID, it would mean that the road-periphery communications unit 102 has already stored group information concerning the group 131 in the database thereof and, therefore, the road-periphery communications unit 102 can manage the message based on the stored group information concerning the group 131. If the received ID is different from the stored ID, it would mean that the road-periphery communications unit 102 has stored no information concerning the group 131 in the database thereof, and the road-periphery

communications unit 102 communicates with the road-periphery communications unit having the same ID as the received ID to obtain group information regarding the group 131 stored in a database of the road-periphery communications unit.

- [45] Further, referring to Fig. 2, the road-periphery communications unit 207 may transmit to the road-periphery communications unit 102 a message indicative of presence of a group 206 when the group 206 is going to enter a lane on which a group 204 is travelling. Upon receipt thereof, the road-periphery communications unit 102 relays this message to the leading vehicle of the group 204. The leading vehicle recognizes the presence of the group 206, and adjusts its speed to thereby allow the group 206 to join the group 204. Further, the leading vehicle informs other vehicles in the group of the adjusted speed, so that the other vehicles may adjust their speed accordingly.
- [46] Next, descriptions will be made on the traffic signal communications unit 103. Installed, for example, in a traffic-flow controller, the traffic signal communications unit 103 regulates the signals for traffic lights 104 based on the group driving information received from a road-periphery communications unit installed in the road section 110.
- [47] Hereinafter, the inventive method of controlling a plurality of group drivings will be described in conjunction with Figs. 5 to 18.
- [48] Fig. 5 is a diagram showing an initial process for a vehicle to join a group so as to perform a group driving by way of registering on a road-periphery communications unit. In the first place, the driver of a vehicle 401 who wants to join a new group to engage in a group driving registers on a road-periphery communications unit 402 by way of providing information regarding his destination and registration request through a GUI of the automatic driving system of the vehicle 401. Then, a message "Group Formation REQ" is sent to the road-periphery communications unit 402 installed in a road section on which the registration requesting vehicle 401 is running and the vehicle 401 is registered as a member of the new group (step S401). The message "Group Formation REQ" may include a vehicle ID, position and destination information of the vehicle 401. The road-periphery communications unit 402 receives the message "Group Formation REQ" and determines a group ID for the group, the lane to be taken by the group, communications resources to be allocated to the group, a safety distance between two successive vehicles in the group, a size of the group (e.g., the maximum number of vehicles in the group) and a speed of the group, by way of referencing the received message "Group Formation REQ" and the group information registered in the road-periphery communications unit 402. Then, the road periphery communications unit 402 stores the message "Group Formation REQ" and the determined information as group information in the database thereof and then responds to the registration re-

requesting vehicle 401 with a message “Group Formation RES” inclusive of the determined group information and an ID of the road section in step S402. Thereafter, ad-hoc communications among the vehicles in the group may be performed through the communications resources assigned to the group at the stage of initial group formation. The resources assigned to the group can be modified by the road-periphery communications unit in accordance with the driving environment of the group. The registration requesting vehicle 401, which may be a leading vehicle of the group, may store the group information including the above-mentioned message “Group Formation RES” until dissolution of the group so that an automatic driving system thereof may serve to automatically maintain the group driving on the road section based on the group information.

- [49] Fig. 6 is a diagram that shows how a particular vehicle participates in a registered group. In step S501, a road-periphery communications unit 501 broadcasts to vehicles within a road section a message “Group Information Broadcast” including, for example, a group ID, destination of the group, present position of the vehicles within the group, speed, and size (e.g. the number of vehicles) of each of the groups registered in the database thereof and the vehicles periodically receive the relevant message. The driver of a vehicle 503 who wants to join one of the groups 504 chooses a desired group 504 by inputting the message through a GUI thereof, which displays the received message “Group Information Broadcast” and then the vehicle 503 sends back to the road-periphery communications unit 501 a message “Group Participation REQ” including information necessary to participate in the group, e.g., the group ID of the chosen group 504, the current position and speed of the vehicle, and its vehicle ID in step S502. The road-periphery communications unit 501 that receives the message “Group Participation REQ” determines whether or not to grant the request depending upon the situation of the chosen group 504. For example, the road-periphery communications unit 501 compares a current size of the group with a maximum size determined when registering the group and if the current size is smaller than the maximum size, then the road-periphery communications unit 501 allows the group-participation vehicle 503 to join the group 504. Otherwise, the road-periphery communications unit 501 rejects the request. In case the road-periphery communications unit 501 grants the request, a message “First Group Participation RES” including information about when, where (or which group) and how to join the group 504, the safety distance and the speed of the vehicles in the group is sent to the group-participation vehicle 503, and further a message “Second Group Participation RES” including an ID of the road section of the periphery communications unit 501 and the vehicle ID of the group-participation vehicle 503 is sent to a leading vehicle 505 of the group 504 in step S503. The group-participation vehicle 503 that receives the message

“First Group Participation RES” can participate in the group under the control of an automatic driving system thereof based on the driving information contained in the received message in step S504. If the vehicle 503 is added to the group 504, the leading vehicle 505 of the group 504 informs the road-periphery communications unit 501 of group driving information including the updated group information in step S505.

[50] On the other hand, when the road-periphery communications unit 501 rejects the request from the group-participation vehicle 503, a message “Third Group Participation RES” including information that rejects group participation is sent to the group-participation vehicle 503. The road-periphery communications unit 501 updates the database thereof, based on the updated group information. Because vehicles move continuously, a situation may develop wherein a vehicle cannot keep on communicating with the same road-periphery communications unit or road-periphery communications units within the same road section. In such event, such problem can be resolved by utilizing communications between the road-periphery communications unit 501 and another road communications unit (e.g., road communications unit 502) having an ID of the road section received from the leading vehicle 505. The above-mentioned communications between road-periphery communications units, installed in different road sections, may be applied to a breakaway process from a group, a participation process in a group, a dissolution process, and a reformation process, all of which are explained below in detail.

[51] Fig. 7 is a diagram that illustrates how a vehicle 604 registered in a group 602 breaks away from it. A group breakaway vehicle 604 informs, by way of inputting such information through a GUI thereof, the leading vehicle 603 of its departure through a message “Group Breakaway Alarm”, for example, inclusive of a vehicle ID of the breakaway vehicle 604 in step S601 and departs from the registered group 602 in step S602, while the leading vehicle 603 that received the message “Group Breakaway Alarm” rearranges the vehicles in the group 602 by transmitting to the succeeding vehicles within the group a message “First Group Rearrangement Instruction” in order to adjust a safety distance and sends to a road-periphery communications unit 601 group driving information including the updated group information, for example, including the vehicle ID of the breakaway vehicle 604 and the reduced size of the group 602 in step S603. The road-periphery communications unit 601 updates corresponding group information stored in the database thereof, based on the group driving information received from the leading vehicle 603. A vehicle may leave a group either to drive independently thereof or to participate in a different group. Fig. 7 depicts the former case where a breakaway vehicle becomes independent of a group driving simply by performing the breakaway process. The latter case in which the breakaway

vehicle participates in another group after the breakaway will now be explained.

- [52] Figs. 8 and 9 show how a vehicle breaks away from a registered group to participate in another group. A driver of a vehicle 704 who wants to move to a different group chooses a desired group through a GUI thereof, which displays a message "Group Information Broadcast" received from the road-periphery communications unit 701 and then the vehicle 704 sends a message "Group Participation REQ" inclusive of e.g., a chosen group 703, speed information, the vehicle ID of the group-shift vehicle 704 and position information thereof in step S701. The road-periphery communications unit 701 that receives the message "Group Participation REQ" determines whether or not to grant the request from the group-shift vehicle 704 depending upon the situation of the chosen group 703. For example, the road-periphery communications unit 701 compares a current size of the group 703 with the maximum size predetermined when registering the group 703 and if the current size is smaller than the predetermined size, then the road-periphery communications unit 501 approves the request. Otherwise, the road-periphery communications unit 701 rejects the request. When the road-periphery communications unit 701 is to grant the request from the group-shift vehicle 704, a message "First Group Participation RES" including information as to when, where (or which group) and how to join the group 703 that the group-shift vehicle 704 has chosen, a safety distance and speed of the group 703 is sent to the group-shift vehicle 704 and a message "Second Group Participation RES" including the ID of a road section of the periphery communications unit 701 and the ID of the group-shift vehicle 704 is sent to the leading vehicle 705 of the group 703 in step S702. Afterwards, the leading vehicle 705 transmits to succeeding vehicles a message "Second Group Rearrangement Instruction" in order to rearrange vehicles in the group 703 so that the group-shift vehicle 704 can join the group 703 in accordance with the sent information. The group-shift vehicle 704, upon receiving the message "First Group Participation RES", can move to the chosen group under the control of an automatic driving system thereof based on its information in step S705. Before shifting between groups, the group-shift vehicle 704 has to inform the leading vehicle 706 of the previous group of its departure by sending a message "Group Breakaway Alarm" in step S704 and the leading vehicle may rearrange vehicles in the group by transmitting to the succeeding vehicles the message "First Group Rearrangement Instruction" in order to adjust a safety distance thereof. And when the move of the group-shift vehicle 704 is completed, each of the leading vehicles 705 and 706 of the two groups informs the road-periphery communications unit 701 of the respective group driving information including the updated group information in step S706. The road-periphery communications unit 701 updates the database thereof, based on the group driving information received from each of the leading vehicles 705 and 706.

- [53] Figs. 10 and 11 are diagrams showing the process of dissolution of a group. Referring to Fig. 8, the request for dissolution of a group can be sent by a leading vehicle 802 of a group 801 to a road-periphery communications unit 803. If it is necessary to dissolve the group when e.g., the group arrives at its destination or an accident has taken place ahead of the road, the leading vehicle 802 sends a message "Group Dissolution IND" to the road-periphery communications unit 803 and a succeeding vehicle in its own group in step S811. Then the succeeding vehicle sends the message to a succeeding vehicle thereof in step S812. On the other hand, a road-periphery communications unit 804 may give a dissolution order to a leading vehicle 806 of a group 805. For example, when the road or other infrastructures for group driving are not supported any more or the traffic situation cannot support a group driving, the road-periphery communications unit 804 sends in advance a message "Group Dissolution IND" to the leading vehicle 806 to prevent, e.g., an accident in step S821. Referring to Fig. 9, the leading vehicle 806, upon receiving the message "Group Dissolution IND", passes the message to a succeeding vehicle in step S822. Then the succeeding vehicle transmits it to a succeeding vehicle thereof in step S823. The vehicles that receive the message "Group Dissolution IND" stop their group driving. When a group driving is dissolved, the road-periphery communications units 803 and 804 delete the corresponding group information stored in the database thereof, withdraw the group ID and communications resources assigned to the group, and broadcast the updated group information to vehicles travelling on respective road sections having the road-periphery communications units 803 and 804.
- [54] Figs. 12 and 13 are diagrams depicting a process of re-formation or splitting of a group. For example, when a vehicle 902 which was not in a group 901 enters between two vehicles in the group 901 in step S901 or some of the vehicles in the group 901 cannot pass a traffic light together with the other vehicles in the group, the group needs to be re-formed or split into two groups 903 and 906 since it may become no longer possible to communicate among the vehicles in the group 901 via ad-hoc communications. Then the new leading vehicles 904 and 907 of the re-formed groups 903 and 906 send their respective updated group driving information concerning the re-formed groups 903 and 906 to the respective road-periphery communications units 905 and 910. Then, the road-periphery communications units 905 and 910 update group information stored in their respective databases based on the updated group driving information. The sequence of re-formation will now be elaborated in reference to Fig. 14.
- [55] Fig. 14 is a diagram that shows a process of confirming the maintenance of a group driving among the electric vehicles engaged in the group driving. Included in a message "Group Maintenance Confirmation Request/Response" are the size of the

group and a vehicle ID and position information of each of one or more vehicles that have previously sent a request or response message. The vehicle which sends/receives the message "Group Maintenance Confirmation Request/Response" can recognize its present position occupied within the group by counting the number of the received IDs included therein. A leading vehicle 1011 sends periodically to its succeeding vehicle 1012 a message "Group Maintenance Confirmation Request" for confirming maintenance of the group in step S1001. The succeeding vehicle 1012 receiving the message sends a message, if it is not the last vehicle of the group, including the received message, position information thereof and its own ID to its immediate successor 1013 in step S1002. A similar process takes place in step S1003. When the vehicle receiving the message "Group Maintenance Confirmation Request" is the last vehicle 1014 of the group, the vehicle 1014 transmits to its preceding vehicle the message "Group Maintenance Confirmation Response" in step S1004. Similar response processes take place in S1005 to S1006, until the message "Group Maintenance Confirmation Response" reaches the leading vehicle 1011.

- [56] Figs. 15 and 16 respectively illustrate how a group is re-formed when a non-participating vehicle enters the group and when some of the vehicles in the group are caught at a traffic light while the other vehicles have passed the traffic light. In an exemplary group consisting of four (4) vehicles, it is assumed that a vehicle 1101 breaks in between the second and the third vehicles 1112 and 1121, or that the last two vehicles, 1121 and 1122, are caught at the traffic light. In such circumstances, certain vehicles, e.g., the vehicle 1121, cannot send/receive messages, "Group Maintenance Confirmation Request" and "Group Maintenance Confirmation Response" via ad-hoc communications. Accordingly, it would be determined that the group should be split into two groups. The vehicle 1121 that cannot receive the message "Group Maintenance Confirmation Request" sends a message "Group Re-formation" to its succeeding vehicle 1122 in step S1103 so as to become a leading vehicle of a new group that includes the vehicle 1121 and its succeeding vehicles and registers on the road-periphery communications unit in a similar way as the above-mentioned initial process of group formation. In addition, a vehicle 1112 that cannot receive the message "Group Maintenance Confirmation Response" sends a message "Group Re-formation" to a leading vehicle 1111 in step S1105, the leading vehicle 1111 informs the road-periphery communications unit of information about the re-formed group, and the road-periphery communications unit performs the corresponding update based on the received information regarding the new group and the re-formed group.

- [57] Fig. 17 depicts how lanes are assigned to vehicles engaged in their respective group drivings. As shown in Fig. 17, for example, a lane is assigned, by a road-periphery communications unit, to groups of vehicles travelling at a like speed. In this manner,

groups of vehicles can travel efficiently while maintaining their respective group driving speeds. That is to say, the effect of group drivings can be optimized through a judicious assignment of lanes in accordance with the group driving speeds. Further, if a non-participating vehicle breaks into between two vehicles engaged in a group driving, it would trigger the re-formation or splitting process discussed above and frequent executions of reformation process will reduce the efficiency of the group driving.

Therefore, if a particular lane is assigned exclusively, by the road-periphery communications unit, to non-group driving vehicles, such inefficiencies can be minimized. If vehicles engaged in a group driving find a need to change their speed during their travel, they may preferably change their lane to a different one through communications among the road-periphery communications unit and the vehicles engaged in the group driving.

[58] Fig. 18 depicts a diagram to show how communications resources are assigned in order to avoid communications interferences between respective lanes.

[59] Signal interferences between two neighboring lanes can be prevented by assigning a different communications resource to each lane. However, this method alone cannot prevent possible interferences that may arise in a same lane, e.g., among a plurality of groups travelling in the same lane. In accordance with the present invention, however, such interferences can be prevented by way of further dividing orthogonally the communications resources assigned to a lane. Fig. 18 shows an exemplary method to avoid signal interferences among neighboring vehicles during communications in a road section. On a four-lane road, the time is divided into four slots (e.g., time slot 1 to 4) and each vehicle can communicate with other vehicles only during a time slot assigned to the lane it travels. Further, to avoid interferences among vehicles in a same lane, the time slot assigned to that lane is subdivided into subchannels (e.g., subchannel 1 to N) to allow vehicles travelling in the same lane to use different frequency channels and to thereby avoid mutual interferences. In Fig. 18, it is shown that a road-periphery communications unit assigns time slot 1 and subchannel 1 to a group 1311 and time slot 1 and subchannel 3 to a group 1313. Similarly, it is shown that time slot 2 and subchannel 2 are assigned to a group 1322 travelling in the second lane, while time slot 3 and subchannel 3 are assigned to a group 1333 travelling in the third lane.

[60] Even with the above method, a problem of mutual interference may still arise when two or more vehicles that use a same communications resource are nearing each other. In such case, in accordance with the present invention, the road-periphery communications unit reassigns communications resources for those vehicles based on positional relationships among the nearing groups in order to avoid any interferences.

[61] Although Fig. 18 exemplifies that TDMA may be adopted for resource allocation among lanes and that FDMA may be applied to communications within a lane,

different combinations of conventional TDMA, FDMA and CDMA technologies can be applied in a variety of ways.

- [62] While the invention has been shown and described with respect to some of the preferred embodiments only, it will be understood by those skilled in the art that various changes and modifications may be made without departing from the scope of the invention as defined in the following claims.

Claims

- [Claim 1] A system for controlling multiple groups of electric vehicles, each of the groups engaged in a respective group driving on a road section, comprising:
an under-road communications unit for providing each of the electric vehicles with location information from which a position of said each electric vehicle is estimated;
a road-periphery communications unit, installed in a vicinity of the road section, for providing group driving information to said each electric vehicle, the group driving information including the position of said each electric vehicle and information required to maintain a group driving in which said each electric vehicle is engaged; and
an automatic driving unit, installed in or attached to said each electric vehicle, for enabling said each electric vehicle to maintain the group driving based on the group driving information.
- [Claim 2] The system of claim 1, wherein the under-road communications unit is embedded under the road section.
- [Claim 3] The system of claim 1 or 2, further comprising a power supply unit embedded in the road section for providing power to said each electric vehicle, wherein the under-road communications unit detects said each electric vehicle by a change in the magnetic inductance of the power supply unit.
- [Claim 4] The system of claim 3, wherein the automatic driving unit controls a driving direction of said each electric vehicle by sequentially detecting the magnetic inductance of the power supply unit.
- [Claim 5] The system of any one of claims 1 to 4, wherein the group driving information includes:
a group registration request message for requesting the registration of a new group, the request message being sent by one of the electric vehicles and including a vehicle ID, a position and a destination of said one of the electric vehicles; and
a group registration acceptance message provided to said one of the electric vehicles.
- [Claim 6] The system of claim 5, wherein the group registration acceptance message includes a group ID assigned to the new group, a speed thereof, a lane assigned thereto and communications resources to be used for communications among electric vehicles within the new

- group.
- [Claim 7] The system of claim 6, wherein the lane assigned to the new group is determined based on the speed thereof.
- [Claim 8] The system of claim 6 or 7, wherein different time slots are assigned to different lanes.
- [Claim 9] The system of any one of claims 6 to 8, wherein different frequency bands are assigned to different groups assigned with a same lane.
- [Claim 10] The system of any one of claims 1 to 9, wherein the road-periphery communications unit provides group information to another road-periphery communications unit installed in another road section, the group information including a group ID, a destination, a present position and a speed of a group of electric vehicles engaged in a group driving.
- [Claim 11] The system of claim 10, wherein the road-periphery communications unit broadcasts the group information to the group of electric vehicles.
- [Claim 12] The system of claim 11, wherein the group driving information includes:
a group participation request message requesting participation of an electric vehicle in a particular group indicated in the broadcasted group information, the group participation request message including a speed, a position and a vehicle ID of the requesting electric vehicle, and a group ID of the particular group; and
a group participation acceptance message provided to the requesting electric vehicle.
- [Claim 13] The system of claim 12, wherein the group participation acceptance message includes information about when, where and how to enter the particular group, a safety distance and a speed of the particular group.
- [Claim 14] The system of any one of claims 1 to 13, wherein the group driving information includes information requesting withdrawal of an electric vehicle from a group driving.
- [Claim 15] A method for controlling multiple groups of electric vehicles, each of the groups engaged in a respective group driving on a road section, comprising the steps of:
providing each of the electric vehicles with location information from which a position of said each electric vehicle is estimated;
receiving a group registration request message for requesting the registration of a new group from one of the electric vehicles, the request message including a vehicle ID, a destination and the position of said

one of the electric vehicles; and
transmitting a group registration acceptance message to said one of the electric vehicles.

[Claim 16] The method of claim 15, wherein the group registration acceptance message includes a group ID assigned to the new group, a speed thereof, a lane assigned thereto and communications resources to be used for communications among electric vehicles within the new group.

[Claim 17] The method of claim 16, wherein the lane assigned to the new group is determined based on the speed thereof.

[Claim 18] The method of claim 16 or 17, wherein different time slots are assigned to different lanes and a time slot assigned to a particular lane is used for communications among electric vehicles belonging to a group assigned with the particular lane.

[Claim 19] The method of any one of claims 16 to 18, different frequency bands are assigned to different groups assigned with a same lane and a frequency band assigned to a specified group is used in communications among electric vehicles belonging to the specified group.

[Claim 20] The method of any one of claims 16 to 19, further comprising the steps of:
broadcasting group information including a group ID, a destination, a present position, a speed of a group of electric vehicles engaged in a group driving;
transmitting a group participation request message from an electric vehicle;
determining whether to accept or reject the group participation request to generate a group participation acceptance or rejection message; and
transmitting the group participation acceptance or rejection message to the requesting electric vehicle.

[Claim 21] The method of claim 20, wherein the group participation request message includes a speed, a position and a vehicle ID of the requesting electric vehicle, and a group ID of a particular group chosen by the requesting electric vehicle from the groups indicated in the broadcasted group information.

[Claim 22] The method of claim 21, wherein the group participation acceptance message includes information about when, where and how to enter the particular group, a safety distance and a speed thereof.

[Claim 23] The method of any one of claims 16 to 22, wherein the requesting

electric vehicle serves as a leading vehicle of the new group when its group participation request has been accepted.

[Claim 24] The method of claim 23, wherein the leading vehicle stores the group registration acceptance message.

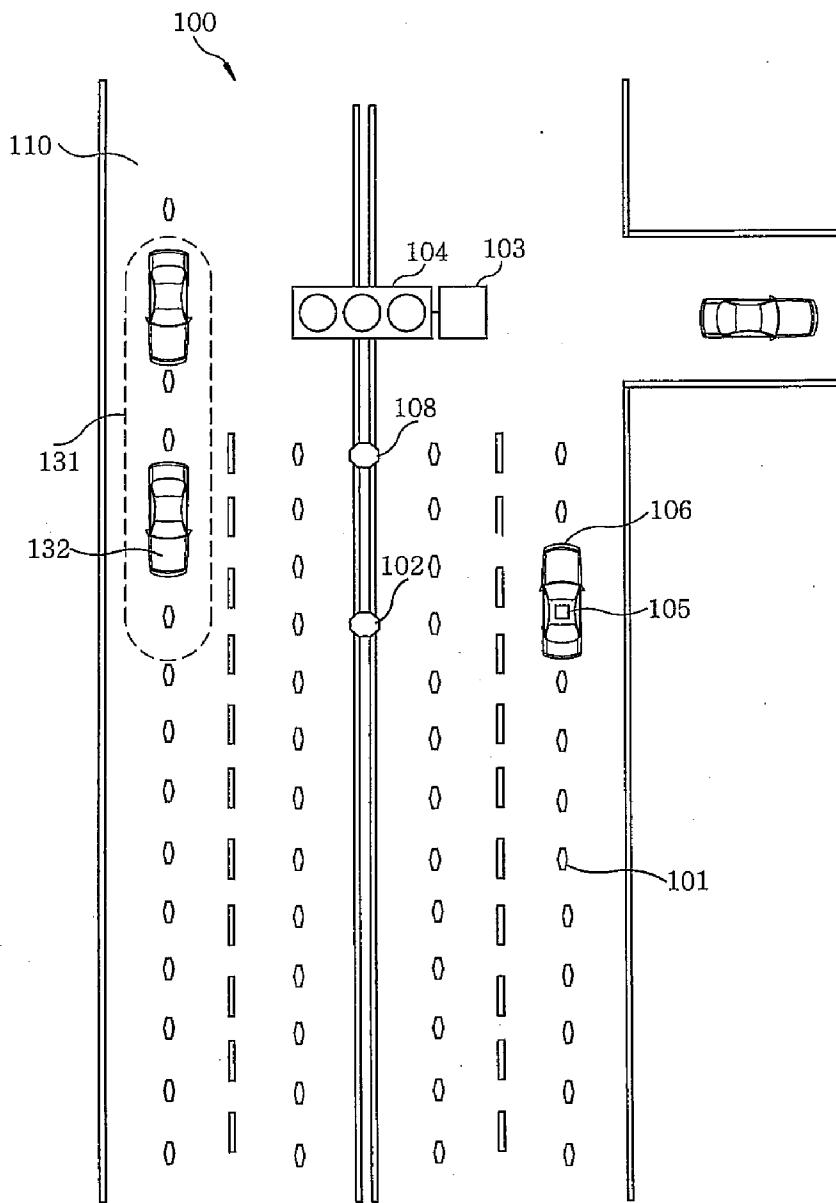
[Claim 25] The method of claim 23 or 24, wherein the leading vehicle communicates a message for maintaining the new group of electric vehicles in a group driving using the assigned communications resources.

[Claim 26] The method of any one of claims 23 to 25, wherein the leading vehicle controls rearrangement of the electric vehicles in the new group.

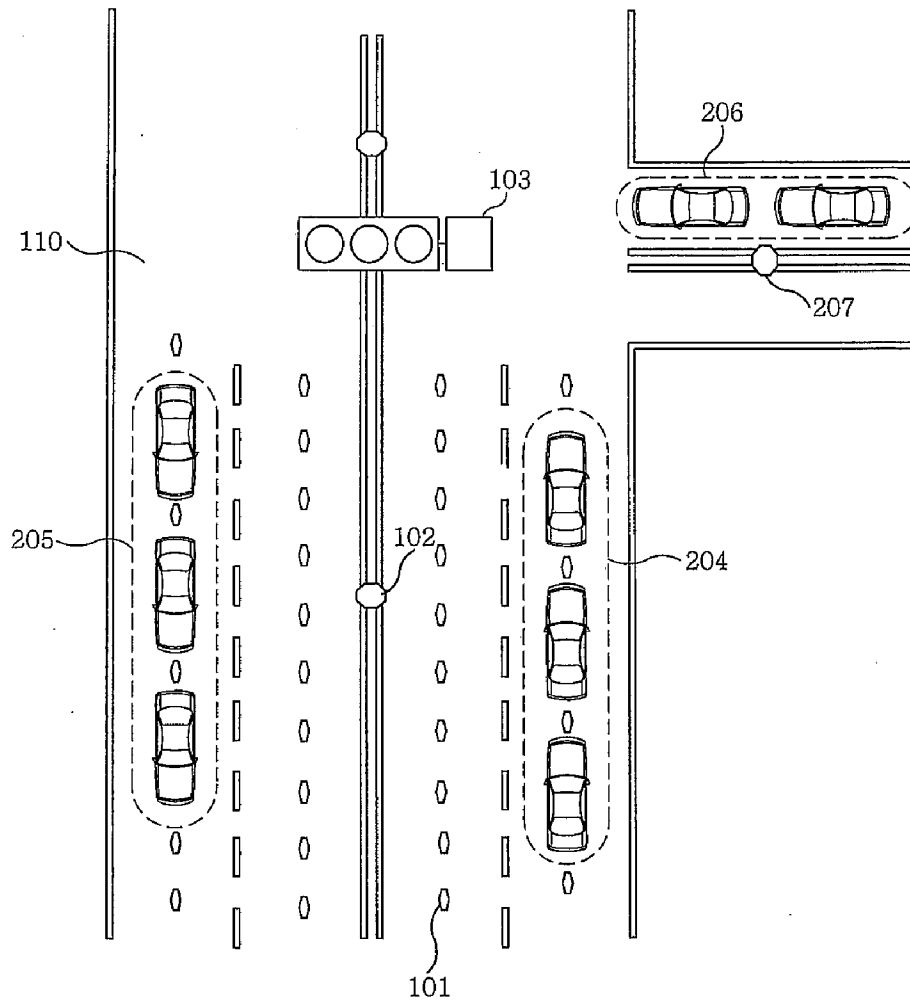
[Claim 27] The method of any one of claims 23 to 26, further comprising the steps of:

receiving a message requesting dissolution of a group driving performed by a registered group of electric vehicles; and
cancelling the group ID and the communications resources assigned to the registered group.

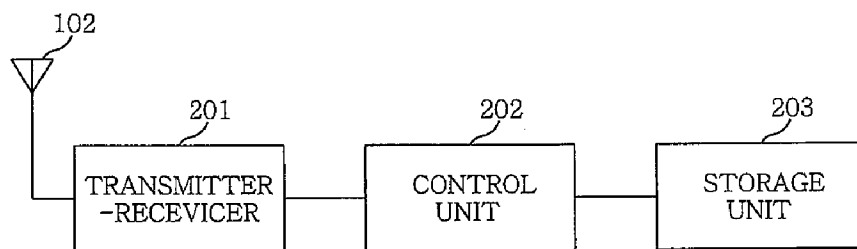
[Fig. 1]



[Fig. 2]



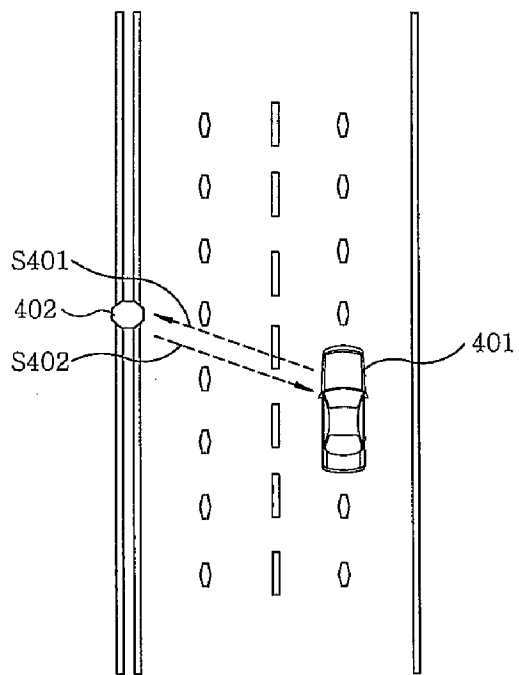
[Fig. 3]



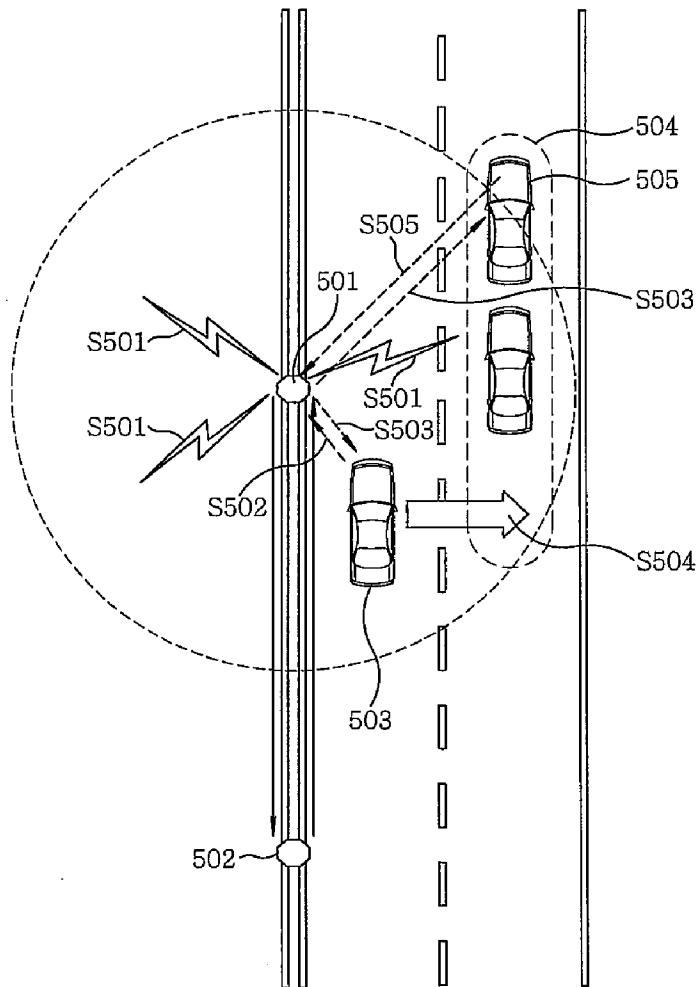
[Fig. 4]

Lane No.	Group No.	Group Size	Max Size of Group	Leading vehicle	Current Participants	Vehicle Locations	Resources for communication	Vehicle Speed	Destination	Safety Distance
L1	G1	3	6	VID 111	VID 117 VID 129	(x1, y1) (x2, y2) (x3, y3)	Frequency: f1 Time slot: t1	50 mph	(D1, D1)	2m
L4	G2	3	4	VID 122	VID 132 VID 133	(x4, y4) (x5, y5) (x6, y6)	Frequency: f1 Time slot: t4	60 mph	(D3, D4)	3m

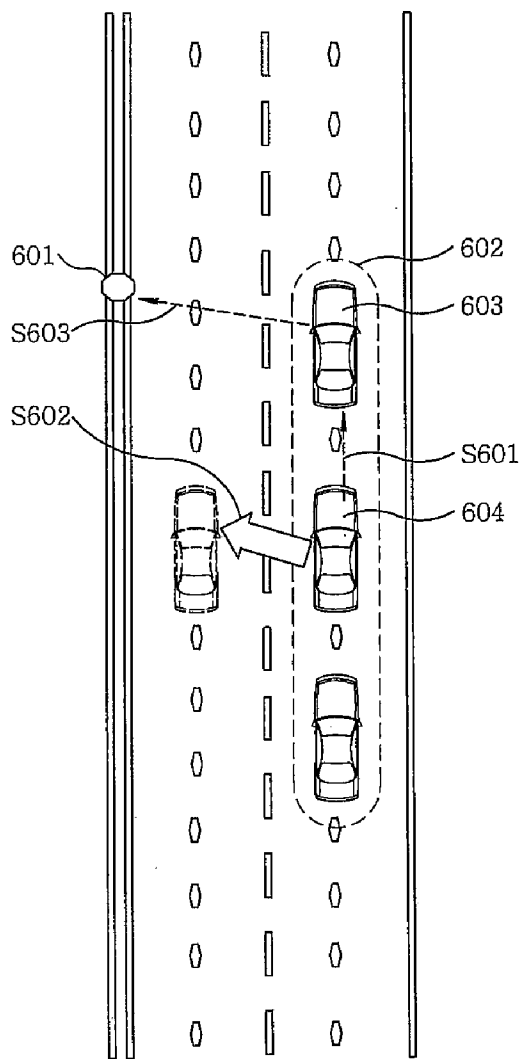
[Fig. 5]



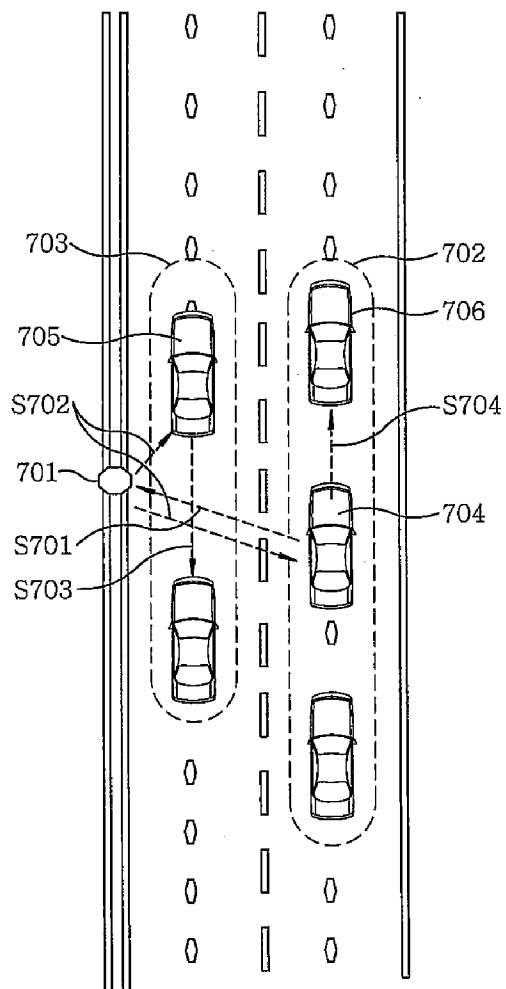
[Fig. 6]



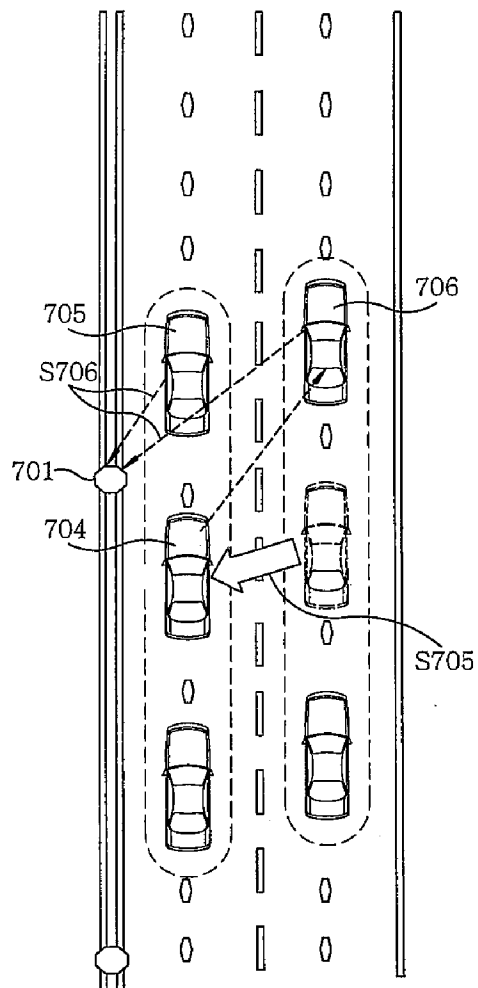
[Fig. 7]



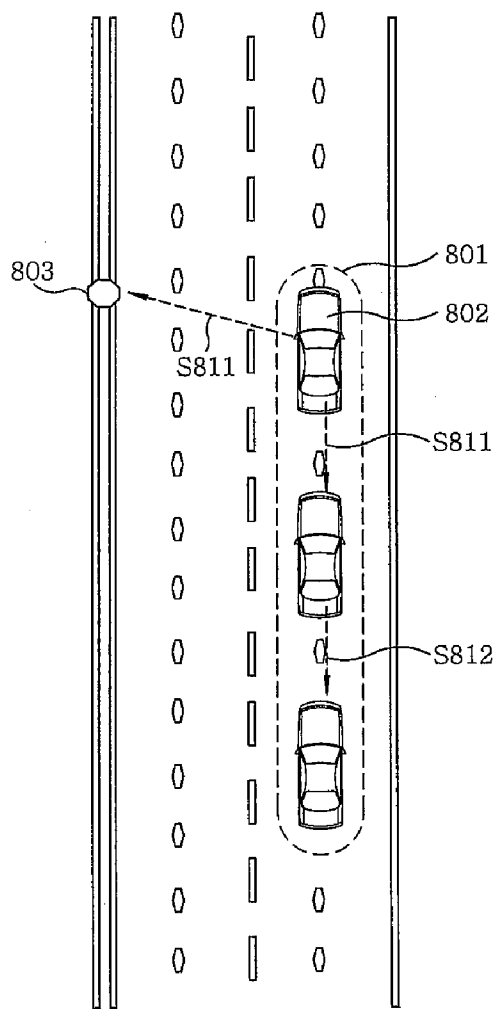
[Fig. 8]



[Fig. 9]

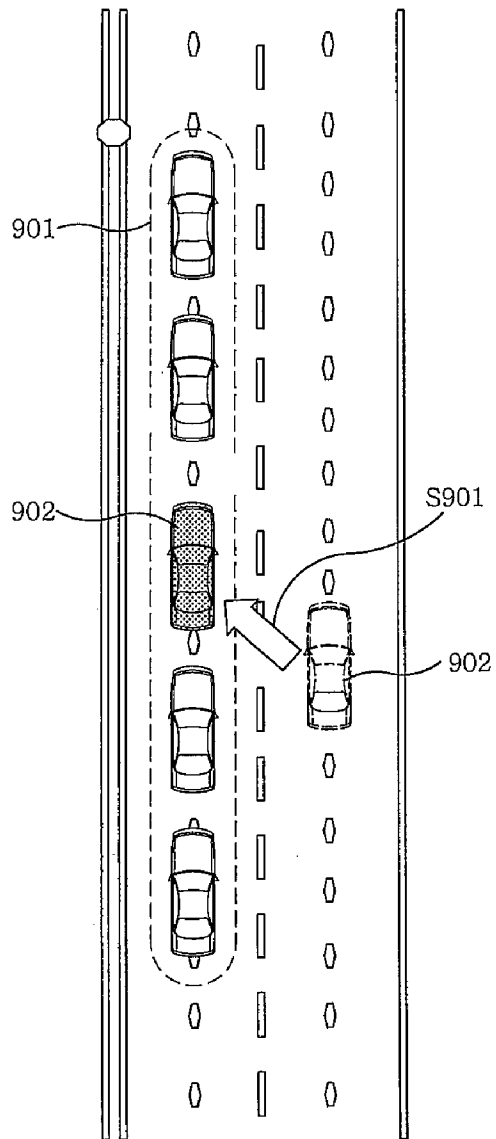


[Fig. 10]

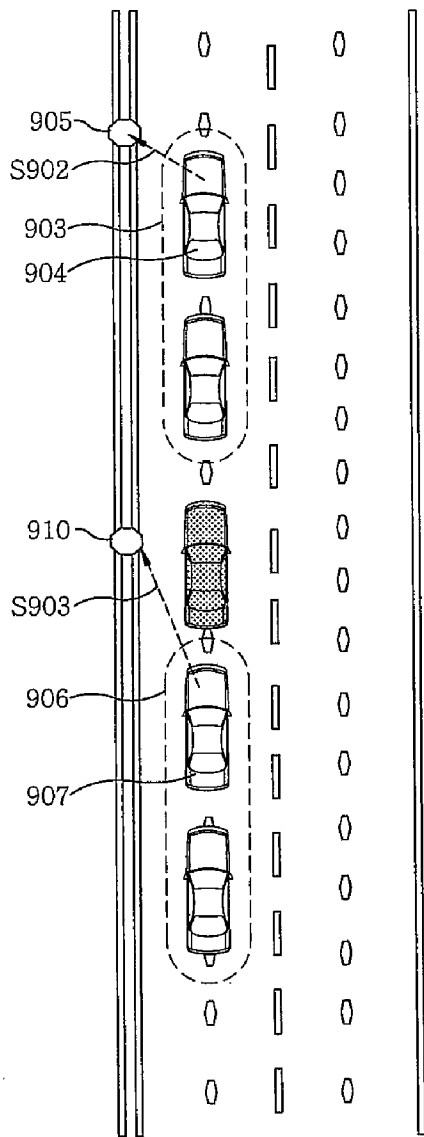


This diagram illustrates a vehicle lane with a sensor unit 804 positioned on the left side. A dashed line indicates the sensor's field of view, which includes three vehicles labeled 805, 806, and 807. The vehicles are arranged in a line, with 805 at the top, 806 in the middle, and 807 at the bottom. The sensor unit 804 is connected to a control unit 801 via a dashed line. The vehicles are also connected to a communication system 802 via dashed lines. The vehicles are labeled 805, 806, and 807. The sensor unit is labeled 804. The control unit is labeled 801. The communication system is labeled 802. The vehicles are labeled 805, 806, and 807. The sensor unit is labeled 804. The control unit is labeled 801. The communication system is labeled 802. The vehicles are labeled 805, 806, and 807.

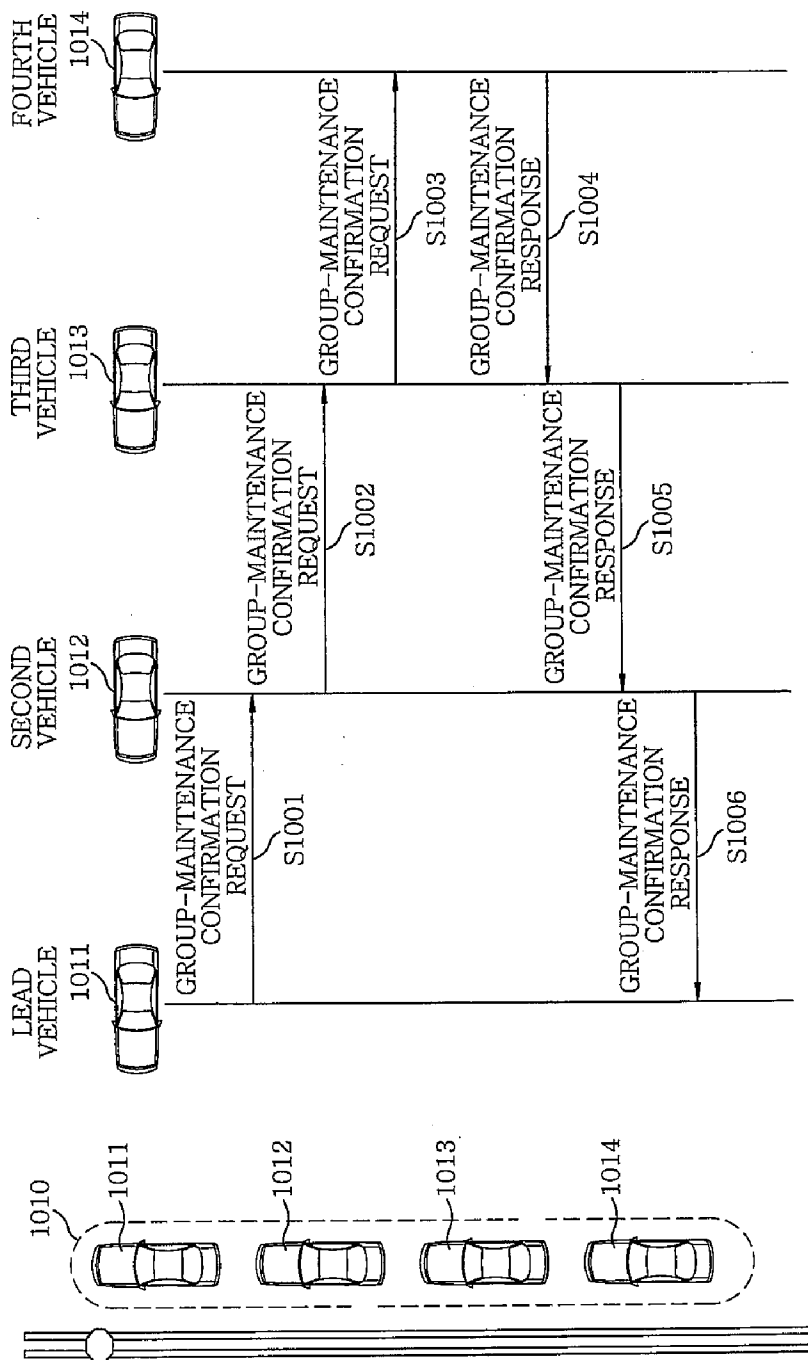
[Fig. 12]



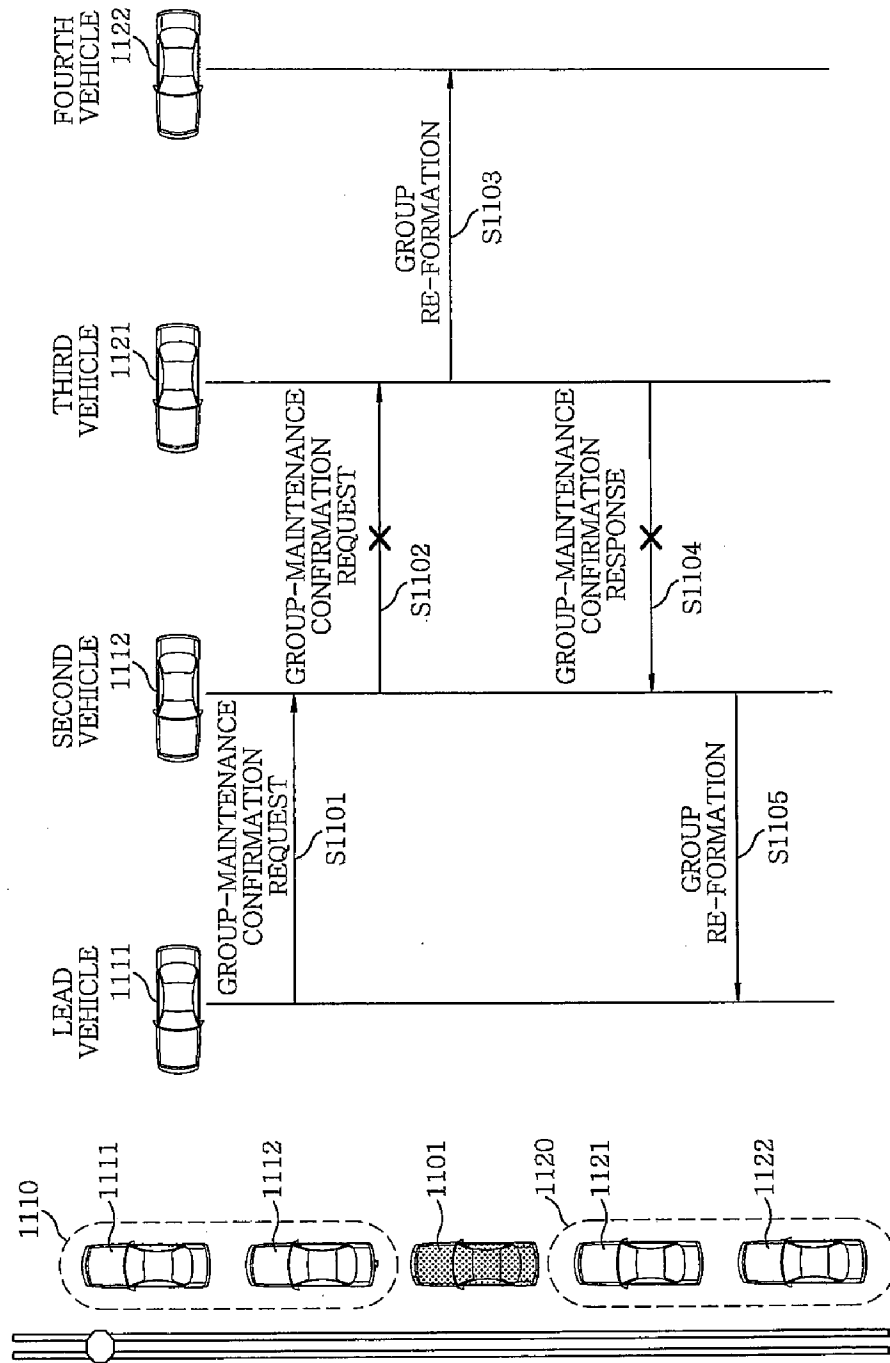
[Fig. 13]



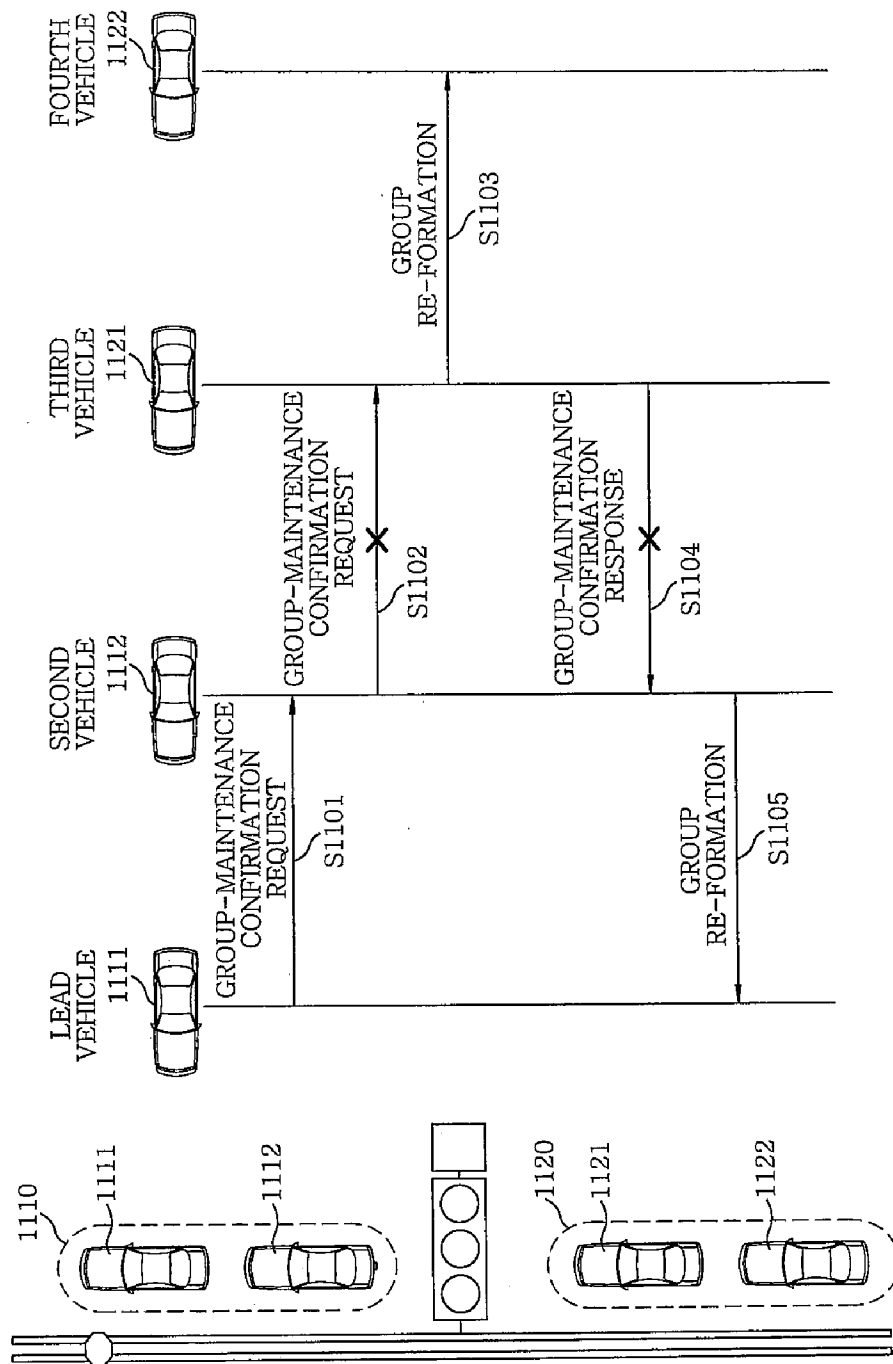
[Fig. 14]



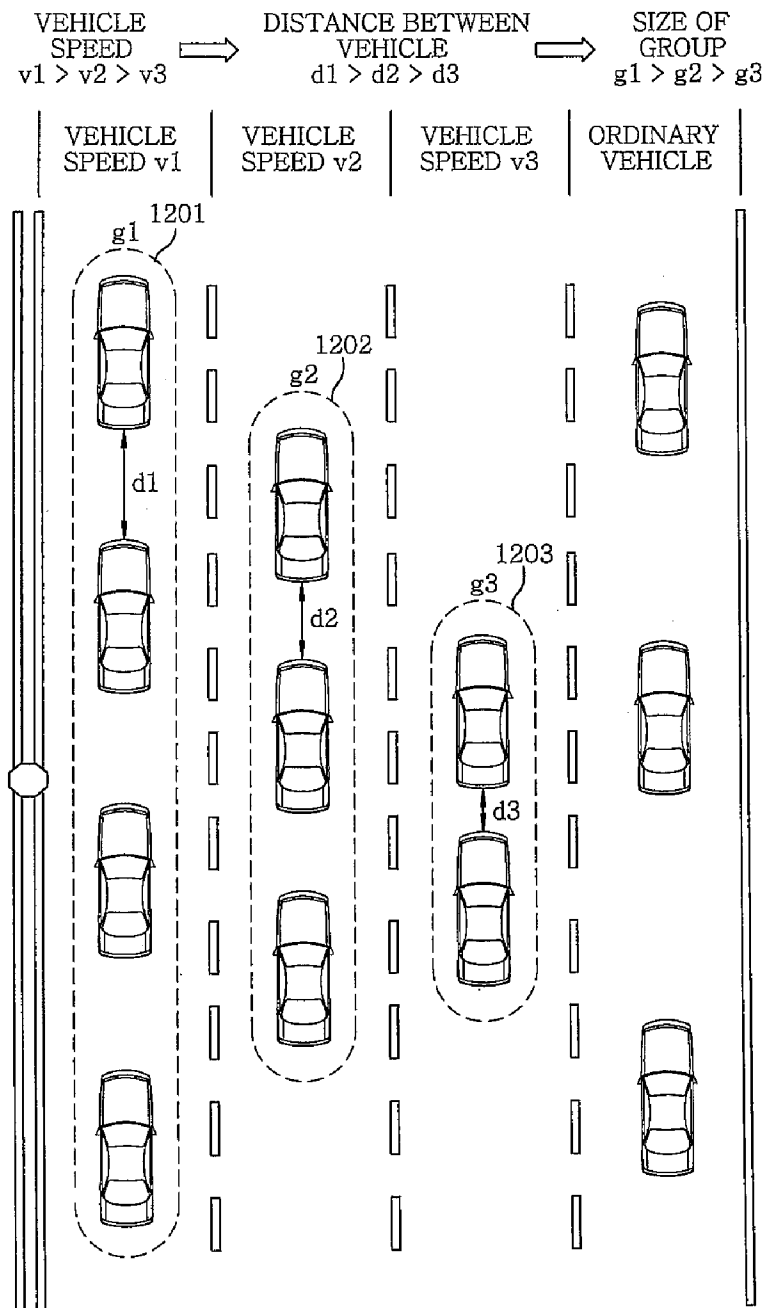
[Fig. 15]



[Fig. 16]



[Fig. 17]



[Fig. 18]

