Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation"

ITS FORUM RC-017 Version 1.0
(Simplified version)

Established on June 24, 2022

ITS Info-communications Forum of Japan

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Revision History

Version	Date	Chapter/Section	Reason	Revised Content
1.0	June 24, 2022	Establishment	Newly established	

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Introduction

This document is a simplified version of the Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation" ITS FORUM RC-017 ver. 1.0.

This document is organized into 10 chapters. Chapter 1 describes the prerequisites. Chapters 2 to 9 describe the communication scenarios and requirements for each use case. Chapter 10 summarizes the communication requirements of the use cases. Appendix 1 describes the analysis of message structure for which further detailed discussions is expected to be carried out. Please note that there are still issues and items that have not been completed in the contents of this document.

Regarding use cases, the preconditions and service requirements may be reconsidered as further studies are made by the stakeholders in the discussion toward the realization of the communication for driving automation. This document will be updated accordingly. Based on this study, we expect the further promotion of the study of communication for driving automation.

(1) Background

The Advanced ITS Info-communication System Committee Radio System Technology Task Group has been studying communication technologies for use cases assuming driving automation. To date, the Task Group has been studying provisional communication technologies based on the "ITS Communications Use Cases and Communications Procedures for Automated Driving (Draft)" specified by the Japan Automobile Manufacturers Association, INC. (JAMA) assuming driving automation on expressways. The Task group published the "Guideline for Experiments of Communications System for Use Cases of Automated Driving on Expressways ITS FORUM RC-015 version 1.0" in October 2019. Meanwhile, Task Force on V2X Communication for Cooperative Driving Automation was established in the Cross-Ministerial Strategic Innovation Promotion Program (SIP). The Task Force subsequently investigated use cases for study on the communication systems necessary for future cooperative driving automation and they released the first version of the SIP Use Cases for Cooperative Driving Automation in September 2020. Accordingly, the communication scenarios and requirements for the realization of each use case in the SIP Use Cases for Cooperative Driving Automation in coordination have been studied by the Task Group cooperatively with the Task Force on V2X Communication for Cooperative Driving Automation and other related organizations.

(2) Purpose

In order to specify the communication systems for SIP Use Cases for Cooperative Driving Automation, this document summarizes the current study results on communication scenarios and requirements for each use case.

The communication scenarios and requirements will be utilized for the feasibility study and the identification of the necessary update of the candidate communication technologies to the SIP Use Cases for Cooperative Driving Automation. The candidate communication technologies are based on the “Guideline for Experiments of Communications System for Use Cases of Automated Driving on Expressways” ITS FORUM RC-015.

(3) Target use cases

In this document, the following 25 SIP Use Cases for Cooperative Driving Automation version 1 [1] were studied.

Target SIP Use Cases for Cooperative Driving Automation.

Classification by function	Use case name	Communication
a. Merging/lane change assistance	a-1-1. Merging assistance by preliminary acceleration and deceleration	V2I
	a-1-2. Merging assistance by targeting the gap on the main lane	V2I
	a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control	V2I
	a-1-4. Merging assistance based on negotiations between vehicles	V2V
	a-2. Lane change assistance when the traffic is heavy	V2V
	a-3. Entry assistance from non-priority roads to priority roads during traffic congestion	V2V
b. Traffic signal information	b-1-1. Driving assistance by using traffic signal information (V2I)	V2I
	b-1-2. Driving assistance by using traffic signal information (V2N)	V2N
c. Lookahead information: collision avoidance	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly	V2V
	c-2-1. Driving assistance based on intersection information (V2V)	V2V

	c-2-2. Driving assistance based on intersection information (V2I)	V2I
	c-3. Collision avoidance assistance by using hazard information	V2V
d. Lookahead information: trajectory change	d-1. Driving assistance by notification of abnormal vehicles	V2I, V2N
	d-2. Driving assistance by notification of wrong-way vehicles	V2I, V2N
	d-3. Driving assistance based on traffic congestion information	V2I, V2N
	d-4. Traffic congestion assistance at branches and exits	V2I, V2N
	d-5. Driving assistance based on hazard information	V2I, V2N
e. Lookahead information: emergency vehicle notification	e-1. Driving assistance based on emergency vehicle information	V2V, V2I, V2N
f. Information collection/distribution by infrastructure	f-1. Request for rescue (e-Call)	V2N
	f-2. Collection of information to optimize the traffic flow	V2I, V2N
	f-3. Update and automatic generation of maps	V2N
	f-4. Distribution of dynamic map information	V2N
g. Platooning/adaptive cruise control	g-1. Unmanned platooning of following vehicles by electronic towbar	V2V
	g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control	V2V
h. Teleoperation	h-1. Operation and management of mobility service cars	V2N

(4) Note on the simplified version

This simplified version omits some of the description from ITS FORUM RC-017 Ver. 1.0. The omitted descriptions include the preconditions, the reasons for deriving communication requirements, and issues for future consideration and so on. The chapter numbers, section numbers, comment numbers, etc., are the same as the original Japanese version. The section and chapter numbers are discontinuous when some the sections or chapters are omitted.

(5) References

[1] SIP Use Cases for Cooperative Driving Automation - Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2019
https://en.sip-adus.go.jp/rd/rddata/usecase.pdf

Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation"

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Chapter 1. Prerequisites

The prerequisites in this study are described below.

1.1 Basic conditions

The “own vehicle” is a vehicle utilizing the cooperative driving automation system defined in the SIP Cooperative Driving Automation Use Case. The driving automation system enables safer and smoother automated driving control by providing information outside the detection range of on-board sensors and information of the vehicle, as well as communicating via V2V and I2V.

There are “other vehicles” in the vicinity of the own vehicle. “Cooperative driving vehicles” uses the cooperative driving automation system. “V2X non-supported vehicles” are not equipped with a cooperative driving automation system, which driven by a human, or by automatically with an autonomous driving system.

1.2 Relationship with Dynamic Maps

Dynamic maps associate the static high-precision 3D map information and dynamic data (semi-static information, semi-dynamic information and dynamic information). The dynamic map is used by the automated driving vehicles to decide trajectory. Depending on use cases, the dynamic map is also used by roadside infrastructure.

1.3 Definition of delay

For the definition of delay in this document, the relationship of delay in each part of the system is described in Fig. 1.3-1. It is the example case where roadside infrastructure transmits to the vehicle.

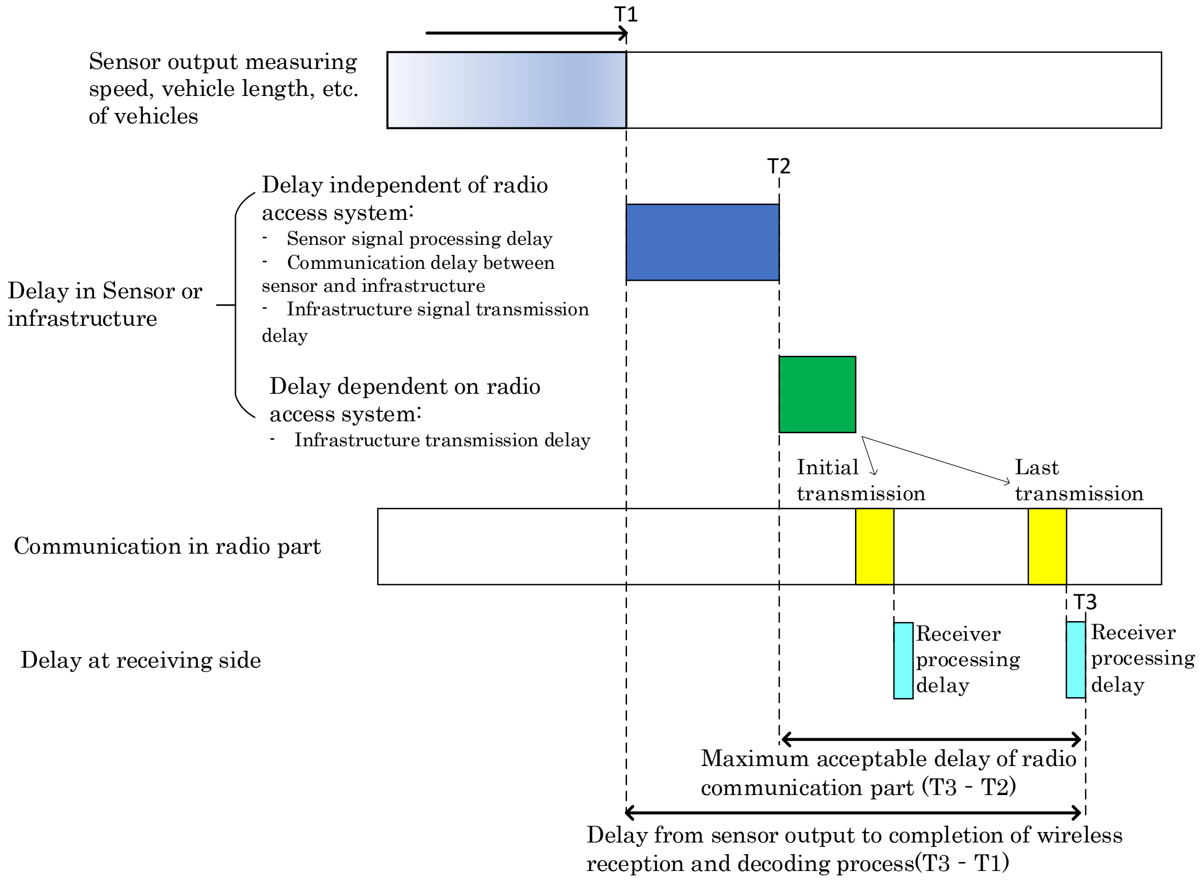

Fig. 1.3-1 Relationship of delay in each part of the system

In this study, the delay derived by T3-T2 in the overall system as shown in Fig. 1.3-1 is defined as the maximum acceptable delay of radio communication. Maximum acceptable delay of radio communication is the maximum delay which the system can accept for the radio access layer to achieve the required quality (required packet arrival rate, communication range, etc.). It can be used for comparison of radio access systems. The radio access layer is assumed to the communication system in ITS FORUM RC-015 Guideline for Experiments of Communications System for Use Cases of Automated Driving on Expressways.

1.4 Communication quality

The communication quality in this document is defined as the Packet Arrival Rate (PAR) per message within the maximum acceptable delay of radio communication described in section 1.3.

1.5 Reference

[1] SIP Use Cases for Cooperative Driving Automation - Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2019
https://en.sip-adus.go.jp/rd/rddata/usecase.pdf

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Chapter 2. a. Merging/lane change assistance use case

2.4 Merging/lane change assistance use case

2.4.1 Use case a-1-1. Merging assistance by preliminary acceleration and deceleration

In use case a-1-1, a spot measurement sensor to measure the speed and length of a vehicle driving on a main lane is installed upstream of a main lane next to a merging lane. The measurement results are distributed from a roadside infrastructure to a cooperative automated driving vehicle on a connecting road and used to decide preliminary speed control.

2.4.1.1 Assumed communication scenario

The assumed scenario for this use case is as follows.

① The roadside infrastructure periodically sends location information messages containing measurement time, speed, vehicle length, and estimated arrival time. When the vehicle driving on the merging lane enters the communication area, it receives a location information message.

② Based on the received estimated arrival time (to the merging starting point), considering the time required for speed adjustment, the vehicle decides the merging point and time. The vehicle reviews the trajectory plan.

③ When the vehicle judges merging can be performed by driving automation, it performs preliminary speed control within the legal speed limit toward the merging point (passing through the communication area during speed control), and starts acceleration toward the expected merging point when passing the merging starting point.
(The information from on-board sensor of the vehicle is reflected during acceleration, and the decision of the merging point and speed control are performed.)

2.4.1.5 Message sequence

Since it is a common sequence for merging/lane change assistance, it is described in the section of use case a-1-3 (Section 2.4.3.5).

2.4.2 Use case a-1-2. Merging assistance by targeting the gap on the main lane

In use case a-1-2, an area measurement sensor is installed to measure the location and speed of vehicles driving on a main lane. The measurement results are distributed to cooperative automated driving vehicles on connecting road, and used to adjust the speed towards the planned merging point (the gap between the vehicles).

2.4.2.1 Assumed communication scenario

The assumed scenario for this use case is as follows.

① The roadside infrastructure periodically sends location information messages containing measurement time, speed, vehicle length, and estimated arrival time. When the vehicle driving on the merging lane enters the communication area, it receives a location information message.

② Based on the received estimated arrival time (to the merging starting point), the vehicle decides the merging point and time. The vehicle reviews the trajectory plan.

③ When the vehicle judges merging can be performed by driving automation, it performs preliminary speed control within the legal speed limit toward the merging point while updating its trajectory plan based on location information message updated at a certain periodicity.

④ When the vehicle passes the merging starting point, it starts accelerating toward the expected merging point.
(The vehicle passes through the communication area during acceleration, and the information from on-board sensor of the vehicle is reflected, thereby determining the merging point and performing speed control.)

2.4.2.5 Message sequence

Since it is a common sequence for merging/lane change assistance, it is described in the section of use case a-1-3 (section 2.4.3.5).

2.4.3 Use case a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control

In use case a-1-3, a roadside infrastructure grasps the driving status of each vehicle within the control area by obtaining their information on speed and location from measurement sensors and cooperative automated driving vehicles. It provides the information to the vehicles on the main lane and the merging late and also instructs the driving target to the cooperative automated driving vehicle that agrees to the control from the road infrastructure.

It is noted that the communication sequences are specified separately for location information provision and control/agreement use case, and this section focuses on location information provision (see section 2.5.1 for control/agreement use case).

2.4.3.1 Assumed communication scenario

The assumed scenario for location information provision in use case a-1-3 is the same as that in use case a-1-2 (see section 2.4.2.1). However, the difference from use case a-1-2 is a communication sequence of control/agreement use case is carried out in a communication area.

2.4.3.5 Message sequence

Figure 2.4.3.5-1 shows the message sequence for location information provision in use case a-1-3.

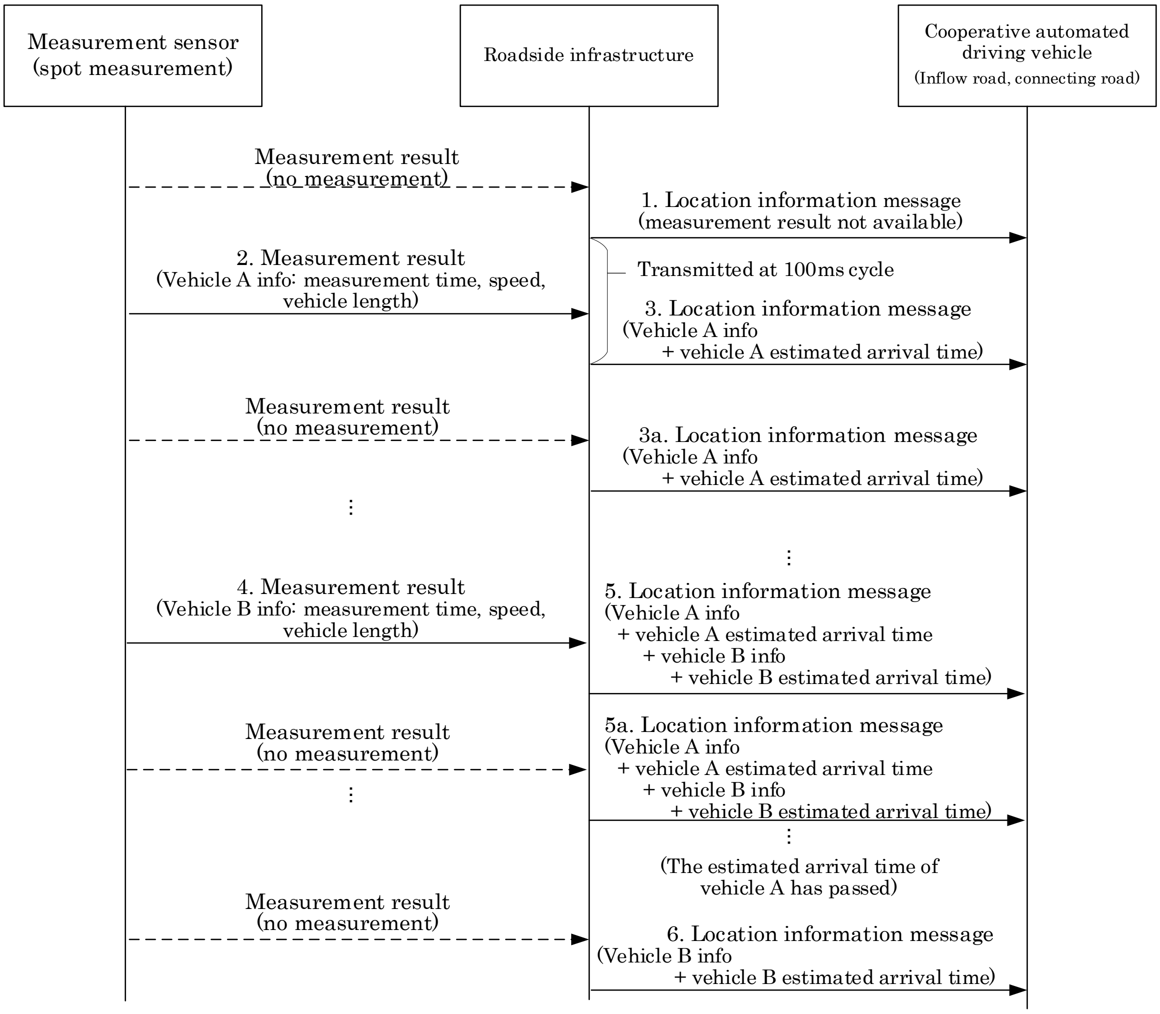

Figure 2.4.3.5-1 Message sequence for location information provision in use case a-1-3

1. The roadside infrastructure transmits the location information message to the vehicles on the main lane and the merging lane at 100 ms cycle regardless of the presence or absence of measurement results (measurement time, speed, and vehicle length) from the measurement sensors (When roadside sensor does not provide any information, “measurement result not available” is transmitted).
2. When the measurement sensor detects vehicle A, it provides the measurement result (vehicle A information) to the roadside infrastructure. The roadside infrastructure assigns a vehicle ID to the vehicle A information provided, and calculates the estimated arrival time of vehicle A, which is upwardly compatible with use case a-1-1.

3. In periodic transmission, the roadside infrastructure transmits location information messages based on the information from the measurement sensors and the estimated arrival time.

3a. In use case a-1-1, if no new measurement results are provided by the spot measurement sensor used, the same location information message as in 3 is repeatedly transmitted until the estimated arrival time of vehicle A has passed. In use case a-1-2 and a-1-3, if it is an area sensor used in use cases a-1-2 and a-1-3, until the update information of vehicle A is provided by the area measurement sensor, the same location information message as in 3 is transmitted, or the location information message with the estimated position updated at the transmission time is transmitted if a roadside infrastructure is capable of it.

4. When the measurement sensor detects vehicle B, it provides the measurement result (vehicle B information) to the roadside infrastructure. The roadside infrastructure calculates the estimated arrival time of vehicle B based on the vehicle B information provided.

5. The roadside infrastructure transmits location information messages including vehicle A and vehicle B as use case a-1-3.

5a. If no new measurement result is provided from the measurement sensor, the same communication sequence as 3a is executed.

6. After the estimated arrival time of vehicle A has passed, the roadside infrastructure switches to transmit the location information message including only vehicle B as use case a-1-3.

2.5 Control/agreement use case

2.5.1 Use case a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control

In use case a-1-3 roadside control, the roadside infrastructure issues a negotiation request to cooperative automated driving vehicles on the main lane and merging lane and instructs the driving target.

It is noted that, the communication sequences are specified separately for location information provision and control/agreement use case, and this section focuses on control/agreement use case (for location information provision, see section 2.4.3).

2.5.1.1 Assumed communication scenario

The scenario for control/agreement use case in use case a-1-3 is as follows.

It is assumed that all vehicles driving on the merging lane are considered cooperative automated driving vehicles, and their location information can be obtained by roadside infrastructure.

① When the vehicle driving on the merging lane receives the location information message and the conditions are met, it transmits the control request message.

② The roadside infrastructure transmits negotiation request messages for vehicles driving on the merging lane at the discretion of the roadside infrastructure.

③ The vehicle driving on the connecting road continues to receive the negotiation request message and the location information message. Upon receiving the negotiation request message, the cooperative automated driving vehicle on the main lane transmits a negotiation response message indicating its on-board unit ID and response on whether to accept the merging.

④ The roadside infrastructure transmits an update request message the appropriate vehicle on-board unit ID to multiple vehicles that require roadside control for agreement.

⑤ If the cooperative automated driving vehicle to be controlled receives the update request message including the on-board ID matching the o- board unit ID of its own vehicle, it starts control for merging and transmits an agreement response to the roadside infrastructure with the update response message.

⑥ The roadside infrastructure repeats the update request message and the update response message at regular intervals until it determines that control is unnecessary.

2.5.1.3 Message sequence

The message sequence for the control request of use case a-1-3 is realized combining the following three sets of message sequences.

Location information message and Control request message

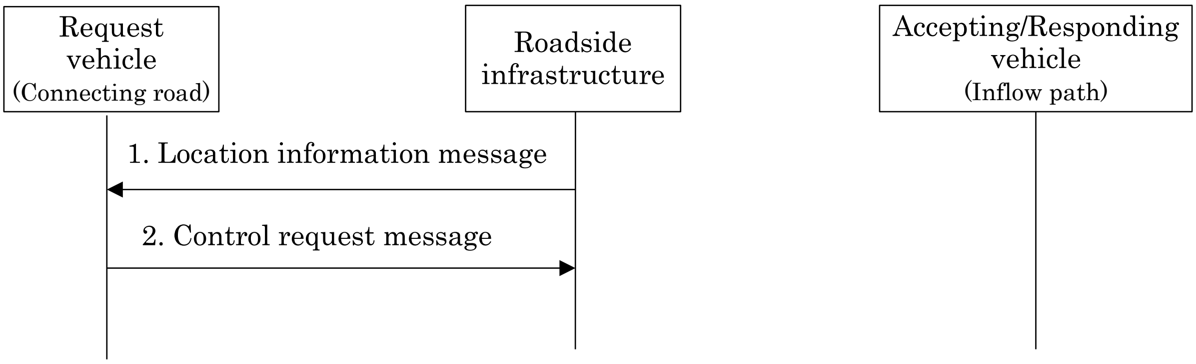

Figure 2.5.1.3-1 Location information and control request message sequence

1. The roadside infrastructure transmits location information messages as in use cases a-1-1 and a-1-2. The difference from use cases a-1-1 and a-1-2 is that the roadside control information is included to indicate whether it accepts a control request message.
2. The own vehicle (request vehicle) driving on the merging lane receives the location information message, if the following conditions a and b are satisfied, and the vehicle transmits the control request message at its own discretion.

    a. The location information message from the roadside infrastructure informs that control requests will be accepted.

    b. The vehicle judges it locates at the specific point for the merging of control/agreement use case (the position 5.9 seconds before the merging starting point at merging lane).

<u>**Negotiation request message and Negotiation response message**</u>

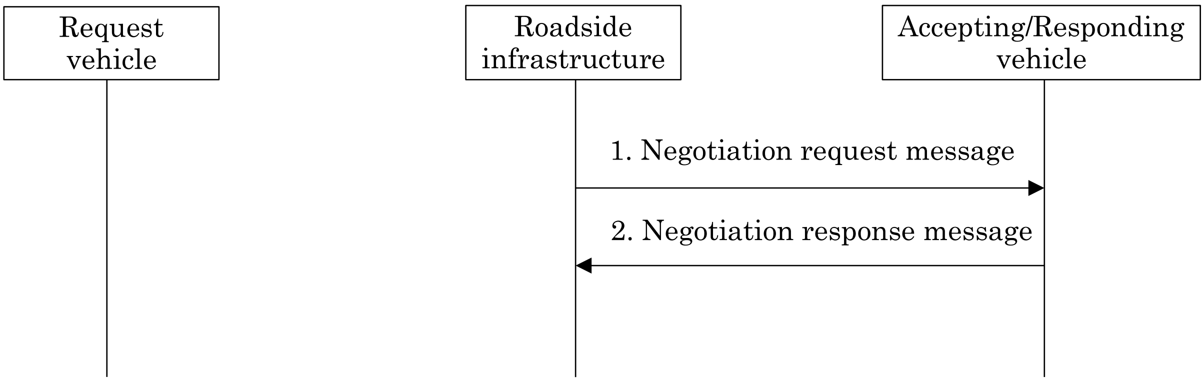

Figure 2.5.1.3-2 Negotiation request message and Negotiation response message sequence

1. The roadside infrastructure transmits a negotiation request message. The negotiation request message includes location information indicating which location of the vehicle needs to transmit the negotiation response message.
2. If the vehicle which has received the negotiation request message satisfies the following condition (a), the vehicle transmits a negotiation response message at the judgment of the vehicle itself.
    a. It is determined that its current location matches the location information indicating which location of the vehicle needs to transmit the negotiation response message.

   The negotiation response message includes “on-board unit ID becoming a unique ID" and "location information of the vehicle and intention to accept the agreement decided by the surrounding vehicle."

<u>**Update request message and update response message**</u>

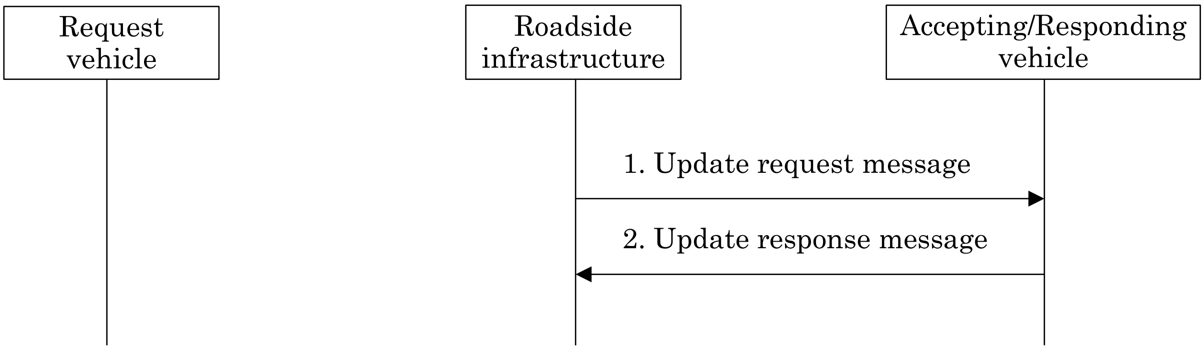

Figure 2.5.1.3-3 Update request message and update response message sequence

1. The roadside infrastructure transmits an update request message. The update request message includes the on-board unit ID that the roadside infrastructure has determined to be the accepting vehicle.
2. If the vehicle which has received the update request message satisfies the following condition (a), the vehicle transmits an update response message at the judgment of the vehicle itself.

   a. The own vehicle's on-board unit ID matches the on-board unit ID in the update request message.

   The update response message includes whether agreement is reached for the roadside infrastructure. The decision of whether to agree or not is a decision of the vehicle, but as an example, "whether or not it is within the requested range in comparison with the current location of the own vehicle," is considered.

An example of realizing control for use case a-1-3

A case in which one requesting vehicle enters from a merging lane and one recipient/responding vehicle reacts on an inflow path is described. Two options, one that uses an update request message and an update response message and the other that uses a location information message, were considered and the former option is described as implementation example 1. When multiple request vehicles and accepting/responding vehicles are present, the roadside infrastructure issues a combination of location information messages, negotiation request messages, and update request messages.

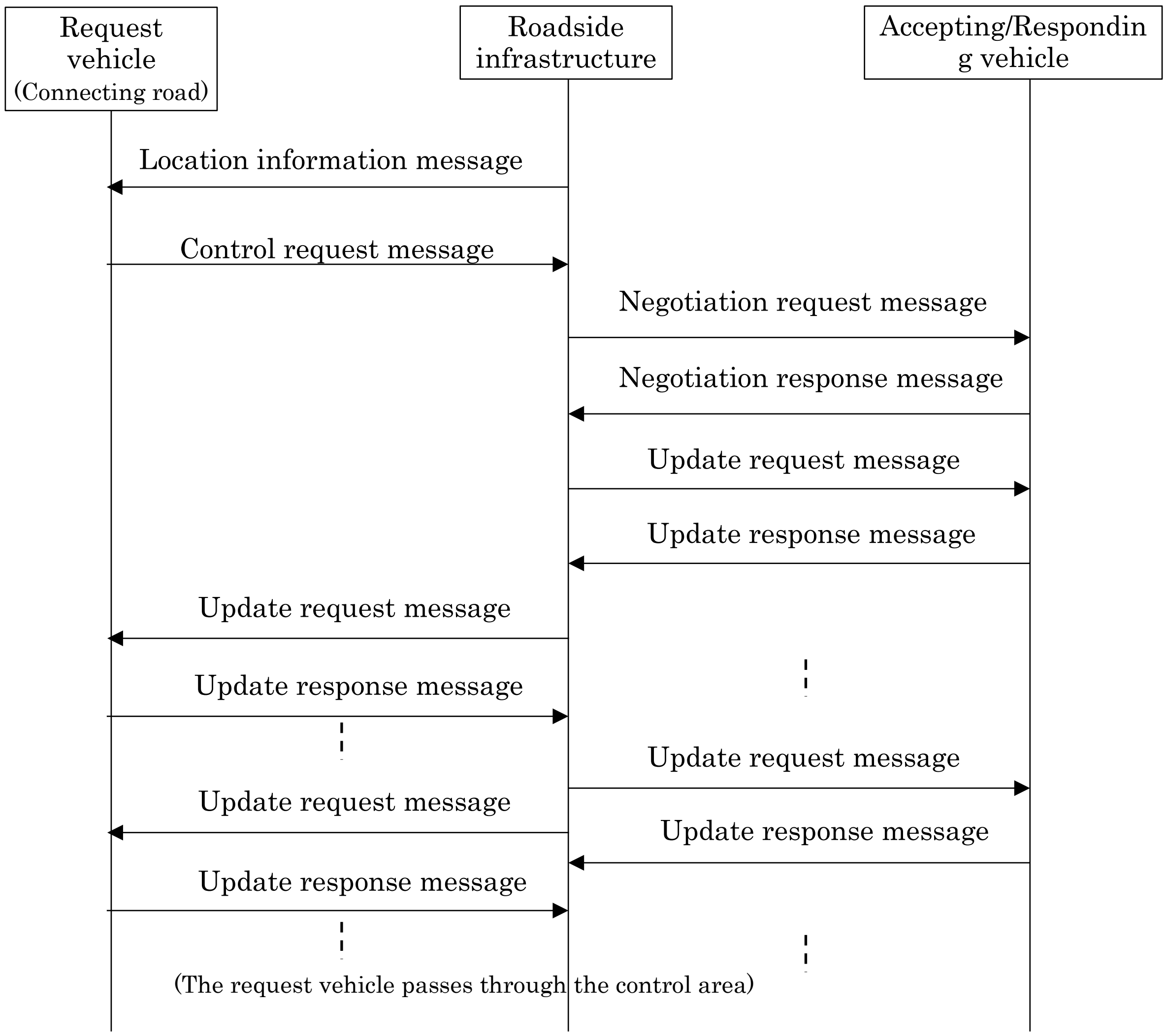

Figure 2.5.1.3-4 Implementation example 1 of control request for use case a-1-3

2.5.2 Use case a-1-4. Merging assistance based on negotiations between vehicles

In use case a-1-4, vehicles exchange driving information for smooth merging when there is a temporary stop before entering a merging lane or when roadside infrastructure cannot perform roadside control since the speed of the vehicles on the main lane is low due to congestion, etc.

2.5.2.1 Assumed communication scenario

For use case a-1-4 merging assistance by negotiation between vehicles, the scenario for a-1-3 can be applied excluding the control request message (see section 2.5.2.3 for details).

The negotiation request and the negotiation response are used to determine whether there are few vehicles driving on the main lane so that a merging by driving automation is possible, or the speed of the vehicles driving on the main lane is sufficiently low due to congestion, etc. An update request and an update response are issued only when the speed of the vehicles driving on the main lane is sufficiently low.

2.5.2.3 Message sequence

Figure 2.5.2.3-1 shows the message sequence in use case a-1-4.

As explained in section 2.5.2.1, the sequence may be completed with only the negotiation request and negotiation response, but the following describes the sequence until the merging by cooperative automated driving is completed (update request and update response).

The difference from the control/agreement sequence is that the own vehicle transmits a negotiation request message and an update request message instead of the roadside infrastructure, and there is no control request message (basically it is executed with the sequence in Figure 2.5.1.3-2 and Figure 2.5.1.3-3).

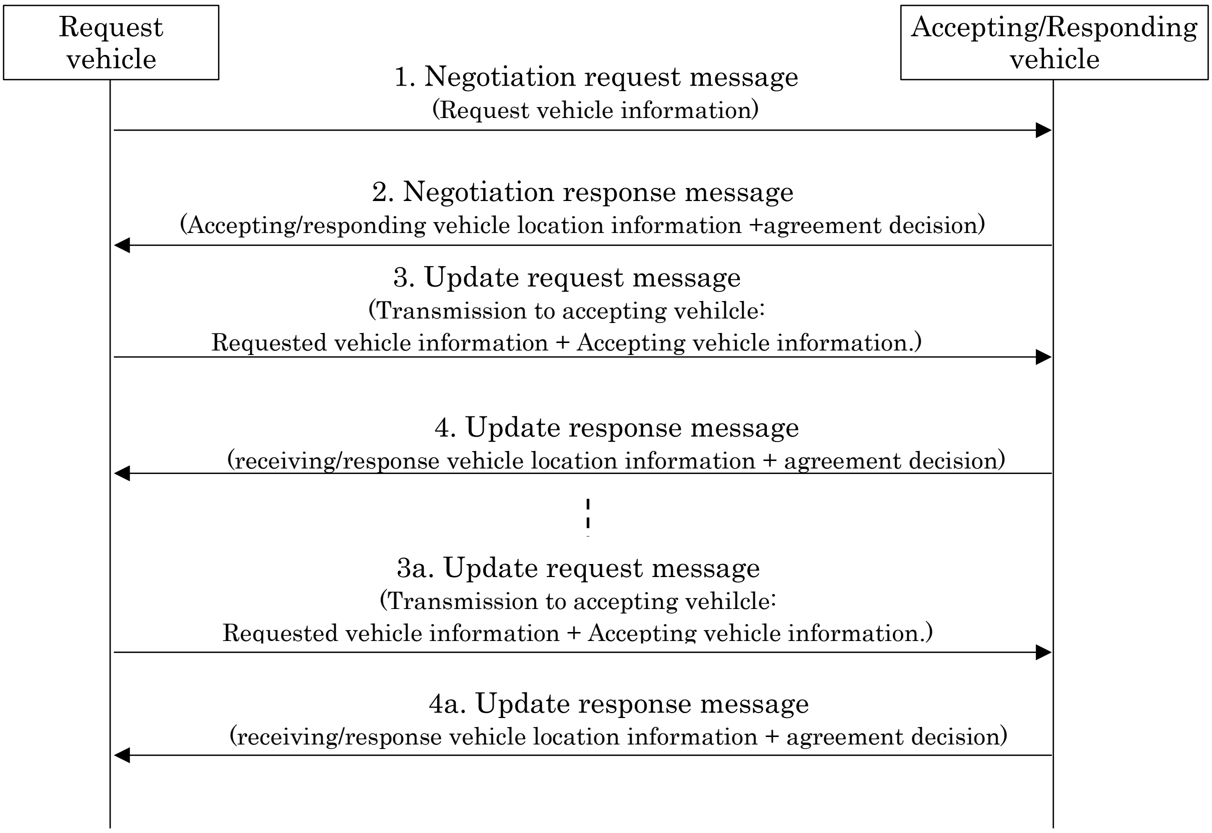

Figure 2.5.2.3-1 Message sequence in control/agreement

1. The request vehicle transmits a negotiation request message to the surrounding vehicles within the request range by its own judgment.
2. When the surrounding vehicle receives the negotiation request message from the request vehicle, if it determines that it is within the request range by comparing it with the current location of the vehicle, it transmits the negotiation response message including the on-board unit ID as a unique ID, the location information, and the decision result

(negotiation) on whether it can accept the agreement (thereafter, the on-board unit ID is fixed until it passes through the request range or an update request from the request vehicle is confirmed).

3. The request vehicle determines whether to issue an update request message (whether or not the speed of the vehicles on the main lane is low due to congestion, etc.) based on the negotiation response messages from the surrounding vehicles and the autonomous information (e.g., information acquired via on-board sensors) of the vehicle. In a case where an update request message is issued, it determines the location for merging or lane change, and at the judgment of the vehicle, transmits an update request message (request to accepting vehicle) with the on board unit ID for agreement to the responding vehicle (accepting vehicle) which would be the following vehicle.
4. When the cooperative automated driving vehicle (accepting vehicle) receives the update request message matching the on-board unit ID of the vehicle, it starts control for accepting the request vehicle in accordance with the information of the message, and at the judgment of the vehicle, transmits an update response message notifying that agreement has been made regarding the request vehicle.
5. It is assumed that the request vehicle will start control for merging or changing lanes if it confirmed the agreement from the accepting vehicle.

3a. The request vehicle repeatedly transmits update request messages to the accepting vehicle at its own discretion until either of the following conditions is met.
- Determines that the request vehicle can perform merging or changing lanes with its on-board sensors.
- Receives an update response message to complete the agreement from the accepting vehicle

4a. The accepting vehicle responds to the update request message transmitted repeatedly by the request vehicle. When it determines that it has recognized the request vehicle or has moved out of the request range, it transmits the update response message with the agreement response as "agreement completion" at the judgment of the vehicle.

2.5.3 Use case a-2. Lane change assistance when the traffic is heavy

In use case a-2, when changing lanes from lanes with poor visibility due to congestion, etc., the driving information is exchanged between related vehicles for smooth lane changes.

2.5.3.1 Assumed communication scenario

Scenario assumed in use case a-2 applies the scenario in section 2.5.2.1.

When, as a trigger for transmitting a negotiation request message, the vehicle is forced to drive at a speed that is less than a legal speed due to congestion, etc., and it cannot change the lane by its on-board sensors because the visibility of the adjacent lane is poor, a negotiation request message is transmitted to a cooperative automated driving vehicle on the adjacent lane.

2.5.3.3 Message sequence

The common control/agreement sequence in section 2.5.2.3 applies.

2.6 Intersection entry assistance use case

2.6.1 Use case a-3. Entry assistance from non-priority roads to priority roads during traffic congestion

In an intersection without a signal, after a temporary stop, information on location and speed, and an intention to enter are communicated between vehicles are exchanged. Driving assistance is performed for entering a priority road from a non-priority road.

2.6.1.1 Assumed communication scenario

The scenario assumed in use case a-3 is basically in accordance with the scenario of section 2.5.2.1. However, compared with the use case of merging or lane change where the update request is for a single lane, the update requests for multiple lanes are required depending on the scenario.

In this scenario, all the vehicles driving on the priority road(s) are cooperative automated driving vehicles, and it is considered that vehicles entering from the non-priority road cross the priority roads are congested.

2.6.1.3 Message sequence

Basically, a common sequence of control/agreement (see section 2.5.2.3) applies, except that negotiation request message/negotiation response message and update request message/update response message are exchanged for multiple lanes.

1. After an automated driving vehicle (request vehicle) on non-priority road stops temporarily on the stop line at the intersection, it then slowly runs until just before entering the priority road. During the period, it transmits negotiation request message(s) to vehicle(s) driving on the priority road(s) at the judgment of the vehicle.
2. Upon receiving the negotiation request message, each vehicle driving in the targeted lane on the priority road compares it with the location information of the vehicle, if it is determined that the own vehicle is within the request range and is positioned ahead, it transmits the negotiation response message including the on-board unit ID as the unique ID, the location information and the decision result on whether it can make agreement as response (thereafter, the on-board unit ID is fixed until the vehicle passes the request range).
3. The request vehicle receives the negotiation response messages from the surrounding vehicles, determines a location where the request vehicle merges, and transmits an update request message including the on-board unit ID to the vehicle (accepting vehicle) of which

the request vehicle intersects in front.

When message sequence of update request message and the update response message is executed in parallel or collectively for the plurality of lanes, the update request message and the update response message are exchanged with all the target accepting vehicles. When such message sequence is executed lane by lane, the message exchange is performed sequentially from the accepting vehicles of the adjacent lanes at the own judgment of the vehicle.

4. When the cooperative automated driving vehicle (accepting vehicle) receives the update request message matching the on-board unit ID of the vehicle, it determines that a vehicle crossing the front of the vehicle occurs, starts deceleration to a speed at which the vehicle can stop in front of the intersection, and transmits an update response message to the request vehicle.
5. When the request vehicle receives the update response from the accepting vehicle, while keeping transmitting the update request to the accepting vehicle, it transmits a negotiation request message to an accepting vehicle on the next crossing lane at the own judgment of the vehicle.

3a. The request vehicle repeatedly transmits an update request message to the accepting vehicle until either of the following conditions is met.

- Judges that the request vehicle has passed through the lane where the accepting vehicle runs.
- Receives the update response message to complete the agreement from accepting vehicle.

4a. The accepting vehicle responds to the update request message transmitted repeatedly by the request vehicle. When it determines that it has recognized the request vehicle or has moved out of the request range, it transmits the update response message with the agreement response as "agreement completion."

Chapter 3. b. Traffic signal information use case

3.3 Use cases for driving assistance by using traffic signal information

3.3.1 Use case b-1-1. Driving assistance by using traffic signal information (V2I)

This use case aims to enable a cooperative automated driving vehicle to pass through an intersection while in compliance with traffic signals.

The current traffic signal light color and signal cycle information (the sequence and switching timing of the signal light color) at an intersection are provided from a roadside infrastructure to a vehicle entering the intersection, and assistance so that the vehicle, which has received the traffic signal cycle lookahead information in V2I, decelerates and stops with sufficient margin.

3.3.1.1 Assumed communication scenario

・ The roadside infrastructure broadcasts the latest information such as the current signal light color and signal cycle information of traffic signals at intersections at a 100 ms cycle.

・ Information for all directions will be provided for each intersection. Information on multiple intersections can be transmitted in the same communication area.

3.3.1.5 Message sequence

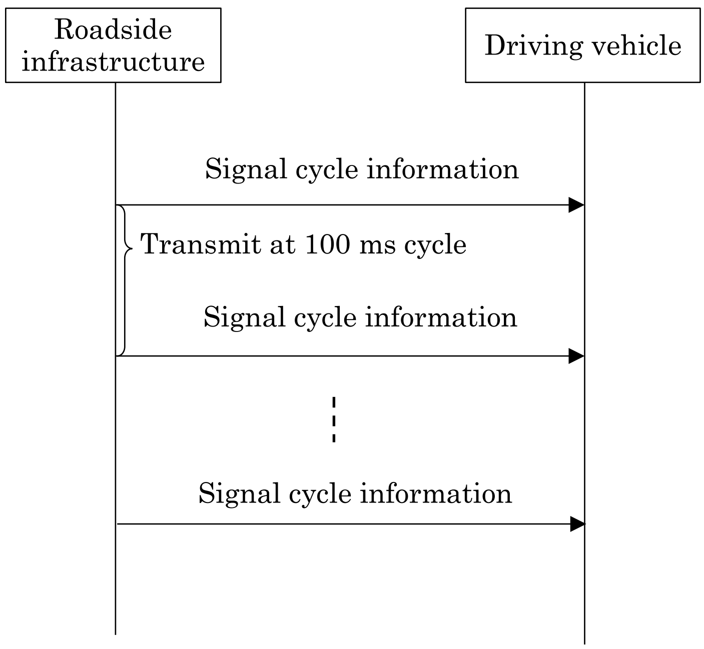

Figure 3.3.1.5-1 Message sequence in use case b-1-1

3.3.2 Use case b-1-2. Driving assistance by using traffic signal information (V2N)

This use case aims to enable a cooperative automated driving vehicle to pass through an intersection while in compliance with traffic signals.

Signal cycle information, etc., of traffic signals at intersections is provided to vehicles entering the intersection via the network, and dilemmas are avoided by assisting vehicles in decelerating and stopping.

In this study, we refer to the results of R&D on signal information provision using SIP Stage II/Cloud [6].

3.3.2.1 Assumed communication scenario

According to [6], the system that transmits signal cycle information, etc., by V2N is shown in the following figure. In this study, the target is "between the Delivery Center and the on-board unit."

Since the signal schedule information in the use case is expressed based on the absolute time, the signal schedule information will not be affected by the communication delay if it is generated well in advanced in comparison with the communication delay. However, in a traffic signal intersection where a traffic signal controls a traffic signal cycle in real time according to the amount of traffic around the intersection, such as sensing control, it is impossible to generate signal schedule information in advance, and communication delay becomes an issue.

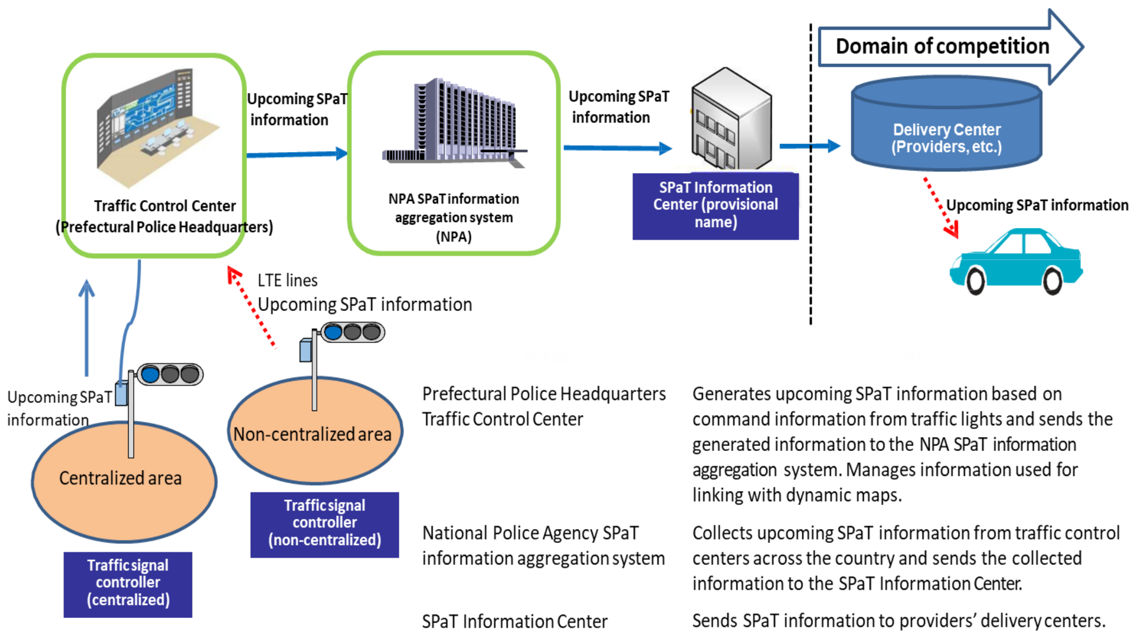

Figure 3.3.2.1-1 Driving Assistance by signal information (V2N) system configuration and communication path [6]

There are the following sequence options for the realization of "between the Delivery Center and the on-board unit."

・ **Full pull method:** When a vehicle approaches a designated place near a traffic signal, information of the present location or identification information of the traffic signal is transmitted from a vehicle to a Delivery Center described at [6] and the corresponding signal information is obtained from the Delivery Center. Since the traffic signal information is notified to the vehicle only when a pull request is made, it is impossible to notify the vehicle of the traffic signal information in response to an event such as a sensitive signal from a SPaT Information Center or an event such as a traffic signal failure.

・ **Location information aperiodic/signal information push method:** When a vehicle approaches a designated location near a traffic signal, the vehicle transmits the current location information or traffic signal identification information to the Delivery Center described in [6]. It maintains the V2N communication and traffic signal information is pushed to vehicles in response to the occurrence of signal information events from the SPaT Information Center.

・ **Location information periodic/signal information push method:** In use cases of lookahead information (abnormal vehicle, wrong-way driving vehicle, traffic jam, branch, hazard, emergency vehicle notification: d-1, d-2, d-3, d-4, d-5), for unicast of V2N, location information of each vehicle is periodically transmitted to a management server, and the information is used to link the vehicle and the traffic signal. It maintains the V2N communication and traffic signal information is pushed to vehicles in response to the occurrence of signal information events from the SPaT Information Center.

3.4 References

[6] "Strategic Innovation Promotion Program (SIP) Phase Two / Automated Driving (Expansion of Systems and Services)/Research and Development on the Provision of Signal Phase and Timing (SPaT) Information using Cloud and other technologies", Progress Report for Fiscal Year 2020, March 2021. https://en.sip-adus.go.jp/rd/rddata/rd04/e212s.pdf

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Chapter 4. c. Look ahead information: collision avoidance use case

4.4 Collision avoidance use case

Use case c-1 and c-3 are specified as separate use cases in the SIP Use Cases for Cooperative Driving Automation because they are different events. On the other hand, c-1 can be seen as a subset of c-3 from communication requirements. Therefore, in this study, the assumptions and communication requirements considered for c-3 are applied to c-1 as well.

4.4.1 Use case c-3. Collision avoidance assistance by using hazard information

In use case c-3, when a cooperative automated driving vehicle suddenly decelerates or changes lanes, emergency hazard information is delivered to the following vehicle, and the following vehicle smoothly performs avoidance control. Also, when the cooperative automated driving vehicle receives emergency hazard information from the vehicle ahead, it distributes the emergency hazard information to the following vehicle even if it does not perform sudden deceleration or emergency lane change.

4.4.1.1 Assumed communication scenario

The scenario is shown below.

① A cooperative automated driving vehicle on a road periodically transmits its driving status.

② The cooperating automated driving vehicle transmits hazard information to the following vehicle when it determines that the own vehicle has "executed sudden deceleration or emergency lane change."

③ Upon receiving the sudden deceleration information, the cooperative automated driving vehicle reflects the information of the preceding vehicle on its dynamic map, and decelerates or stops as necessary to avoid collision with the preceding vehicle.

④ If the receiving vehicle's position is within the range of the hazard information sharing, the cooperative automated driving vehicle forwards the information to the following vehicle further.

4.4.1.5 Message sequence

Figure 4.4.1.5-1 shows the message sequence.

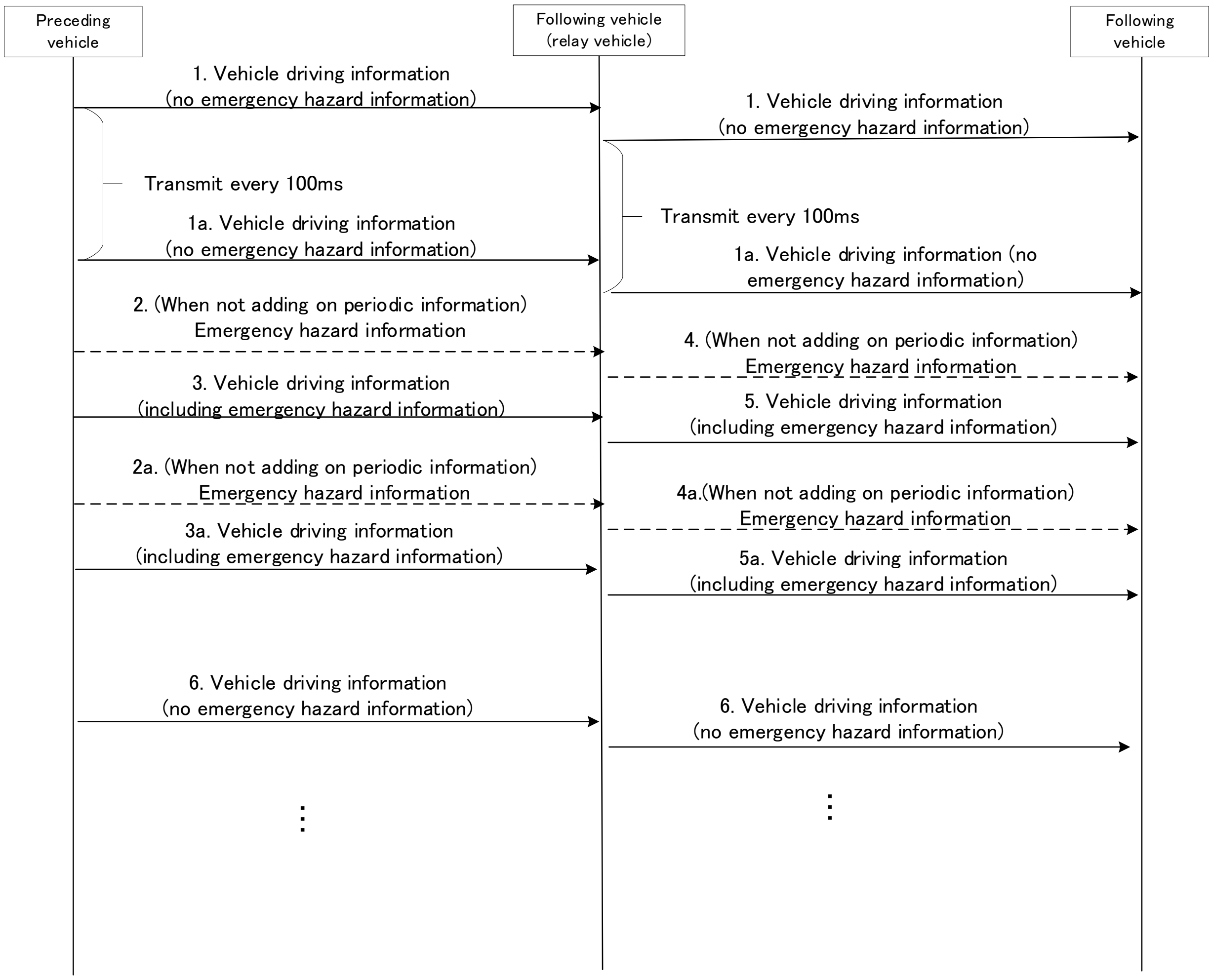

Figure 4.4.1.5-1 Message sequence

1/1a. The preceding vehicle, the following vehicle (relay vehicle), and the following vehicle transmit their own vehicle's driving information (location information, acceleration/deceleration information, speed information, etc.) to surrounding vehicles at 100 ms intervals.

2/2a/3/3a. When the preceding vehicle performs sudden deceleration, as long as the sudden deceleration continues, the sudden deceleration information is transmitted every 100 ms either on a message (2/2a) different from the periodic message or on the periodic message (3/3a).

4/4a/5/5a. When the following vehicle (relay vehicle) receives emergency hazard information from the preceding vehicle, it will forward the emergency hazard information to the following vehicle if it is within the range of the hazard information sharing.

6. The preceding vehicle stops the transmission of emergency hazard information when the sudden deceleration and emergency lane change are stopped (following the stop, the transmission of the emergency hazard information from the following vehicle (relay vehicle) to the following vehicle will be also stopped).

4.5 Use cases for driving assistance based on intersection information

4.5.1 Use case c-2-1. Driving assistance based on intersection information (V2V)

In use case c-2-1, for right-turn assist at an intersection, a vehicle approaching the intersection provides a vehicle approaching or passing the intersection with its own information on the location and speed.

4.5.1.1 Assumed communication scenario

The scenario is described below. Since the communication is between cooperative automated driving vehicles, it is assumed that the right-turning vehicle and the oncoming vehicle are cooperative automated driving vehicles.

① The oncoming vehicle transmits its own vehicle information to the surrounding vehicles at certain interval.

② When a right-turning vehicle receives the information from the oncoming vehicle, it reflects the information on its dynamic map and determines whether to turn right.

③ A right-turning vehicle executes a right turn when it determines that a right turn is possible.

4.5.1.5 Message sequence

The message sequence in c-2-1 is as shown in Figure 4.5.1.5-1.

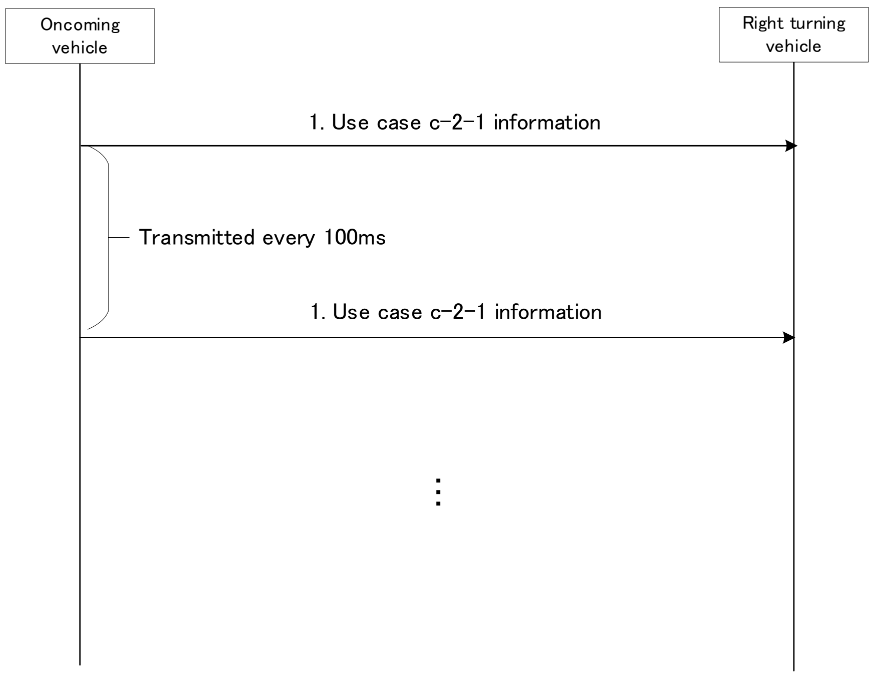

Figure 4.5.1.5-1 Message sequence

1. Oncoming vehicles of right-turning vehicles transmit use case c-2-1 information (measurement time, speed, vehicle length, direction) at 100 ms intervals.

4.5.2 Use case c-2-2. Driving assistance based on intersection information (V2I)

In the use case c-2-2, for right-turn assist at an intersection, a roadside infrastructure provides vehicle(s) approaching the intersection or passing through the intersection with traffic signal information and information on the position and speed of a vehicle approaching the intersection acquired from a roadside sensor.

NOTE: In the SIP Use Cases for Cooperative Driving Automation, it is assumed that the roadside infrastructure collects information also from the oncoming vehicle via V2I. However, it is not considered as condition in this study since in the case of c-2-2, information from the roadside sensor is available, and when the oncoming vehicle is a cooperative automated driving vehicle, direct information transmission to the right-turning vehicle is possible by the case of c-2-1.

4.5.2.1 Assumed communication scenario

The scenario is as follows. Is it noted that V2X non-supported vehicles are also assumed as oncoming vehicles in this use case.

① The roadside infrastructure periodically transmits the use case c-2-2 information to the right-turning vehicle.

② When the roadside infrastructure obtains the measurement result from the roadside sensor, it transmits the use case c-2-2 information reflecting the detected vehicle information to the vehicle turning right.

③ When the right-turning vehicle enters the communication area with the roadside infrastructure, it starts receiving the use case c-2-2 information, reflects it on its dynamic map, and determines whether it is possible to turn right.

④ A right-turning vehicle executes a right turn when it determines that a right turn is possible.

4.5.2.5 Message sequence

Figure 4.5.2.5-1 shows the message sequence in c-2-2.

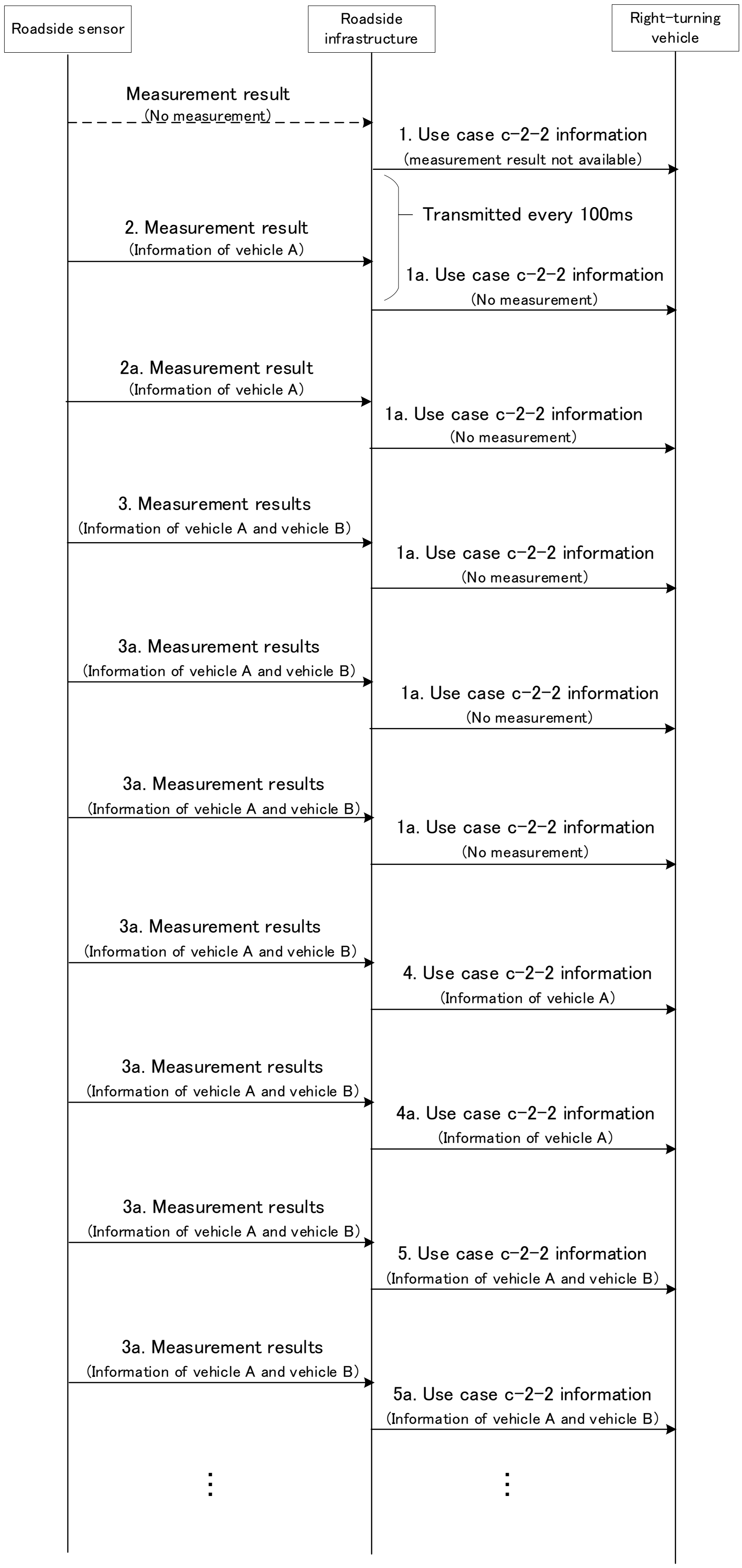

Figure 4.5.2.5-1 Message sequence

1/1a The roadside infrastructure transmits use case c-2-2 information at 100 ms intervals. When roadside sensor does not provide any information, "measurement result not available" is transmitted to the right-turning vehicle.
2/2a When the roadside sensor detects an oncoming vehicle A, it provides the measurement result (measurement time, speed, vehicle length) to the roadside infrastructure.
3/3a When the roadside sensor detects an oncoming vehicle B, it provides the measurement result (measurement time, speed, vehicle length) to the roadside infrastructure.
4/4a The roadside infrastructure transmits use case c-2-2 information including information of vehicle A.
5/5a The roadside infrastructure transmits use case c-2-2 information including information of vehicle A and vehicle B.

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Chapter 5. d. Lookahead information: trajectory change use case

5.1 Prerequisites

5.1.1 Communication system prerequisites

A use case scenario with the communication system shown in the figure below is assumed.

For communication, there is no priority order of V2I and V2N, and the vehicle uses what is available under the specific conditions.

- Carrier wide area network(V2N) : Unicast

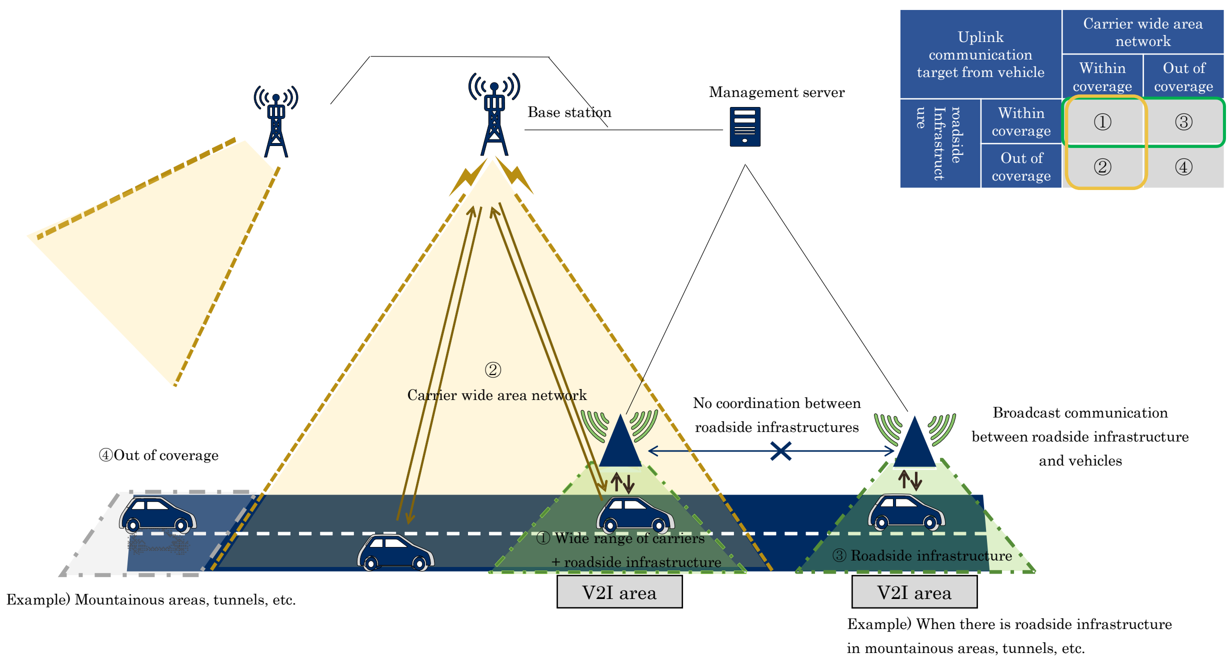

Figure 5.1.1-1 Carrier wide area network (V2N): Unicast

・ Carrier Wide Area Network(V2N) : Broadcast

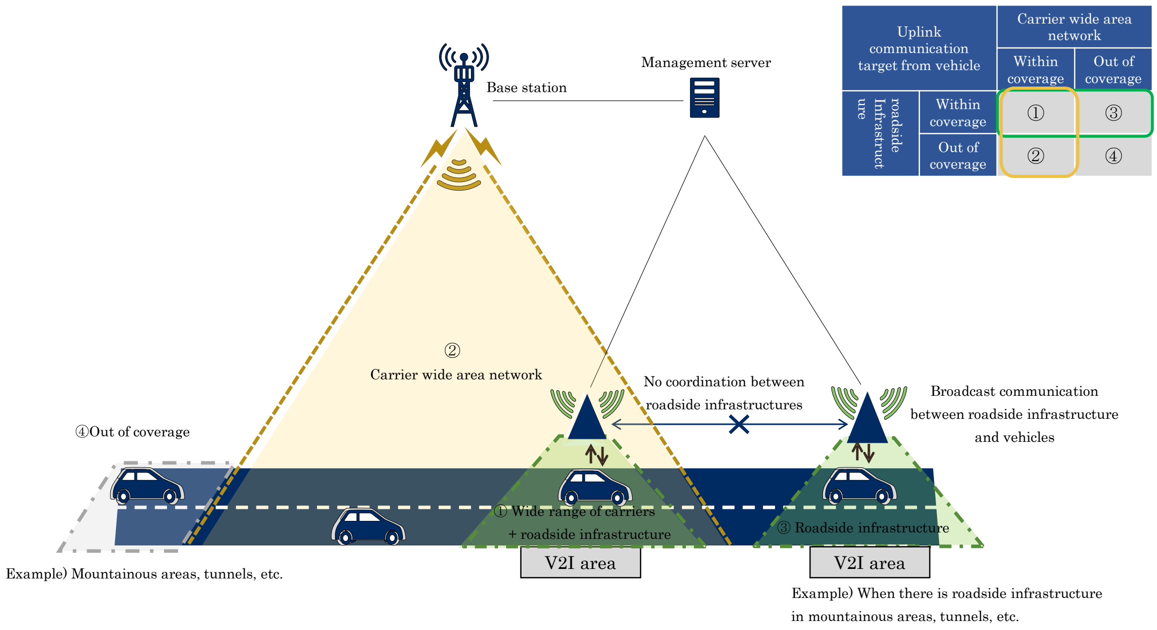

Figure 5.1.1-2 Carrier Wide Area Network(V2N): Broadcast

The roadside infrastructure and the management server have the following roles.

(1) Roadside infrastructure

- Not manage the location information (latitude and longitude information) of surrounding vehicles.
- Transmit the V2I message received from the vehicle to the management server.
- Broadcast the I2V message received from the management server to vehicles within the communication area.

(2) Management server

- Manage the location information (latitude and longitude information) of surrounding vehicles.
- Manage area information of roadside infrastructure.
- Judge the event based on the message received from the vehicle.
  (Judgment and confirmation of incidents)
- Process the message based on the message received from the vehicle.

  Check the incident and add information whether the vehicles can pass the location to the message as necessary.
- Determine the area to deliver the message.

- Distribute messages to surrounding vehicles using V2N.
  Distribute the specified vehicle in the delivery area via unicast.
  Alternatively, broadcast within the delivery area.
- Distribute V2I messages to surrounding vehicles via roadside infrastructure.
  Identify and transmit to the roadside infrastructure within the delivery area.
  (Transmit I2V messages periodically.)

5.1.6 Concept of using carrier wide area communication (V2N)

- The communication rate of service provision via V2N unicast was assumed to be set as 7.65 sec/time.
  Necessary information is transmitted to the management server in uplink from the vehicle at this interval.
  At the same time, event information currently occurring is transmitted from the management server to each vehicle in downlink.
  At this time, the management server considers the location information of the incident and the location information of each vehicle, and distributes the information only to vehicles within the target area.
  Each vehicle that receives the information determines whether the information is within a valid area based on its own vehicle's location information and speed information, and determines whether to utilize the information for changing the trajectory plan.

5.2 Lookahead information: trajectory change use case

5.2.1 Use case d-1. Driving assistance by notification of abnormal vehicles

5.2.1.1 Purpose of communication

Driving Assistance by notification of abnormal vehicle

5.2.1.2 Overview of communication

Event information (a broken vehicle, an accident vehicle, etc.) and location information (a section, a lane) of an abnormal vehicle stopped on a road are provided from an infrastructure to the surrounding vehicle or from the abnormal vehicle to the surrounding vehicle to assist early lane change and trajectory plan change.

5.2.1.3 Hazard information delivery method

When abnormality occurs in the vehicle, the abnormal vehicle transmits hazard information to the management server by automatic hazard detection or manual switch operation.

When receiving hazard information from the abnormal vehicle, the management server determines an area to distribute the hazard information and periodically provides the hazard information to the surrounding vehicles until the hazard of the abnormal vehicle is eliminated such that the surrounding vehicles can perform early lane change and trajectory plan change,.

While communication methods include V2I, V2N (unicast), and V2I (broadcast), an image of the communication method is shown below using V2N (unicast) as an example.

V2N

(a) Uplink side

The abnormal vehicle immediately transmits hazard information to a management server via a network (base station), if it is within a communication area of a carrier wide area communication network.

(b) Downlink side

Unicast method

The management server identifies vehicles within the area to which hazard information is to be distributed, and unicasts hazard information to surrounding vehicles via the network (base station) of the carrier wide area network.

It will be delivered periodically every 7.65s (provisional) until the hazard of the abnormal vehicle is resolved.

5.2.1.4 Assumed communication scenario

Scenarios assumed for driving assistance by notification of abnormal vehicles are as follows.

Expected utilization of V2N

Unicast delivery

(1) An abnormal vehicle sends hazard information to the management server via the network (base station) of the carrier wide area network, triggered by automatic hazard detection or manual switch operation.

(2) The management server determines the distribution area based on the hazard information received from the abnormal vehicle.
If the management server receives duplicate hazard information, it treats it as one hazard information.

(3) The management server identifies a vehicle in the area to which the hazard information is to be distributed and periodically distributes the hazard information to the surrounding vehicle by unicast via a network (base station) of a carrier wide area communication network in the distribution target area.

(4) The surrounding vehicle receives the hazard information, reflects the main lane vehicle information on its dynamic map, and reviews its trajectory plan.

(5) After confirming the safety of the abnormal vehicle and its surroundings, the road administrator stops the distribution of hazard information from the management server.

5.2.1.5 Message sequence and content

The message sequence to provide abnormal vehicle information in use case d-1 is as shown in the figure below.

Expected utilization of V2N

Unicast method

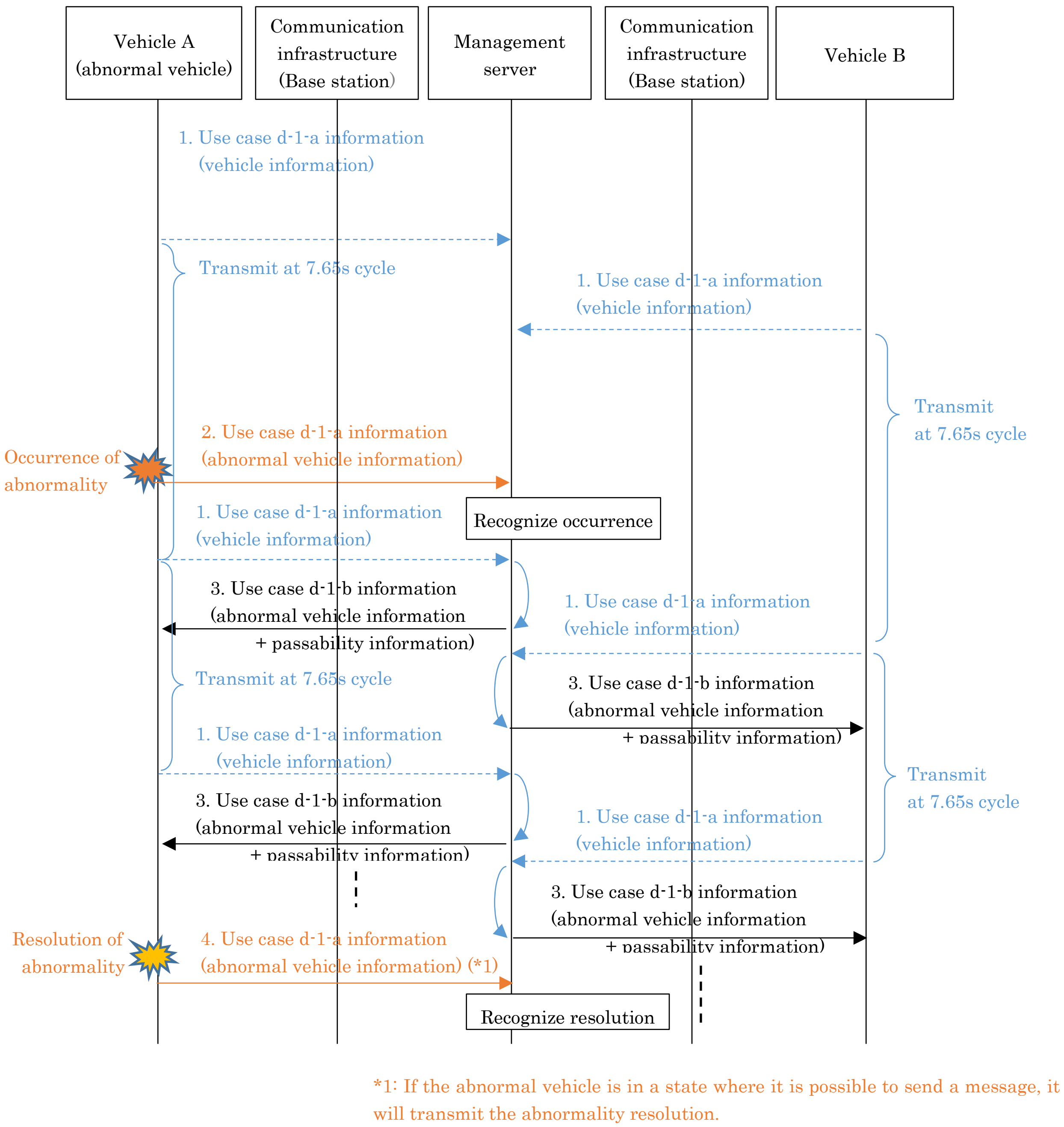

Figure 5.2.1.5-1 Message sequence assumed in use case d-1 (V2N, unicast).

1. The vehicle periodically transmits d-1-a information including its own location information to the management server.
2. The vehicle immediately sends use case d-1-a information to the management server upon automatic hazard detection or manual switch operation.

   The management server makes the following determinations with respect to the provided abnormal vehicle information.

   - The validity of the provided abnormal vehicle information is authenticated by a road administrator or equivalent.
   - A judgment is made whether or not there is overlap with already provided abnormal vehicle information, and if there is overlap, subsequent abnormal vehicle information is discarded.
3. The management server, upon receiving location information of the 7.65s cycle (provisional) from the vehicle until the hazard is eliminated after the abnormal vehicle information is authenticated, determines whether the vehicle is within an area to which the hazard information is distributed, and transmits use case d-1-b information in response to the vehicle. If the vehicle is outside the target area for distributing hazard information, no response is sent to it.
4. When the validity of hazard termination is authenticated by the road administrator through detection of hazard elimination in the vehicle or confirmation of hazard elimination on the management server side, transmission of the distribution information d-1-b to the vehicle is stopped.

5.2.2 Use case d-2. Driving assistance by notification of wrong-way vehicles

5.2.2.1 Purpose of communication

Information about wrong-way driving vehicles on the road is transmitted to surrounding vehicles, prompting them to change lanes and evacuate to the shoulder as soon as possible.

5.2.2.2 Overview of communication

Information on the location and speed of the wrong-way driving vehicle and information on the presence of the wrong-way driving vehicle will be provided from the infrastructure to surrounding vehicles to assist in avoiding collisions by prompting them to change lanes in advance.

5.2.2.3 Detection of wrong-way driving vehicle

The detection of wrong-way driving vehicles is as follows.

(1) Automatically detected from the location information and driving lane of the wrong-way driving vehicle.

Depending on the case, detection by manual switch operation is also assumed.

(2) Detection of wrong-way driving vehicle by surrounding vehicles.

(3) Detection of wrong-way driving vehicle by roadside unit sensors.

The communication method to surrounding vehicles, communication area conditions, and communication delays are in accordance with Chapter 5.1.

5.2.2.4 Assumed communication scenario

The scenario for driving assistance by notification of a wrong-way driving vehicle is as follows. While the communication methods include V2I, V2N (unicast), and V2I (broadcast), V2N (unicast) is shown as an example.

Expected utilization of V2N

Unicast delivery

(1) Vehicles driving in the wrong direction and surrounding vehicles send hazard information to the management server via the network (base station) of the carrier wide area communication network, triggered by automatic wrong-way detection or manual switch operation.

(2) The management server judges the validity of the received hazard information, and if it determines that the vehicle is driving in the wrong direction, it determines the distribution area based on that information.

If the management server receives duplicate hazard information, it treats it as one hazard information.

(3) The management server periodically distributes hazard information to surrounding vehicles by unicast via the network (base station) of the carrier wide area communication network within the distribution target area.

(4) The surrounding vehicle receives the hazard information, reflects the main lane vehicle information on its dynamic map, and reviews its trajectory plan.

(5) After confirming the safety of the wrong-way driving vehicle and its surroundings, the road administrator stops the distribution of hazard information from the management server.

5.2.2.5 Message sequence and content

Expected utilization of V2N

The message sequence to provide wrong-way driving vehicle information in use case d-2 is as shown in the figure below.

Unicast method

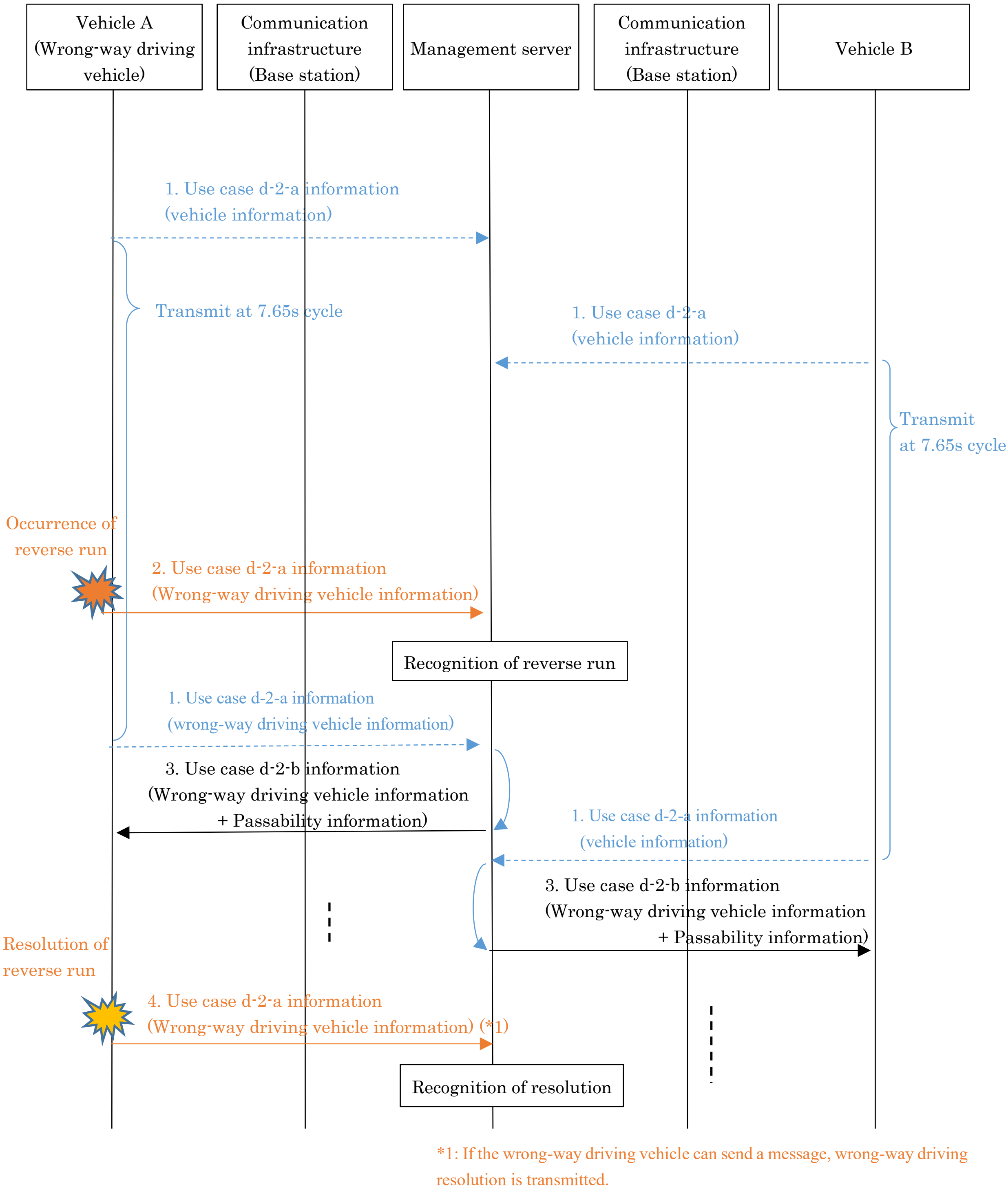

Figure 5.2.2.5-1 Message sequence assumed in use case d-2 (V2N, unicast).

1. The vehicle periodically sends d-2-a information (vehicle information: vehicle ID + time of occurrence + speed + latitude/longitude/altitude) including its own location information to the management server.
2. The vehicle immediately sends use case d-2-a information to the management server upon automatic hazard detection or manual switch operation.

   The management server makes the following determinations with respect to the provided wrong-way driving vehicle information.

   - The validity of the wrong-way driving vehicle information provided is authenticated by a road administrator or the like.
   - Whether the wrong-way driving vehicle information already provided is overlapped is determined, and if the wrong-way driving vehicle information is overlapped, the wrong-way driving vehicle information issued later is discarded.
3. The management server, upon receiving the provision of vehicle information or wrong-way driving vehicle information of 7.65s cycle (provisional) from the vehicle until the hazard is eliminated after the wrong-way driving vehicle information is authenticated, determines whether the information is within an object area to which the hazard information is distributed, and transmits use case d-2-b information in response to the vehicle. If it is outside the target area for distributing hazard information, no response is sent to the vehicle.
4. If the validity of the hazard elimination is authenticated by the road administrator through detection of hazard elimination on the vehicle or confirmation of hazard elimination on the management server side, distribution of information d-2-b to the vehicle will be stopped.

5.2.3 Use case d-3. Driving assistance based on traffic congestion information

5.2.3.1 Purpose of communication

Driving assistance by distributing traffic jam information for trajectory plan change, speed adjustment, stopping operation

5.2.3.2 Overview of communication

Vehicle information (location information and speed information) measured by the vehicle is transmitted to the road administrator via the carrier wide area network (base station) or roadside infrastructure. The traffic congestion presence/absence information determined by the road manager is notified to the base station or the roadside infrastructure of the carrier wide area communication network, and notified to the vehicle by broadcast or unicast from the network (base station) of the carrier wide area communication network and broadcast from the roadside infrastructure respectively.

5.2.3.3 Transmitting method of traffic jam information

The vehicle periodically transmits vehicle information (time, location information, speed information) to the management server from the time the engine is started until the vehicle stops.

When vehicle information is received from a vehicle, the management server determines an area to distribute congestion information and periodically provides congestion information to the surrounding vehicle until the congestion ends in such a manner that it can perform an early lane change or a trajectory plan change.

While the communication methods include V2I, V2N (unicast), and V2I (broadcast), an image of the communication method is shown below using V2N (unicast) as an example.

Expected utilization of V2N

(a) Uplink side

If the vehicle is within the communication area of the carrier wide area network, the vehicle transmits vehicle information to the management server via the network (base station).

(b) Downlink side

(i) Unicast method

The management server identifies vehicles within the area to which traffic congestion information is to be distributed, and unicasts traffic congestion information to surrounding vehicles via the network (base station) of the carrier wide area network.

It will be delivered periodically every 7.65s (provisional) until the congestion is resolved.

5.2.3.4 Assumed communication scenario

d-3 Scenario for driving assistance based on traffic congestion information is as follows.

Assumed use of V2N - Unicast distribution.

(1) The vehicle periodically transmits vehicle information (time, position information, speed information) to the management server via the carrier wide area network (base station) from the engine start to engine stop.

(2) The management server determines the occurrence/elimination of congestion and determines the distribution area based on vehicle information received from the vehicle.
If the management server receives duplicate vehicle information, it treats it as one of vehicle information.

(3) The management server identifies a vehicle in the area to which the congestion information is to be distributed, and periodically distributes the congestion information by unicast to the surrounding vehicles via a network (base station) of the carrier wide area communication network in the distribution target area.

(4) The surrounding vehicle receives the traffic congestion information, reflects the main lane vehicle information on its dynamic map, and reviews its trajectory plan.

(5) After confirming that the congestion has been resolved, the road administrator stops the distribution of traffic congestion information from the management server.

5.2.3.5 Message sequence and content

The message sequence to provide congestion information in use case d-3 is as shown in the figure below.

Expected utilization of V2N

Unicast method

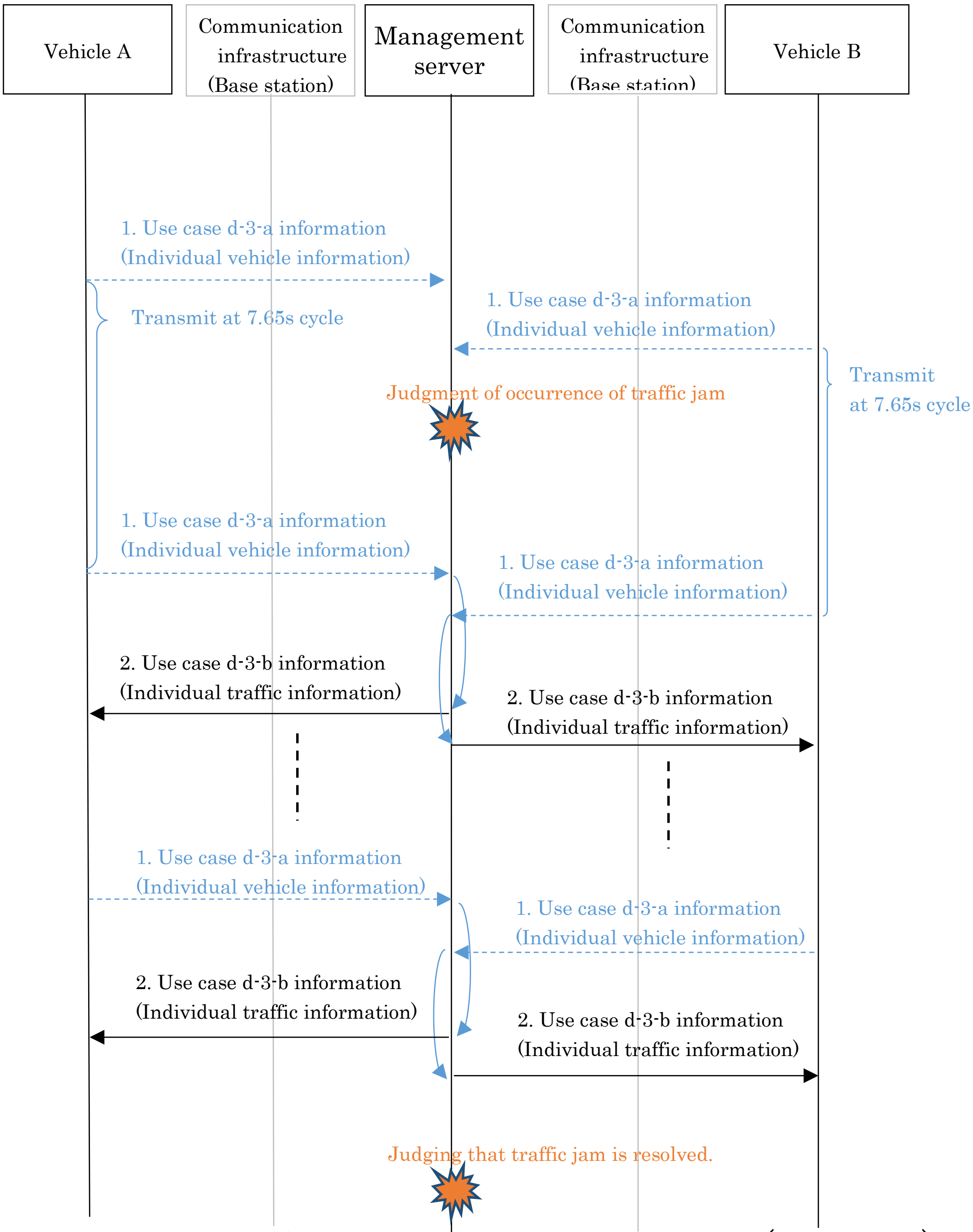

Figure 5.2.3.5-1 Message sequence assumed in use case d-3 (V2N, unicast).

1. When the vehicle is within a communication area of a carrier wide area communication network during a period from engine start to stop, use case d-3-a information is provided in a 7.65s cycle (provisional).
2. Based on the use case d-3-a information, the management server judges the occurrence and resolution of traffic congestion, determines the area to distribute the information and sends the use case d-3-b information to vehicles in the target area in a cycle of 7.65 seconds (provisional). Note that the target surrounding vehicle is identified by management server and the information is sent to it via dedicated communication.

5.2.4 Use case d-4. Traffic congestion assistance at branches and exits

5.2.4.1 Purpose of communication

Driving assistance by the notification of road shoulder congestion information for the trajectory plan of the main lane vehicle.

5.2.4.2 Overview of communication

The information on the road-shoulder congestion (location and speed) is provided from the infrastructure to the main lane vehicle, and assistance for entry into the branch is provided.

5.2.4.3 Judgment of branch/exit congestion

- Assuming that roadside infrastructure (branch) is installed at branch/exit.
  (If not installed, carrier wide area network is used.)
- Based on the vehicle information (time and location information) periodically transmitted from a vehicle and area information of a branch/exit, the management server determines that a traffic jam has occurred.
  ※ It is assumed that the vehicle periodically transmits vehicle information (time and location information) to the management server from the engine start to the engine stop. Based on the information, the management server judges the occurrence/resolution of traffic congestion.

5.2.4.4 Distribution of branch/exit traffic congestion information (V2I, V2N)

The management server performs the following processes for information distribution.

- Judge occurrence and resolution of traffic congestion
- Determine the distribution method based on the information on the area to be distributed (distribution target area), the communication area of the surrounding roadside infrastructure and the location of the vehicle (see next page).

(1) Delivery to areas covered by roadside infrastructure

Broadcast to each vehicle via roadside infrastructure.

(2) Delivery to areas not covered by roadside infrastructure

Unicast delivery to each vehicle within the notification area based on the location information of the vehicle through the carrier wide area network

.

5.2.4.6 Assumed communication scenario

Scenarios assumed for branch/exit congestion assistance are as follows. While the communication methods include V2I, V2N (unicast), and V2I (broadcast), V2N (unicast) is shown as an example.

Expected utilization of V2N

Unicast delivery

① The vehicle transmits vehicle information to the management server through the carrier wide area network.

② The management server monitors traffic conditions in branch/exit areas based on the received vehicle information. When it is determined that traffic congestion has occurred, the vehicle in the distribution target area is identified based on the location information, and branch/exit congestion information is notified (unicast).

③ Each vehicle that receives branch/exit congestion information reflects the information on its dynamic map and reviews its trajectory plan.

④ When the management server judges that the congestion has been resolved based on the vehicle information sent from each vehicle, it stops delivering the congestion information notification.

5.2.4.7 Message sequence and content

The message sequence to provide traffic congestion information in use case d-4 is shown in the figure below.

Communication sequence (V2N) delivered to main lane vehicles via the management server.

(a) Unicast method

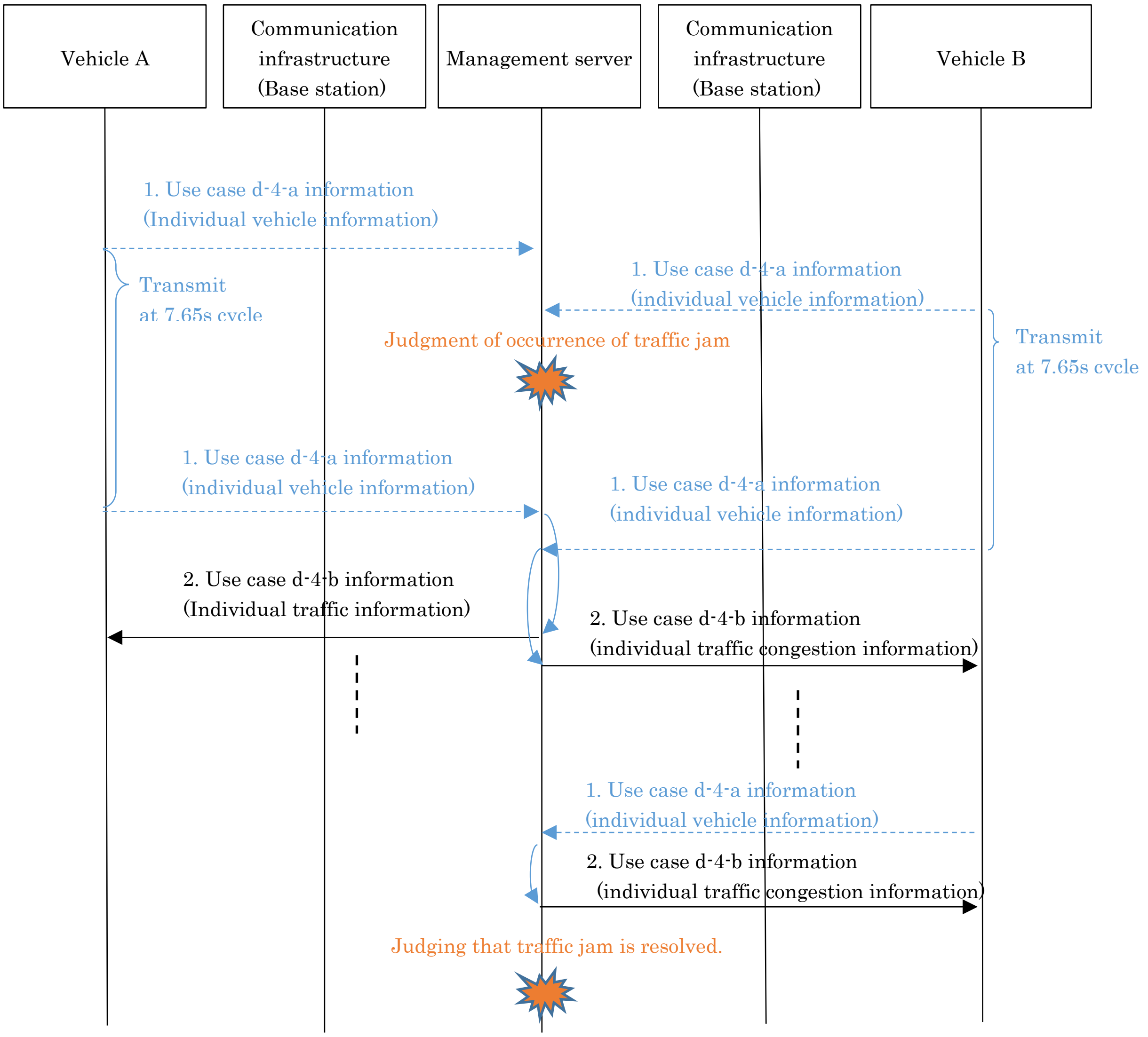

Figure 5.2.4.7-1 Message sequence assumed in use case d-4 (V2N, unicast).

1. When the vehicle is within the communication area of the carrier wide area network from the time the engine is started until it stops, use case d-4-a information is provided at a cycle of 7.65 s (provisional).
2. Based on the use case d-4-a information, the management server judges the occurrence and resolution of traffic congestion, determines the area to distribute the information and sends the use case d-4-b information to vehicles in the target area in a cycle of 7.65 seconds (provisional). Note that the target surrounding vehicle is identified by management server and the information is sent to it via dedicated communication.

5.2.5 Use case d-5. Driving assistance based on hazard information

5.2.5.1 Purpose of communication

Driving Assistance based on hazard information

5.2.5.2 Overview of communication

The information on obstacles, construction work, traffic jams, etc., is provided from the infrastructure to surrounding vehicles, and assistance for driving is provided.

5.2.5.3 Hazard information delivery method

The management server determines an area to distribute hazard information and periodically provides from the point of occurrence of the hazard to surrounding vehicles requiring the service with the hazard information obtained and determined by the road operator as necessary for smooth traffic until the hazard is resolved [*1] such that the surrounding vehicles can perform early lane changes and trajectory plan changes.

※1: It is assumed that after the road administrator confirms the safety of the abnormal vehicle and the surrounding area, it will be notified of the resolution by cooperating with the management server by some means.

While the communication methods include V2I, V2N (unicast), and V2I (broadcast), an image of the communication method is shown below using V2N (unicast) as an example.

Expected utilization of V2N

(a) Unicast method

The management server identifies vehicles within the area to which hazard information is to be distributed, and unicasts hazard information to surrounding vehicles via the network (base station) of the carrier wide area network.

It will be delivered periodically every 7.65s (provisional) until the hazard of the abnormal vehicle is resolved.

5.2.5.4 Assumed communication scenario

Scenarios assumed for driving assistance using hazard information are as follows.

Expected utilization of V2N

Unicast delivery

(1) The management server determines the distribution area based on the hazard information registered in the management server.

If the management server receives duplicate hazard information, it treats it as one hazard information.

(2) The management server identifies a vehicle in the area to which the hazard information is to be distributed and periodically distributes the hazard information to the surrounding vehicle by unicast via a network (base station) of a carrier wide area communication network in the distribution target area.

(3) The surrounding vehicle receives the hazard information, reflects the main lane vehicle information on its dynamic map, and reviews its trajectory plan.

(4) After confirming the safety of the abnormal vehicle and its surroundings, the road administrator stops the distribution of hazard information from the management server.

5.2.5.5 Message sequence and content

The message sequence to provide hazard information in use case d-5 is as shown in the figure below.

Expected utilization of V2N Unicast method

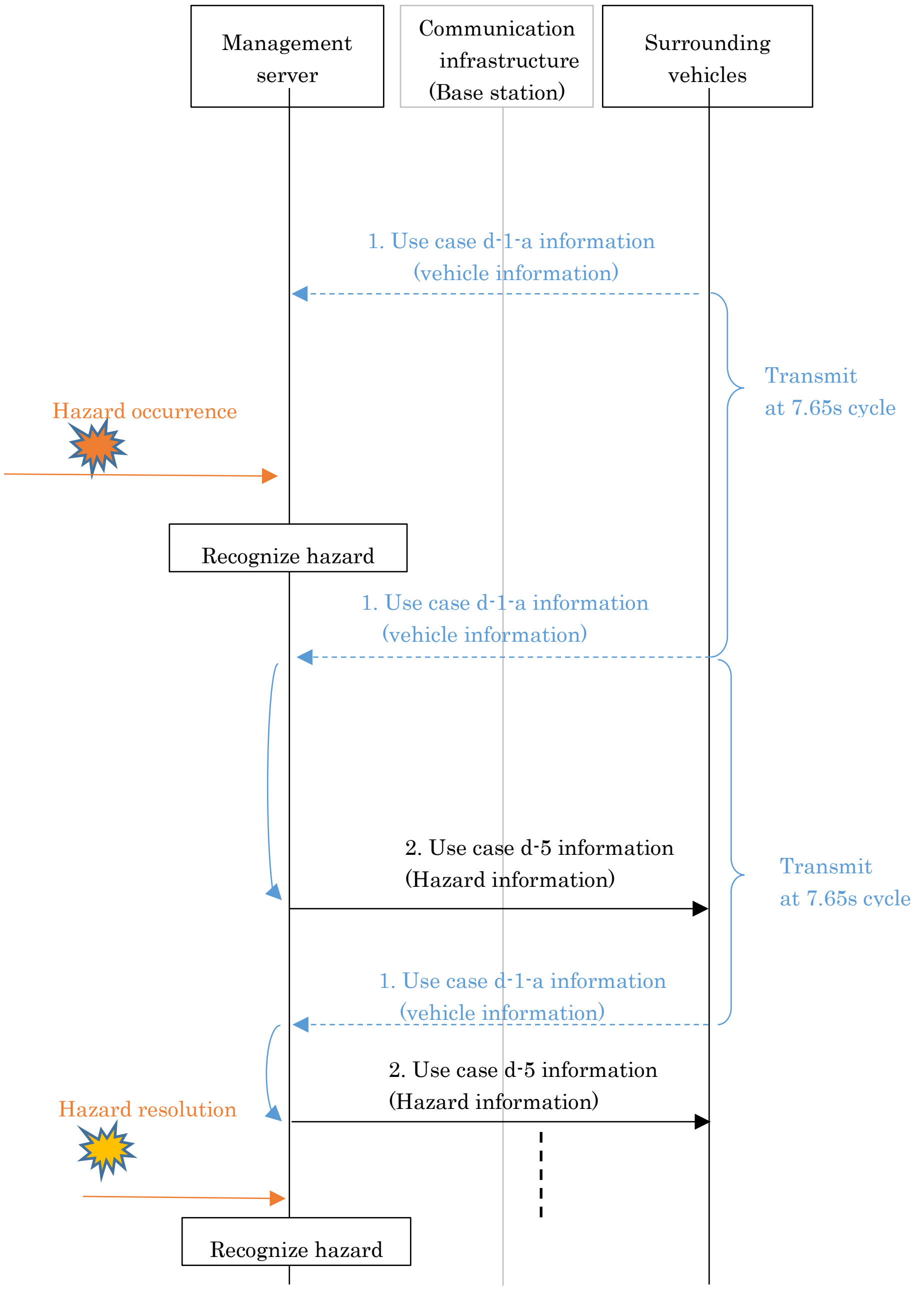

Figure 5.2.5.5-1 Message sequence assumed in use case d-5 (V2N, unicast).

1. The vehicle periodically transmits d-1-a information including its own location information to the management server.

2. When hazard information that needs to be distributed is registered, the management server determines an area to be distributed and transmits use case d-5 information to a vehicle in the area to be distributed in a 7.65s period (provisional). Note that the target surrounding vehicle is identified by management server and the information is sent to it via dedicated communication.

Chapter 6. e. Lookahead information: emergency vehicle notification use case

6.1 Prerequisites

The prerequisites for this chapter are the same as in Section 5.1.1.

6.2 Lookahead information: Emergency vehicle avoidance use case

6.2.1 Use case e-1. Driving assistance based on emergency vehicle information

6.2.1.1 Purpose of communication

Driving assistance based on emergency vehicle information

6.2.1.2 Overview of communication

To Assistance the smooth passage of the emergency vehicle, information on its direction, speed, and planned trajectory (planned driving lane) is provided to surrounding vehicles to encourage them to slow down or stop.

6.2.1.5 Distribution of emergency vehicle approaching information

Emergency vehicles deliver information in 2 ways.

(1) Delivery by direct communication (V2V)
(2) Delivery by carrier wide area network (V2N)

Each delivery is described below.

(1) Delivery by direct communication (V2V)

Until the emergency vehicle arrives at its destination, it delivers information on the approach of the emergency vehicle to surrounding vehicles via V2V at 100 ms intervals.

Delivery by carrier wide area network (V2N)

While the communication methods include V2N (unicast), and V2I (broadcast), an image of the communication method is shown below using V2N (unicast) as an example.

The management server identifies a vehicle in an area to which the emergency vehicle approach information is to be distributed, and unicast-distributes the emergency vehicle approach information to a surrounding vehicle via a network (base station) of a carrier wide area communication network.

Emergency vehicle periodically delivers every 7.65s (provisional) until it arrive at their destination.

6.2.1.8 Assumed communication scenario

Scenarios for driving assistance by notification of emergency vehicles are as follows.

(1) Delivery via direct communication (V2V)

① The emergency vehicle broadcasts emergency vehicle approaching information including location information of 30s later.

② The surrounding vehicle which has received the emergency vehicle approaching information reflects the vehicle information on its dynamic map and reviews its trajectory plan.

③ After the emergency vehicle reaches its destination, it stops delivering emergency vehicle approaching information.

(2) Expected utilization of V2N: Emergency vehicle → Base station → Management server → Base station → Surrounding vehicle

① The emergency vehicle transmits emergency vehicle approaching information including the point information of 30s later to the management server via the network (base station) of the carrier wide area communication network.

② The management server determines the distribution area based on the emergency vehicle approaching information received from the emergency vehicle.

③ The management server identifies the vehicle in the distribution area for the emergency vehicle approaching information, and transmits the emergency vehicle approach information to the surrounding vehicle by unicast via the network (base station) of the carrier wide area communication network in the distribution area.

④ The surrounding vehicles receive the emergency vehicle approaching information, reflect the main lane vehicle information on their dynamic map, and review their trajectory plans.

⑤ After the emergency vehicle reaches its destination, it stops delivering emergency vehicle approaching information.

6.2.1.9 Message sequence and content

(1) V2V

The message sequence to provide emergency vehicle approach information in use case e-1 (V2V) is as shown in the figure below.

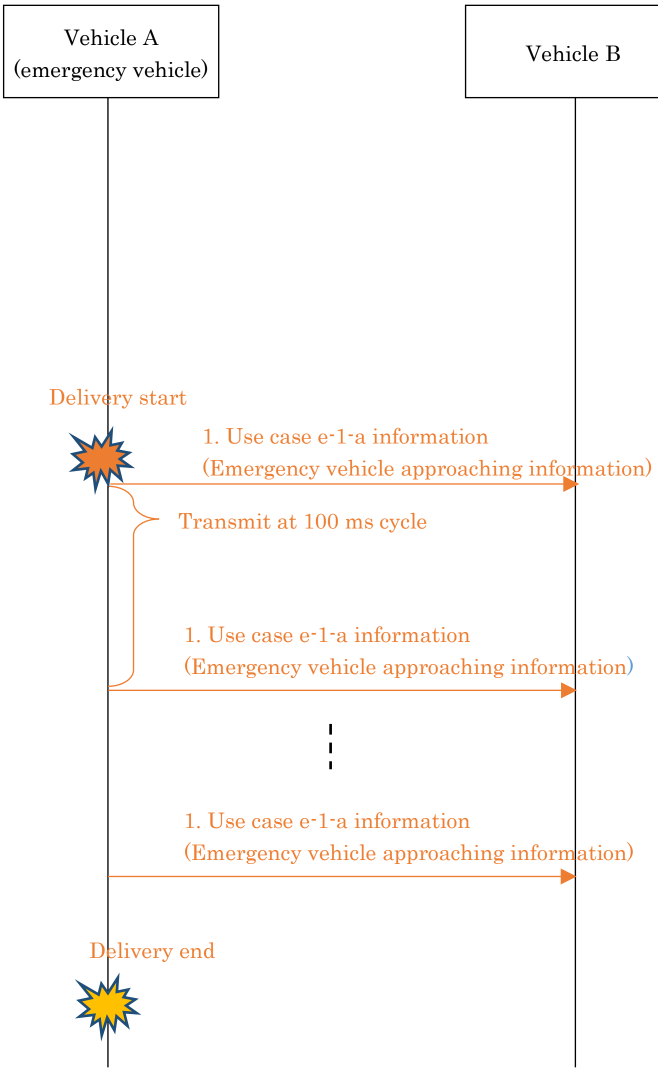

Figure 6.2.1.9-1 Message sequence assumed in use case e-1 (V2V).

1. While it is necessary to transmit emergency vehicle approaching information, the emergency vehicle distributes use case e-1-a information by broadcast in the 100 ms cycle during the period when an abnormal vehicle has occurred or ended.
   When the emergency vehicle reaches its destination, it stops delivering use case e-1-a information (emergency vehicle approaching information).

(2) V2N:

Unicast

The message sequence to provide emergency vehicle approach information in method use case e-1 (V2N) is as shown in the figure below.

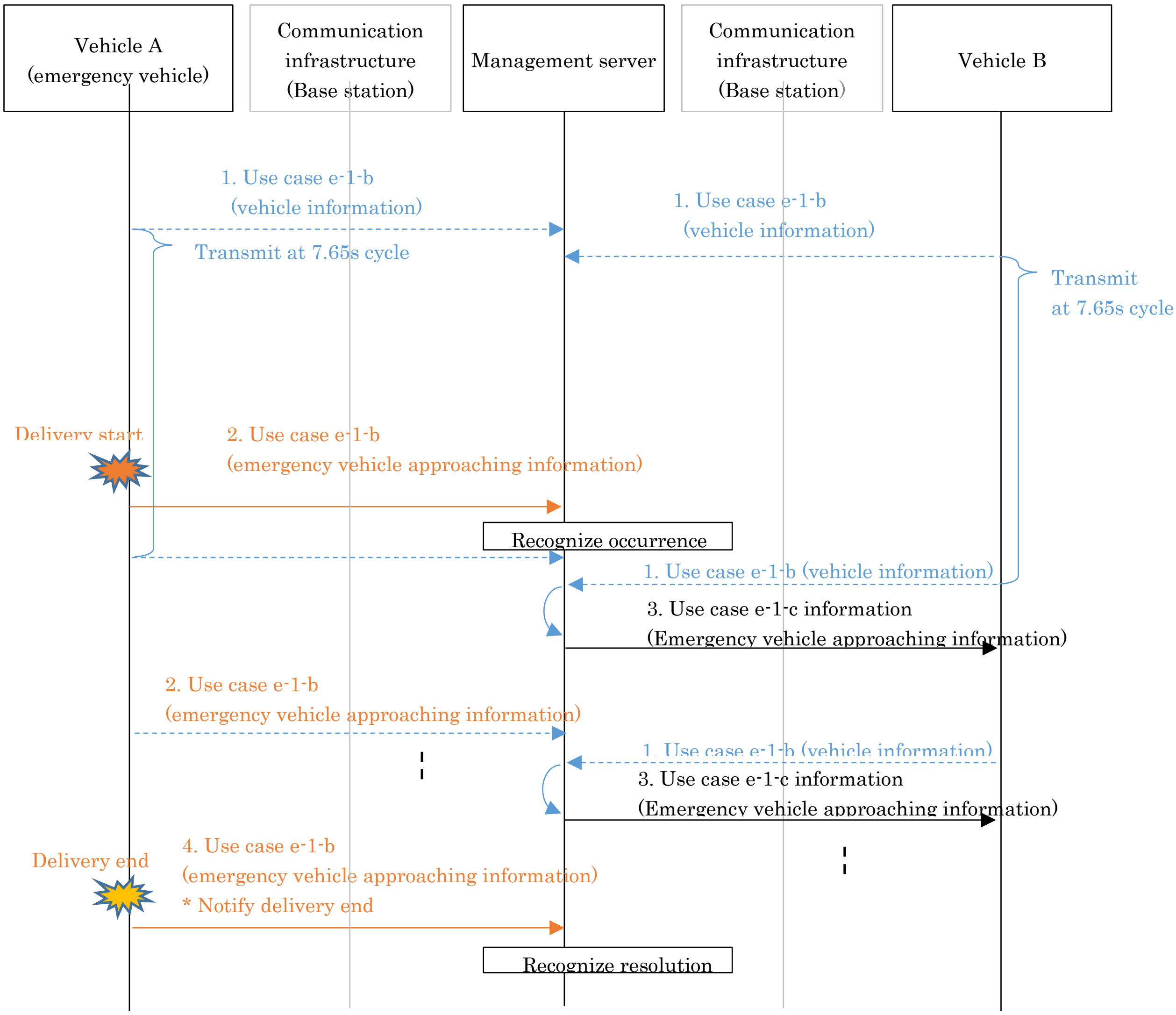

Figure 6.2.1.9-2 Message sequence assumed in use case e-1 (V2N).

1. When the vehicle is within the communication area of the carrier wide area network, the vehicle transmits the e-1-b information to the management server at a cycle of 7.65 s (provisional). Note that the management server does not respond to the vehicle when there is no emergency vehicle approaching information to be notified.
2. If the emergency vehicle is within the communication area of the carrier wide area network when distribution of the emergency vehicle approaching information is started,

the use case e-1-b information (emergency vehicle approaching information) is sent once to the management server. After that, use case e-1-b information (emergency vehicle approaching information) is sent to the management server at the next 7.65s cycle.

3. Based on the use case e-1-b information, the management server determines the occurrence of an emergency vehicle, determines the area to be distributed, and distributes the use case e-1-c information (emergency vehicle approaching information) to vehicles within the target area as a response. Note that the target surrounding vehicle is identified by management server and the information is sent to it via dedicated communication.
4. If the emergency vehicle is within the communication area of the carrier wide area network when the delivery of the emergency vehicle approaching information is stopped, the emergency vehicle once transmits the use case e-1-b information (vehicle information) to the management server.

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Chapter 7. f. Information collection and distribution by infrastructure use case

7.2 f. Use cases for information collection and distribution by infrastructure

7.2.1 Use case f-1. Request for rescue (e-Call)

7.2.1.1 Purpose of communication

Rescue request from an abnormal vehicle such as an accident vehicle.

7.2.1.2 Overview of communication

An abnormal vehicle such as an accident vehicle sends a request for assistance automatically or manually by the vehicle occupant to a rescue service provider with events, location information, etc., to request assistance. After message communication is completed between the abnormal vehicle and the rescue service provider, further details are collected by voice communication and utilized for rescue.

7.2.1.3 Transmitting method of rescue request

When an abnormality occurs in the vehicle, the abnormal vehicle transmits the rescue information to the rescue service provider by automatic abnormality detection or switch operation by the vehicle occupants. It periodically sends a rescue request until a response is received from the rescue service provider.

When a rescue service provider receives a rescue request from an abnormal vehicle, the rescue service provider grasps the information (time, position, traveling direction, etc.) included in the rescue request and transmits a response message to the abnormal vehicle. After sending a response message, the vehicle operator communicates with an abnormal vehicle occupant by voice and hears the detailed situation (whether the vehicle is in an accident or an abnormality, etc.).

The carrier wide area network (V2N) is used for the transmission of the rescue request from the abnormal vehicle to the rescue service provider and the subsequent voice communication means (uplink side) from the vehicle passenger to the rescue service provider.

The carrier wide area network (V2N) is used also for the transmission of the response from the rescue service provider to the abnormal vehicle and the subsequent voice communication means (downlink side) from the rescue service provider to the passenger of the vehicle.

The V2N communication method is shown in (1) below.

(1) V2N

(a) Uplink side

The abnormal vehicle transmits a rescue request message to the rescue service provider via the network (base station) within the communication area of the carrier wide area network.

Moreover, the voice of the direction of the rescue service provider from the abnormal vehicle (occupant) in the voice speech after receiving the response from the rescue service provider is also transmitted to the rescue service provider via the network (base station).

(b) Downlink side

When the rescue service provider receives the rescue request message from the abnormal vehicle, it transmits a response to the abnormal vehicle via the network (base station).

Moreover, in a voice call after reaching the responding abnormal vehicle, the voice in the direction of the abnormal vehicle (occupant) from the rescue service provider is also transmitted to the abnormal vehicle via the network (base station).

7.2.1.7 Assumed communication scenario

The scenario for a rescue request by notification of an abnormal vehicle is as follows.

1. Upon automatic abnormality detection such as sudden deceleration exceeding a specified threshold or switch operation by the vehicle occupants, an abnormal vehicle transmits a rescue request message to a server of a rescue service provider in which use case f-1 information (common information + abnormal vehicle information) to be notified to the rescue service provider is set.

   Note that the message is periodically transmitted to the infrastructure (base station) until the response message is received within a predetermined time.
2. The rescue service provider having received the rescue request message from the abnormal vehicle transmits a rescue request response message indicating that the rescue request message has been received to the abnormal vehicle.
3. When the abnormal vehicle having received the rescue request response message from the server of the rescue service provider notifies the rescue service provider of all the information, the transmission of the message is terminated, the voice call with the rescue service provider is started, and the communication is terminated at the end of the voice call. If there is information to be notified to the rescue service provider yet, a rescue request message for which the information is set is transmitted to the server of the rescue service provider. After that, repeat 1–2 until all information is sent to the rescue service provider's server.

4. When the voice call ends, the rescue service provider operates the device and sends a communication termination message from the server to the abnormal vehicle.
5. The abnormal vehicle having received the communication termination message from the server of the rescue service provider transmits the communication termination response message to the server of the rescue service provider.
6. Upon receiving the communication termination response message from the abnormal vehicle, the rescue service provider's server terminates all communications.

7.2.1.8 Message sequence

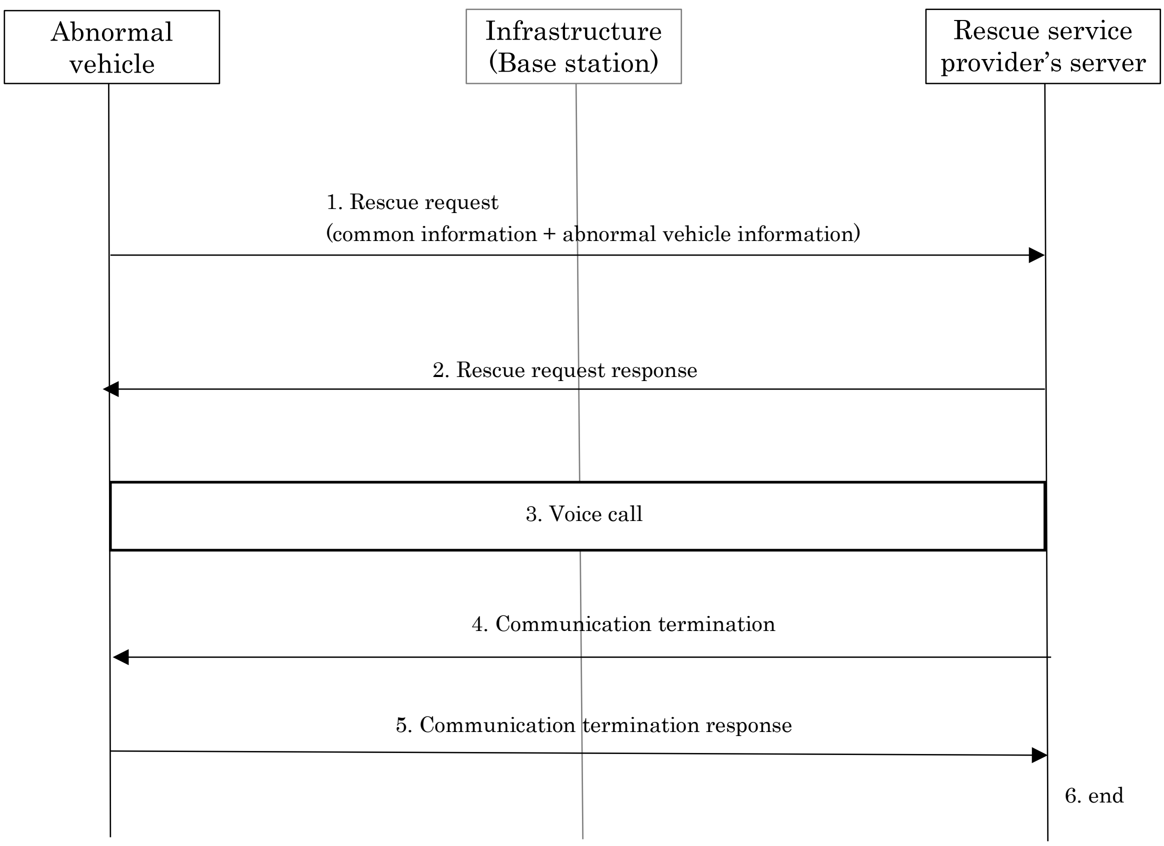

Figure 7.2.1.8-1 Use case f-1 Message sequence

7.2.2 Use case f-2. Collection of information to optimize the traffic flow

7.2.2.1 Purpose of communication

Optimizing traffic flow based on vehicle information sent from automated driving vehicle.

7.2.2.2 Overview of communication

A message, in which data on the location and speed of a driving vehicle is added, is transmitted from an automated driving vehicle to an automobile manufacturer, a traffic information provider, etc., via a public communication network or a roadside infrastructure, and is collected for analyzing and optimizing the amount of traffic.

7.2.2.3 Transmitting method of vehicle information

The following three types of triggers are used to collect information from automated driving vehicles. They process independently without interfering with each other.

- Collecting information around intersections
- Collecting information when a predetermined event related to vehicle operation occurs (such as sudden deceleration exceeding a specified threshold)
- Collecting information at regular intervals that does not depend on driving area or vehicle movement

In addition, the communication methods used for information collection for each trigger are as follows.

- Collecting information around intersections

  Send messages from automated driving vehicle to automobile manufacturers, traffic information providers, etc., via roadside infrastructure (V2I).
- Collecting information when a predetermined event related to vehicle operation occurs (such as sudden deceleration exceeding a specified threshold)
- Collecting information at regular intervals that does not depend on driving area or vehicle movement

  Send messages from automated driving vehicle to automobile manufacturer, traffic information provider, etc., via carrier wide area communication network (V2N).

As communication methods, V2I and V2N are possible. V2N is explained as an example.

Method of distribution via carrier wide area network (V2N)

The automated driving vehicle starts communication when it detects that a predetermined event (such as sudden deceleration exceeding a specified threshold) has occurred, or when a fixed period (60 seconds) has passed.

The automated driving vehicle transmits vehicle information (time, vehicle location, vehicle status, etc.) to servers of automobile manufacturers, traffic information providers, etc., via public networks during communication.

(c) Assumed communication scenario (V2N)

・ Event trigger (such as sudden deceleration exceeding a specified threshold)

The scenario assumed for information collection (V2N) (activation by a predetermined event) for optimizing traffic flow is as follows.

1. Each time the automated driving vehicle detects that a predetermined event (such as sudden deceleration exceeding a specified threshold) has occurred, the automated driving vehicle transmits a message, in which data (time, vehicle location, lane, vehicle speed, rapid acceleration/deceleration value, etc.) to be notified to an automobile manufacturer, traffic information provider, etc., to the server of the automobile manufacturer, traffic information provider, etc.
2. If there is still data to be notified to the automobile manufacturer, traffic information provider, etc., the automated driving vehicle sends a message containing the data to be notified to the server of the automobile manufacturer, traffic information provider, etc. After that, step 1 is repeated until all data is sent to the server of the automobile manufacturer, traffic information provider, etc.

・ Periodic trigger

1. The automated driving vehicle transmits a message, in which data (time, vehicle location, lane, vehicle speed, rapid acceleration/deceleration value, etc.) to be notified to an automobile manufacturer, traffic information provider, etc., at regular intervals to a server of the automobile manufacturer, the traffic information provider, etc.

(d) Message sequence (V2N)

- Event trigger (such as sudden deceleration exceeding a specified threshold)

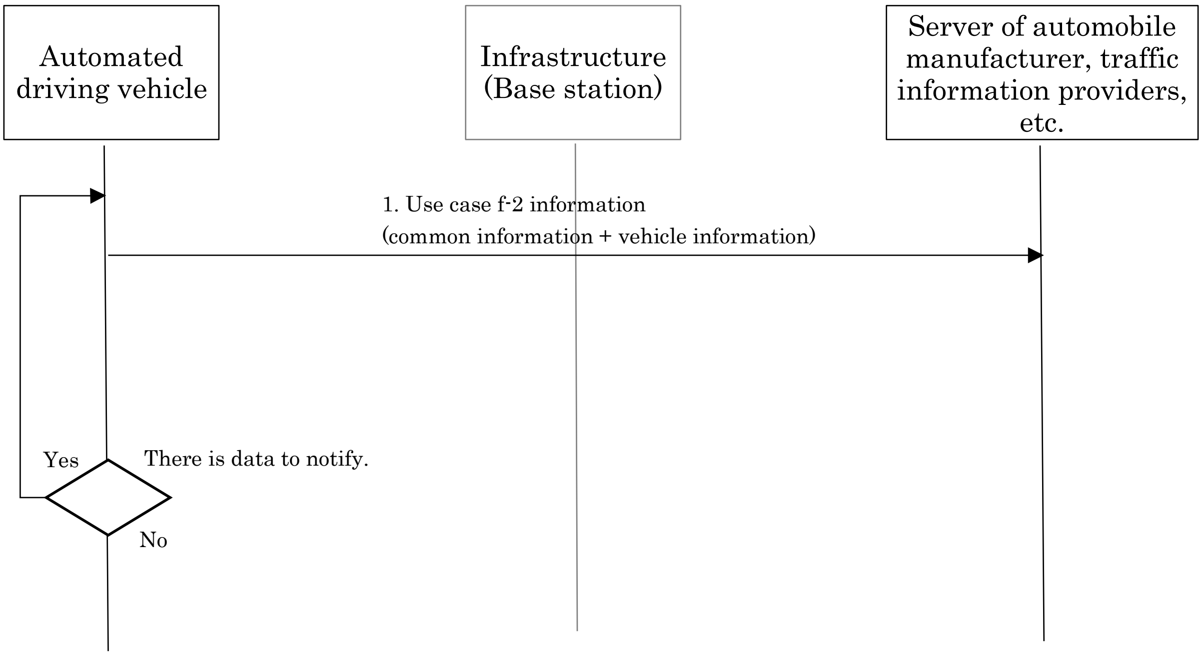

Figure 7.2.2.3-5 Use case f-2. (V2N) Message sequence (event trigger)

- Periodic trigger

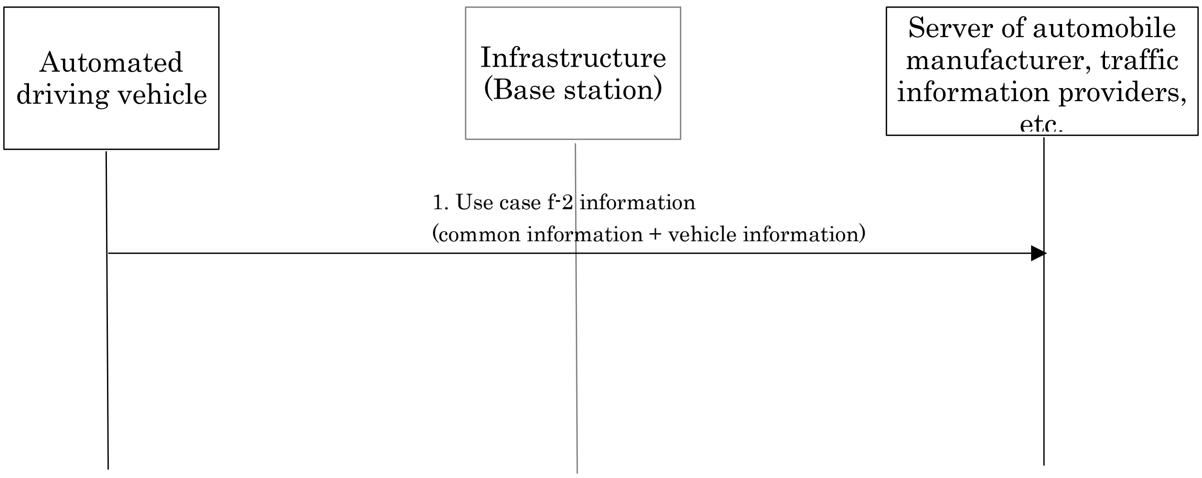

Figure 7.2.2.3-6 Use case f-2. (V2N) Message sequence (periodic trigger)

7.2.3 Use case f-3. Update and automatic generation of maps

7.2.3.1 Purpose of communication

Provision of map information collected by vehicles to automobile manufacturers and map information providers.

7.2.3.2 Overview of communication

When a change point is detected in the collected detection target information and the stored map information while the vehicle is running, the map information (change point information) is transmitted from the vehicle to the automobile manufacturer and the map information provider.

7.2.3.3 Method for sending map information (information on changes)

When a vehicle detects a change point between its map information and information to be detected and collected while driving, the vehicle immediately transmits the map information related to the change point to a data collection center (hereinafter referred to as a data collection center) of an automobile manufacturer or a map information provider via infrastructure (base station). When the data collection center receives the map information from the vehicle, it stores it and sends a response to the vehicle.

A carrier wide area communication network (V2N) is used for transmitting map information from the vehicle to the data collection center (uplink side).

The carrier wide area communication network (V2N) is also use for transmitting the response from the data collection center to the vehicle (downlink side).

The V2N communication method is shown in (1) below.

(1) V2N

(a) Uplink side

The vehicle transmits map information to an automobile manufacturer or a map information provider via a network (base station) within a communication area of a carrier wide area communication network.

(b) Downlink side

When map information from a vehicle is received, the data collection center transmits a response to the vehicle via a network (base station).

7.2.3.8 Message sequence

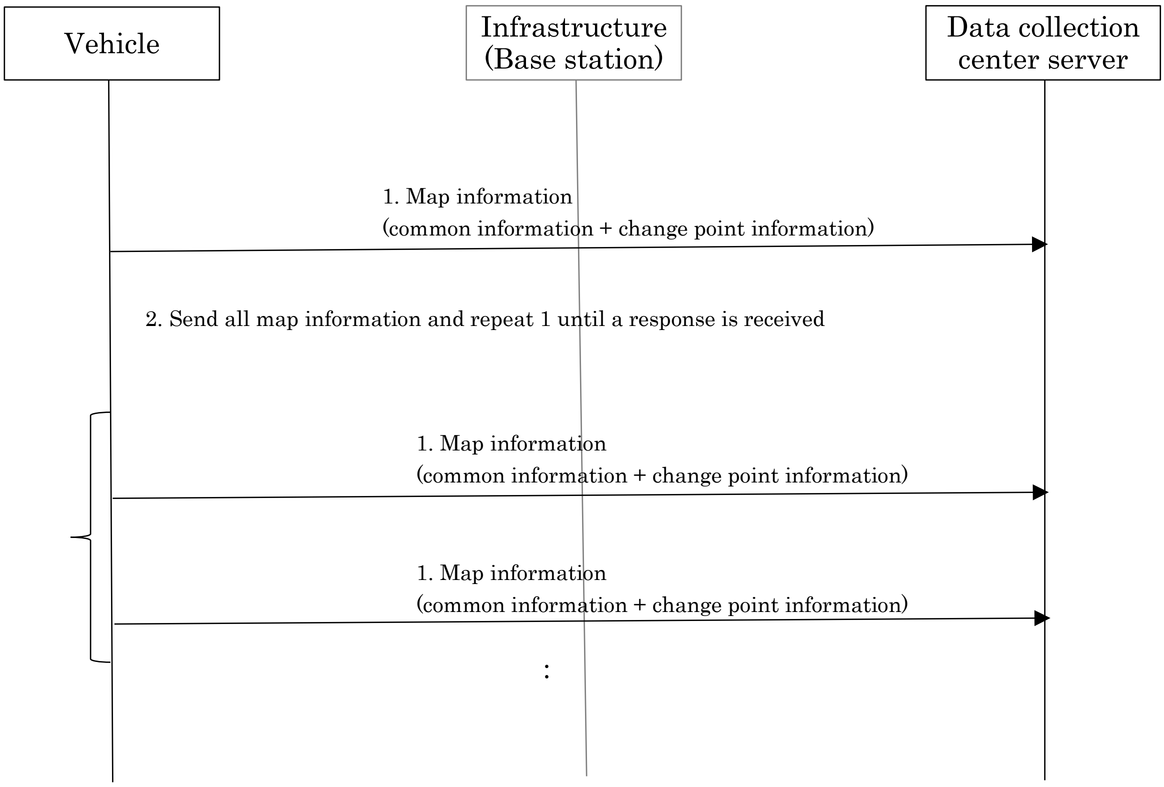

Figure 7.2.3.8-1 Use case f-3 message sequence

7.2.4 Use case f-4. Distribution of dynamic map information

7.2.4.1 Purpose of communication

Provides dynamic map information from the infrastructure to the vehicle.

7.2.4.2 Overview of communication

In this section, dynamic map information distribution focuses on the update of difference on static information of map due to changes in terrain, etc. (dynamic information of map will be considered by other use cases). While the automated driving vehicle is driving, the static information of the map on the driving target route is updated by Push or Pull type communication. The data to be distributed includes information on both the competitive area and the cooperative area, and is distributed per automobile manufacturer and per vehicle type or system. Therefore, at least for now, it is assumed that the distribution will be performed by unicast communication.

7.2.4.8 Assumed communication scenario

In this communication scenario, for simplification, the communication requirements are investigated for the form of prefetching map tiles in a rectangular area of W km × D km, which is L km ahead. Here, L is set based on design values such as fluctuations in communication speed, map prefetch hit rate, map distribution waiting time before starting driving, etc., and is not specifically defined in this document. W and D are set based on design values such as reroute probability, map prefetch hit rate, etc., by setting the area to a certain size or more, it is possible to avoid reroute NG judgments due to map updates not being done in time. In the following, from the viewpoint of ensuring a certain degree of freedom in route decision, the communication requirements will be considered by assuming W and L for expressways and local roads that allow reroute decision up to 60 seconds before the route change point.

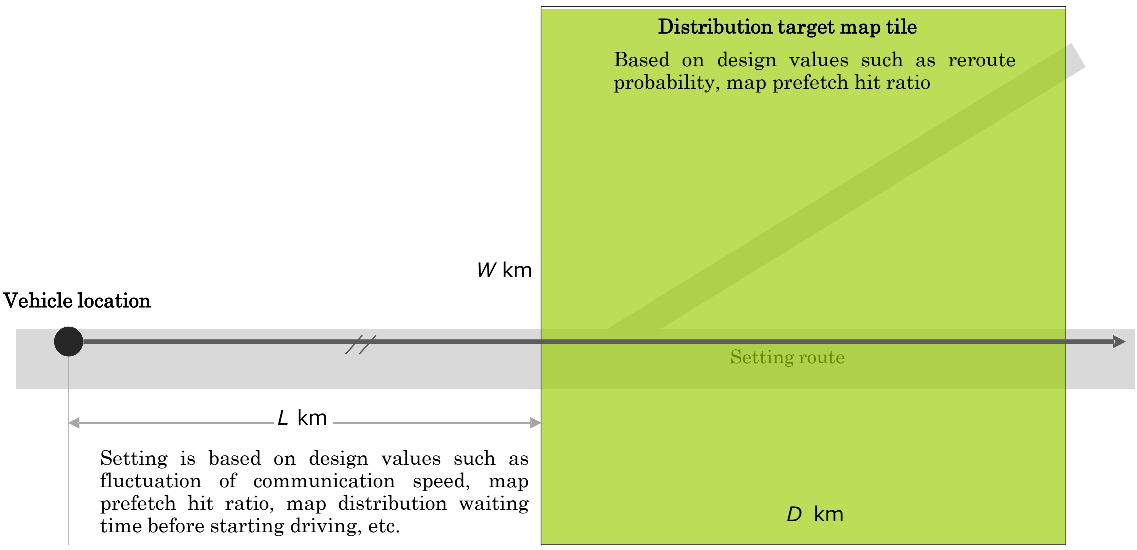

Figure 7.2.4.8-1 Dynamic map information distribution model

7.2.4.9 Message sequence

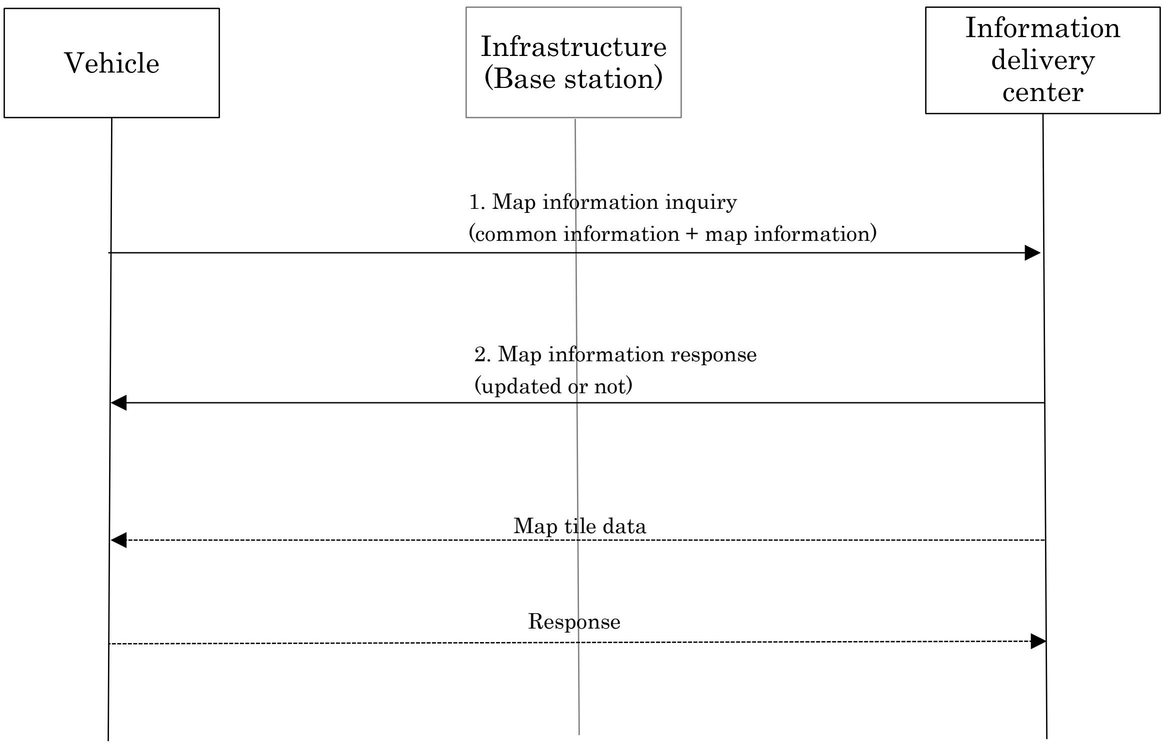

Figure 7.2.4.9-1 Use case f-4 message sequence

Chapter 8. g. Use cases for Platooning/adaptive cruise control

8.3 Platooning use case

8.3.1 Use case g-1. Unmanned platooning of following vehicles by electronic towbar

In use case g-1, for assistances platooning (electronic towbar), operation information of platoon vehicles will be communicated among trucks forming a platoon. It is assumed that the following vehicle is unmanned, and a mix of manned and unmanned is not considered.

8.3.1.1 Assumed communication scenario

① When planning the drive

The following are to be determined in advance. (Not covered by communication)

- Vehicle for platoon formation
- Location of platoon formation

② During operation

- Form a platoon with all vehicles stopped in a straight line. The platoon is started by starting communication from the leading vehicle.
- The distance between vehicles is 5 m at low speed and 10 m at maximum. (Maximum platoon length of 60 m with 3 vehicles)
- All vehicles continuously communicate while driving. The communication may be 1:1 communication or may use broadcast communication to virtually perform the 1:1 communication by the application.
- Communication while driving consists of non-rich content (accelerator, brake, steering operation, following vehicle information, location, speed, inter-vehicle distance, acceleration/deceleration) and rich content (video transmission from second vehicle to the leading vehicle using electronic mirrors) as separate messages. Transmission of a non-rich content is prioritized over a rich content.
- The non-rich contents are periodically transmitted at 100 ms to the other vehicles. The communication reliability is 98%, and in emergencies, it sends five consecutive transmissions in a 20 ms cycle.
- If necessitated by the system, communication is performed by the multiplex manner.
- The rich content is transmitted by a periodicity and a data amount required for video transmission.

- The platoon is released when the vehicles are stopped in a straight line. (No releasing via communication while driving)
- If communication is interrupted, it will be treated as an abnormality that makes it difficult to maintain the platooning state, and the following vehicles will decelerate and stop with the hazard lights on.

8.3.1.4 Message sequence

- Normal case

Each vehicle sends non-rich content such as acceleration and braking to other vehicles at 100 ms intervals.

Images from the electronic mirrors are transmitted from second vehicle to the leading vehicle.

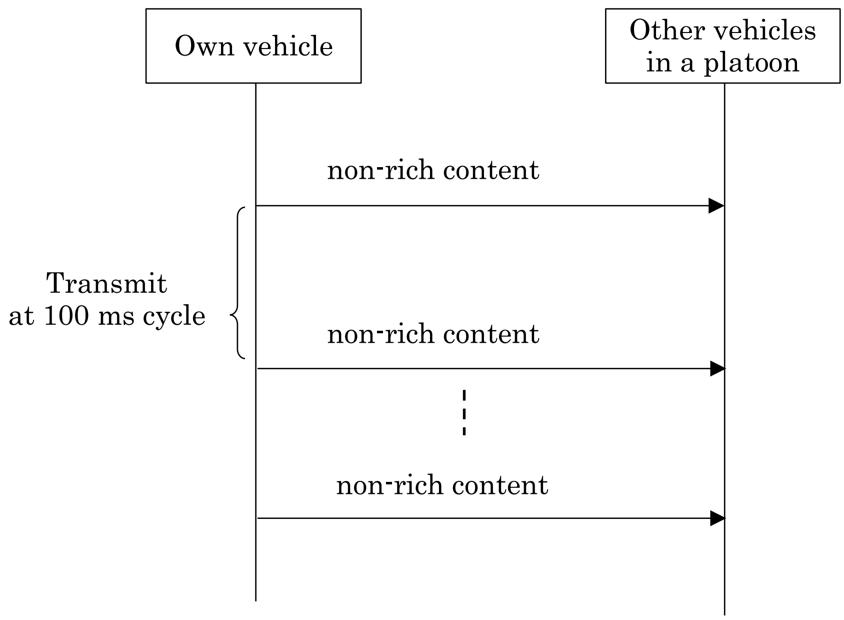

Figure 8.3.1.4-1: Non-rich content message sequence in normal case

・ Sudden braking case

Sudden braking information is sent five times in a 20 ms cycle from the leading vehicle to the following vehicles.

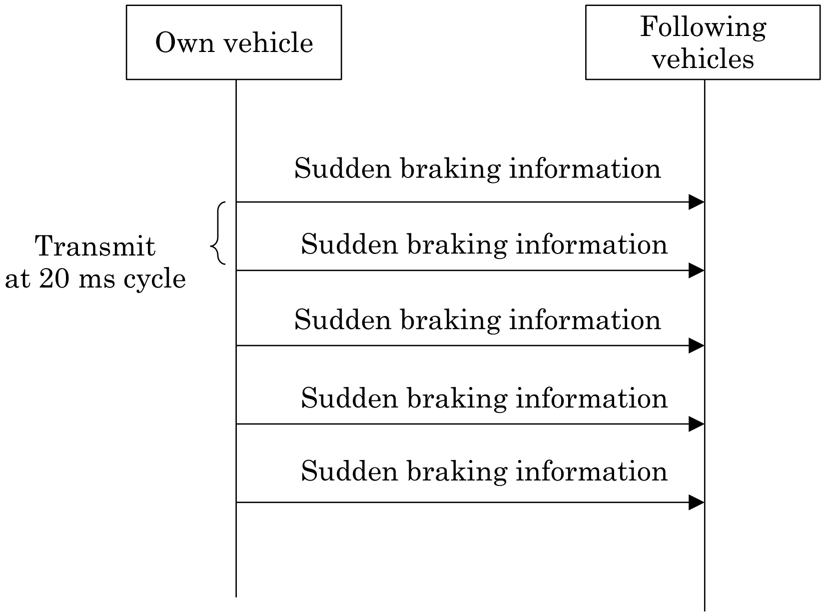

Figure 8.3.1.4-2: Non-rich content message sequence in emergency case

8.3.2 Use case g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control

The location, speed, driving operation information of the vehicle in front, etc., are communicated between the front and rear vehicles to assist adaptive cruise control.

This use case is divided into “Adaptive cruise control” and “Manned platoon of following vehicle”.

Overview of “Adaptive cruise control”

(2) Service concept

- Adaptive cruise control by CACC (Cooperative Adaptive Cruise Control) makes the ACC follow-up function even smoother. The preceding vehicle periodically transmits basic safety information (location, heading, vehicle speed, acceleration, etc.), and the following vehicle performs the following control more smoothly by utilizing the basic safety information of the preceding vehicle in addition to the information from the on-board sensors.

(4) Service scenario

(1) Start of follow-up driving by ACC

(2) The leading vehicle periodically transmits basic safety information

(3) The following vehicles verifies whether the preceding vehicle detected via their on-board sensors (ACC) matches the preceding vehicle in communication.

(4) The basic safety information of the preceding vehicle is used for ACC control to follow the vehicle more smoothly than the control of the on-board sensors alone.

“Manned platoon of following vehicle”

(2) Service concept

CACC platooning makes the ACC follow-up function even smoother. Each vehicle in the platoon periodically transmits basic safety information (location, heading, vehicle speed, acceleration, etc.), and in addition to information from the on-board sensors, each vehicle's basic safety information is used to smoothly follow the vehicle. In case CACC follow-up, the acceleration/deceleration of the first vehicle is propagated to following vehicles one-by-one, i.e., the second vehicle follows the acceleration/deceleration of the first vehicle, the third vehicle follows the second. On the other hand, if it is a CACC platooning, for example, it can be assumed that the second to fourth vehicles are aligned with the acceleration/deceleration of the first vehicle and follow smoothly.

(4) Service scenario

(1) Start of follow-up driving by ACC

(2) Each vehicle periodically transmits basic safety information

(3) Each following vehicle verifies whether each of the preceding vehicles detected by its on-board sensors (ACC) matches the preceding vehicle in communication.

(4) Each vehicle transmits the ID of the preceding vehicle in communication, and identifies the order of each vehicle within the platoon.

(5) The following vehicle uses basic safety information from the leading vehicle and all the preceding vehicles for ACC control to follow faster than the control of the on-board sensors alone.

8.3.2.1 Assumed communication scenario

・In all steps of this service scenario, the preceding and following vehicles continue to broadcast basic safety information every 100 ms.

8.3.2.5 Message sequence

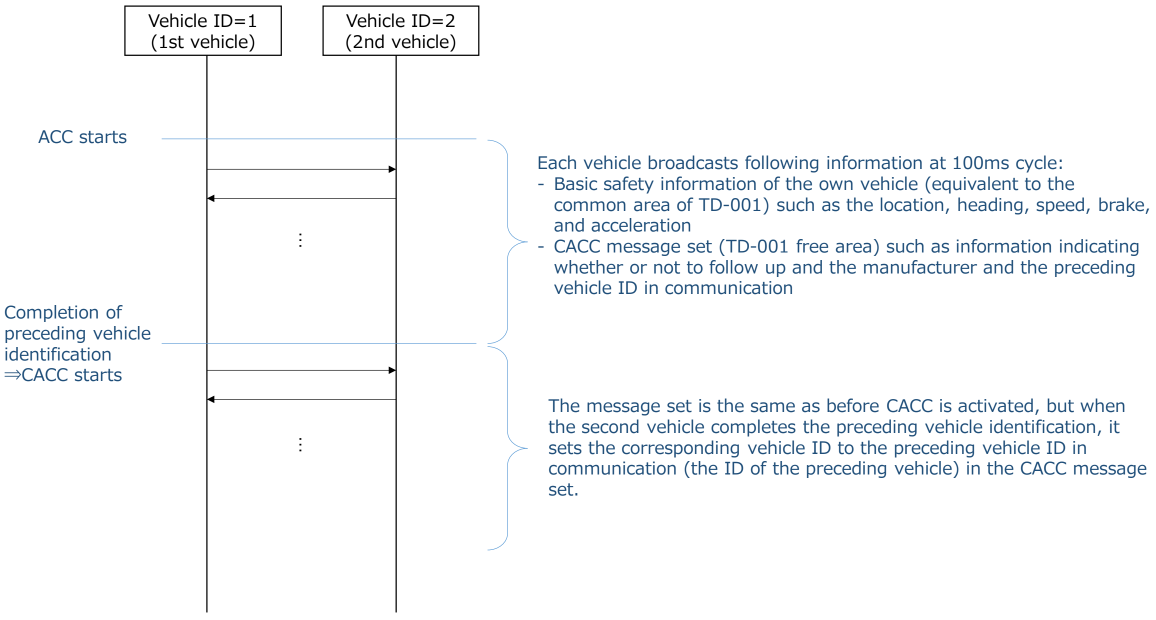

Figure 8.3.2.5-1 Message sequence for adaptive cruise control

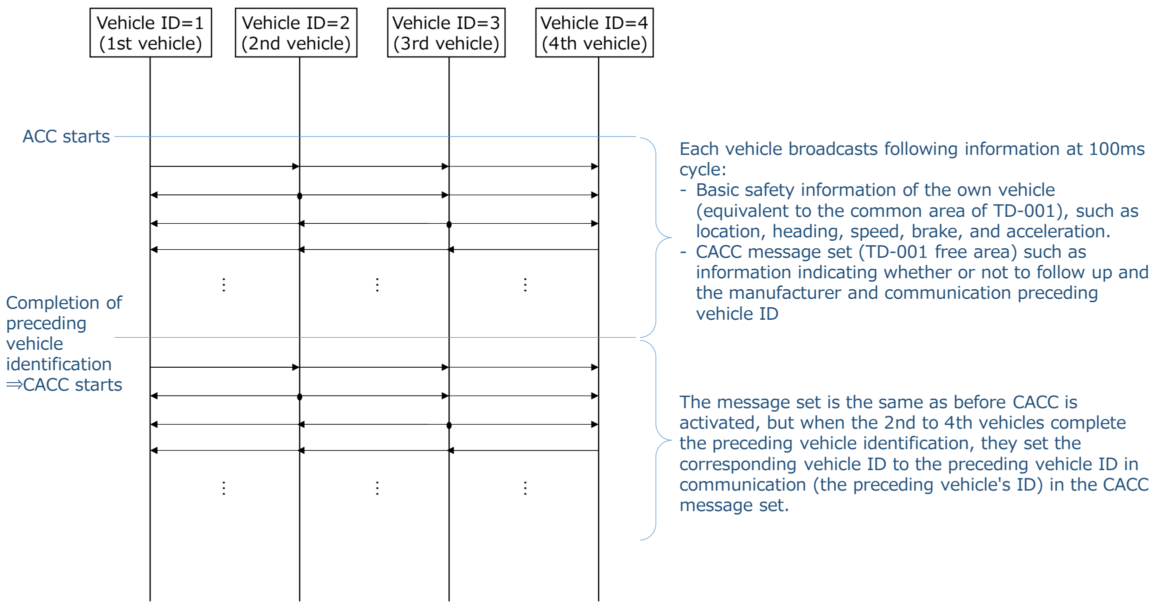

Figure 8.3.2.5-2 Message sequence for manned platooning of following vehicles.

- Broadcast basic safety information periodically before and after the service.
- Transmission cycle is 100 ms

Chapter 9. h. Teleoperation use case

9.2.1 Use case h-1. Operation and management of mobility service cars

9.2.1.1 Purpose of communication

In the case of a traffic environment that an autonomous driving system cannot handle, video information or the like from a mobility service vehicle and teleoperation instruction from an operation manager are communicated between the two to operate and manage the vehicle remotely.

9.2.1.2 Overview of communication

An autonomous driving system assumes a vehicle that supports autonomous driving Level 4 or Level 5, and performs the following communications.

・ Confirmation of communication between vehicle and remote monitoring center

When performing teleoperation, it is assumed that the content of the teleoperation (e.g., route instruction, teleoperation) differs depending on the communication delay (responsiveness) between the operation manager and the mobility service vehicle. A communication delay (responsiveness) is periodically measured between a vehicle and a remote monitoring center so that the content of the teleoperation can be accurately determined between the vehicle and the remote monitoring center when the vehicle encounters a traffic environment that it cannot handle.

・ When the vehicle encounters a traffic environment that it cannot handle

Communication is performed according to the following two cases.

Case h-1a: Teleoperation from the remote monitoring center

Teleoperation is performed from the remote monitoring center based on the teleoperation request information, the vehicle peripheral image, and the like received from the vehicle. Teleoperation is terminated when the vehicle reaches a location where it can operate autonomously. During this time, remote monitoring is performed by the remote monitoring center based on vehicle peripheral images send from the vehicle.

Case h-1b: A route is instructed to the vehicle from the remote monitoring center, and the vehicle performs autonomous driving.

Based on the teleoperation request information received from the vehicle, the remote monitoring center transmits the route information for the vehicle to move to a location where autonomous driving is possible. The vehicle performs autonomous driving based on the route information received from the remote monitoring center. During this time, remote monitoring is performed by the remote monitoring center based on vehicle peripheral images sent from the vehicle.

9.2.1.5 Assumed communication scenario

(1) Confirmation of communication between vehicle and remote monitoring center

1. When started, the vehicle transmits a remote monitoring communication confirmation message to the server of the remote monitoring center to confirm communication with the remote monitoring center.
2. The server of the remote monitoring center that has received the remote monitoring communication confirmation message from the vehicle transmits a response to the vehicle.
3. After receiving a response from the remote monitoring center, the vehicle continues to perform steps 1 and 2 at regular intervals until the power is turned OFF.
4. If the communication quality requirements are not satisfied in the communication confirmation, the mobility service vehicle notifies the vehicle or the control center that use case h-1 cannot be served.

(2) The vehicle encounters a traffic environment that it cannot handle: case h-1a
<Teleoperation from the remote monitoring center>

1. When a vehicle encounters a traffic environment that it cannot handle, it transmits a teleoperation request message in which information necessary for remote operation such as location information is set to the server of the remote monitoring center to request assistance from it.
2. Upon receiving the teleoperation request message from the vehicle, the server of the remote monitoring center transmits a response to the vehicle.
3. Upon receiving the response from the server of the remote monitoring center, the vehicle constantly sends images of the surroundings of the vehicle to the server of the remote monitoring center.
4. The remote monitoring center performs teleoperation based on the information in the teleoperation request message and the image around the vehicle received from the vehicle. Teleoperation data is constantly sent from the server to the vehicle.
5. The vehicle transmits a teleoperation request message setting information necessary for teleoperation such as location information to the server of the remote monitoring center so that the vehicle can move to a location where autonomous driving is possible.

After that, repeat 3–4 until the vehicle reaches a point where it can operate autonomously.

6. When the remote monitoring center detects that the vehicle has reached a location where it can operate autonomously, the server of the remote monitoring center transmits a teleoperation termination message to the vehicle.
7. The vehicle that receives the teleoperation termination message from the remote monitoring center server recognizes that the teleoperation from the remote monitoring center has ended. After that, autonomous operation by the vehicle itself is carried out.

(3) The vehicle encounters a traffic environment that it cannot handle: case h-1b

<The route is instructed to the vehicle from the remote monitoring center, and the vehicle performs autonomous driving>

1. When a vehicle encounters a traffic environment that it cannot handle, it transmits a teleoperation request message in which information necessary for teleoperation such as location information is set to the server of the remote monitoring center.
2. Upon receiving the teleoperation request message from the vehicle, the server of the remote monitoring center transmits a response to the vehicle.
3. Upon receiving the response from the server of the remote monitoring center, the vehicle constantly sends images of the surroundings of the vehicle to the server of the remote monitoring center.
4. Based on the information and images received from the vehicle in the teleoperation request message, the server of the remote monitoring center sets the route information in the teleoperation instruction message for the vehicle to move to the point where it can operate autonomously.
5. Upon receiving the teleoperation instruction message from the server of the remote monitoring center, the vehicle starts autonomous driving directed by the remote monitoring center toward the location where the autonomous operation is possible by itself based on route information set in the message. When additional information is required for moving to the location, a teleoperation request message is transmitted to the server of the remote monitoring center.
6. The server of the remote monitoring center receives the teleoperation operation request message from the vehicle, sets the route information for the vehicle to move to the location where autonomous operation is possible in the teleoperation instruction message, and transmits the message to the vehicle.

After that, repeat 5–6 until the vehicle reaches the location where it can operate autonomously.

7. When the remote monitoring center detects that the vehicle has reached the location where it can operate autonomously, the server transmits a teleoperation termination message to the vehicle.
8. Upon receiving the teleoperation termination message from the server of the remote monitoring center, the vehicle terminates autonomous driving based on the teleoperation instruction message. After that, autonomous operation by the vehicle itself is carried out.

9.2.1.6 Message sequence

(1) Confirmation of communication between vehicle and remote monitoring center

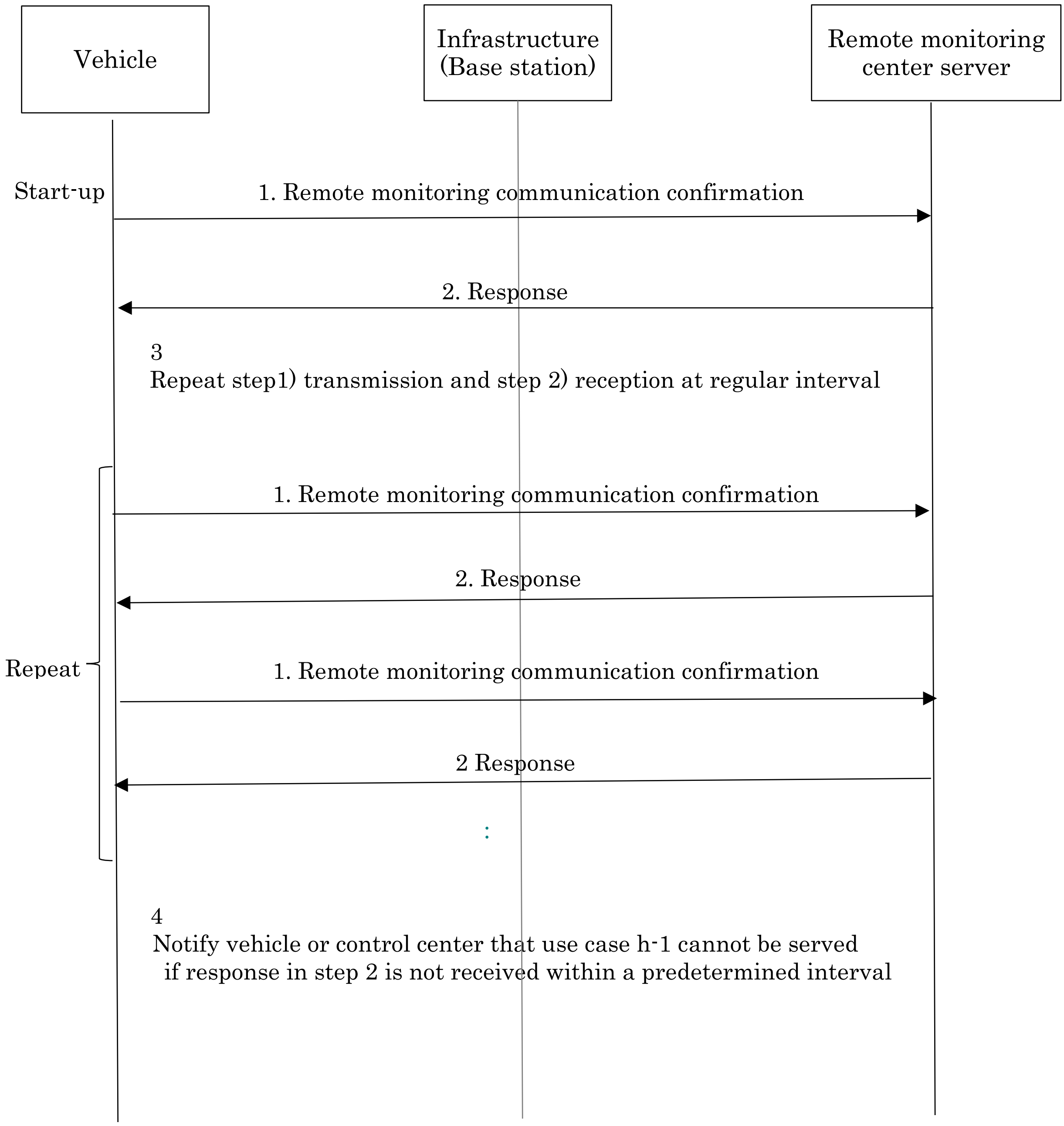

Figure 9.2.1.6-1 Use case h-1 Message sequence for communication confirmation between vehicle and remote monitoring center

(2) The vehicle encounters a traffic environment that it cannot handle: case h-1a

Teleoperation from the remote monitoring center

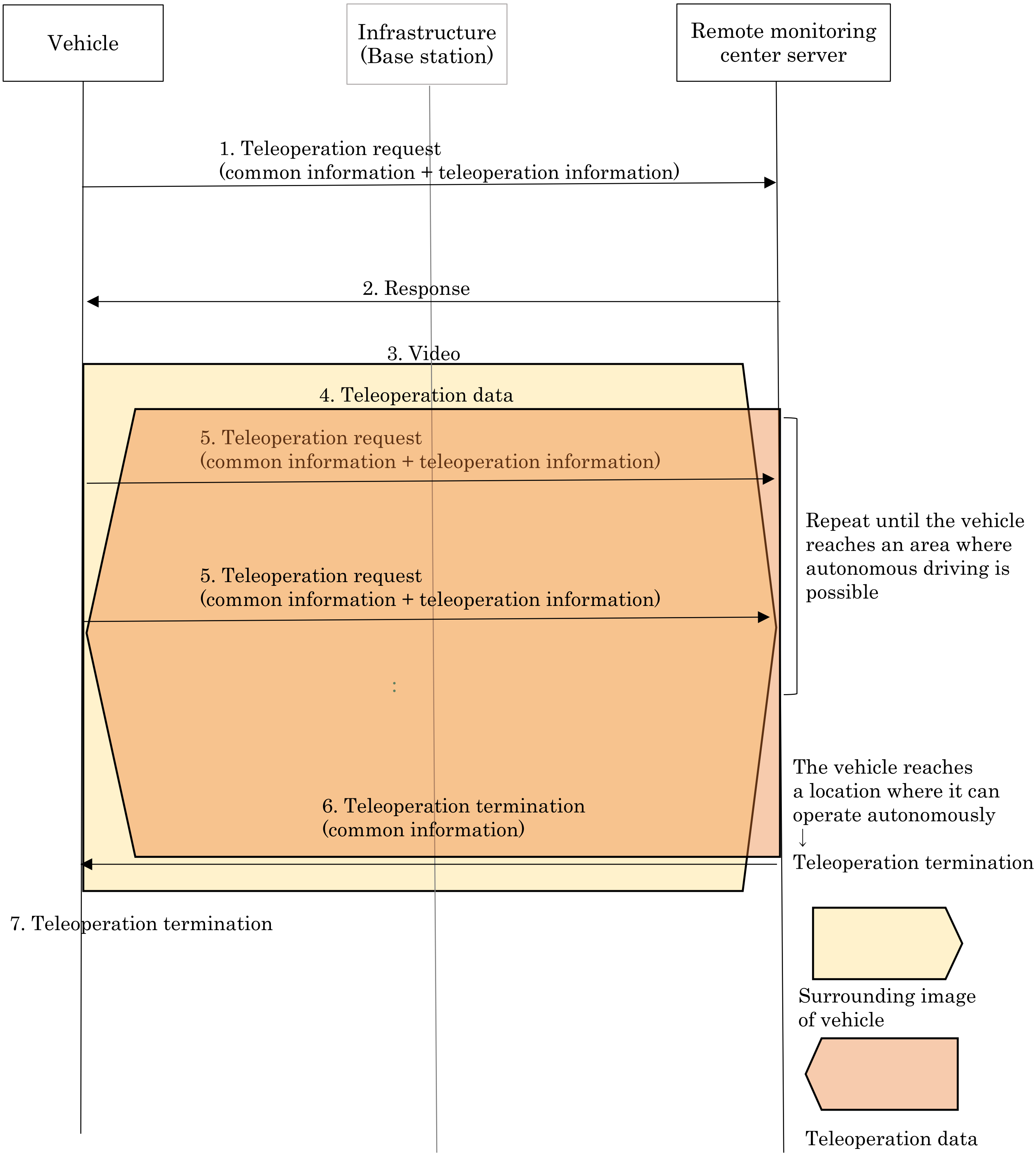

Figure 9.2.1.6-2 Message sequence of use case h-1a

(3) The vehicle encounters a traffic environment that it cannot handle: case h-1b

<The route is instructed to the vehicle from the remote monitoring center, and the vehicle performs autonomous driving>

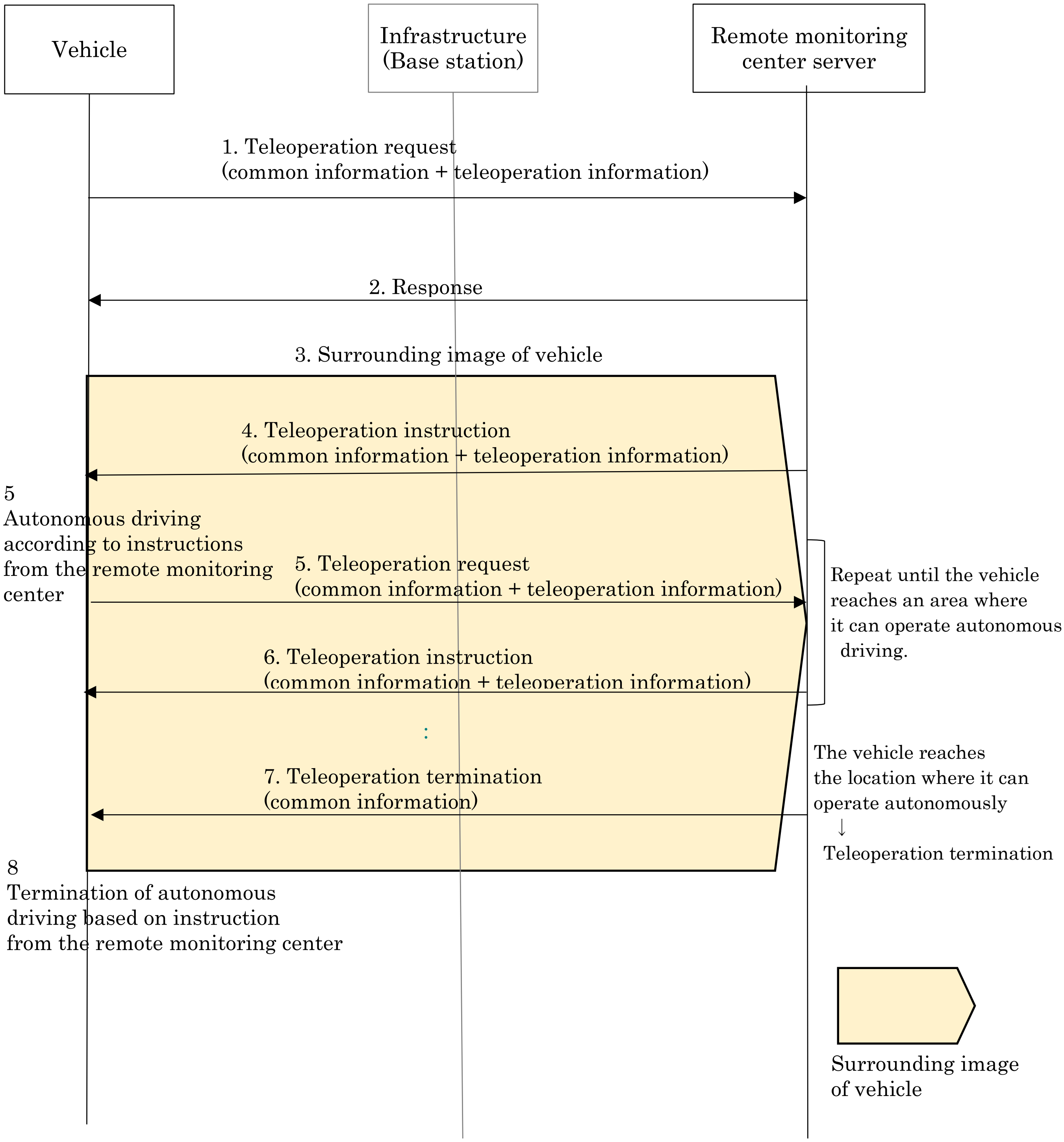

Figure 9.2.1.6-3 Message sequence of use case h-1b

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Chapter 10. Summary of communication requirements

The following tables summarize the communication requirements for each use case.

Item	Explanation
Classification by function	Name of the classification by function
Use case	Use case name
No.	Use case number
Message name	Message name (if available)
Communication method	Classification as V2V, V2I or V2N
Message destination	Specifies the destination of the message: 1) roadside infrastructure, 2) non-specific i.e., all nodes where the message is received including roadside infrastructure or vehicles, or 3) specific i.e., specific vehicles intended by the sender. This distinction may not always be identical to the radio access layer between broadcast or unicast in ITS FORUM RC-015. For instance, the radio access layer may use broadcast transmission, but the message can be targeted to specific vehicles using target identities in the application layer.
Target area (minimum range)	V2V: communication distance. V2I: the infrastructure area. V2N: cellular service range.
Number of transmitting vehicles per area	Number of transmitting vehicles per target area above for V2V or V2I (blank for V2N).
Required communication distance	The required communication distance of V2V or V2I, or the distance range in which information in messages is valid in case of V2V, V2I and V2N.
Maximum relative speed	The maximum relative speed between vehicles forV2V. The maximum vehicle speed for V2I or V2N.
Maximum data size	Maximum data size per message (including 250 bytes of overhead).
Periodic or Aperiodic	Classification as periodic or aperiodic
Transmission periodicity	The update and transmission periodicity of information elements
PAR per message (Packet Arrival Rate)	The packet arrival rate of a message to be realized within the maximum acceptable delay of radio communication part.
Maximum acceptable delay of radio communication	The maximum delay which the system accepts for the radio access layer specified in ITS FORUM RC-015 to achieve the required reliability (including transmission waiting period, repetition/retransmission period, etc., at radio access layer). Messages that exceed the maximum acceptable delay of radio communication part are not considered arrived regardless of the decoding result.

Classification by function	**a. Merging/lane change assistance**					
Use case	Merging assistance by preliminary acceleration and deceleration	Merging assistance by targeting the gap on the main lane	Cooperative merging assistance with vehicles on the main lane by roadside control			
No.	a-1-1	a-1-2	a-1-3			
Message name	Location information	Location information	Location information	Control request	Agreement request Update request	Agreement response Update response
Communication method	V2I (I→V)	V2I (I→V)	V2I (I→V)	V2I (V→I)	V2I (I→V)	V2I (V→I)
Message destination	Non-specific vehicles	Non-specific vehicles	Non-specific vehicles	Roadside infrastructure	Specific vehicles	Specific vehicles
Target area (minimum range)	From the location 6 seconds before merging starting point to the location in the middle between 6 seconds before merging starting point and merging starting point	From 6 seconds before merging starting point to merging starting point	From 6 seconds before merging starting point to merging starting point	Within control request range	Within control request range	Within control request range
Number of transmitting vehicles per area	1 vehicle	1 vehicle	1 vehicle	1 vehicle	1 vehicle (× number of controlled vehicles)	48 vehicles ※5 (the number of controlled vehicles when traffic is heavy)
Required communication distance ※1	33.9 to 59.3 m (NILIM standard: 95 m)	67.8 to 118.6 m	Merging lane: 67.8 to 118.6 m Main lane: 112.5 to 270 m	67.8～118.6m	Merging lane: 67.8 to 118.6 m Main lane: 112.5 to 270.0 m	Merging lane: 67.8 to 118.6 m Main lane: 112.5 to 270.0 m
Maximum relative speed	Merging lane: 20 to 70 km/h	Merging lane: 20 to 70 km/h	Merging lane: 20 to 70 km/h Main lane: 20 to 120 km/h	Merging lane: 20 to 70 km/h Main lane: 20 to 120 km/h	Merging lane: 20 to 70 km/h Main lane: 20 to 120 km/h	Merging lane: 20 to 70 km/h Main lane: 20 to 120 km/h
Maximum data size	1510 bytes (1260 + 250)	2752 bytes (2502 + 250)	5236 bytes (4986 + 250) Number of vehicles: 184	287 bytes (37 + 250)	369 bytes (119 + 250) ※4	287 bytes (37 + 250)

	Number of vehicles: 46	Number of vehicles: 92 ※2	※3			
Periodic or Aperiodic	Periodic	Periodic	Periodic	Aperiodic	Aperiodic	Aperiodic
Transmission periodicity	100 ms	100 ms	100 ms	Not specified		
PAR per message	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)
Maximum acceptable delay of radio communication	Not specified	Not specified	Not specified	100 ms	100 ms	100 ms

※1 Roadside infrastructure is installed at the merging starting point and the height difference is ignored. It is expected that roadside infrastructure antennas may be installed at some distance from the merging starting point, but this has not been taken into account. In practice, it is necessary to calculate the required communication distance, including the location of the roadside infrastructure antenna and elevation.

※2 Cases where information is provided for 2 main lanes. 3744 + 250 = 3994 bytes in case of 3 main lanes (expected number of vehicles: 138). 7470 + 250 = 7720 bytes in case of 6 main lanes (expected number of vehicles: 276).

※3 Cases where information is provided for 3 main lanes and 1 merging lane. 9954 + 250 = 10204 bytes in case of 2 merging lanes and 6 main lanes (expected total number of vehicles: 368).

※4 In case of the control response message, 121 + 250 = 371 bytes by adding 2 bytes of the information element of the scheduled time to start action.

※5 Cases where vehicle density is estimated at 12 vehicles/lane for 3 main lanes and 1 merging lane. With 6 main lanes and 2 merging lanes, the number of transmitting vehicles is 96 vehicles.

Classification by function	**a. Merging/lane change assistance**					
Use case	Merging assistance based on negotiations between vehicles		Lane change assistance when the traffic is heavy		Entry assistance from non-priority roads to priority roads during traffic congestion	
No.	a-1-4		a-2		a-3	
Message name	Agreement request Update request	Agreement response Update response	Agreement request Update request	Agreement response Update response	Agreement request Update request	Agreement response Update response
Communication method	V2V	V2V	V2V	V2V	V2V	V2V
Message destination	Non-specific vehicles (agreement request) Specific vehicles (update request)	Specific vehicles (requesting vehicle)	Non-specific vehicles (agreement request) Specific vehicles (update request)	Specific vehicles (requesting vehicle)	Non-specific vehicles (agreement request) Specific vehicles (update request)	Specific vehicles (requesting vehicle)
Target area (minimum range)	Within agreement request range	Within agreement request range	Within lane change request range	Within lane change request range	Within intersection request range	Within intersection request range
Number of transmitting vehicles per area	When temporarily stopping: 1 vehicle ※7 When starting to merge: 1 vehicle ※7	When temporarily stopping: 27 vehicles ※7 When starting to merge: 36 vehicles ※7	73 vehicles	48 vehicles	2 vehicles	68 vehicles
Required communication distance	255 m	255 m	Agreement request: 255 m Update request: 38.9 m	Agreement response: 255 m Update response: 38.9 m	111.1 m	111.1 m
Maximum relative speed	20 to 70 ㎞/h	20 to 70 ㎞/h	Agreement request: 0 to 120 km/h Update request: 0 to 20 km/h	Agreement response: 0 to 120 km/h Update response: 0 to 20 km/h	0 to 60 km/h	0 to 60 km/h
Maximum data size	291 bytes (41 + 250)	287 bytes (37 + 250)	291 bytes (41 + 250)	287 bytes (37 + 250)	291 bytes (41 + 250) ※9	287 bytes (37 + 250)
Periodic or Aperiodic	Aperiodic	Aperiodic	Aperiodic	Aperiodic	Aperiodic	Aperiodic
Transmission periodicity	Not specified		Not specified		Not specified	

PAR per message	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)
Maximum acceptable delay of radio communication	100 ms	100 ms	100 ms	100 ms	100 ms	100 ms

※7 Number of vehicles assuming temporary stop scenario of merging lane length 190 m @ 70 km/h and merging start time scenario of merging lane length 255 m @ 100 km/h

※9 If intersection information is not available from the dynamic map, 10 bytes should be added.

Classification by function	b. Traffic signal information	
Use case	Driving assistance by using traffic signal information (V2I)	Driving assistance by using traffic signal information (V2N)
No.	b-1-1.	b-1-2
Message name	-	-
Communication method	V2I	V2N
Message destination	Non-specific vehicles	Same as left
Target area (minimum range)	Passenger vehicles: Approx. 138.5 m (provisional) Large vehicles: Approx. 206.3 m (provisional) (yellow 4 sec. 60 km/h)	Same as right for intersection. Service area is a range covered by cellular.
Number of transmitting vehicles per area	RSU installation model (See https://www.soumu.go.jp/main_content/000455914.pdf section 4.2 (in Japanese only))	Same as left
Required communication distance	Passenger vehicles: Approx. 138.5 m (provisional) Large vehicles: Approx. 206.3 m (provisional) (yellow 4 sec. 60 km/h) Note, 700 MHz band system requirement is 240 m	Same as left
Maximum relative speed	70 km/h	Same as left
Maximum data size	About 1 kbytes /intersection	About value in the 700 MHz band system × 3
Periodic or Aperiodic	Periodic	Under consideration
Transmission periodicity	100 ms	
PAR per message	At least 99% in 5 m evaluation period*1 (same as 700 MHz band system)	Under consideration
Maximum acceptable delay of radio communication	Delay not specified. Fluctuation within ±300 ms	Consideration needed throughout systemwide delay

※1: 70 km/h is approx. 20 m/s. 250 ms required in 5 m evaluation distance. Two 100 ms cycle transmissions occur within 250 ms.

The 99% of the cumulative packet arrival rate may satisfy 90% or more of packet arrival per packet from 1-(0.1*0.1) = 0.99. Therefore, 90% packet arrival rate at a maximum acceptable delay of radio communication of 100 ms.

Classification by function	c. Lookahead information: Collision avoidance				
Use case	Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly	Driving assistance based on intersection information (V2V)	Driving assistance based on intersection information (V2I)		Collision avoidance assistance by using hazard information
No.	c-1.	c-2-1.	c-2-2		c-3
Message name	Merged with c-3.	-	Not considered	-	-
Communication method	Merged with c-3.	V2V	V2I (V→I)	V2I (I→V)	V2V
Message destination	Merged with c-3.	Non-specific vehicles	Not considered	Non-specific vehicles	Non-specific vehicles
Target area (minimum range)	Merged with c-3.	(Communication area in which right-turning vehicle needs to cover to receive distributed information) Upstream side: upstream from location right-turning vehicle turns on the turn signal (point 30 m upstream stop line) Downstream side: last stopping point at right turn destination (oncoming vehicle range in which right-turning vehicle needs information) *Target lanes are all straight ahead lanes. Upstream side: Oncoming vehicle(s) in a location far enough away from the intersection such that the right-turn vehicle waiting at waiting point within the intersection can initiate and finish turning right at safe acceleration. (If the right turn waiting point exceeds the center of the intersection, the right turn waiting point shall be the base point, and if there are multiple right turn waiting points, the point closer to the oncoming lane shall be used.) Downstream side: the location not within line of sight (i.e., there is a blind spot) when looking from right-turning vehicle to oncoming vehicles moving straight through the intersection. If this position is upstream from the stop line of the lane in which the oncoming vehicle moving straight is traveling, it	Not considered	(Communication area in which right-turning vehicle needs to cover to receive distributed information) Same as c-2-1.	Direct V2V communication: 250 m upstream from the point where event occurs If relay: 1 km upstream from the point where event occurs

		shall be the stop line position.			
Number of transmitting vehicles per area	Merged with c-3.	(Number of lanes in one direction: 6; oncoming vehicle speed: 70 km/h) 348 vehicles (Number of lanes in one direction: 3; oncoming vehicle speed: 70 km/h) 125 vehicles	Not considered	N/A	(Vehicle speed: 120 km/h; intervehicle distance: 2 s) 79 vehicles (Vehicle speed: 60 km/h; intervehicle distance: 1 s) 277 vehicles (Total vehicles for 6 lanes in 1 km section from the point where event occurs)
Required communication distance	Merged with c-3.	(Number of lanes in one direction: 6; oncoming vehicle speed: 70 km/h) 190 m (Number of lanes in one direction: 3; oncoming vehicle speed: 70 km/h) 135 m	Not considered	Dependent on roadside infrastructure antenna location. The following if roadside infrastructure antenna installed at the side of intersection and antenna height 6 m: (No. of lanes on one side: 6) 75.2 m (No. of lanes on one side: 3) 52.4 m	Direct V2V communication: 250 m upstream from the point where event occurs If relay: 1 km upstream from the point where event occurs
Maximum relative speed	Merged with c-3.	Up to 70 km/h	Not considered	Up to 70 km/h	Up to 120 km/h
Maximum data size	Merged with c-3.	282 bytes	Not considered	(No. of lanes on one side: 6) 1534 bytes (No. of lanes on one side: 3) 1150 bytes ※1	312 bytes
Periodic or Aperiodic	Merged with c-3.	Periodic	Not considered	Periodic	Periodic
Transmission periodicity	Merged with c-3.	100 ms	Not considered	100 ms	100 ms
PAR per message	Merged with c-3.	PAR≧99% (provisional value to be reviewed if	Not considered	PAR ≥ 99%	PAR ≥ 99% in direct V2V

		needed)		(provisional)	communication (provisional)
Maximum acceptable delay of radio communication	Merged with c-3.	[100] ms (provisional)	Not considered	[100] ms (provisional)	Up to 255 m upstream from place where emergency avoidance action occurs: within [100] ms Points upstream from the above: up to 1 km upstream, relax up to 30 s depending on distance

※1: Message size when traffic signal information, intersection identification information, and vehicle detection information are sent together in a single message.

If each piece of information is sent in a separate message, the security overhead is taken into account for each piece of information.

Classification by function	d. Lookahead information: Trajectory change					
Use case	Driving assistance by notification of abnormal vehicles		Driving assistance by notification of wrong-way vehicles		Driving assistance based on traffic congestion information	
No.	d-1		d-2		d-3	
Message name	-	-	-	-	-	-
Communication method	V2I	V2N	V2I	V2N	V2I	V2N
Message destination	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used
Target area (minimum range)	Minimum 66.6 m and up	Up to 1 km upstream from the point where event occurs (provisional)	Minimum 66.6 m and up	Up to 2 km upstream from the point where event occurs (provisional)	Minimum 66.6 m and up	Up to 1 km upstream from the point where event occurs (provisional)
Number of transmitting vehicles per area	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: Broadcast	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: 285 (unicast assumed)	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: Broadcast	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: 567 (unicast assumed)	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: Broadcast	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: 285 (unicast assumed)
Required communication distance	Minimum 66.6 m and up	From 255 m to 1 km upstream from the point where event occurs (provisional) As service provision range	Minimum 66.6 m and up	From 510 m to 2 km upstream from the point where event occurs (provisional) As service provision range	Minimum 66.6 m and up	From 255 m to 1 km upstream from the point where event occurs (provisional) As service provision range
Maximum relative speed	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h
Maximum data size	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)
Periodic or Aperiodic	Periodic	Periodic	Periodic	Periodic	Periodic	Periodic
Transmission periodicity	Minimum 1 second	Minimum 7.65 seconds	Minimum 1 second	Minimum 7.65 seconds	Minimum 1 second	Minimum 7.65 seconds
PAR per message	PAR ≥ 99%	PAR ≥ 99%	PAR ≥ 99%	PAR ≥ 99%	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)

	(provisional)	(provisional)	(provisional)	(provisional)		
Maximum acceptable delay of radio communication	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified

Classification by function	d. Lookahead information: Trajectory change			
Use case	Traffic congestion assistance at branches and exits		Driving assistance based on hazard information	
No.	d-4		d-5	
Message name	-	-	-	-
Communication method	V2I	V2N	V2I	V2N
Message destination	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used	Non-specific vehicles present in areas where hazard information can be effectively used
Target area (minimum range)	Minimum 66.6 m and up	Up to 1 km upstream from the point where event occurs (provisional) and from the last branch or exit upstream to 1 km upstream.	Minimum 66.6 m and up	Up to 1 km upstream from the point where event occurs (provisional)
Number of transmitting vehicles per area	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: Broadcast	Uplink: Number of abnormal vehicles (typically 1 vehicle) Downlink: 570 (unicast assumed)	Downlink: Broadcast	Downlink: 285 (unicast assumed)
Required communication distance	Minimum 66.6 m and up	From 255 m to 1 km upstream from the point where event occurs (provisional) As service provision range	Minimum 66.6 m and up	From 255 m to 1 km upstream from the point where event occurs (provisional) As service provision range
Maximum relative speed	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h
Maximum data size	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)	715 bytes (465 + 250)
Periodic or Aperiodic	Periodic	Periodic	Periodic	Periodic
Transmission periodicity	Minimum 1 second	Minimum 7.65 seconds	Minimum 1 second	Minimum 7.65 seconds
PAR per message	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)
Maximum acceptable delay of radio communication	Not specified	Not specified	Not specified	Not specified

Classification by function	e. Lookahead information: Emergency vehicle notification	
Use case	Driving assistance based on emergency vehicle information	
No.	e-1	
Message name	-	-
Communication method	V2V	V2N
Message destination	Non-specific vehicles present in areas where emergency vehicle information can be effectively used	Non-specific vehicles present in areas where emergency vehicle information can be effectively used.
Target area (minimum range)	150 m semicircle	Local road: Semicircle with radius of 700 m Expressway: Semicircle with radius of 1000 m
Number of transmitting vehicles per area	Downlink: broadcast	Uplink: Number of emergency vehicles (typically 1 vehicle) Downlink: 285 (provisional, unicast assumed)
Required communication distance	Minimum 150 m	Local road: Semicircle with radius of 700 m Expressway: Semicircle with radius of 1000 m
Maximum relative speed	20 km/h to 120 km/h	20 km/h to 120 km/h
Maximum data size	302 bytes (52 + 250)	1035 bytes (785 + 250)
Periodic or Aperiodic	Periodic	Periodic
Transmission periodicity	100 ms	Minimum 7.65 seconds
PAR per message	PAR ≥ 99% (provisional)	PAR ≥ 99% (provisional)
Maximum acceptable delay of radio communication	V2V: 100 ms or less	Not specified

Classification by function	f. Information collection/distribution by infrastructures			
Use case	Request for rescue (e-Call)	Collection of information to optimize the traffic flow	Update and automatic generation of maps	Distribution of dynamic map information
No.	f-1	f-2	f-3	f-4
Message name	-	-	-	-
Communication method	V2N	V2I／V2N	V2N	V2N
Message destination	Non-specific vehicles	Non-specific vehicles	Non-specific vehicles	Non-specific vehicles
Target area (minimum range)	Communication area of public network by mobile operator	V2I：circle of a 171.8 m radius※1 V2N：communication area of public network by mobile operator	Communication area of public network by mobile operator	Communication area of public network by mobile operator
Number of transmitting vehicles per area	Not specified	V2I：389 vehicles(maximum case) ※1 V2N：Not specified	Not specified	Not specified
Required communication distance	-	Minimum 33.3 m (distance traveled in 1 second at 120 km/h)	-	-
Maximum relative speed	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h	20 km/h to 120 km/h
Maximum data size	Uplink：675 bytes (425 + 250) Downlink: not specified *Voice always communicated during communication for both Uplink and Downlink in addition to the above	Uplink：279 bytes (29 + 250) Downlink: not specified	Uplink: 20.5M bytes (including image data (up to 5 images)) Downlink: not specified	Uplink: not specified Downlink：67 Mbps (maximum case)
Periodic or Aperiodic	Aperiodic	Periodic	Aperiodic	Aperiodic
Transmission periodicity	-	V2I： 1 second minimum V2N： 1 minute minimum	-	-
PAR per message	-	PAR ≥ 99% (provisional)	-	-
Maximum acceptable delay of radio communication	Not specified	Not specified	Not specified	Not specified

※1: Assumed communication area: 171.8 m (360°), maximum 3 lanes in one direction, two-way intersection, vehicle speed 20 km/h, vehicle interval 1 s, average vehicle length 5 m.

Transmitting vehicles per area: 171.8 × 3 × 2 × 4 ÷ (5.6 × 1 + 5) ＝ 389 vehicles)

Classification by function	**g. Platooning/adaptive cruise control**		
Use case	Unmanned platooning of following vehicles by electronic towbar (non-rich content)	Unmanned platooning of following vehicles by electronic towbar (Rich content)	Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control
No.	g-1	g-1	g-2
Message name	-	-	-
Communication method	V2V	V2V	V2V
Message destination	Specific vehicles (use one-to-N to achieve one-to-one)	Specific vehicles (use one-to-N to achieve one-to-one)	Non-specific vehicles
Target area (minimum range)	Relative distance about 60 m	Relative distance about 60 m	141 m
Number of transmitting vehicles per area	3 vehicles	3 vehicles	Calculated with 4 vehicles
Required communication distance	Relative distance about 60 m	Relative distance about 60 m	141 m
Maximum relative speed	Large vehicles 80 km/h	Large vehicles 80 km/h	Passenger vehicles 100 km/h; large vehicles 80 km/h
Maximum data size	Up to same as 700 MHz band system	※1	Up to same as the 700 MHz band system
Periodic or Aperiodic	Periodic	※1	Periodic
Transmission periodicity	100 ms, in emergencies 20 ms	※1	100 ms
PAR per message	98% per 100 ms in normal, 99.99% per 100 ms in emergency	※1	95% accumulate packet arrival rate in 10 m of travel (same as the 700 MHz band system)
Maximum acceptable delay of radio communication	100 ms (intervehicle distance 10 m; speed 80 km/h)	※1	100 ms or less

※1: Full high definition real-time communication is needed, and United Nations Economic Commission for Europe Regulation 46 electronic mirror regulations can be used as a reference for delay and communication quality in the camera-to-display section. However, the delay for encoding and decoding images will differ depending on what image encoding method is used, resulting in different transmission bandwidth and communication delay required for the radio communication part. It is necessary to specify the communication delay in the radio section, taking into account implementation of the delay in the camera and display as well. From these, specific content and size cannot be specified in this document.

Classification by function	**h. Remote control**	
Use case	Operation and management of mobility service cars (instructions for remote control outside ODD conditions)	Operation and management of mobility service cars (instructions for travel routes under ODD conditions)
No.	h-1a	h-1b
Message name	-	-
Communication method	V2N	V2N
Message destination	Non-specific vehicles	Non-specific vehicles
Target area (minimum range)	Communication area of public network by mobile operator	Communication area of public network by mobile operator
Number of transmitting vehicles per area	Not specified	Not specified
Required communication distance	-	-
Maximum relative speed	T.B.D.	T.B.D.
Maximum data size	Uplink: video information around vehicle, teleoperation request Downlink: teleoperation data (when teleoperation is used)	Uplink: video information around vehicle, teleoperation request Downlink: driving route (when teleoperation instruction is used)
Periodic or Aperiodic	Aperiodic	Aperiodic
Transmission periodicity	-	-
PAR per message	T.B.D.	T.B.D.
Maximum acceptable delay of radio communication	T.B.D.	T.B.D.

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Appendix 1. Analysis of message structure

1. Overview

Based on the communication contents studied for SIP Use Cases for Cooperative Driving Automation, we studied the composition of messages sent and received by vehicles and roadside infrastructure via V2V and V2I. Considering the support of multiple use cases simultaneously, we extracted and grouped the information elements common among the messages used in each use case.

3. Message structure

Figure 3-1 and Figure 3-2 show the message classification framework and example message structure respectively. A message consists of (1) Message information, (2) Roadside infrastructure basic information, (3) Vehicle basic information, and (4) Use case-specific information. (1) Message information, (2) Roadside infrastructure basic information and (3) Vehicle basic information can be sent without depending on use cases and events such as location, time, and driving conditions. (4) Use case-specific information is sent according to use cases. As for (4) Use case-specific information, roadside control information, surrounding vehicle information, negotiation information, intersection information, hazard information, unmanned platooning information, and manned platooning information were investigated.

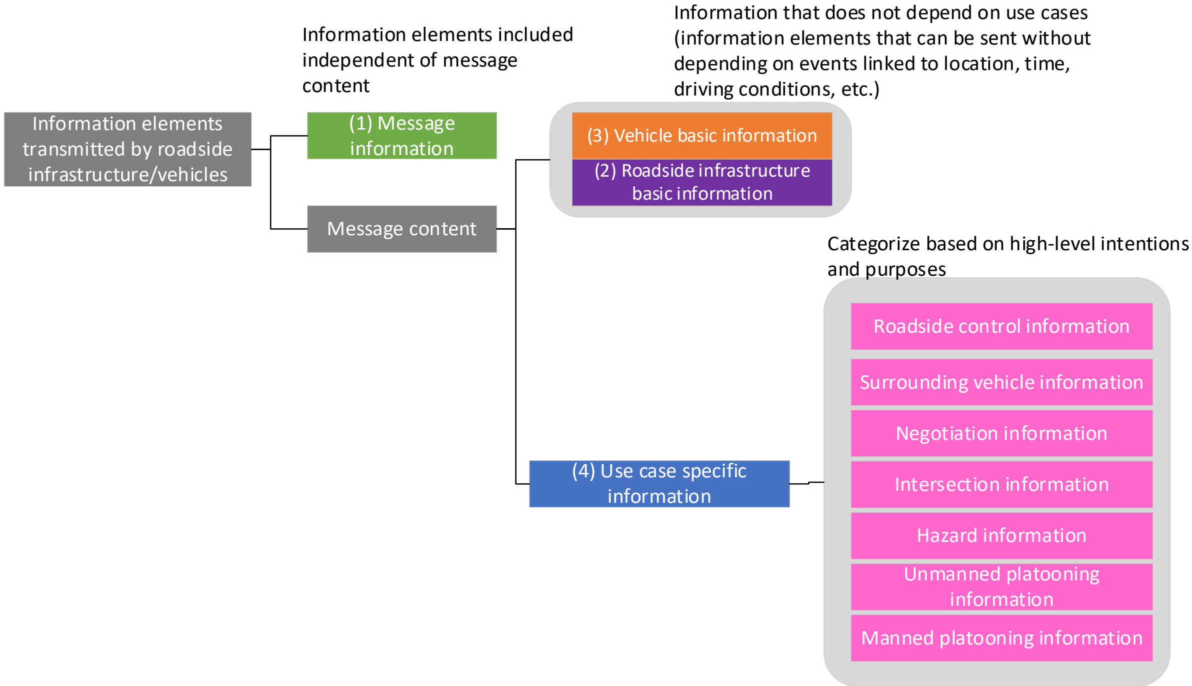

Figure 3-1 Framework for information element classification

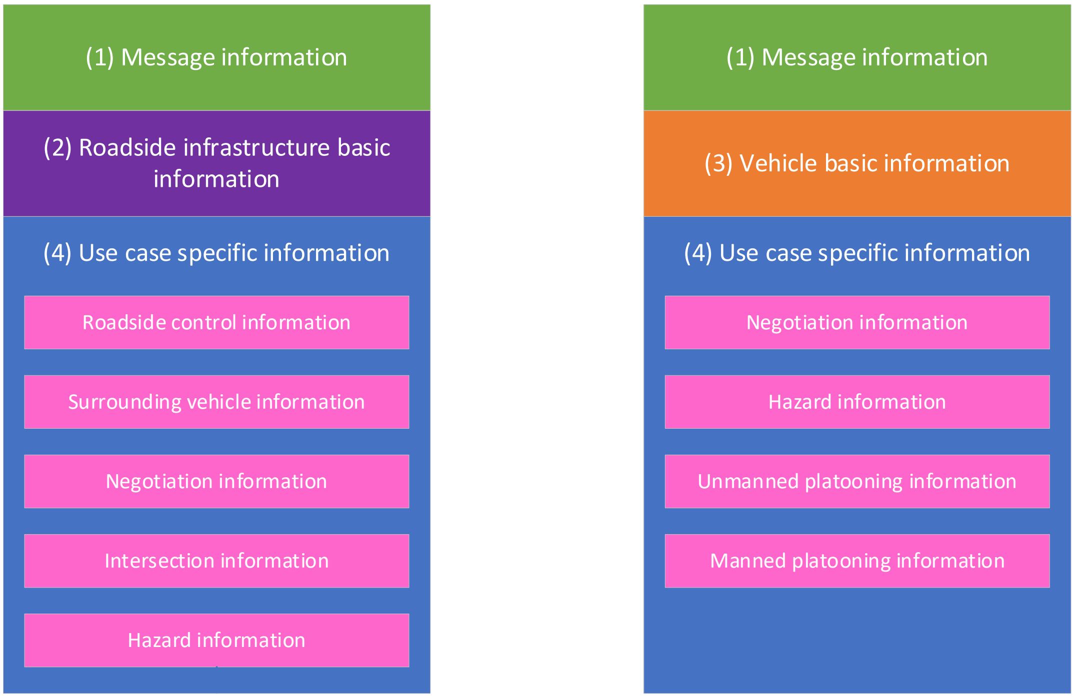

Figure 3-2 Message structure example

(left: roadside infrastructure message, right: vehicle message)

3.1 Message information

Information elements included independent of message contents.

3.1.1 Usage use case

all use cases

3.2 Roadside infrastructure basic information

Among the information elements transmitted from the roadside infrastructure, the information elements that can be transmitted basically without depending on use cases or events.

3.2.1 Applicable use case

Currently not in use

3.3 Vehicle basic information

Among the information elements transmitted from the vehicle, the information elements that can be transmitted basically without depending on the use case, location, time, driving state, etc., such as the position, speed, length, and attribute of the vehicle.

3.3.1 Usage use case

All use cases with vehicle communication.

3.4 Use case specific information

Among the information elements transmitted from vehicles and roadside infrastructure, the information elements that can be transmitted depending on use cases, and events such as location, time and driving conditions such as position, speed, length, and attribute of the vehicle.

3.4.1 Roadside control information

An information element used by roadside infrastructure to notify the roadside control reception status.

3.4.1.1 Applicable use case

a-1-3

3.4.2 Surrounding vehicle information

An information element used by roadside infrastructure to notify detected vehicle information.

3.4.2.1 Applicable use case

a-1-1, a-1-2, a-1-3 and c-2-2

3.4.3 Negotiation information

Information elements used by roadside infrastructure and vehicles to notify negotiation information.

3.4.3.1 Applicable use case

a-1-3, a-1-4, a-2 and a-3

3.4.4 Intersection information

Information elements used by roadside infrastructure to notify intersection information.

3.4.4.1 Applicable use case

b-1 and c-2-2

3.4.5 Hazard information

Information elements used by roadside infrastructure and vehicles to notify hazard information.

3.4.5.1 Applicable use case

c-1, c-3, d-1, d-2, d-3, d-4, d-5 and e-1

3.4.6 Unmanned platooning information

Information elements used by vehicles to notify unmanned platooning information.

3.4.6.1 Applicable use case

g-1

3.4.7 Manned platooning information

Information elements used by vehicles to notify manned platooning information.

3.4.7.1 Applicable use case

g-2