**FY2022 Report of Outcomes**
**Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 - Automated Driving for Universal Services**
**A Study on 5.9 GHz Band V2X Communication Protocol for Achieving Use Cases for Cooperative Driving Automation**

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This report documents the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 2nd Phase, Automated Driving for Universal Services (SIP-adus, NEDO management number: JPNP18012) that was implemented by the Cabinet Office and was served by the New Energy and Industrial Technology Development Organization (NEDO) as a secretariat.

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# 1. Overview

## 1.1 Purpose of project

The Council for Science, Technology and Innovation (CSTI) aims to create “the most innovation-friendly country” by strengthening industry-academia-government collaboration that is cross-sector and cross-ministry, and enhancing its control tower functions. Since 2014 when the Expenditure on Science, Technology and Innovation Promotion (Promotional Expenditures) was created to accelerate basic research through to exit, the Cabinet Office has allocated the budget as a newly established reserve fund.

The solution of important national issues will create promising future markets for Japanese industry. Amid demands for the revitalization of the Japanese economy, the Strategic Innovation Promotion Program (SIP) is designed to oversee the initiatives of ministries and agencies to create innovation across such organizational boundaries. Under the program, CSTI allocates its own budget selectively without being constrained by government frameworks, for projects that solve important issues such as development of key strategic technologies. SIP Phase 2 began, ahead of its initial schedule, in fiscal 2018 with the 2017 Supplementary Budget. While maintaining excellent characteristics such as clear and strict management of government ministries, industry-academia-government collaboration, and project achievement milestone, it further strengthened efforts for system reform such as international standardization and venture support.

In SIP Phase 2, in order to overcome a wide range of technological issues for the practical application of automated driving, development is being promoted as a cooperative area, focusing on the development of basic technologies necessary to create an environment in which automated vehicles can be driven with safety ensured. And in the course of work such as studying the development of the driving environment, efforts are being made to determine the format of road traffic information and communication requirements necessary for automated driving and to standardize them.

In the Research into communications technologies for automated driving systems, conducted under SIP Phase 2 in 2019, basic materials were prepared concerning the use of existing or new wireless communication systems in automated driving systems, for the purpose of discussions about communication concerning automated driving in SIP Phase 2. Specifically this involved (1) the detailed research and analysis of use cases and (2) research and analysis into the expectations of corporations and organizations about 5 GHz band V2X, and discussions concerning implementation in various countries. Further, in the Task Force (TF) on V2X Communication for Cooperative Driving Automation in SIP Phase 2, 25 use cases of 3 types (Use cases for Cooperative Driving Automation) were brought together, by providing prior reading and sorting the use cases for expressways and prefectural and municipal roads where the use of communications for automated driving is anticipated, into categories such as merging or lane change assistance.

Also, in fiscal 2020 and 2021, as SIP Phase 2, Study into communication technologies to implement Use cases for Cooperative Driving Automation was conducted. For the Use cases for Cooperative Driving Automation where use of V2X was anticipated, created by the Task Force (TF) on V2X communication for Cooperative Driving Automation, the technical practicality of communications, e.g. the specific requirement specifications for wireless technology, were validated and also a roadmap was formulated of the specific required specifications for the various use cases and their respective wireless communication technologies, having regard to future anticipated evolution of communication technology.

In addition to what is indicated by the roadmap, V2X systems using the 5.9 GHz band radio waves are increasingly becoming the mainstream trend internationally. However in Japan, the situation is that no decisions have been made on the communication protocols required for equipment development.

In this project, to accelerate problem resolution and study relating to the implementation of a V2X system using 5.9 GHz band radio waves to help realize cooperative driving automation, a radio unit specifications draft was compiled that includes the communication protocols necessary for such implementation.

## 1.2 Project overview/goals

This project was jointly implemented by two companies, Oki Electric Industry and NEC Corporation. It aimed to help realize cooperative driving automation by accelerating problem solving and study relating to the implementation of a V2X system using 5.9 GHz band radio waves, and by formulating the radio unit specifications including communication protocols necessary for such implementation. Implementation was based on development of studies into SIP-related operations, such as SIP Phase 1, “The Investigation and study of message sets and protocols for autonomous driving support communication assuming a real environment” (2018). Note that regarding the above Use cases for Cooperative Driving Automation, in parallel with this issue, the communications requirements (data volume, communications area, allowed delay time, communication speed, packet arrival rate, etc. Hereinafter, ITS Forum communication requirements) required for the spread of automated vehicles that were being studied in the ITS Info-communications Forum (hereinafter, the ITS Forum) and the message sets related to DSRC (dedicated short range communication) (vehicle-to-infrastructure (V2I) communication and vehicle to vehicle (V2V) communication) were studied, with tight collaboration with the ITS Forum.

Based on the above medium to long-term outlook, research and study were conducted into items shown in Fig. 1.2-1. Specific results are discussed in Chapter 2 and following.

(1) Project item a. Survey of trends internationally

Trends in systematization and standardization were researched and analyzed for the communication protocols, message sets and related communication specifications for 5.9 GHz band V2X systems, in countries/regions that included US, Europe and China.

(2) Project item b. Study for drafting of a communication protocol

Based on the results of study of the communication requirements and the message sets and roadmap in the ITS Forum, the communication requirements for 5.9 GHz band V2X systems required for the technical consideration of communications protocols were studied.

(3) Project item c. Design of communication protocol proposal

Based on the evaluation results from communication simulation, the communication protocols for 5.9 GHz V2X systems were designed, and summarized in draft communication protocols of communications procedures and protocol stacks, and draft message sets.

(4) Project item d. Drafting of radio unit specifications

The functions required for actual operation and the links with existing radio wave systems were considered, the specifications of on board equipment and road side units for 5.9 GHz band V2X systems were devised and implementation issues and strategies for solving them were consolidated.

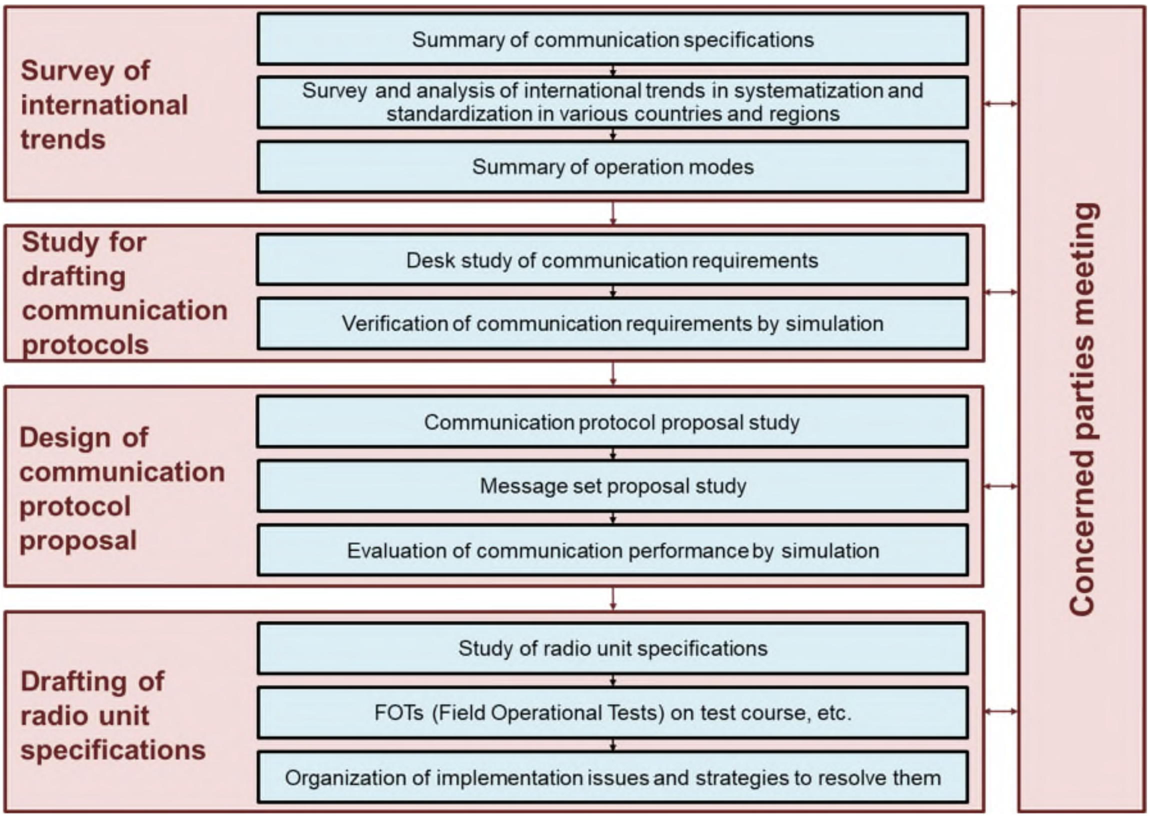


**Fig. 1.2-1 Survey study items**

### 1.3 Process of study consideration, inputs/outputs

The research and study in this project are carried out in the related parties meeting shown in Fig. 1.3-1, which continuously checks and discusses the study results and issues, and works to reflect those results in an appropriate way.

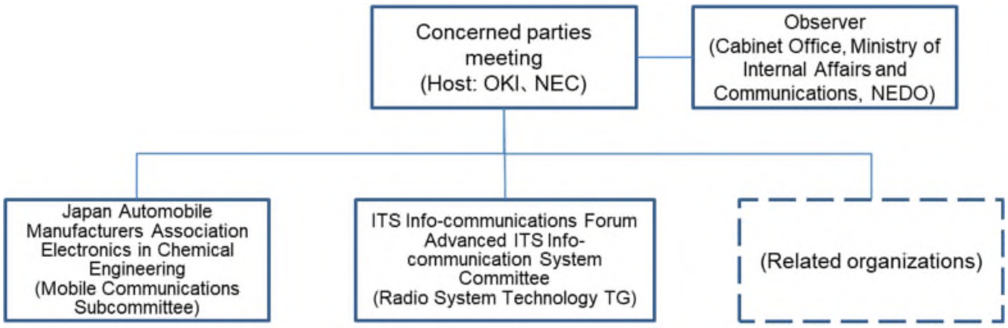


**Fig. 1.3-1 Concerned parties meeting system**

Further, as shown in Fig. 1.3-2, based on the system requirements of the vehicle to infrastructure (V2I) communication use cases and the vehicle to vehicle (V2V) communication use cases, of the Use cases for Cooperative Driving Automation, research and study was progressed using as inputs the communication requirements studied in the ITS Forum. The communication protocols proposal and the radio unit specifications draft that came out of the research and study, the items required for creation of communication standards (guidelines) envisaged in the above use cases, will be input to the ITS Forum and the system requirements organizations as communications conditions to assist in system performance evaluation.

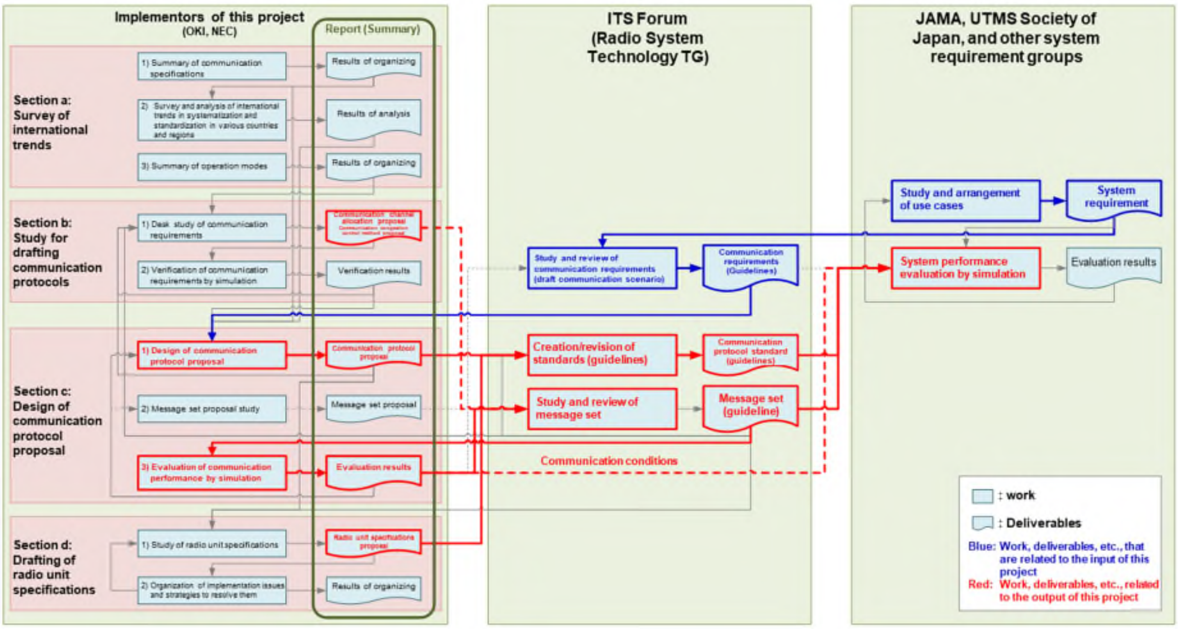


**Fig. 1.3-2 Inputs/outputs for this project**

## 2. Executive summary

Based on the results of validation of technical possibilities for communications such as specific required specifications for wireless communications technologies in Use Cases for Cooperative Driving Automation[1] (SIP use cases), obtained in the R&D project "Study of communications technologies to implement Use Cases for Cooperative Driving Automation" implemented during SIP Phase 2 in 2020 and 2021, along with a roadmap (roadmap[2]) that formulated concrete requirement specifications for various use cases and their respective wireless communications technologies as they would evolve in future, this research and development drafted radio unit specifications that included the communications protocols required for its introduction. This aimed to accelerate the problem solving and study related to the implementation of V2X systems that use 5.9 GHz radio waves, to realize Cooperative Driving Automation.

The implementation details for this project are shown below.

### 2.1 Project item a. Survey of international trends

Based on the results of study of the SIP Phase 1 "Survey and study regarding message sets and protocols in automated driving assistance technologies envisaged in real environments" (2018) and of the roadmap, a comprehensive survey of the latest international trends was conducted, and an analysis made, of the standardization and institutionalization of the 5.9 GHz band V2X system communications protocol (communications procedures and stacks, etc.), and the message sets and related communications specifications in the traffic environments of the US, Europe and China. We provided the trends research results necessary for the study of items b), c), d).

Specifically, relevant documents concerning standard specifications studies on V2X system communication protocols and radio units etc., from SAE International (Society of Automotive Engineers, or SAE) of the US, the European Telecommunications Standards Institute (ETSI) of Europe, and the China Communications Standards Association (CCSA), the most strongly influential standardization organizations/bodies internationally, were researched and analyzed. Use cases and messages related to cooperative automated driving being considered in the US and Europe do not vary greatly from the SIP use cases, and it was decided to focus the communications specifications study in the US and Europe on project items b to d.

### 2.2 Project item b. Research aimed at developing communication protocol proposals

Of the results obtained in project item a, and the ITS Forum communication requirements and message sets (RC-017[3]) required for communication according to the spread of automated vehicles studied in the ITS Forum[4]for SIP use cases, based on those relating to DSRC (dedicated short range communication), as well as the results of roadmap study, coordination with 700 MHz band ITS (Intelligent Transport Systems) Driving safety support systems was considered, and study materials provided on the communication requirements of 5.9 GHz band V2X systems required for technical consideration of communication protocols in project items c and d.

Specifically, it proposed communication channel allocation in 5.9 GHz band V2X systems, and a congestion control technology in the upper layers. Also, the effect of 5.9 GHz band V2X systems were evaluated using traffic simulation in case studies, and the effect on vehicle behavior (degree of deceleration, acceleration) was confirmed.

Items raised during the above study were reflected in the discussions in the ITS Forum and the Japan Automobile Manufacturers Association.

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1 SIP Use Cases for Cooperative Driving Automation, Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2019, 2019

2 Roadmap that formulated specific requirement specifications for wireless communication technology for Use cases for Cooperative Driving Automation in the R&D conducted in SIP Phase 2

3 https://itsforum.gr.jp/Public/J7Database/p70/ITS_FORUM_RC-017_v10.pdf
Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation"

4 ITS Info-communications Forum

### 2.3 Project item c. Design of communication protocol proposal

#### 2.3.1 Design of communication protocol proposal

- Regarding the draft communications protocols for realizing the SIP use cases for Cooperative Driving Automation in the 5.9 GHz band, design was conducted based on the communication scenario proposal from the ITS Forum (ITS FORUM RC-017), and the protocol stacks, congestion control flow and communications elements (functions, operation, interfaces) were brought together in a summary proposal.
- New functions (destination identification, request/response processing) for control/agreement use cases were added after studying the feasibility of SIP use cases based on European and U.S. specifications. As similar use cases are being standardized in other countries, confirmation of future trends is needed.
- Assuming that security would be provided in the same way as in US/European specification (electronic signature methodology), the interfaces and inter-layer processing procedures were studied and summarized. The detailed specifications for cyber security requires future consideration.
- A desk study of the developed communication protocol proposals was conducted. By detailing message sequences and organizing the relationship between applications, protocol stacks and information providers, it was confirmed that there were no inconsistencies with the communication scenarios.
- The study proposal for co-ordination methods with the 700 MHz band produced a proposal that did not change existing protocols. Based on the development roadmap and relative prevalence, future study will be needed on the method of allocating communication channels including to the 700 MHz band and 5.9 GHz band in each use case.
- The following may be listed as future issues.
  - ➢ Revision and study reflecting new version of communication scenario draft and overseas trends
  - ➢ Study of interface specifications with non-communication functions (control systems, etc.)
  - ➢ Study of detailed procedures including state transition, exception processing, etc.

#### 2.3.2 Message set proposal study

- Regarding the message structure in SIP use cases for Cooperative Driving Automation, based on study results at ITS FORUM (ITS FORUM RC-017), the information elements, use cases used, sizes, etc., were arranged, taking account of commonization across different use cases.
- The consistency of the channel allocation proposal and the communication protocol proposal could be verified by implementing a study of the above results as preconditions of Section 2.3.1 and Section 2.3.3.
- Based on the results of study of the communication protocol draft, multiplexing of the information elements was studied. Multiple information elements with different destinations or use cases were brought together in one packet, and a check performed of whether a reduction in data traffic could be anticipated through such reduction in overheads by security.
- The following may be listed as future issues.
  - ➢ Study reflecting future message set revisions
  - ➢ Study and evaluation of detailed procedures for information element multiplexing

#### 2.3.3 Evaluation of communication performance by simulation

- Based on the results of study in Section 2.3.1, and Section 2.3.2, in an expressway merge and a prefectural and municipal road intersection, and in an environment with mixed SIP use cases for Cooperative Driving Automation (and interference sources), multiple channels are allocated within a 30 MHz bandwidth in the 5.9 GHz band, and the communications performance is evaluated by CV2X (LTE V2X) in the case where multiple use case messages (information elements) are multiplexed.
- A comparison of multiple channel allocation proposals showed that communication quality was generally better when V2V use cases were assigned to one channel than when they were assigned to two channels within a 20 MHz bandwidth. When information elements on the same channel is multiplexed and combined into a single packet, a smaller number of channels means fewer packets per bandwidth, which can reduce transmission frequency and security overhead (communications traffic) and is considered effective in reducing intra- and inter-channel interference.
- Compared to single channel cases (up to 20 MHz bandwidth), the result did not necessarily show an improvement in the communication quality. In cases where vehicles transmissions are distributed across the multiple channels due to the multiple channel allocation, this is considered to be due to inability to multiplex information elements

across the different channels, which increases the number of packets per bandwidth and thus increases intra- and inter-channel interference.

- To verify the effectiveness of the congestion control technology, the communication performance with a longer vehicle transmission interval was evaluated. Under conditions where communication is congested and PAR required value cannot be achieved, it was confirmed that improved communication quality can be expected.
- Based on the evaluation results, to improve communication quality in situations where multiple use cases occur simultaneously and communications traffic is high, it is considered effective to transmit information elements together in a single packet on a small number of channels (with less communications traffic and lower transmission frequency by decreasing the number of packets per bandwidth) and to control transmission periods and the number of retransmission according to congestion conditions (and reduce transmission frequency during congestion).
- The following may be listed as future issues.
  - Comparison of performance with single/multiple channels in the same bandwidth
    (Example: In the case of NR V2X, is it better to have one channel in a 30 MHz bandwidth or to split it into two or more channels?)
  - Verification of effectiveness by channel allocation method other than by use case units
    (Example: When multiplexing information elements, it is possible that dividing the channel not by use case units but by transmission source units could offer better channel use efficiency. divide into roadside infrastructure transmission (I -> V direction in V2I communication) and vehicle transmission (V -> I direction in V2I communication + V2V communication))
  - Detailed evaluation of congestion control technology that considers transmission interval time changes, priority level, etc.

### 2.4 Project item d. Drafting of radio unit specifications

#### 2.4.1 Study of radio unit specifications

- By arranging the specification proposal to support the communications protocol overview draft that was the output of this project, the system configuration, equipment configuration, functions/characteristics/interfaces were brought together in the 5.9 GHz V2X wireless specification proposal.
- When identifying items in the specifications proposal, the existing radio unit specifications were referenced in order to ensure that all required items for a radio unit were covered.
- Based on the communication technology roadmap, an equipment configuration proposal was arranged that considered the introduction of 5.9 GHz-band radio units, and the methods of linking with existing ITS radio equipment, at various times after introduction.
- The following may be listed as future issues.
  - Continuous study of multi-channel support methods by quantitative evaluation
  - Consideration of specifications for items whose priority has been lowered
    (e.g. Interface hardware specifications, functions other than communications (fault detection, power supply, etc.))
  - Detailed study of requirements of interface with vehicles

#### 2.4.2 FOTs (Field Operational Tests) on test course, etc.

- The effect of communication channel allocation was checked by FOTs (Field Operational Tests) envisaged with multiple use cases mixed on a test course, with evaluation and analysis of the communication performance when using a single channel (10 MHz or 20 MHz) or multiple channels (10 MHz × 3 channels or 10 MHz + 20 MHz × 2 channels).
- In specific terms, communication performance was measured in an environment that simulated the communication traffic volume in each channel during the expressway merging section and general road intersection assumed for the simulation, and the results compared with the simulation. In the comparison of results in the single channel and multiple channels, the same trend as in the simulation were obtained, as below.
  - Concerning channel allocation, in both V2V and V2I communication, allocating V2V communication use cases to one channel of 20 MHz bandwidth resulted in better communication quality than allocating to two channels of 10 MHz bandwidth.
- The following may be listed as future issues.
  - Validation on actual equipment of deterioration factors when multi-channel sending and receiving were implemented using one radio unit

#### 2.4.3 Implementation issues and strategies to eliminate them

- Based on the results of radio unit specification study and the preconditions for study, issues for implementation were raised. These include update of radio unit specifications based on methods of linking to 700 MHz Intelligent Transport Systems, and promotion of standardization of communication upper layers. The strategy for the respective solving of various issues was also documented.

Overview is shown in Fig. 2-1.

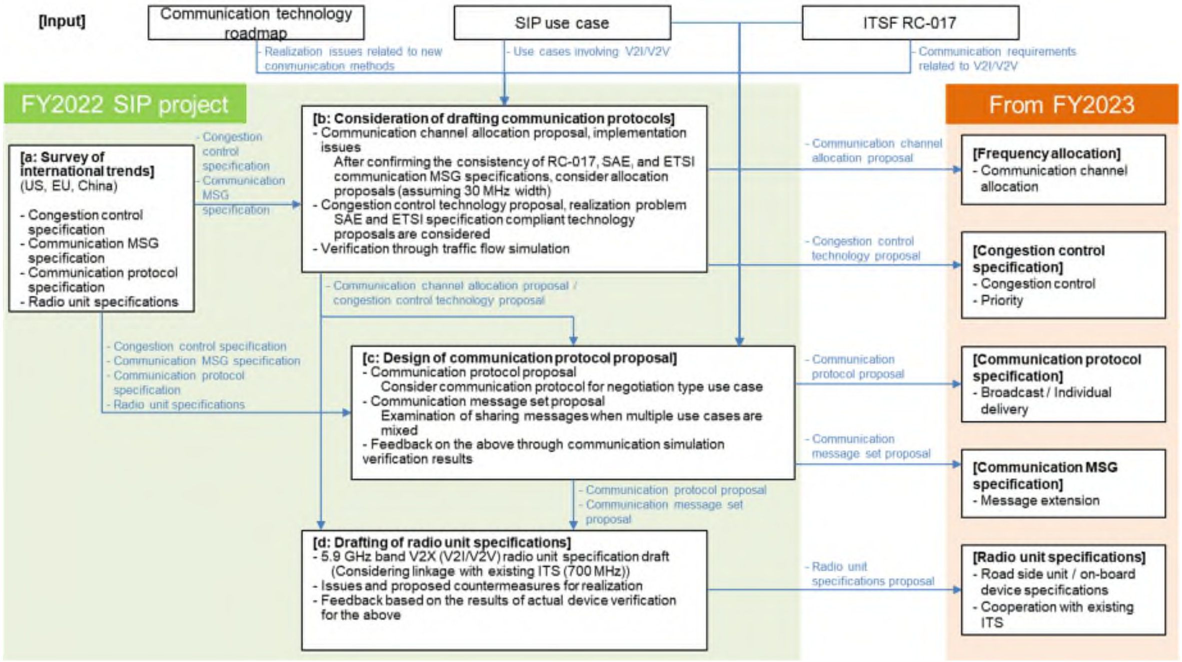


**Fig. 2-1 Overview of this project**

# 3. Survey of international trends

Following on from the results of a study of the 2021 Communication Requirements Roadmap, a comprehensive survey of the latest international trends was conducted, and an analysis made, of the control and regulation of the 5.9 GHz band V2X system communications protocol (communications procedures and stacks, etc.), and the message sets and related communications specifications in the traffic environments mainly of the USA, Europe and China. The goal was to provide the survey results required for research aimed at developing communication protocol proposals, designing communication protocol proposals and proposing wireless device specifications. This was primarily a literature survey, involving collection and analysis of papers and technical information from bodies such as international standardization organizations.

## 3.1 Overview of communication specifications

An outline of, and the relationship between, communications specifications regulated by standardization organizations/bodies has been prepared.

To the American SAE International (Society of Automotive Engineers, or SAE), and the European Telecommunications Standards Institute (ETSI), the most strongly influential standardization organizations/bodies internationally, we have added the Chinese organization, China Communications Standards Association (CCSA).

### 3.1.1 Communication specification standards

In SAE and ETSI, the communications specifications for V2X systems have been standardized on DRSC (WAVE, ITS-G5) and C-V2X (LTE-V2X). In CCSA, communications have been standardized on LTE (PC5, Uu).

The standards related to the overall configuration of these communication specifications are shown in Table 3.1.1-1.

**Table 3.1.1-1 Standards related to overall configuration of communications**

| Organization | Standards | Overview |
|---|---|---|
| SAE | SAE J2945<br>DSRC Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts | • Cross-cutting standards for SAE DSRC<br>• Engineering recommendations and requirements are included as guidance in the other J2945 series |
| | SAE J3161<br>Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters for Single Radio Channel Multi-Service Coexistence | • Provides a reference system architecture that meets the needs of a vehicular system that uses LTE-V2X (Release14) communications<br>• Also describes the cross-cutting functions of LTE-V2X PC5 side link (mode4) that can be used in ITS applications |
| ETSI | ETSI EN 302 665<br>ITS; Communications Architecture | • Defines the architecture shown in a basic ITS-G5 communications configuration, etc., (also assumed for non ITS-G5, etc.) in ITS |
| | ETSI TS 103 723<br>ITS; Profile for LTE-V2X | • Specifies the common standards necessary for providing direct communication between ITS stations via LTE-V2X PC5 mode4, and specifies the set parameter values and references |
| CCSA | YD/T 3400<br>General Technical Requirements of LTE-Based Vehicular Communication | • Specifies service requirements for vehicular communications using LTE, the system configuration and basic functional requirements for vehicular communications systems that use LTE |

An overall view of the related standards, an umbrella standard for these standards, is summarized in Fig. 3.1.1-1.

| | | SAE | ETSI | CCSA (China Communications Standards Association) |
|---|---|---|---|---|
| General | | [DSRC] SAE J2945; *Guidance*<br>[C-V2X] SAE J3161; *Profiles* | [DSRC] ETSI TS302 665; *Communi-cation architecture*<br>[C-V2X] ETSI TS103 723; *LTE-V2X Profile* | [C-V2X] YD/T 3400 ; *General Requirements* |
| Profile | Application facility | [BSM, etc.] SAE J2735; *Message Set Dictionary*<br>**Includes BSM, ICA, MAP, PSM, SPaT, etc. CPM, etc., under consideration* | [CAM/DENM] ETSI EN302 637; *Basic Set of Applications*<br>** SPAT, MAP, VAM, etc., are separate. CPM, etc., under consideration* | [BSM/etc.] YD/T 3709; *Message Layer*<br>**Includes BSM, MAP, PSM, RSM, etc.* |
| | Transport network | [WSMP] IEEE 1609.3; *WAVE Networking services (WAVE short message protocol)* | [GeoNetwork] ETSI EN302 636-5; *GeoNetworking: Basic transport protocol*<br>[DSRC] ETSI EN302 636-4-1; *Addressing/ forwarding*<br>[C-V2X] ETSI TS102 636-4-3; *Addressing/ forwarding* | [DSMP] YD/T 3707; *Network layer (Dedicated short message, Adaptation Layer)* |
| | Access | [DSRC] IEEE 1609.4; *Multi-channel operation*<br>IEEE 802.11p<br>[C-V2X] 3GPP TS23.285; *(LTE V2X PC5)* (cf. 3GPP TR 21.914) | [DSRC] EN302 663; *ITS-G5 Access layer*<br>IEEE 802.11p<br>[C-V2X] EN303 613; *LTE-V2X Access layer* | [C-V2X] YD/T 3340; *Air interface of LTE - based vehicular communication* |
| Operation | Congestion control | [DSRC] SAE J2945/1; *On-Board System*<br>[C-V2X] SAE J3161/1; *On-Board System* | [DSRC] TS102 687; *Decentralized Congestion Control*<br>[C-V2X] TS103 574; *Congestion Control Mechanisms* | [C-V2X] *(See 3GPP C-V2X; assumed similar to ETSI TS 103 574)* |
| | Cyber security | [Security] IEEE 1609.2; *WAVE Security Services*<br>IEEE 1609.2.1; *Certificate Management*<br>SAE SS V2X 001; *Security Specification*<br>SAE J2945/5; *Service Specific permissions* | [Security] *ITS communications; security*<br>TS102 940;*architecture*<br>TS102 941;*trust/privacy*<br>TS102 942;*access control,*<br>TS102 943;*confidentiality*<br>TS102 731:*Security Services and Architecture*<br>TS103 097;*Security header/certificate format* | [Security] YD/T 3594: *General technical requirements of security for vehicular communication based on LTE* |

* Collates the communications standards formulated and published by the organizations, as at June 2022

**Fig. 3.1.1-1 Overall configuration of communications standards**

### 3.1.2 Application facilities layer-related standards

In each of the regions of the USA, Europe and China, the message sets used in V2X systems are being standardized by the SAE, ETSI and CCSA, respectively. In terms of the application facilities layer that directly links to services, development was started for the initial DSRC, and then subsequently, the C-V2X standard has also been developed.

Basic messages have been standardized on BSM (US and China) and CAM/DENM (Europe).

- BSM (Basic safety message): SAE, CCSA
- CAM/DENM (Cooperative awareness message/ Decentralized environmental notification message): ETSI

Some messages used in other specific services are also being standardized as SPaT, MAP (US, Europe, China), etc.

- SPaT (Signal phase and timing): SAE, ETSI, CCSA
- MAP (Map information): SAE, ETSI, CCSA
- VAM/PSM (Vulnerable road user (VRU) awareness message/Personal safety message): SAE, ETSI
- etc.

Note that, even if the names are the same (similar), the contents of services and messages are not always the same.

Also, recently messages related to Cooperative Perception Services (CPS) that use information detected from other vehicles are under consideration.

- CPS (Collective Perception Service): ETSI
- CPS (Cooperative Perception System): SAE

The application facilities layer-related standards of each organization are shown in Table 3.1.2-1.

**Table 3.1.2-1 Application facilities layer-related standards**

| Organization | Standards | Overview |
| --- | --- | --- |
| SAE | SAE J2735<br>V2X Communications Message Set Dictionary | • Specifies the American V2X service message set (refer to DSRC (WAVE)/C-V2X), and includes ICA, MAP, PSM, SPaT, etc., together with the basic BSM |
| | SAE J2945/1<br>On-Board System Requirements for V2V Safety Communications<br>SAE J3161/1<br>On-Board System Requirements for LTE-V2X V2V Safety Communications | • Specifies a broad range of requirements for V2V communication<br>J2945/1 applies to DSRC (WAVE), J3161/1 to C-V2X<br>• Specifies the system requirements, etc., in the SAE J2945 series (J2945/2 Safety Awareness, J2945/3 Road weather, J2945/9 Vulnerable Road User, J2945/C Probe Data)<br>• Cooperative perception is also under consideration as the SAE J2945/8 Cooperative Perception System |
| ETSI | ETSI EN 302 637<br>ITS; Vehicular Communications; Basic Set of Applications<br>Part2: Specification of Cooperative Awareness Basic Service<br>Part3: Specifications of Decentralized Environmental Notification Basic Service | • Used in DSRC (ITS-G5)/C-V2X<br>• Specifies the European V2X service message set<br>• Consists of the basic vehicle messages, CAM (Cooperative awareness message: Part 2), and the environmental information messages, DENM (Decentralized environmental notification message: Part 3) (Part 1 Functional Requirements describes basic matters) |
| | ETSI TS 103 300<br>ITS; Vulnerable Road Users (VRU) awareness<br>ETSI TS 103 324 (under consideration)<br>ITS; Cooperative Perception Services | • VRU perception (used in DENM or CPM)<br>• Cooperative perception is also under consideration as Cooperative Perception System |
| CCSA | YD/T 3709<br>Technical requirements of message layer of LTE-based vehicular communication | • Specifies the message set for services in C-V2X, and specifies MPA, SPaT and RSM, etc., in addition to the base BSM |

### 3.1.3 Transport network

In the transport network layer in the communications protocol, the standards developed for DSRC are basically also used in C-V2X. Also in CCSA, the adaption function is being standardized.

Transport network layer-related standards of each organization are shown in Table 3.1.3-1.

**Table 3.1.3-1 Transport network layer-related standards**

| Organization | Standards | Overview |
|---|---|---|
| SAE | • IEEE 1609.3<br>IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services | • Used in DSRC (WAVE)/C-V2X (reference from SAE standards)<br>• Specifies networking services and messaging services, etc., in WAVE (WAVE short message protocol) |
| ETSI | • ETSI EN 302 636<br>Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking<br>  • Part 5: Transport Protocols; Sub-part 1: Basic Transport Protocol<br>  • Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications;<br>    • Sub-part1: Media-Independent Functionality<br>    • (TS)Sub-part3: Media-Independent Functionality for LTE-V2X | • Used in DSRC (ITS-G5)/C-V2X<br>• Specifies position information use type routing protocols in European V2X services<br>• GeoNetworking consists of Part 1: Requirements, Part 2: Scenarios, Part 3: Network architecture, Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications, Part 5: Transport Protocols, etc.<br>• Specifies the port number used by BTP in ETSI TS 103 248 |
| CCSA | • YD/T 3707<br>Technical requirements of network layer of LTE-based vehicular communication | • Specifies the message frame (Dedicated short message) in C-V2X, and the Adaptation Layer for merging with the lower layer |

### 3.1.4 Access layer related standards

Different standards for communications access functions have been developed for DSRC and C-V2X.

Both SAE and ETSI reference IEEE 802.11p as its access layer standard for DSRC (WAVE, ITS-G5) in the DSRC standards. IEEE 802.11p is a standard enacted by IEEE in 2010. (Note however that as of 2022, it is positioned as an old standard, described as "superseded standard.")

Further, while currently not referenced in the standards, in IEEE 802.11bd is being considered as a standard to replace 802.11p (in advanced communications specifications applying the n, ac, and ax technologies in 802.11p, the use of the millimeter wave band as well as the 5.9 GHz band is also assumed)

In the C-V2X access layer standard, the 3GPP Release 14 specification is also referenced in SAE, ETSI and CCSA. In terms of the target interfaces, SEA and ETSI use the PC5 interface, while CCSA describes the PC5 interface and the Uu interface within the same standard.

Further, while not referenced in the standards currently, in 3GPP, standardization has been performed for NR-V2X which uses 5G (from 3GPP Release 16).

Access layer-related standards of each organization are shown in Table 3.1.4-1.

**Table 3.1.4-1 Access layer related standards**

| Organization | Standards | Overview |
|---|---|---|
| SAE | • IEEE 1609.4<br>IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation | • Used in DSRC (WAVE) (reference from SAE standards)<br>• Specifies the use of multiple channels in WAVE (control channel (CCH) and service channel (SCH), priority access parameters and channel switching, etc.) |
| | • IEEE 802.11p<br>Wireless LAN MAC and PHY Specifications, Amendment 6: Wireless Access in Vehicular Environments | • Used in DSRC (WAVE) (reference from SAE standards)<br>• Specifies MAC layer and physical layer<br>• Separately, IEEE 802.11bd is under consideration as the successor standards |
| | • 3GPP TS 23.285 Release 14/ ETSI TS 123 285 (and others)<br>LTE; Architecture enhancements for V2X services | • C-V2X from the SAE standards refer to the 3GPP LTE (Rel. 14) standard (the description refers to the ETSI document as a reference standard)<br>• Note that the National ITS reference architecture (US DOT) provides 3GPP TR 21.914 (Release 14 Description) |
| ETSI | • ETSI EN 302 663<br>ITS; ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band | • Specifies operation of the DSRC (ITS-G5) access layer<br>• Refer to IEEE 802.11p<br>• Separately, use of IEEE 802.11bd is under consideration (EN303 797) |
| | • ETSI EN 303 613<br>ITS; LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band | • Specifies operation of the C-V2X (LTE-V2X) access layer<br>• Refer to the 3GPP LTE (Rel. 14) standard (the description refers to the ETSI document as a reference standard)<br>• Use of NR-V2X is being considered separately (EN303 798) |

| Organization | Standards | Overview |
| --- | --- | --- |
| CCSA | • YD/T 3340<br>Technical requirements of air interface of LTE-based vehicular communication | • Specifies the air interface requirements of LTE-based vehicular communication<br>• Refer to the 3GPP LTE (Rel.14) standard (PC5 and Uu) |

### 3.1.5 Congestion control-related standards

Standards for control of communication congestion in V2X systems, as well as cyber security standards, are currently being studied in the USA and Europe. Different standards have been developed in DSRC and C-V2X for congestion control functions relating to communications access, which has been an operational problem.

The congestion control-related standards of each organization are shown in Table 3.1.5-1.

**Table 3.1.5-1 Congestion control-related standards**

| Organization | Standards | Overview |
|---|---|---|
| SAE | • SAE J2945/1<br>On-Board System Requirements for V2V Safety Communications | • Used in DSRC (WAVE)<br>• Specifies BSM transmission schedule control and congestion control via output control (interval control based on occupancy rate of wireless resources and packet errors, etc.) in the V2V communication requirements |
| | • SAE J3161/1<br>On-Board System Requirements for LTE-V2X V2V Safety Communications | • Used in C-V2X<br>• Specifies congestion control using transmission interval and congestion ratio, etc., in the application layer, in the V2V communication requirements |
| ETSI | • ETSI TS 102 687<br>Intelligent Transport Systems (ITS);<br>Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part | • Used in DSRC (ITS-G5)<br>• Specifies the mechanisms, etc., in the access layer (DCC access) including DCC (Autonomous Decentralized Congestion Control Method) positioning, transmission power control (TPC) for each packet, transmission rate control (TRC) and transmission data rate control (TDC), for congestion control in ITS-G5 |
| | • ETSI TS 103 574<br>Intelligent Transport Systems (ITS);<br>Congestion Control Mechanisms for the C-V2X PC5 interface; Access layer part | • Used in C-V2X<br>• In LTE-V2X Congestion Control, in the access layer congestion control, specifies allocation based on wireless resource occupancy, and the interface to control entities for priority control, etc. |

The cyber security functions that are very relevant for service operations have been standardized with reference to IEEE 1609.2, which was developed in each of the organizations for the initial DSRC.

Cyber security-related standards of each organization are shown in Table 3.1.5-2.

**Table 3.1.5-2 Cyber security-related standards**

<table>
<tr><th>Organization</th><th>Standards</th><th>Overview</th></tr>
<tr><td rowspan="3">SAE</td><td>• IEEE 1609.2<br>Wireless Access in Vehicular Environments – Security Services for Applications and Management Messages<br>• IEEE 1609.2.1<br>Certificate Management Interfaces for End Entities</td><td>• In DSRC (WAVE)/C-V2X, reference from SAE standards<br>• Specifies methods for preventing message spoofing or message forgery through pseudonym certificates, and mechanisms for update of a pseudonym certificate on a fixed cycle, etc.</td></tr>
<tr><td>• SAE SS V2X 001<br>Security Specification through the Systems Engineering Process for SAE V2X Standards</td><td>• Describes procedures for, and analysis of, cyber security specifications development in V2X applications</td></tr>
<tr><td>• SAE J2945/5<br>Service Specific Permissions and Security Guidelines for Connected Vehicle Applications</td><td>• Describes procedures for, and analysis of, the study of specific permission management in V2X applications</td></tr>
<tr><td>ETSI</td><td>• ETSI TS 102 940<br>ITS; Security; ITS communications security architecture and security management<br>• ETSI TS102 941; Trust and Privacy<br>• ETSI TS102 942; Access Control<br>• ETSI TS102 943; Confidentiality services<br>• ETSI TS103 601; Security management messages communication requirements and distribution protocols<br>• ETSI TS102 731: Security Services and Architecture<br>• ETSI TS103 097; Security header and certificate formats</td><td>• Used in DSRC (ITS-G5)/C-V2X<br>• Regarding the cyber security architecture and management in the European V2X services, specifies the role and positioning of a series of cyber security services including the functional entities required for security services and the relationship of each entity and the elements of the ITS reference architecture, the management of security identifiers and certificates, the PKI process and interfaces, and the basic policies and guidelines, etc.<br>• TS103 601 specifies the requirements for handling TS102 941<br>• TS102 731/TS103 097 is a reference document for TS102 940, etc.</td></tr>
<tr><td>CCSA</td><td>• YD/T 3594<br>General Security requirements for LTE vehicular communication</td><td>• Specifies the technical requirements, interfaces, cyber security requirements and cyber security procedures for cyber security of vehicular communication using LTE</td></tr>
</table>

## 3.2 Survey of international trends in systematization and standardization in various countries and regions

### 3.2.1 Status of communication specifications initiatives

In the regions of the USA, Europe and China, it is assumed that the set of standards respectively developed by SAE, ETSI and CCSA are used for V2X communication.

Communication standards for V2X systems that are under consideration by each organization are shown in Table 3.2.1-1. An overview of the various standards is shown in the following and subsequent chapters (the relevant item is noted in the reference column).

**Table 3.2.1-1 Communication standards for V2X systems of each regional organization**

| Organization | Application | Standards | Reference |
|---|---|---|---|
| SAE | Message | • SAE J2735<br>V2X Communications Message Set Dictionary | 3.2.2(2) |
| | Network*1 | • IEEE 1609.3<br>IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services | 3.2.2(3) |
| | Access*1 | • IEEE 1609.4<br>IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation | 3.2.2(4) |
| | Access*2 | • 3GPP TS 23.285 Release 14/ ETSI TS 123 285 (and others)<br>LTE: Architecture enhancements for V2X services | 3.2.2(5) |
| ETSI | Message | • ETSI EN 302 637<br>ITS: Vehicular Communications; Basic Set of Applications | 3.2.3(2) |
| | Network | • ETSI EN 302 636<br>Intelligent Transport Systems (ITS): Vehicular Communications: GeoNetworking | 3.2.3(3) |
| | Access (ITS-G5) | • ETSI EN 302 663<br>ITS; ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band | 3.2.3(4) |
| | Access (LTE-V2X) | • ETSI EN 303 613<br>ITS; LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band | 3.2.3(5) |
| CCSA | Message | • YD/T 3709<br>Technical requirements of message layer of LTE-based vehicular communication | 3.2.4(2) |
| | Network | • YD/T 3707<br>Technical requirements of network layer of LTE-based vehicular communication | 3.2.4(3) |
| | Access | • YD/T 3340<br>Technical requirements of air interface of LTE-based vehicular communication | 3.2.4(4) |

*1 Refer to IEEE standard
*2 Refer to 3GPP standard

An overview of message communications in US (SEA) and Europe (ETSI) that use these standards is shown in Fig. 3.2.1-1.

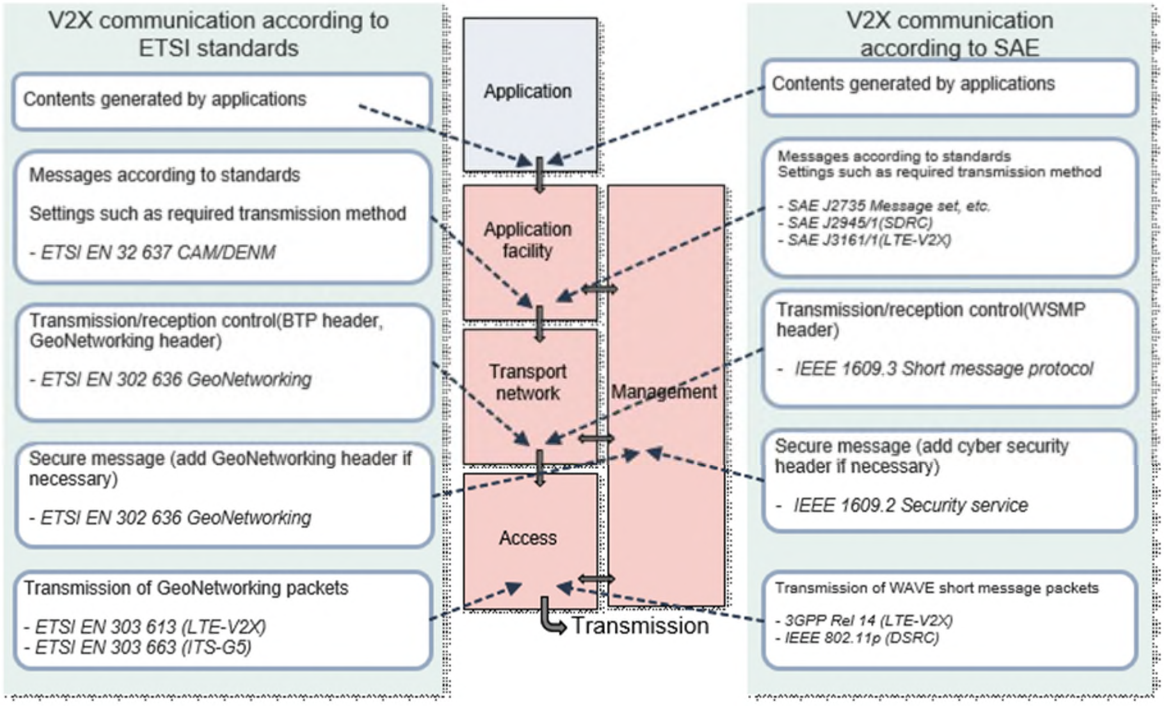


**Fig. 3.2.1-1 Concept of message communication standardized in ETSI and SAE**

### 3.2.2 USA

(1) Message structure

The packet structure for V2X communications standardized by SAE in the USA is arranged as shown in Fig. 3.2.2-1.

| J2735 messages |
|---|
| BasicSafetyMessage (BSM)/CommonSafetyRequest (CSR)/EmergencyVehicleAlert (EVA)/IntersectionCollisionAvoidance (ICA)/MapData (MAP)/ NMEAcorrections (NMEA)/PersonalSafetyMessage (PSM)/ProbeDataManagement (PDM)/ProbeVehicleData (PVD)/RoadSideAlert (RSA)/RTCMcorrections (RTCM)/ SignalPhaseAndTiming Message (SPAT)/SignalRequestMessage (SRM)/MSG_SignalStatusMessage (SSM)/TravelerInformation Message (TIM)/TestMessages<br>• SAE J2735-2020: “V2X Communications Message Set Dictionary”<br>**DSRC** (BSM)<br>• SAE J2945/1-2020: “On-Board System Requirements for V2V Safety Communications”<br>**LTE-V2X** (BSM)<br>• SAE J3161/1-2022: “On-Board System Requirements for LTE-V2X V2V Safety Communications” |

| Security Header (with Security trailer) | Message content |
|---|---|
| Secured message<br>• IEEE 1609.2-2016: “IEEE Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages" | |

| WSMP-N-Header | WSMP-T-Header | WSM Data |
|---|---|---|
| WAVE Short Message Protocol<br>• IEEE 1609.3-2020: “IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services” | | |

| MAC Header | RLC Header | PDCP Header | Non-IP Type Header | WAVE Short Message (WSMP Packet) |
|---|---|---|---|---|
| WAVE Networking Services over **LTE-V2X**<br>• IEEE 1609.3-2020: “IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services” → IEEE 802.11p | | | | |

| MAC Header | LLC sublayer Header | WAVE Short Message (WSMP Packet) |
|---|---|---|
| WAVE Networking Services (**DSRC**)<br>• IEEE 1609.3-2020: “IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services” → 3GPP Rel-14 | | |

**Fig. 3.2.2-1 Structure of V2X communications packet in SAE standard (LTE-V2X PC5, DSRC)**

(2) Message standards

An overview of the standard for V2X communications messages as standardized by SAE in the USA is as follows.

(a) SAE J2735

i. Name
- SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary
- Reference: SAE J2735, JUL2020

ii. Standardization organization/body
- SAE

iii. Standardization status
- First edition: Dec. 2006, Latest revision: July 2020

iv. Standard positioning
- SAE standards
- This standard is a message set, used in the upper layer of the access layer (IEEE 1609.4 or 3GPP TR21.914), and the transport layer/network layer (IEEE 1609.3)

v. Scope and standard details
- Specifies the message sets, the data frames and the data elements characteristic of applications that use 5.9 GHz DSRC (WAVE)
- The message sets are designed for common use in other wireless communications technologies, and are used also in C-V2X

vi. Related standards
- SAE J2540 Messages for Handling Strings and Look-Up Tables in ATIS Standards
- SAE J2540-2 ITIS Phrase Lists (International Traveler Information Systems)
- IEEE Std 1609.2™-2016, IEEE Std 1609.3™-2016, IEEE Std 1609.4™-2016(WAVE related standards: cyber security services, network services, multichannel operations)
- RTCM 10402.3, RTCM Standard 10403.1(GNSS service recommended standard)
- NMEA 183 Interface Standard v3.01(Position information transmission protocol-related standards)

vii. Description

SAE J2735 contents structure is shown in Table 3.2.2-1.

**Table 3.2.2-1 SAE J2735 contents structure**

| No. | Contents[5] | Remarks |
|---|---|---|
| 1. | SCOPE | — |
| 2. | REFERENCES | — |
| 3. | TERMS AND DEFINITIONS | — |
| 4. | THE USE OF DSRC MESSAGES IN APPLICATIONS | • Introduces this version and gives background information on the logical basis of these standards and user needs |
| 5. | MESSAFE SET (Basic Safety Message, Common Safety Request, Emergency Vehicle Alert, Intersection Collision Avoidance, Map Data, NMEA corrections, Personal Safety Message, Probe Data Management, Probe Vehicle Data, Road Side Alert, RTCM corrections, Signal Phase And Timing Message, Signal Request Message, Signal Status Message, Traveler Information Message, Test Messages) | • For messages sets including BSM, specifies the various general outlines, methods of use and ASN.1 (structural details of data concepts such as accuracy, and range of effective values) |
| 6. | DATA FRAMES | • For 156 data frames, specifies the various general outlines, methods of use and ASN.1 (structural details of data concepts such as accuracy, and range of effective values) |
| 7. | DATA ELEMENTS | • For 231 data elements, specifies the respective general outlines, methods of use and ASN.1 (structural details of data concepts such as accuracy, and range of effective values) |
| 8. | EXTERNAL DATA ENTRIES | • For 58 data concepts (data frames or data elements) being considered for use in DSRC, by other standardization organizations/bodies and/or other standards, specifies the respective general outlines and methods of use, and ASN.1 (structural details of data concepts such as accuracy, and range of effective values) |
| 9. | REGIONAL DATA CONCEPTS | • For the data frame set, message set and test message set for regional extension, specifies the respective general outlines and methods of use, and ASN.1 (provision and range of effective values, structural details of data concepts) |
| 10. | CONFORMANCE | • Specifies the requirements for conformance |
| 11. | FUNDAMENTAL CONCEPTS USED IN DSRC MESSAGES | • Selects the general design approach used in these standards and the topics that provide information on use and normative information |
| 12. | COMMENTS ON 2016 REVISION OF SAE J2735 [INFORMATIVE] | — |
| 13. | NOTES | — |

[5] Source: The table of contents is, SAE, J2735® JUL2020, V2X Communications Message Set Dictionary

(3) Network standards

An overview of the IEEE standard for V2X communications networks referenced in the American SAE standard is as follows.

(a) IEEE 1609.3

i. Name
- IEEE 1609.3: IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services
- Reference: IEEE Std 1609.3-2020

ii. Standardization organization/body
- IEEE Vehicular Technology Society

iii. Standardization status
- First edition: Dec. 2007, Latest revision: Mar. 2020

iv. Standard positioning
- IEEE standards
- This is a network layer and transport layer standard, operating in the upper layer of the access layer (IEEE 1609.4 or 3GPP TR21.914), and using SAE J2735 for the message set

v. Scope and standard details
- In the wireless connection between vehicles, road side units and the ITS devices, defines the services that operate in the network layer and the transport layer
- (WAVE networking services, message services (WAVE short message protocol), etc.)
- Used in DSRC (WAVE)/C-V2X

vi. Related standards
- ATIS.3GPP.24.301V14100-2019;3GPP TS 24.301 version 14.10.0 Release 14 (In UMTS/LTE/5G, non-access layer protocol standard specification for EPS (Evolved Packet System))
- ATIS.3GPP.24.386V1440-2019; 3GPP TS 24.386 version 14.4.0 Release 14 (Protocol standard specification in V2X control function from LTE user devices)
- ATIS.3GPP.36.211V14120-2019; 3GPP TS 36.211 version 14.12.0 Release 14, ATIS.3GPP.36.212V14100-2019; 3GPP TS 36.212 version 14.10.0 Release 14, ATIS.3GPP.36.213V14120-2019; 3GPP TS 36.213 version 14.12.0 Release 14, ATIS.3GPP.36.300V14110-2019; 3GPP TS 36.300 version 14.11.0 Release 14, ATIS.3GPP.36.214V1440-2018; 3GPP TS 36.214 version 14.4.0 Release14, ATIS.3GPP.36.321V14110-2019; 3GPP TS 36.321 version 14.11.0 Release 14, ATIS.3GPP.36.322V1410-2017; 3GPP TS 36.322 version 14.1.0 Release 14, ATIS.3GPP.36.323V1450-2018; 3GPP TS 36.323 version 14.5.0 Release 14, ATIS.3GPP.36.331V14120-2019; 3GPP TS 36.331 version 14.12.0 Release 14, ATIS.3GPP.36.101V14150-2020; 3GPP TS 36.101 version 14.15.0 Release 14E-UTRA-related standard specification: Multiplex channel coding, physical channels and modulation, physical layer processing and measurement, E-UTRA and E-UTRAN overall definition (MAC protocol specification, wireless link control protocol specification, Packet Data Convergence Protocol (PDCP) specification, Radio Resources Control (RRC) protocol specification, user device wireless sending/receiving specification)
- IEEE Std 802®, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.
- IEEE Std 802.11™, IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
- IEEE Std 1609.0™, IEEE Std 1609.2™, IEEE Std 1609.2a™-2017, IEEE Std 1609.4™, IEEE Std 1609.12™ (WAVE related standards: architecture, cyber security service, multi-channel operation, identifier allocation)

- IETF RFC 4291, IETF RFC 4861, IETF RFC 4862, IETF RFC 8200 (IPv6-related specifications: IPv6 definition, IPv6 protocol addressing architecture definition, Neighbor Discovery protocol specification, Interface automatic setting procedure)
- ISO/IEC 8802-2:1998, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control
- SAE J2735 (defines message sets of BSM, etc.)

vii. Description

IEEE 1609.3 contents structure is shown in Table 3.2.2-2.

**Table 3.2.2-2 IEEE 1609.3 contents structure**

| No. | Contents[6] | Remarks |
|---|---|---|
| 1. | Overview | — |
| 2. | Normative references | — |
| 3. | Definitions, acronyms, and abbreviations | — |
| 4. | General description | • Explains the applicable scope of this standard (Fig. 3.2.2-2), with data services and management plane constituent elements specified in section 5 and following |
| 5. | Data plane | • Specifies the constituent elements of the networking services data plane for support of vehicular applications<br>• Specifically, in 5.1 and following, specifies logical link control for IEEE 802.11 devices, handling for IPv6, IETF (Internet Engineering Task Force) protocol, WAVE Short Message Protocol (WSMP) specifications |
| 6. | Management plane | — |
| 7. | Service primitives | • Specifies the SAP (Service Access Point) for support of communications between entities in WAVE Networking Services<br>• Specifically in 7.1 and following, defines the specifications of channel identifiers, WSM (WAVE Short Message) SAP, WME (WAVE Management Entity) SAP, WAVE LSAP (link service access point), MLMEX (MLME and MLME extension) SAP, and Sec SAP |
| 8. | WAVE information formats | • Specifies the format of information sent within the network service<br>• Specifically, from 8.1, specifies the WAVE service advertisement format and the WAVE short message format |
| 9. | Annex A (informative) Bibliography | — |

[6] Source: The table of contents is, IEEE, IEEE Std 1609.3™-2020 (Revision of IEEE Std 1609.3-2016), IEEE Standard for Wireless Access in Vehicular Environments (WAVE)— Networking Services, Mar. 9, 2021

| No. | Contents[6] | Remarks |
|---|---|---|
| 10. | Annex B (informative) Wireless Access in Vehicular Environments (WAVE) Management Entity (WME) management information base (MIB) table | – |
| 11. | Annex C (normative) ASN.1 encoding of the Wireless Access in Vehicular Environments (WAVE) Management Entity (WME) management information base (MIB) | – |
| 12. | Annex D (normative) Protocol Implementation Conformance Statement (PICS) proforma | – |
| 13. | Annex E (informative) Service usage examples | – |
| 14. | Annex F (normative) Allocated Wireless Access in Vehicular Environments (WAVE) Information Element IDs | – |
| 15. | Annex G (informative) Packet format examples | – |
| 16. | Annex H (normative) IEEE Std 1609.2 security specification for WAVE Service Advertisement (WSA) 155 | – |
| 17. | Annex I (informative) General Wireless Access in Vehicular Environments (WAVE) Service Advertisement (WSA) security | – |
| 18. | Annex J (normative) ASN.1 specification for Wireless Access in Vehicular Environments (WAVE) extension elements | – |
| 19. | Annex K (normative) ASN.1 specification for Wireless Access in Vehicular Environments (WAVE) Short Message (WSM) | – |
| 20. | Annex L (normative) ASN.1 specification for WAVE Service Advertisement (WSA) | – |
| 21. | Annex M (normative) WAVE Networking Services over Long Term Evolution–based vehicle-to everything (LTE-V2X) | – |
| 22. | Annex N (normative) Protocol Type values | – |

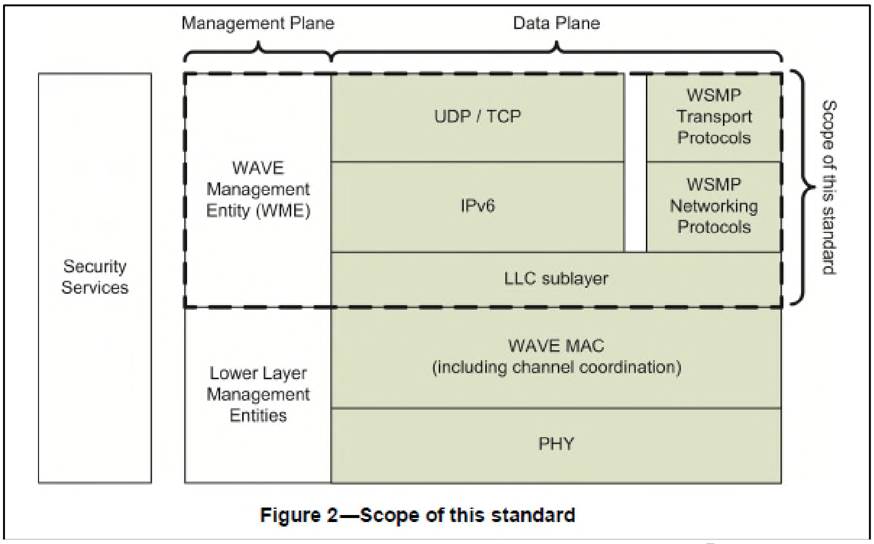


**Fig. 3.2.2-2 IEEE 1609.3 applicable scope[7]**

(4) DSRC access standard

The following gives an overview of the IEEE standard for the DSEC access layer in V2X communications referenced in the American SAE standard.

(a) IEEE 1609.4

i. Name
- IEEE 1609.4: IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-Channel Operation
- Reference: IEEE Std 1609.4™-2016

ii. Standardization organization/body
- IEEE Vehicular Technology Society

iii. Standardization status
- First edition: Nov. 2006, Latest revision: Mar. 2016

iv. Standard positioning
- IEEE standards
- This standard specifies the access layer, and as an upper layer standard it corresponds to the transport layer/network layer (IEEE 1609.3) and the application layer (SAE J2735)

v. Scope and standard details
- Specifies the MAC sub-layer function and services specification that supports multichannel radio connections between WAVE devices (control channel (CCH) and service channel (SCH), priority access parameters, channel switching, etc.)
- Used in DSRC (WAVE)

vi. Related standards
- IEEE Std 802.11™, IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
- IEEE Std 1609.0™, IEEE Std 1609.2™, IEEE Std 1609.3™, IEEE Std 1609.12™ (WAVE related standards: architecture, cyber security services, networking services, identifier allocation)

---

[7] Source: IEEE, IEEE Std 1609.3™-2020 (Revision of IEEE Std 1609.3-2016), IEEE Standard for Wireless Access in Vehicular Environments (WAVE)— Networking Services, P20, Mar. 9, 2021

vii. Description

IEEE 1609.4 contents structure is shown in Table 3.2.2-3.

**Table 3.2.2-3 IEEE 1609.4 contents structure**

| No. | Contents[8] | Remarks |
|---|---|---|
| 1. | Overview | — |
| 2. | Normative references | — |
| 3. | Definitions, acronyms, and abbreviations | — |
| 4. | General description | • Explains the applicable scope of this standard (Fig. 3.2.2-3), the constituent elements of MAC sublayer data services and MLME (MAC sublayer management entity) services specified in Section 5 and following |
| 5. | Data plane services | • Specifies a conceptual diagram of the multichannel MAC internal architecture, and the priority access specification for channel coordination, channel routing, and data transmission |
| 6. | Management services | • Specifies the extended specification for the MAC sublayer management entity (MLME)<br>• Specifically, in 6.2 and following, specifies the multichannel time synchronization, channel access function, the channel-unique access function for other IEEE 802.11 services, MIB (Management Information Base) maintenance and re-addressing specification |
| 7. | Service primitives | • Explains the relationship between the data plane entity and the management entity, in an overview of the management model<br>• In addition, specifies a list of primitives called in this standard, channel identifiers and the specifications of WAVE MLME extended SAP and WAVE MAC SAP |
| 8. | Annex A (informative) Bibliography | — |
| 9. | Annex B (informative) Channel congestion phenomenon following a channel switch | — |
| 10. | Annex C (informative) Avoiding transmission at scheduled guard intervals | — |
| 11. | Annex D (informative) MIB table | — |
| 12. | Annex E (informative) Precise timing sources and timing quality estimation | — |
| 13. | Annex F (normative) ASN.1 encoding of the IEEE 1609.4 MIB | — |
| 14. | Annex G (normative) Protocol implementation conformance statement (PICS) proforma | — |

[8] Source: The table of contents is, IEEE, IEEE Std 1609.4™-2016, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-Channel Operation, Mar. 21, 2016

| No. | Contents[8] | Remarks |
|---|---|---|
| 15. | Annex H (normative) System characteristic values | — |

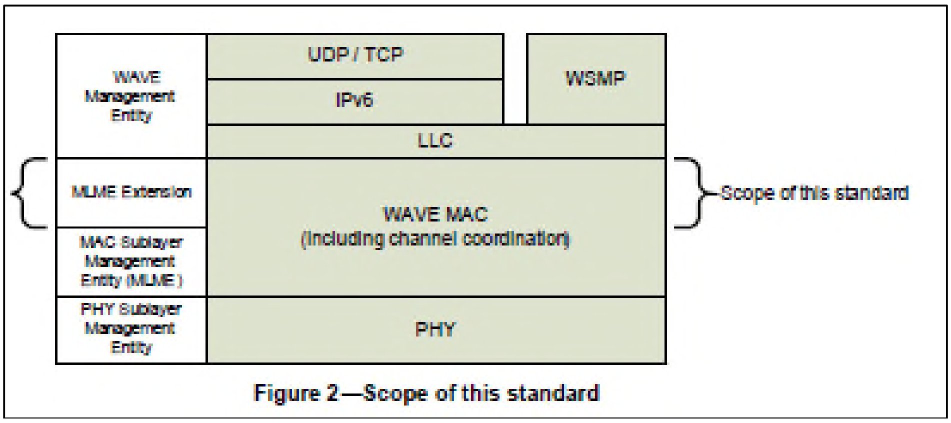


**Fig. 3.2.2-3 IEEE 1609.4 applicable scope[9]**

(5) LTE-V2X access standard

The following provides an overview of the 3GPP standard for the access layer for C-V2X referenced from the SAE standard in USA.

(a) Summary of Rel-14 Work Items

i. Name
- 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Release 14 Description; Summary of Rel-14 Work Items (Release 14)
- Reference: 3GPP TR 21.914 V14.0.0 (2018-05)

ii. Standardization organization/body
- 3rd Generation Partnership Project

iii. Standardization status
- First edition: 2017-03, 21.914 V0.1.0, Revised: 2018-05, 21.914 V14.0.0 (Stage 3)

iv. Standard positioning
- Technical report (TR)
- This document itself is not a standard, but has been provided as an introductory overview to the standard content

v. Scope and standard details
- Mission-critical improvements
- V2X communication system requirements/architecture
- Improvement of cooperative IoT through support of inter-device communications that use 2G/3G/4G
- Improvement of wireless interfaces
- Improvements in Voice over LTE/IP Multimedia Subsystem/Location reporting, etc.

vi. Related standards
- ETSI TR 102 638 V1.1.1 ITS; Vehicular Communications; Basic Set of Applications; Definitions (Defines the base set of applications focused on V2V/V2I/I2V communications in the V2X dedicated frequency band)

---

[9] Source: IEEE, IEEE Std 1609.4™-2016, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-Channel Operation, P15, Mar. 21, 2016

- ETSI TS 102 637-1 V1.1.1 ITS; Vehicular Communications; Basic Set of Applications; Part 1: Functional Requirements
  (Specifies modifications to the ETSI EN 302 636 specification that is a transport network layer standard)

vii. Description
Summary of Rel-14 Work Items contents structure is shown in Table 3.2.2-4.

**Table 3.2.2-4 Table of Contents of the Summary of Rel-14 Work Items**

| No. | Contents[10] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | Reference | — |
| 3. | Definitions, symbols and abbreviations | — |
| 4. | Process to get further information | — |
| 5. | Rel-14 Executive Summary | — |
| 6. | Mission Critical related items | — |
| 7. | Vehicle-to-Everything (V2X) related items<br>7.1 LTE support for V2X services<br>7.2 Support for V2V services based on LTE sidelink | • PC5 (direct communications) Uu (via radio base station) are specified as interface methods for V2X communication<br>• Specifies the V2X system architecture from the user terminal through the V2X communication application server<br>• Specifies the transmission latency, transmission capacity, number of messages transmitted per second, etc., as requirements for the V2X communications system applications |
| 8. | Cellular Internet of Things (CIoT) related items | — |
| 9. | Voice and Multimedia related items | — |
| 10. | Location and positioning related items | — |
| 11. | Radio improvements | — |
| 12. | System improvements | — |
| 13. | Rel-14 Work Items not subject to summaries | — |
| 14. | Annex A: Change history | — |

(b) Rel14: TS 36.300
i. Name
- 3GPP TS 36.300
  3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 14)
- Reference: 3GPP TS 36.300 V14.2.0 (2017-03)

[10] Source: Table of Contents is 3GPP, 3GPP TR 21.914 V14.0.0 (2018-05), 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Release 14 Description; Summary of Rel-14 Work Items (Release 14), May 2018

ii. Standardization organization/body
- 3rd Generation Partnership Project

iii. Standardization status
- First edition: 2016-09, V14.0.0, Revised: 2017-03, V14.2.0 (Version corresponding to ETSI TS 136 300)

iv. Standard positioning
- Technical Specification (TS)
- LTE (Rel14) overall architecture

v. Scope and standard details
- Specifies LTE (Rel14) overall architecture
- Within that, also describes the architecture of V2X services, etc., that use Sidelink communication (PC5), PC5 and Uu

vi. Related standards
- Refer to 3GPP LTE documentation
- Note that ETSI has also published standards documents with equivalent content that corresponds to the 3GPP standard. The ETSI document may be referenced in the LTE-V2X-related standard

vii. Description

TS 36.300 contents structure is shown in Table 3.2.2-5.

**Table 3.2.2-5 Rel14：TS 36.300 contents structure**

| No. | Contents[11] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | Reference | — |
| 3. | Definitions, symbols and abbreviations | — |
| 4. | Overall architecture | — |
| 5. | Physical Layer for E-UTRA | — |
| 6. | Layer 2 | — |
| 7. | RRC | — |
| 8. | E-UTRAN identities | — |
| 9. | ARQ and HARQ | — |
| 10. | Mobility | — |
| 11. | Scheduling and Rate Control | — |
| 12. | DRX in RRC_CONNECTED | — |
| 13. | QoS | — |
| 14. | Security | — |
| 15. | MBMS | — |
| 16. | Radio Resource Management aspects | — |
| 17. | Void | — |
| 18. | UE capabilities | — |
| 19. | S1 Interface | — |
| 20. | X2 Interface | — |
| 21. | Void | — |
| 22. | Support for self-configuration and self-optimization | — |
| 22A. | LTE-WLAN Aggregation and RAN Controlled LTE-WLAN Interworking | — |
| 22B. | Xw Interface | — |
| 23. | Others<br>23.10 Support for sidelink communication<br>23.14 Support for V2X services | • 23.10 Specifies Sidelink communication<br>• 23.14 Specifies V2X (including PC5 and Uu interfaces) |

[11] Source: The table of contents is, 3GPP, 3GPP TS 36.300 V14.2.0 (2017-03) Technical Specification, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 14), Mar. 2017

(c) Rel14: TS 23.285

i. Name

- 3GPP TS 23.285
  3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Architecture enhancements for V2X services (Release 14)
- Reference: 3GPP TS 23.285 V14.9.0 (2019-12)

ii. Standardization organization/body

- 3rd Generation Partnership Project

iii. Standardization status

- First edition: 2016-09, V14.0.0, Revised: 2019-12, V14.9.0 (Version corresponding to ETSI TS 123 285)

iv. Standard positioning

- Technical Specification (TS)
- Extension for V2X in LTE (Rel14) architecture

v. Scope and standard details

- In the LTE (Rel 14) architecture, specifies the architecture extension to facilitate vehicular communications of vehicle-to-everything services (V2X) including Vehicle-to-Vehicle (V2V), Vehicle-to-Pedestrian (V2P), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle Network (V2N).

vi. Related standards

- Refer to 3GPP LTE documentation
- Note that ETSI has published a standard with the same content as the 3GPP document (refer to the ETSI document which in ETSI is not the same as the 3GPP document itself)

vii. Description

TS 23.285 contents structure is shown in Table 3.2.2-6.

**Table 3.2.2-6 Rel14：TS 23.285 contents structure**

| No. | Contents[12] | Remarks |
|---|---|---|
| 1. | Scope | ― |
| 2. | Reference | ― |
| 3. | Definitions, symbols and abbreviations | ― |

[12] Source: The table of contents is, 3GPP, 3GPP TS 23.285 V14.9.0 (2019-12) Technical Specification, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Architecture enhancements for V2X services (Release 14), Dec. 2019

| No. | Contents[12] | Remarks |
|---|---|---|
| 4. | Architecture model and concepts<br>4.1 General concept<br>4.2 Architectural reference model<br>4.3 Functional entities<br>4.4 High level function<br>4.4.1 Authorization and Provisioning for V2X communications<br>4.4.2 V2X message transmission/reception over PC5 reference point<br>4.4.3 V2X message transmission/reception over LTE-Uu reference point<br>4.4.4 V2X Application Server discovery<br>4.4.5 QoS handling for V2X communication<br>4.4.6 Subscription to V2X services<br>4.4.7 MBMS bearer announcement for V2X use<br>4.4.8 Support for V2X communication for UEs in limited service state<br>4.4.9 Charging support for V2X communication<br>4.4.10 Security and privacy protection support for V2X communication<br>4.5 Identifiers | • 4.4.2 Specifies V2X communication through PC5 (Sending and receiving) |
| 5. | Functional description and information flows<br>5.1 Control and user plane stacks<br>5.2 Service authorization and update for V2X communications<br>5.3 Procedure for V2X communication over PC5 reference point<br>5.4 Procedure for V2X communication over LTE-Uu reference point<br>5.5 V2X impacts to EPC procedures | • 5.3 (Procedures) Specifies V2X communication through PC5 |

### 3.2.3 Europe

(1) Message structure

The structure for packet communications in V2X communications under the ETSI European standard is collated as shown in Fig. 3.2.3-1.

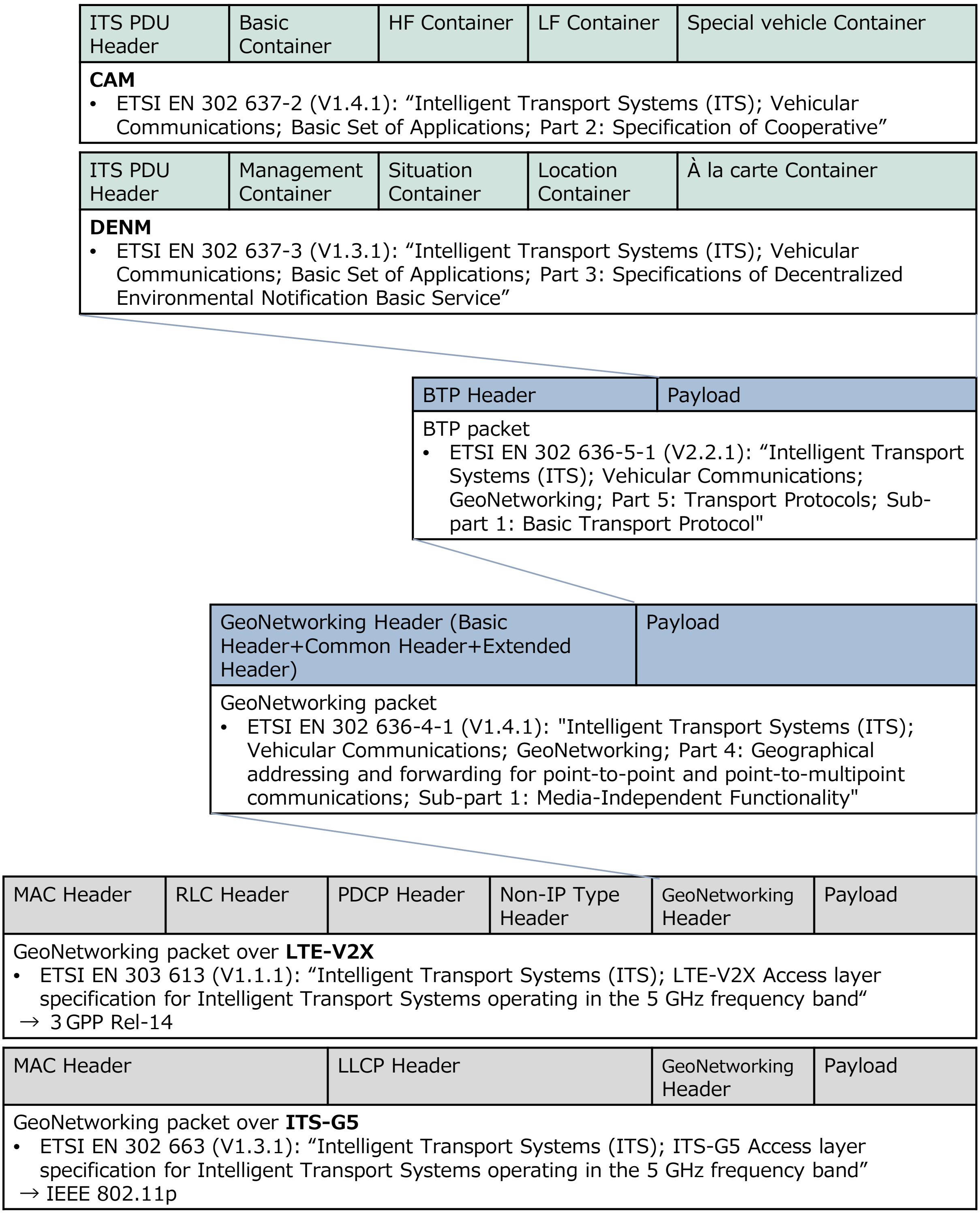


**Fig. 3.2.3-1 Structure of the ETSI standard V2X communications packet (LTE-V2X PC5, ITS-G5)**

(2) Message standards

The following provides an overview of the standards relating to V2X communications messages as standardized by ETSI in Europe.

(a) EN 302 637 CAM/DENM

i. Name
- EN 302 637-2 (CAM) Part 2: Specification of Cooperative Awareness Basic Service (CAM)
- EN 302 637-3 (DENM) Part 3: Specifications of Decentralized Environmental Notification Basic Service (DENM)
- Reference: ETSI EN 302 637-2 V1.4.1, ETSI EN 302 637-3 V1.3.1, TC ITS WG4 (Media and Medium Related)

ii. Standardization organization/body
- ETSI

iii. Standardization status
- ETSI EN 302 637 part 2: First edition 2014.11.28, Revised 2019.4.2
- ETSI EN 302 637 part 3: First edition 2014.11.28, Revised 2019.4.2

iv. Standard positioning
- EN standard
- Specifies the message set of the European V2X service (Basic Set of Applications) in DSRC (ITS-G5)/C-V2X

v. Scope and standard details
- Part 2: Specifies the specifications of Cooperative Awareness base services that support the traffic safety applications (this includes the CAM syntax and semantics definition, and the detailed message processing specifications)
- Part 3: Provides specifications for the Decentralized Environment Notifications (DEN) basic services that support RHW applications (Specifies syntax and semantics of Decentralized Environment Notification Messages (DENM) and handling of DENM protocols, and DEN basic services can be deployed to Vehicular ITS stations, roadside ITS stations, individual ITS stations and central ITS stations)

vi. Related standards
- The requirements of the CAM/DENM content and the data element quality are set according to the basic applications defined by ETSI TS 102 638 (Basic Set of Applications; Definitions) and the road safety applications defined by ETSI TS 101 539 (V2X Applications; application requirements specification)

vii. Description

1) EN 302 637-2
- Describes the Cooperative Awareness Message (CAM: Part 2) that sends the vehicle position and its speed, etc., and the Decentralized Environmental Notification Message (DENM: Part3), the notification message when an event is generated, both standardized in Europe
- Note that Part 1 specifies the Functional Requirements

EN 302 637-2 contents structure is shown in Table 3.2.3-1.

**Table 3.2.3-1 EN 302 637-2 contents structure**

| No. | Contents[13] | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | References | – |
| 3. | Definition of terms, symbols and abbreviations | – |
| 4. | CA basic service introduction | • Provides basic concepts<br>• Role in sharing vehicular information such as vehicle-to-vehicle position and travel status, etc., with the shared information used in road safety and in traffic efficiency applications |
| 5. | CA basic service functional description | |
| 6. | CAM dissemination | • Specifies CAM<br>• Because real-time communications are demanded for the dissemination of vehicle travel information that changes second to second, CAM is designed as a single-hop broadcast at a frequency from 1Hz to 10Hz |
| 7. | CAM Format Specification | – |
| 8. | Annex A (normative): ASN.1 specification of CAM | – |
| 9. | Annex B (normative): Description for data elements and data frames | – |
| 10. | Annex C (informative): Protocol operation of the CA basic service | – |
| 11. | Annex D (informative): Flow chart for CAM generation frequency management | – |
| 12. | Annex E (informative): Extended CAM generation | – |

2) EN 302 637-3

- Describes the Decentralized Environmental Notification Message (DENM: Part 3) which is a notification message when an event is generated

EN 302 637-3 contents structure is shown in Table 3.2.3-2.

**Table 3.2.3-2 EN 302 637-3 contents structure**

| No. | Contents[14] | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | References | – |
| 3. | Definitions, symbols and abbreviations | – |
| 4. | DEN basic service introduction | • Provides basic concepts |

[13] Source: The table of contents is, ETSI, ETSI EN 302 637-2 V1.4.1 (2019-04), Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service, Apr. 2019

[14] Source: The table of contents is, ETSI, ETSI EN 302 637-3 V1.3.1 (2019-04), Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service, Apr. 2019

| No. | Contents[14] | Remarks |
|---|---|---|
| 5. | DEN basic service functional description | • DENM is an event-driven message that is sent when an event is detected in the road traffic. It establishes various events such as detection of a one-way traffic violation, or the detection of traffic congestion, etc. |
| 6. | DENM dissemination | • Specifies DENM<br>• For each event it sets the condition for ending the DENM transmission, and the required range for notification of that event, and each vehicle sends messages at a fixed frequency until an end condition is satisfied by the event detection |
| 7. | DENM format specification | − |
| 8. | Protocol operation of the DEN basic service | − |
| 9. | Annex A (normative): ASN.1 specification of DENM | − |
| 10. | Annex B (normative): Description for data elements and data frames | − |
| 11. | Annex C (informative): Bibliography | − |

(3) Network standards

The following provides an overview of the standards for the V2X communications network layer as standardized by ETSI in Europe.

(a) EN 302 636 GeoNet/BTP

i. Name
- ETSI EN 302 636 Geo Networking Basic transport protocol
- Reference: ETSI EN 302 636-5 V2.2.1, ETSI EN 302 636-3 V1.2.1, ETSI TC ITS WG4 (Media and Medium Related)

ii. Standardization organization/body
- ETSI

iii. Standardization status
- ETSI EN 302 636 part 1: First edition 2014.4.29
- ETSI EN 302 636 part 2: First edition 2013.11.7
- ETSI EN 302 636 part 3: First edition 2014.12.11
- ETSI EN 302 636 Part 4-1 First edition 2014.7.25, Revised 2020.1.23
- ETSI EN 302 636 part 5-1 First edition 2014.8.1, Revised 2019.5.22
- ETSI EN 302 636 part 6: First edition 2014.5.28

iv. Standard positioning
- EN standard
- Specifies the message set of the European V2X service (Basic Set of Applications) in DSRC (ITS-G5)/C-V2X

v. Scope and standard details
- Part1: Requirements
- Part2: Scenarios
- Part3: Network Architecture
- Part4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality

- Part5: Transport Protocols; Sub-part 1: Basic Transport Protocol
- Part6: Internet Integration; Sub-part 1: Transmission of IPv6 Packets over Geo Networking Protocols

The following describes the content of Part 3 and Part 5.
<Part3>
- Specifies the network architecture of ITS communications
- While the focus is on vehicular communications, realizes a wide range of ITS applications such as road safety, traffic efficiency, infotainment, and business
- Defines the framework of the network and data transmission protocols for realizing data exchange between ITS stations
- In particular, specifies the Geo Networking protocol for realizing ad hoc communications and multiple hop communications over short range wireless technology using geographical position

<Part5>
- Specifies the Basic Transfer Protocol (BTP) for packet transmission between ITS stations
- BTP is positioned at the top of the Geo Networking protocol specified in ETSI EN 302 636-4-1, and at the bottom of the ITS-S facilities layer

vi. Related standards
Normative reference
<Part3>
- ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture."
- ISO/IEC 7498-1: "Information technology - Open Systems Interconnection - Basic Reference
- Model: The Basic Model."
- ETSI TS 102 637: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications."
- ETSI EN 302 663: "Intelligent Transport Systems (ITS); Access layer specification for Intelligent
- Transport Systems operating in the 5 GHz frequency band."
- ETSI EN 302 636: "Intelligent Transport Systems (ITS); Vehicular Communications;
- Geo Networking; Part 1: Requirements."
- ETSI TS 102 723 (all parts): "Intelligent Transport Systems (ITS); OSI cross-layer topics."
- ETSI TS 102 731: "Intelligent Transport Systems (ITS); Security; Security Services and Architecture."
- ETSI TS 102 940: "Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management."
- ISO/IEC 8802-2: "Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements; Part 2: Logical Link Control."

<Part5>
- ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture."
- ETSI EN 302 636-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 1: Requirements."
- ETSI EN 302 636-2: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 2: Scenarios."
- ETSI EN 302 636-3: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network architecture."
  - ETSI EN 302 636-4-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality."
  - ETSI TS 103 248: "Intelligent Transport Systems (ITS); GeoNetworking; Port Numbers for the Basic Transport Protocol (BTP)."

vii. Description
EN 302 636 GeoNet/BTP (Part3) contents structure is shown in Table 3.2.3-3.

**Table 3.2.3-3 EN 302 636 GeoNet/BTP (Part3) contents structure**

| No. | Contents[15] | Remarks |
| --- | --- | --- |
| 1. | Scope | – |
| 2. | References | – |
| 3. | Definitions and abbreviations | – |
| 4. | Network architecture for ITS stations | – |
| 5. | Deployment scenarios of the generic network architecture | – |
| 6. | Components of the network architecture | – |
| 7. | ITS station protocol architecture<br>7.3 Assembly of networking and transport protocols in the ITS station protocol stack | • Specifies the architecture<br>• The GeoNetworking protocol stack can be assembled as shown in Fig. 3.2.3-2, with the ITS-specific transport protocol assumed in ETSI TS 102 636-5-1 at the apex |
| 8. | Interfaces and service access points | – |
| 9. | Framework for networking and transport protocols | – |
| 10. | Annex A (informative): Bibliography | – |

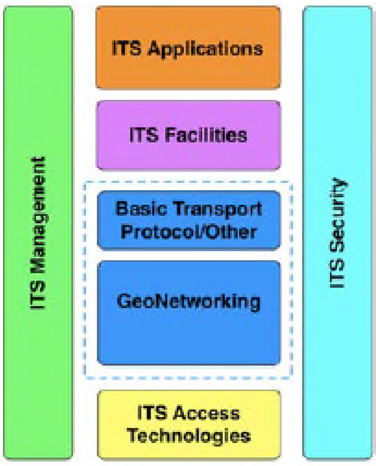


**Figure 14: GeoNetworking protocol stack in an ITS station**

**Fig. 3.2.3-2 GeoNetworking protocol in the ITS station[16]**

EN 302 636 GeoNet/BTP (Part5) contents structure is shown in Table 3.2.3-4.

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[15] Source: About the table of contents, ETSI, ETSI EN 302 636-3 V1.2.1 (2014-12), Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network Architecture, Dec. 2014

[16] Source: ETSI, ETSI EN 302 636-3 V1.2.1 (2014-12), ETSI EN 302 636-3 V1.2.1 (2014-12), Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network Architecture, P17, Dec. 2014

**Table 3.2.3-4 EN 302 636 GeoNet/BTP (Part5) contents structure**

| No. | Contents | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | References | – |
| 3. | Definition of terms, symbols and abbreviations | – |
| 4. | Services provided by the Basic Transport Protocol | – |
| 5. | Format convention | – |
| 6. | BTP packet structure | • Specifies the packet structure of the basic transport protocol, the header structure and operation |
| 7. | BTP header | |
| 8. | Protocol operations | |
| 9. | Annex A (informative): BTP data services | – |
| 10. | Annex B (informative): Bibliography | – |

(4) DSRC access standard

The following provides an overview of the standards for the V2X communications DSRC access layer as standardized by ETSI in Europe.

(a) EN 302 663

i. Name
- ETSI EN 302 663 ITS-G5 Access layer
  ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band
- Reference: ETSI EN 302 663 V1.3.1, TC ITS WG4 (Media and Medium Related)

ii. Standardization organization/body
- ETSI

iii. Standardization status
- First edition 2013.7.5, Revised 2020.1.7

iv. Standard positioning
- EN standard
- The lowest two layers, the physical layer and the datalink layer, are split and defined in the access layer (ITS station reference architecture ETSI EN 302 665)

v. Scope and standard details
- This is an upgrade to EN of ES 202 663, considering the final changes to 802.11p and the migration to 802.11
- Clarification related to TS 102 792, and other changes based on new information from G5-related projects

vi. Related standards

Normative reference
- IEEE 802.11TM-2016: IEEE Information Technology standard - electronic communications and information exchange between systems, local and metropolitan area networks -Specific requirements- Part 11: Wireless LAN Media Access Control (MAC) and physical layer (PHY) specifications
- IEEE/ISO/IEC 8802-2-1998: Information Technology - Electronic communications and information exchange between systems, local and metropolitan area networks -Specific requirements- Part 2: Relation with physical link control
- ETSI TS 102 687 (V1.2.1): ITS (Intelligent Transport Systems), Distributed congestion control mechanisms for Intelligent Transport Systems operating on the 5 GHz band; Access layer part

- IEEE 802TM-2014: Local and metropolitan area networks IEEE standards (Overview and architecture)
- ETSI EN 302 571 (V2.1.1): ITS; Wireless communications devices operating in the 5 855 MHz to 5 925 MHz frequency band; corresponds to Essential requirements of Article 3.2 of Directive 2014/53/EU
- ETSI TS 102 792 (V1.2.1): ITS; Mitigation technology for avoidance of interference between ITS (Intelligent Transport System) and European CEN DSRC devices operating on the 5 GHz band

vii. Description

- In EN 302 663, the lowest two layers based on EN 302 665 are called the access layers, with the technology specified in the access layer given the general name of ITS-G5 (the ITS-G5 access layer technology uses a standard that already exists in communications)

EN 302 663 contents structure is shown in Table 3.2.3-5.

**Table 3.2.3-5 EN 302 663 contents structure**

| No. | Contents[17] | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | References | – |
| 3. | Definition of terms, symbols and abbreviations | – |
| 4. | Access layer requirements | • Provides concepts<br>• The access layer bundles the data link layer and the physical layer and is positioned as the lowest layer of the ITS protocol stack<br>• The access layer technology is comprised of IEEE 802.11-2016, IEEE/ISO/IEC 8802-2-1998, IEEE 802-2014 and ETSI TS 102 687<br>• Of the physical layer and the data link layer, the media access control layer is covered by IEEE 802.11-2016 |
| 5. | ITS-G5 radio tests | – |
| 6. | Annex A (normative): Channel models for testing dynamic sensitivity values | – |
| 7. | Annex B (Informative): Data and management service | – |
| 8. | Annex C (informative): Introduction to IEEE 802.11-2016 | – |
| 9. | Annex D (informative): Change History | – |

[17] Source: The table of contents is, ETSI EN 302 663 V1.3.1 (2020-01), Intelligent Transport Systems (ITS); ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band, Jan. 2020

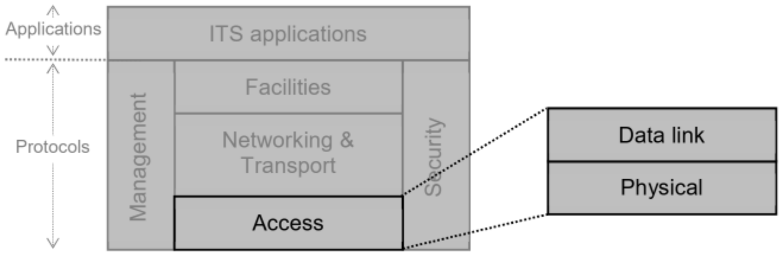



Figure 1: ITS station reference architecture

**Fig. 3.2.3-3 Access layer protocols in the ITS station[18]**

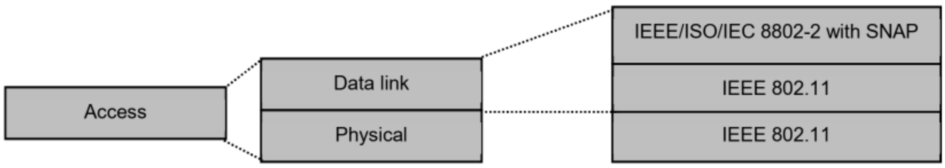



Figure 2: Protocols comprising the access layer

**Fig. 3.2.3-4 Access layer protocol configuration[19]**

(5) LTE-V2X access standard

The following provides an overview of the standards for the V2X communications LTE-V2X access layer as standardized by ETSI in Europe.

(a) EN 303 613

i. Name
- Intelligent Transport Systems (ITS); LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band
- Reference: ETSI EN 303 613 V1.1.1 (2020-01)

ii. Standardization organization/body
- ETSI

iii. Standardization status
- First edition: v1.1.1 (Active)

iv. Standard positioning
- EN standards
- Specifies the access layer that is used at the lower level of the transport/network layer (ETSI EN 302 636 GeoNetworking Basic transport protocol)
- DSRC (ETSI EN 302 663) is specified alongside the access layer

v. Scope and standard details
- Specifies the technology for the access layer in the ITS Station reference architecture
- The technology of the access layer in this standard targets sidelink/PC5 in the 5.9 GHz band

vi. Related standards

Normative references

[18] Source: ETSI EN 302 663 V1.3.1 (2020-01), Intelligent Transport Systems (ITS); ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band, P9, Jan. 2020

[19] Source: ETSI EN 302 663 V1.3.1 (2020-01), Intelligent Transport Systems (ITS); ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band, P10, Jan. 2020

- ETSI TS 136 331 (V14.6.2): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (3GPP TS 36.331 version 14.6.2 Release 14).”
- ETSI TS 136 300 (V14.7.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 version 14.7.0 Release 14).”
- ETSI TS 136 321 (V14.7.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (3GPP TS 36.321 version 14.7.0 Release 14).”
- ETSI TS 136 322 (V14.1.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification (3GPP TS 36.322 version 14.1.0 Release 14).”
- ETSI TS 136 323 (V14.5.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification (3GPP TS 36.323 version 14.5.0 Release 14).”
- ETSI TS 136 211 (V14.7.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 14.7.0 Release 14).”
- ETSI TS 136 212 (V14.6.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (3GPP TS 36.212 version 14.6.0 Release 14).”
- ETSI TS 136 213 (V14.6.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (3GPP TS 36.213 version 14.6.0 Release 14).”
- ETSI TS 136 214 (V14.4.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements (3GPP TS 36.214 version 14.4.0 Release 14).”
- ETSI TS 123 285 (V14.7.0): “Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for V2X services (3GPP TS 23.285 version 14.7.0 Release 14).”
- ETSI TS 124 385 (V14.4.0): “LTE; V2X services Management Object (MO) (3GPP TS 24.385 version 14.4.0 Release 14).”
- ETSI TS 124 386 (V14.3.0): “LTE; User Equipment (UE) to V2X control function; protocol aspects; Stage 3 (3GPP TS 24.386 version 14.3.0 Release 14).”
- ETSI TS 136 101 (V14.7.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 14.7.0 Release 14).”
- ETSI TS 136 133 (V14.8.0): “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management (3GPP TS 36.133 version 14.8.0 Release 14).”
- ETSI TS 124 301 (V14.9.0): “Universal Mobile Telecommunications System (UMTS); LTE; 5G; Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 (3GPP TS 24.301 version 14.9.0 Release 14).”
- ETSI TS 136 413 (V14.7.0): “LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP) (3GPP TS 36.413 version 14.7.0 Release 14).”
- ETSI TS 136 414 (V14.1.0): “LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 data transport (3GPP TS 36.414 version 14.1.0 Release 14).”
- ETSI TS 102 792 (V1.2.1): “Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range.”
- ETSI TS 103 574 (V1.1.1): “Intelligent Transport Systems (ITS); Congestion Control Mechanisms for C-V2X PC5 interface; Access layer part.”

Handling of the main 3GPP standard referenced in ETSI EN 303 613 can be summarized as shown in Fig. 3.2.3-5.

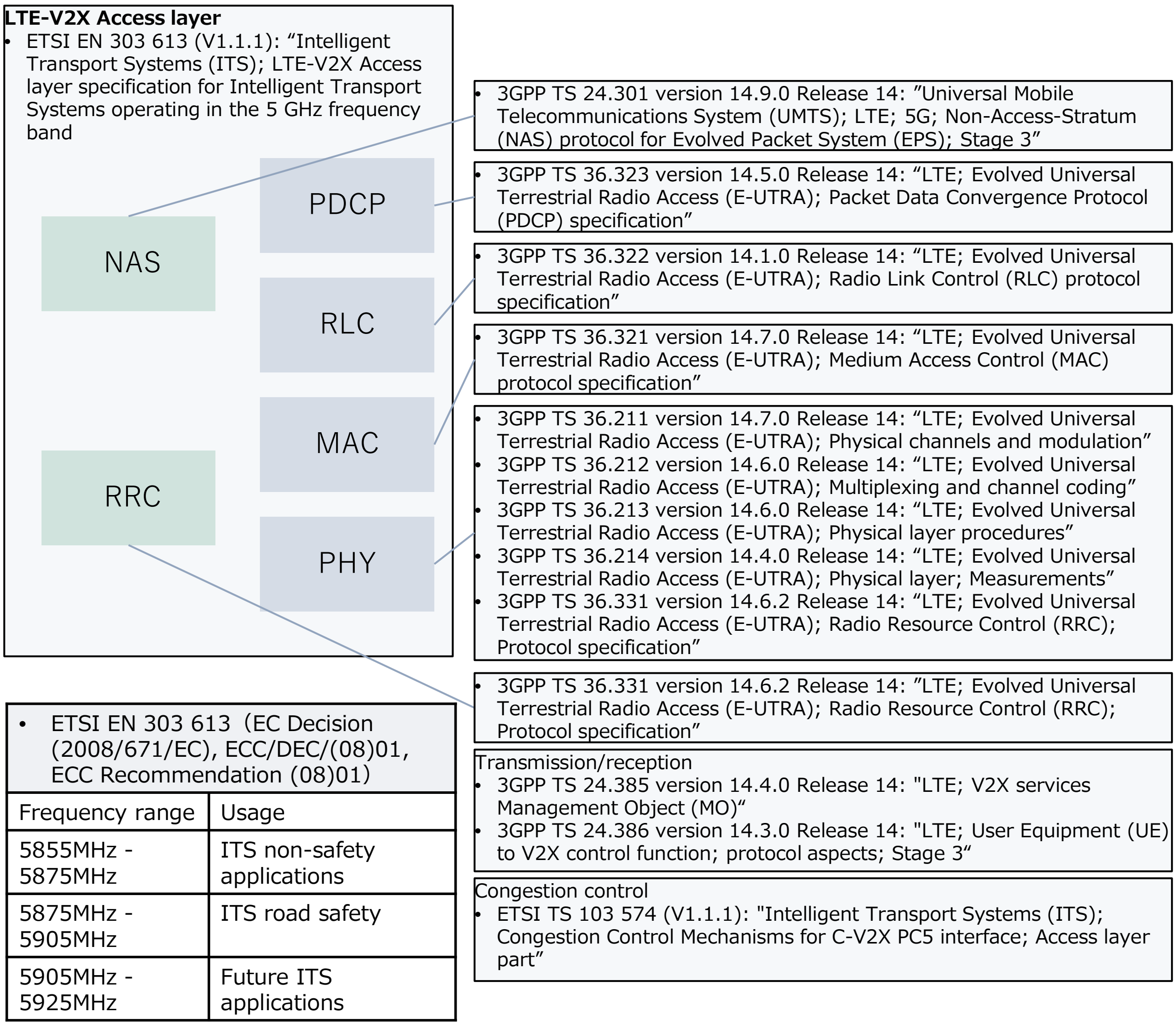



**Fig. 3.2.3-5 Reference specification in the ETSI LTE-V2X PC5 access layer**

vii. Description

EN 303 613 contents structure is shown in Table 3.2.3-6.

**Table 3.2.3-6 EN 303 613 contents structure**

| No. | Contents[20] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | Reference | — |
| 3. | Definition of terms, symbols and abbreviations | — |
| 4. | General requirements<br>4.1 Architecture<br>4.2 Operating Frequencies<br>4.3 Transmit and receive requirement | • 4.1: Explains the ITS Station architecture and the LTE-V2X access layer protocol stack<br>• 4.2: Specifies the LTE-V2X operating frequency band<br>• 4.3: Specifies the communication requirements to be satisfied by ITS stations that use LTE-V2X |

[20] Source: The table of contents is, ETSI, ETSI EN 303 613 V1.1.1 (2020-01), Intelligent Transport Systems (ITS); LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band, Jan. 2020

| No. | Contents[20] | Remarks |
|---|---|---|
| 5. | LTE-V2X access layers<br>5.1 Physical layer<br>5.2 MAC layer<br>5.3 RLC layer<br>5.4 PDCP layer<br>5.5 RRC layer<br>5.6 NAS layer<br>5.7 Additional LTE-V2X access layer functionality for PC5 interface | • 5.1 - 5.6: Specify the main roles of the physical layer, the MAC layer, the Radio Link Control (RLC) layer, the Packet Data Convergence Protocol (PDCP) layer, the Radio Resources Control (RRC) layer and the Network Connected Storage (NAS) layer<br>• 5.7: Specifies the functions required of the LTE-V2X access layer and the standards that the functions conform to, for V2X communications via PC5 |
| 6. | Annex A (informative): Introduction of LTE-V2X | — |
| 7. | Annex B (normative): LTE-V2X information elements | — |
| 8. | Annex C (normative): List of MCS-RB problematic cases | — |
| 9. | Annex D (informative): Interface to higher layers of ITS station | — |

### 3.2.4 China

(1) Message structure

The communications packet structure for V2X communications standardized by CCSA in China is summarized as shown in Fig. 3.2.4-1.

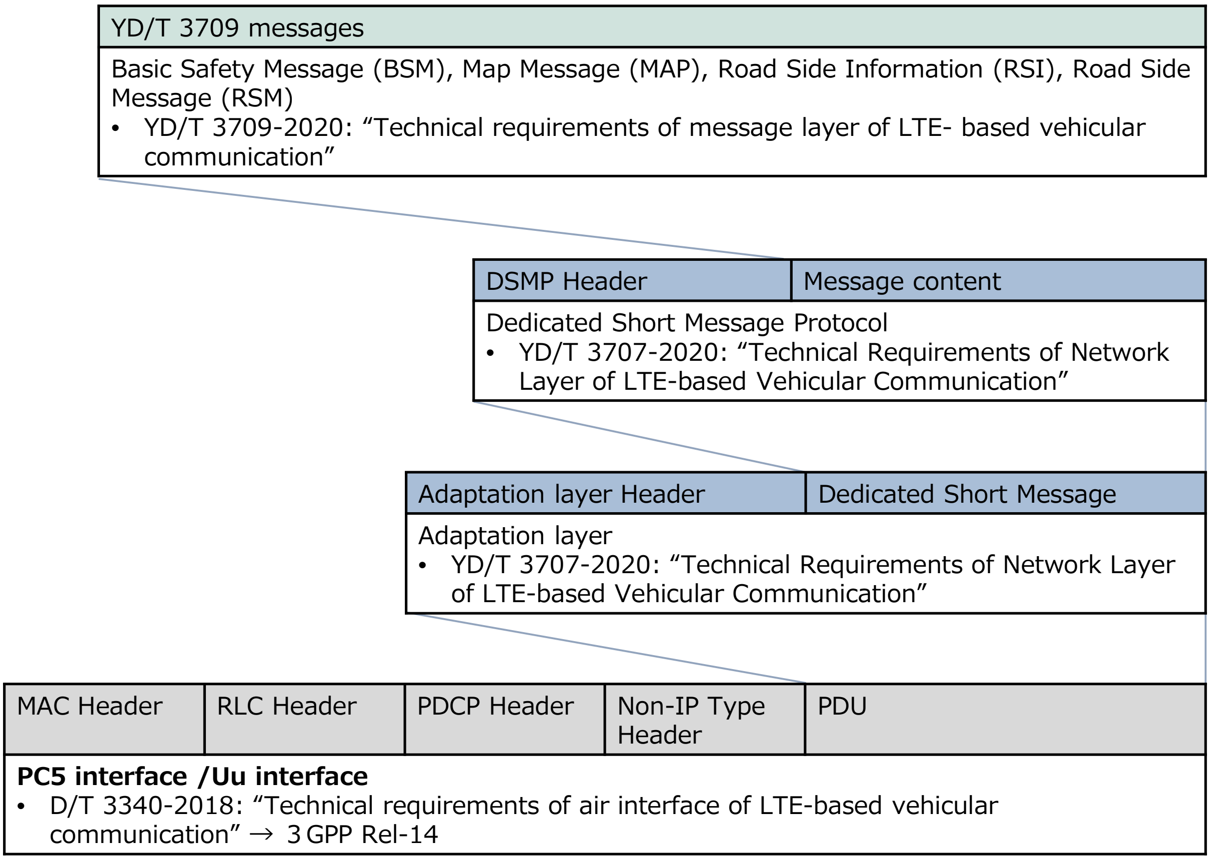



**Fig. 3.2.4-1 Structure of V2X communications packet in CCSA standard (LTE Uu, PC5)**

(2) Message standards

The following provides an overview of the standard for V2X communications messages as standardized by CCSA in China.

(a) YD/T 3709

i. Name
- YD/T 3709-2020 Technical requirements of message layer of LTE-based vehicular communication
- Reference: YD/T 3709-2020

ii. Standardization organization/body
- China Communication Standards Association

(Drafting ; China Academy of Information and Communications Technology)

iii. Standardization status
- Established in 2020

iv. Standard positioning
- Issued as a standard of the Ministry of Industry and Information Technology

v. Scope and standard details
   - Specifies the technical requirements relating to the message layer in the vehicular communications technology that uses LTE (structure of the data set in the message layer, data definitions, encoding method)

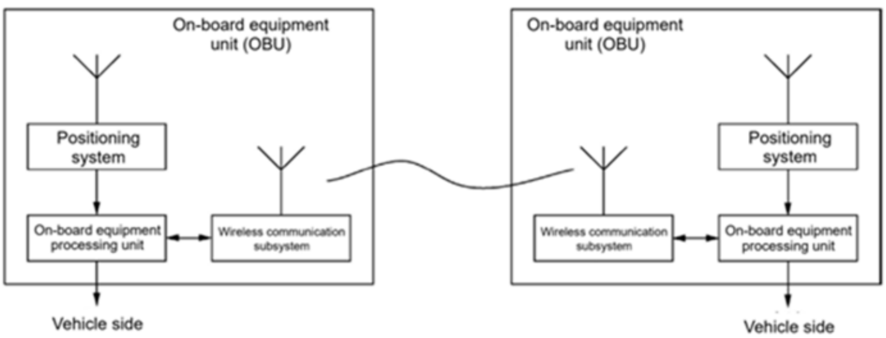
vi. Related standards
   - YD/T 3340-2018 Technical requirements of air interface of LTE-based vehicular communication
   - YD/T 3400-2018 General technical requirements of LTE-based vehicular communication
   - GB 2312-1980 Code of Chinese graphic character set for information interchange - Primary set
   - GB 5768.2-2009 Road traffic signs and markings - Part 2: Road traffic signs
   - GB 14886 Specifications for road traffic signal setting and installation
   - GB/T 27967-2011 Format of weather forecast on highway traffic
   - GB/T 29100-2012 Road traffic information service - Traffic event classification and coding

vii. Description
   - Specifies messages for V2X (BSM: Basic Safety Message, MAP: Map information, RSI: Road side Information, RSM: Road side Message, SPaT: Signal Phase and Timing message) and the DF (Data frame) that contains the message

YD/T 3709 contents structure is shown in Table 3.2.4-1.

**Table 3.2.4-1 YD/T 3709 contents structure**

| No. | Contents[21] | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | Normative references | – |
| 3. | Terms, definitions, abbreviations | – |
| 4. | Message layer of LTE-based vehicular communication technology<br>4.1 System introduction<br>4.2 Architecture of message layer | • Presents the architecture |
| 5. | Technical requirements for the message layer<br>5.1 Basic introduction and requirements of the message layer<br>5.2 Definition of data set of message layer | • Specifies message requirements |
| 6. | Appendix A (Informative) Type and value of DE_EventType (traffic event index) | – |




[21] Source: The table of contents is, COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA, YD/T 3709-2020: Technical requirements of message layer of LTE-based vehicular communication, Apr. 16, 2020

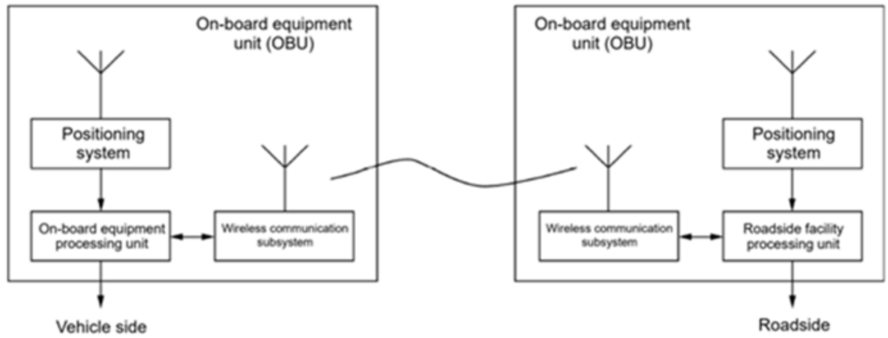



**Fig. 3.2.4-2 V2V and V2I communications structure[22]**

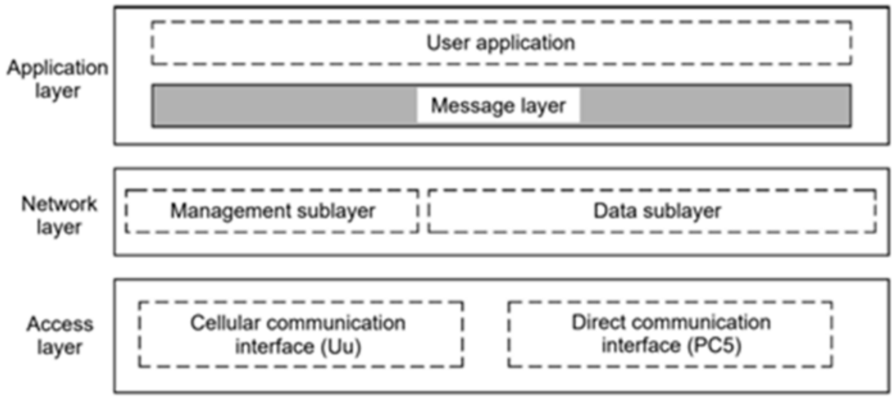



**Fig. 3.2.4-3 Message layer structure[23]**

(3) Network standards

An overview of the standard for V2X communications network layer as standardized by CCSA in China is as follows.

(a) YD/T 3707

i. Name
- YD/T 3707-2020 Technical requirements of network layer of LTE-based vehicular communication
- Reference: YD/T 3707-2020

ii. Standardization organization/body
- China Communication Standards Association

(Drafting；China Academy of Information and Communications Technology)

iii. Standardization status
- Established in 2020

iv. Standard positioning
- Issued as a standard of the Ministry of Industry and Information Technology

v. Scope and standard details
- Specifies technical requirements of the network layer (including short message protocol, application registration, service management, service advertisement) in vehicular communication

[22] Source: COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE’S REPUBLIC OF CHINA, YD/T 3709-2020 Technical requirements of message layer of LTE-based vehicular communication, Pages 6-7, Apr. 16, 2020

[23] Source: COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE’S REPUBLIC OF CHINA, YD/T 3709-2020 Technical requirements of message layer of LTE-based vehicular communication, P7, Apr. 16, 2020

technology that uses LTE (network layer framework, data sublayer, management sublayer, access points, primitives)

vi. Related standards
- YD/T 3340-2018 Technical requirements of air interface of LTE-based vehicular communication
- YD/T 3400-2018 General technical requirements of LTE-based vehicular communication

vii. Description
- Specifies the DSMP (Dedicated Short Message Protocol) for communication of V2X messages, and the DME (Dedicated Management Entity) for management with the Adaptation Layer

YD/T 3707 contents structure is shown in Table 3.2.4-2.

**Table 3.2.4-2 YD/T 3707 contents structure**

| No. | Contents[24] | Remarks |
|---|---|---|
| 1. | Scope | – |
| 2. | Normative references | – |
| 3. | Abbreviations | – |
| 4. | Technical Requirements of Network Layer<br>4.1 System Introduction<br>4.2 Network Layer Framework<br>4.3 Technical Requirements for Data Sublayer<br>4.4 Technical Requirements for Management Sublayer<br>4.5 Access Point and Service Primitive | • Specifies network layer requirements |
| 5. | Appendix A (normative) Type and Value of Protocol Type | – |
| 6. | Appendix B (normative) Frame Structure of Extension | – |
| 7. | Appendix C (normative) MIB Messages | – |
| 8. | Appendix D (normative) Mapping Relations between Priority and PPPP | – |
| 9. | Appendix E (informative) Example of Source Address / Destination Address<br>Design of Adaptation Layer | – |

[24] Source: The table of contents is, COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE’S REPUBLIC OF CHINA, YD/T 3707-2020: Technical Requirements of Network Layer of LTE-based Vehicular Communication, Apr. 16, 2020

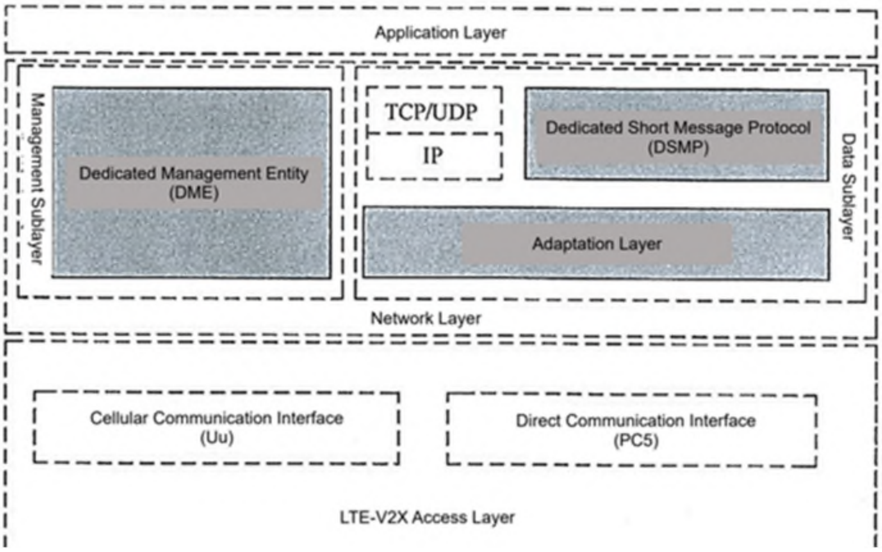



**Fig. 3.2.4-4 Network layer structure[25]**

(4) LTE-V2X access standard

An overview of the standard for V2X communication LTE-V2X access layer as standardized by CCSA in China is as follows.

(a) YD/T 3340

i. Name
- YD/T 3340-2018 Technical requirements of air interface of LTE-based vehicular communication
- Reference: YD/T 3340-2018

ii. Standardization organization/body
- China Communication Standards Association

(Drafting；China Academy of Information and Communications Technology)

iii. Standardization status
- Set up in 2018

iv. Standard positioning
- Issued as a standard of the Ministry of Industry and Information Technology

v. Scope and standard details
- For air interfaces of vehicular communications technology that use LTE, specifies the technical requirements of the PC5 interface for the side link communications mode between terminals, and of the Uu interface of the uplink/down link between the terminal and the base station (UE processing during idle model in the physical layer, the MAC layer, the RLC layer, the PDCP layer, the RRC layer, and these layers)

vi. Related standards
- YD/T 3400-2018 General technical requirements of LTE-based vehicular communication
- LTE standards;
- 3GPP TS 23.285 (Release 14) Technical Specification Group Services and System Aspects; Architecture enhancements for V2X services
- 3GPP TS 24.334 (Release 14) Proximity-services (ProSe) User Equipment (UE) to ProSe function protocol aspects; Stage 3

[25] Source: COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE’S REPUBLIC OF CHINA, YD/T 3707-2020: Technical Requirements of Network Layer of LTE-based Vehicular Communication, P6, Apr. 16, 2020

- 3GPP TS 24.386 (Release 14) User Equipment (UE) to V2X control function; protocol aspects; Stage 3
- 3GPP TS 36.101 (Release 14) E-UTRA; User Equipment (UE) radio transmission and reception
- 3GPP TS 36.133 (Release 14) E-UTRA; Requirements for support of radio management
- 3GPP TS 36.211 (Release 14) E-UTRA; Physical channels and modulation
- 3GPP TS 36.212 (Release 14) E-UTRA; Multiplexing and channel coding
- 3GPP TS 36.213 (Release 14) E-UTRA; Physical layer procedures
- 3GPP TS 36.214 (Release 14) E-UTRA; Physical layer - Measurements
- 3GPP TS 36.304 (Release 14) E-UTRA; User Equipment (UE) procedures in idle mode
- 3GPP TS 36.321 (Release 14) E-UTRA; Medium Access Control (MAC) protocol specification
- 3GPP TS 36.322 (Release 14) E-UTRA; Radio Link Control (RLC) protocol specification
- 3GPP TS 36.323 (Release 14) E-UTRA; Packet Data Convergence Protocol (PDCP) Specification
- 3GPP TS 36.331 (Release 14) E-UTRA; Radio Resource Control (RRC) Protocol specification

vii. Description
- Specifies the PC5 and Uu interfaces in V2X with reference to the 3GPP Release 14 specification

YD/T 3340 contents structure is shown in Table 3.2.4-3.

**Table 3.2.4-3 YD/T 3340 contents structure**

| No. | Contents[26] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | Normative references | — |
| 3. | Abbreviations | — |
| 4. | Overview | — |
| 5. | PC5 interface technical requirements<br>5.1 Physical layer<br>5.2 MAC layer<br>5.3 RLC layer<br>5.4 PDCP layer<br>5.5 RRC layer<br>5.6 UE process in idle mode | • Specifies the requirements of the PC5 interface |
| 6. | Uu interface's technical requirements<br>6.1 Physical layer<br>6.2 MAC layer<br>6.3 RLC layer<br>6.4 PDCP layer<br>6.5 RRC layer<br>6.6 UE process in idle mode | • Specifies the requirements of the Uu interface |

[26] Source: The table of contents is, COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA, YD/T 3340-2018: Technical requirements of air interface of LTE-based vehicular communication, Dec. 21, 2018

### 3.2.5 Status of other initiatives

(1) V2X application-related standardization in SAE

In SAE in the USA, in addition to the standards documents already published, there are also many under consideration. The status of V2X application standards documents in SAE is shown in Table 3.2.5-1.

Standards for services that use non-own vehicle external information, such as Cooperative Perception System (J2945/8), Maneuver Sharing and Coordinating (J3186), Sensor-Sharing (J3224) are also under consideration.

**Table 3.2.5-1 Publication status of V2X application-related standards by SAE**[27]

| Type | Publication | Standards |
|---|---|---|
| J2945 series | Published | • J2945 DSRC Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts<br>• J2945/1 On-Board System Requirements for V2V Safety Communications<br>• J2945/1A Vehicle Level Validation Test Procedures for V2V Safety Communications<br>• J2945/2 DSRC Performance Requirements for V2V Safety Awareness<br>• J2945/3 Requirements for Road Weather Applications<br>• J2945/5 Service Specific Permissions and Security Guidelines for Connected Vehicle Applications<br>• J2945/9 Vulnerable Road User Safety Message Minimum Performance Requirements<br>• J2945/C Requirements for Probe Data Collection Applications<br>• J2945/X Documents and Common Design Concepts |
| | Under consideration | • J2945/1B On-Board V2V Safety Systems Requirements for Non Light Duty Vehicles<br>• J2945/4 Road Safety Applications<br>• J2945/6 Performance Requirements for Cooperative Adaptive Cruise Control and Platooning<br>• J2945/7 Positioning Enhancements for V2X systems<br>• J2945/8 Cooperative Perception System<br>• J2945/A Standard for Lane-Level and Road Furniture Mapping for Infrastructure-based V2X Applications<br>• J2945/B Recommended Practices for Signalized Intersection Applications<br>• J2945/D Road user-to-Road User Courteous Communication |
| J3161 series | Published | • J3161/1 On-Board System Requirements for LTE-V2X V2V Safety Communications<br>• J3161/1A Vehicle Level Validation Test Procedures for V2V Safety Communications |
| | Under consideration | • J3161/2 LTE Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters for 10 MHz Channel |
| Other | Published | • J3217 V2X-Based Fee Collection<br>• SS V2X 001 Security Specification through the Systems Engineering Process for SAE V2X Standards |

[27] Source: SAE, Extract of standard thought to be related to V2X applications, https://www.sae.org/standards/ (viewed June 30, 2022)

| Type | Publication | Standards |
|---|---|---|
| | Under consideration | • J3186 Application Protocol and Requirements for Maneuver Sharing and Coordinating Service<br>• J3224 V2X Sensor-Sharing for Cooperative & Automated Driving<br>• J3251 Cooperative perception CDA feature: Jaywalking pedestrian collision avoidance<br>• J3256 Infrastructure-based prescriptive cooperative merge<br>• J3287 V2X Misbehavior Reporting |

(2) V2X application-related standardization in ETSI

Many documents are also under consideration by ETSI in Europe. The status of V2X application standards documents in ETSI is shown in Table 3.2.5-2.

As at SAE, standards for services that use non-own vehicle external information, such as Cooperative Perception System (TS103 324) and Maneuver Coordination (TS103 561), are also under consideration.

**Table 3.2.5-2 Publication status of V2X application-related standards by ETSI[28]**

| Type | Publication | Standards |
|---|---|---|
| Application-related | Published | • EN302 637 Vehicular Communications; Basic Set of Applications;<br>(Basic application)<br>-1: Functional Requirements<br>-2: Specification of Cooperative Awareness Basic Service<br>-3: Specifications of Decentralized Environmental Notification Basic Service<br>TS103 900 Vehicular Communications; Basic Set of Applications; Specification of Cooperative Awareness Basic Service; Release 2<br>• TS103 301 Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services; Release 2<br>• EN302 895 Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM)<br>• TS103 152 V2X Communications; Multimedia Content Dissemination (MCD) Basic Service specification; Release 2<br>• TS101 539 V2X Applications;<br>-1: Road Hazard Signaling (RHS)<br>-2: Intersection Collision Risk Warning (ICRW)<br>-3: Longitudinal Collision Risk Warning (LCRW)<br>TS103 300 Vulnerable Road Users (VRU) awareness<br>-1: Use Cases definition; Release 2<br>-2: Functional Architecture and Requirements definition; Release 2<br>-3: Specification of VRU awareness basic service; Release 2<br>• TS102 894 Users and applications requirements;<br>-1: Facility layer structure, functional requirements and specifications<br>-2: Applications and facilities layer common data dictionary |
| | Under consideration | • TS103 324 Cooperative Perception Services<br>• TS103 882 Automated Valet Parking Service; Release 2<br>• TS103 561 Vehicular Communications; Basic Set of Applications; Maneuver Coordination Service<br>• TS103 693 Vehicular Communications; Basic Set of Applications; Diagnosis, Logging and Status Service<br>• TS103 831 Vehicular Communications; Basic Set of Applications;<br>-3: Specifications of Decentralized Environmental Notification Basic Service; Release 2 |

[28] Source: ETSI, Extract of standard relating to V2X applications, https://portal.etsi.org/webapp/WorkProgram (viewed June 30, 2022)

| Type | Publication | Standards |
|---|---|---|
| Facilities-related | Published | • EN302 890 Facilities layer function;<br>-1: Services Announcement (SA) specification<br>-2: Position and Time management (PoTi); Release 2<br>• TS103 724 Facilities layer function; Interference Management Zone Message (IMZM); Release 2 |
| | Under consideration | • TS103 141 Facilities layer function; Multi-Channel Operation (MCO) for Cooperative ITS (C-ITS); Release 2 |

(3) Cooperative Perception (CPS)

As described above, the V2X services under consideration in SEA in the USA and ETSI in Europe include CPS (Collective Perception Service, Cooperative Perception System). This is a service/system that detects information that cannot be directly detected by one's own vehicle, for example by exchange of information detected by other vehicles via vehicle to vehicle (V2V) communication

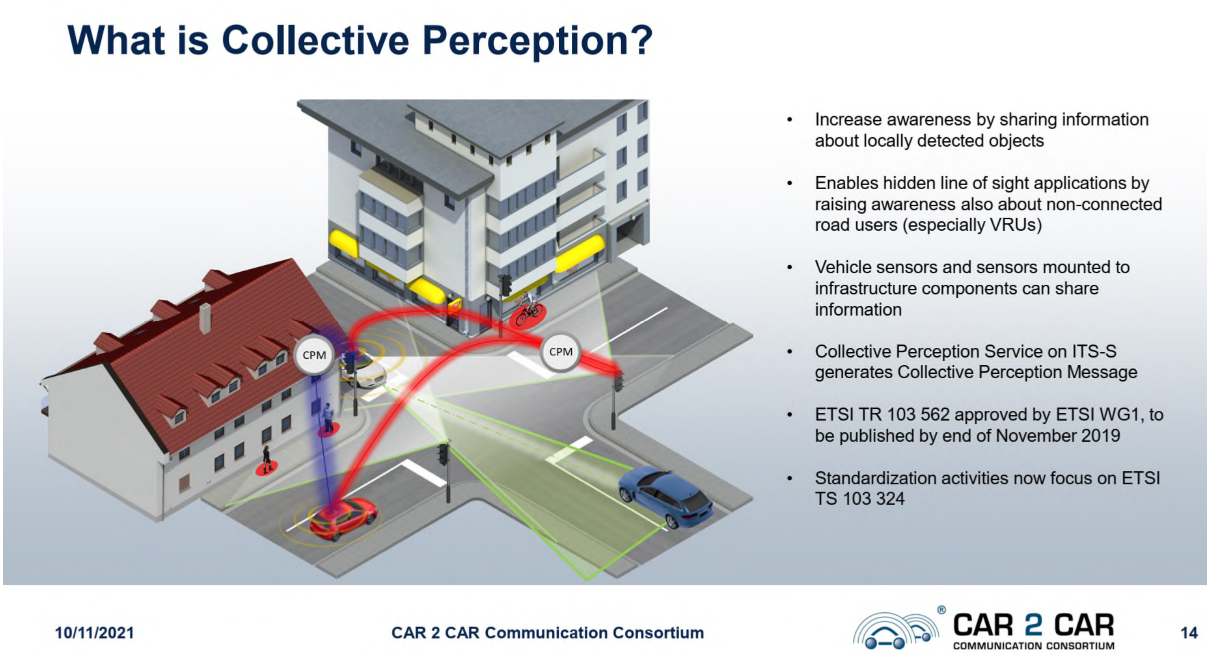



**Fig. 3.2.5-1 Concept of Collective Perception [29]**

(a) Study in SAE

In SAE, studies are progressing towards the publication of the standard for J2945/8 (Cooperative Perception System).

i. SAE J2945/8 (under consideration): vote scheduled during 2022[30]

Cooperative Perception System is a system that notifies detection information of a road user or object that is in the vicinity of a V2X-handling device such as a vehicle, infrastructure, or mobile terminal, and enhances the perception performance of other V2X handling devices or systems through its cooperative perception. In J2945/8, defines the use cases, and the performance for message broadcast, or cyber security requirements (wait time, data elements, accuracy, etc.)

[29]Source: Niels Peter Skov Andersen, C-ITS in Europe, P14, Nov. 10, 2021, https://www.sip-adus.go.jp/evt/workshop2021/file/cv/CV_4E_Andersen.pdf (browsed June 17, 2022)
[30]Not issued as of Jan. 10, 2023

(b) Study in ETSI

In ETSI, as well, publication of the standard as TS 103 324 (Cooperative Perception Services) is under consideration. Note a technical report (TR 103 562) had been published that serves as a basis for TS 103 324 development.

i. ETSI TS 103 324 (under consideration): Publication scheduled for 2022[31]

Intelligent Transport Systems (ITS); Cooperative Perception Services

- Technical specification that specifies Cooperative Perception System (CPS)
  Expected to include data message definition for cooperative environment perception and the facilities layer protocol that supports CPS
- Consideration started in 2015, and final draft prepared in Dec. 2022 (TC ITS/WG1 Application)

ii. ETSI TR 103 562 V2.1.1 (2019-12): Published

Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2

- Technical report regarding concepts of sensor information exchange between ITS-S
  Basis of CPS specification in ETSI TS 103 324
- Consideration started in 2017, and published in Dec. 2019 (TC ITS/WG1 Application)

iii. [Related] ETSI TS 103 300: already published

Intelligent Transport Systems (ITS);Vulnerable Road Users (VRU) awareness -1 Use case (2019/9), -2 Architecture (2021/4), -3 Service (2021/4)

- It is assumed that in VRU perception, DENM or CPM are used

(c) Study in 3GPP, 5GAA

Consideration is also underway in organizations aside from SAE and ETSI, such as 3GPP (3rd Generation Partnership Project) and 5GAA (5G Automotive Association).

i. 3GPP TR 22.886 (2018)

Study on enhancement of 3GPP Support for 5G V2X Services (Release 16)

- In 3GPP, from Release 15, services using cooperative perception are set as 5G V2X services under "Collective perception of environment"

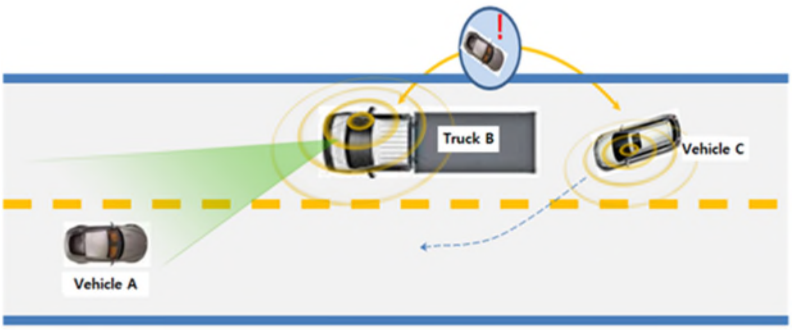



**Fig. 3.2.5-2 Concept of Collective Perception [32]**

ii. 5GAA White paper "C-V2X Use Cases Methodology, Examples and Service Level Requirements" (June 2019)

- In 5GAA, cooperative perception is assumed as one of the use cases, "High Definition Sensor Sharing (Autonomous Driving)"
- The surrounding environment is recognized (e.g.through 3D model creation, LiDAR, etc.) using the own vehicle sensors (HD camera, passengers, etc.) and sensor information from other vehicles, to permit safe lane changes during automated driving

[31]Not issued as of Jan. 10, 2023

[32] Source: 3GPP, 3GPP TR 22.886 V16.2.0 (2018-12) Technical Report, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on enhancement of 3GPP Support for 5G V2X Services (Release 16), P21, Dec. 2018

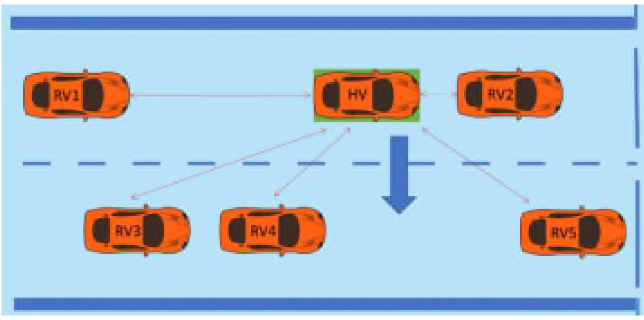



**Fig. 3.2.5-3 Concept of Sensor Sharing** [33]

### 3.2.6 Comparison of use cases and messages in Japan/US/Europe

Having reviewed the results of a survey into the US and European communication specifications, Japan, the US, and Europe use cases and messages were compared.

In specific terms, details from the US and European communication specifications for use cases for Cooperative Driving Automation, and ITS Forum communication requirements and message sets (RC-017), were compared and summarized in a table. Note that some of the US and European communication specifications have parts that are under consideration, and this includes analogous parts to contractors.

[33] Source: 5GAA, White paper, C-V2X Use Cases Methodology, Examples and Service Level Requirements (Version 1.0), P70, June 13, 2019

(1) Result of comparison of use cases and messages in Japan/US/Europe

The results of a comparison of use cases and messages that are under consideration in Japan (Use cases for Cooperative Driving Automation, RC-017), US and Europe are shown in Table 3.2.6-1.

Regarding use case categories and message types for use cases for Cooperative Driving Automation, a comparison from the perspective of communication methods (V2I/V2V), message destinations (specific vehicles/non-specific vehicles), and synchronous/non-synchronous, showed no great differences with the US and European specifications.

Note however that use cases and messages, etc., regarding road-vehicle negotiation, and vehicle-to-vehicle negotiation, are being studied currently in the US and Europe, and in future we must progress formulation of communication specifications on the basis of research into specifications.

**Table 3.2.6-1 Result of comparison of use cases and messages in Japan/US/Europe (1/5)**

| Japan | | US | | Europe | |
|---|---|---|---|---|---|
| Use case | Message | Use case [Related organization] | Message | Use case [Related organization] | Message |
| a-1-1 | Position information message<br>- I -> V<br>- Broadcast fixed interval (100 ms) | (Under consideration in SAE (J3224)) | (CPM) | Cooperative Merging on Highways<br>[C2-CCC]<br>Merging assistance [5GCAR] | CPM<br>(MCM)<br>- V <=> V、I <=> V<br>- Event |
| a-1-2 | Position information message<br>- I -> V<br>- Broadcast fixed interval (100 ms) | (Under consideration in SAE (J3224)) | (CPM) | Cooperative Merging on Highways<br>[C2-CCC]<br>Merging assistance [5GCAR] | CPM<br>(MCM)<br>- V <=> V、I <=> V<br>- Event |
| b-1-1 (V2I) | Traffic signal information messages<br>- I -> V<br>- Broadcast fixed interval (100 ms) | Single phase and timing<br>[Ford Qualcomm Panasonic] | MAP<br>SPAT<br>- I -> V<br>- Event | Green Light Optimal Speed Advisory<br>[C-Road, CONCORDA]<br>Traffic light warning ［MWC2017 demo］ | MAPEM<br>SPATEM<br>- I -> V<br>- Event |

**Table 3.2.6-1 Result of comparison of use cases and messages in Japan/US/Europe (2/5)**

| Japan | | US | | Europe | |
|---|---|---|---|---|---|
| Use case | Message | Use case [Related organization] | Message | Use case [Related organization] | Message |
| c-1 | Messages in use case c-1<br>- V -> V<br>- Broadcast fixed interval (100 ms) | Emergency brake light warning<br>[ITS Strategic Plan (Tampa/NY)]<br>Electronic emergency brake light [Ford<br>Qualcomm Panasonic] | BSM<br>- V <=> V<br>- Broadcast fixed interval (100 to 600 ms) | Warning broadcast in dangerous situations [C2-CCC]<br>Emergency brake light [C-Road]<br>Emergency brake warning [SCOOP F]<br>Emergency electronic brake lamp [CITE project]<br>Warning of sudden braking [ConVeX]<br>Emergency brake [MWC2017 demo] | DENM<br>- V <=> V<br>- Event |
| c-2-1 (V2V) | Messages in use case c-2-1<br>- V -> V<br>- Broadcast fixed interval (100 ms) | Intersection pass-through assistance<br>[ITS Strategic Plan (NY)]<br>Intersection movement assist<br>[Ford Qualcomm Panasonic] | ICA<br>- I <=> V<br>- Event | Across traffic turn collision risk warnings [ConVeX]<br>Intersection collision warning [ConVeX]<br>Right-turn assistance<br>[Experiment by Deutsche Telecom of use of LTE networks and Mobile Edge Computing] | DENM<br>CPM<br>- V <=> V、I <=> V<br>- Event |

**Table 3.2.6-1 Result of comparison of use cases and messages in Japan/US/Europe (3/5)**

| Japan | | US | | Europe | |
|---|---|---|---|---|---|
| Use case | Message | Use case [Related organization] | Message | Use case [Related organization] | Message |
| c-2-2 | Messages in use case c-2-2<br>- I -> V<br>- Broadcast fixed interval (100 ms) | Intersection movement assist<br>[Ford Qualcomm Panasonic]<br>(Under consideration in SAE (J3224)) | ICA<br>(CPM)<br>- I <=> V<br>- Event | Collision warning<br>[Field trial of the vehicle-to-vehicle communication by means of LTE-V technology]<br>Intersection collision warning<br>[Nokia Mobile Edge Computing (MEC) Project] | DENM<br>CPM<br>- V <=> V、I <=> V<br>- Event |
| c-3 | Messages in use case c-3<br>- V -> V<br>- Broadcast fixed interval (100 ms) | Collision warning<br>[ITS Strategic Plan (Wyoming)]<br>Forward collision warning<br>[ITS Strategic Plan (Tampa/NY)] | BSM<br>- V <=> V<br>- Broadcast fixed interval (100 to 600 ms) | Obstacle warning [SCOOP F] | DENM<br>- V <=> V<br>- Event |
| e-1 | Messages in use case e-1<br>- V -> V<br>- Broadcast fixed interval (100 ms) | — | BSM<br>- V <=> V<br>- Broadcast fixed interval (100 to 600 ms) | Emergency vehicle approach warning [C-Road]<br>Emergency vehicle warning system [CITE project]<br>Emergency vehicle approaching [Nokia Mobile Edge Computing (MEC) Project]<br>Emergency vehicle approaching [Towards 5G initiative] | CAM<br>- V <=> V<br>- Broadcast fixed interval (100 to 1000 ms) or<br>Vehicle position, speed, yaw angle change<br>DENM<br>- V <=> V<br>- Event |

**Table 3.2.6-1 Result of comparison of use cases and messages in Japan/US/Europe (4/5)**

| Japan | | US | | Europe | |
|---|---|---|---|---|---|
| Use case | Message | Use case [Related organization] | Message | Use case [Related organization] | Message |
| a-1-3 | Position information message<br>- I -> V<br>- Broadcast fixed interval (100 ms)<br>Control request message<br>Control response message<br>Agreement request message<br>Agreement response message<br>Update request message<br>Update response message<br>- I <=> V<br>- Event, post-fixed cycle | (Under consideration in SAE (J3186)) | — | Cooperative Merging on Highways [C2-CCC]<br>Merging assistance [5GCAR] | (MCM)<br>- V <=> V、I <=> V<br>- Event |
| a-1-4 | Agreement request message<br>Agreement response message<br>Update request message<br>Update response message<br>- V <=> V<br>- Event, post-fixed cycle | (Under consideration in SAE (J3186)) | — | Cooperative Merging on Highways [C2-CCC]<br>Merging assistance [5GCAR] | (MCM)<br>- V <=> V、I <=> V<br>- Event |

Table 3.2.6-1 Result of comparison of use cases and messages in Japan/US/Europe (5/5)

| Japan | | US | | Europe | |
|---|---|---|---|---|---|
| Use case | Message | Use case [Related organization] | Message | Use case [Related organization] | Message |
| a-2 | Agreement request message<br>Agreement response message<br>Update request message<br>Update response message<br>- V <=> V<br>- Event, post-fixed cycle | Lane change warning<br>[ITS Strategic Plan<br>(NY)]<br>(Under consideration in SAE (J3186)) | — | Overtaking assistant<br>[Nokia Mobile Edge Computing (MEC) project] | (MCM)<br>- V <=> V、I <=> V<br>- Event |
| a-3 | Agreement request message<br>Agreement response message<br>Update request message<br>Update response message<br>- V <=> V<br>- Event, post-fixed cycle | (Under consideration in SAE (J3186)) | — | Cooperative Turning at Junctions<br>[C2-CCC] | (MCM)<br>- V <=> V、I <=> V<br>- Event |

## 3.3 Overview of operation specification

### 3.3.1 Standards related to operation (congestion control, interference avoidance, cyber security)

In the regions of USA, Europe and China, standards for V2X communication operations such as congestion control, interference avoidance, and cyber security have been developed by SEA, ETSI and CCSA.

Congestion control standards that are under consideration by each organization are shown in Table 3.3.1-1.

**Table 3.3.1-1 Main standards involved in operation (congestion control)**

| Organization | Application | Standards | Reference |
|---|---|---|---|
| SAE | DSRC | SAE J2945/1<br>On-Board System Requirements for V2V Safety Communications | 3.3.2(1) |
| | LTE-V2X | SAE J3161/1<br>On-Board System Requirements for LTE-V2X V2V Safety Communications | 3.3.2(2) |
| ETSI | ITS-G5 | ETSI TS 102 687<br>Intelligent Transport Systems (ITS);<br>Decentralized Congestion Control Mechanisms for<br>Intelligent Transport Systems operating in the 5 GHz range; Access layer part | 3.3.2(1) |
| | LTE-V2X | ETSI TS 103 574<br>Intelligent Transport Systems (ITS);<br>Congestion Control Mechanisms for the C-V2X PC5 interface; Access layer part | 3.3.2(2) |

In SAE, congestion control is also specified in the "On-Board System Requirements" (J2945, J3161) for DSRC and C-V2X respectively.

For DSRC (WAVE), specifies BSM send schedule control, and control by output control (interval control, etc., based on wireless resources occupancy or packet errors, etc.).

For C-V2X, control is conducted by transmission interval and congestion ratio in the application layer in the same way as for DSRC, but there are differences in the access layer.

In ETSI, TS (ITS-G5; TS 102 687, C-V2X; TS 103 574) is specified for "Congestion control."

For ITS-G5, specifies the mechanisms, etc., in the access layer (DCC access) including DCC (Autonomous Decentralized Congestion Control Method) positioning, transmission power control (TPC) for each packet, transmission rate control (TRC) and transmission data rate control (TDC).

For C-V2X, the congestion control technology in the 3GPP Release14 access layer is specified including an interface to the entities that perform congestion control (allocation based on wireless resource occupancy ratio and priority control, etc.)

In ETSI, for interference avoidance, the standards shown in Table 3.3.1-2 have been developed.

**Table 3.3.1-2 Main standards related to operation (interference avoidance)**

| Organization | Application | Standards | Reference |
|---|---|---|---|
| ETSI | ITS-G5/LTE-V2X | ETSI TS 103 724<br>Intelligent Transport Systems (ITS); Facilities layer function;<br>Interference Management Zone Message (IMZM) | 3.3.3(a) |

Cyber security standards that are under consideration by each organization are shown in Table 3.3.1-3.

**Table 3.3.1-3 Main standards related to operation (cyber security)**

| Organization | Application | Standards | Reference |
|---|---|---|---|
| SAE | DSRC/LTE-V2X | IEEE 1609.2<br>Wireless Access in Vehicular Environments –<br>Security Services for Applications and Management Messages<br>(As a related standard, SS V2X 001: Security Specification through the Systems Engineering Process for SAE V2X Standards) | 3.3.4(a) |
| ETSI | ITS-G5/LTE-V2X | ETSI TS 102 940<br>ITS; Security; ITS communications security architecture and security management<br>(As a series, ETSI TS 102 941: trust/privacy, ETSI TS 102 942: access control, ETSI TS 102 943: confidentiality, ETSI TS 103 097: security header and certificate formats) | 3.3.4(b) |
| CCSA | LTE-V2X | YD/T 3594<br>General Security requirements for LTE vehicular communication | 3.3.4(c) |

In ETSI, specifies cyber security positioning, node registration and authentication, access control, and confidentiality services, split into various respective documents as TS 102 940 to 943 (ITS Security; architecture, trust/privacy, access control, confidentiality).

In TS 102 940 to 943, specifies the role and positioning of a series of cyber security services including the functional entities required for security services and the relationship of each entity and the elements of the ITS reference architecture, the management of security identifiers and certificates, the PKI process and interfaces, and the basic policies and guidelines, etc.

At the same time, Security header/certificate format (TS 103 097), TVRA (TR 102 893) has also been documented.

In SAE, SS V2X 001 (Security Specification through the Systems Engineering Process for SAE V2X Standards) is specified with reference to J2945 (/0, /1, /2, /5) using DSRC, cyber security services in Part 2 of the IEEE 1609 series (IEEE 1609.2, 1609.2.1) through J3161 (/0, /1) using LTE-V2X, and related standards.

IEEE 1609.2 specifies methods for preventing message spoofing or message forgery through pseudonym certificates, and mechanisms for update of a pseudonym certificate on a fixed cycle, etc.

In CCSA, specifies the cyber security for vehicular communications using LTE as YD/T 3594 (General Security requirements for LTE vehicular communication). Specifies the overall technical requirements, interfaces, cyber security requirements and cyber security procedures, including IEEE 1609.2 as a reference standard.

The respective cyber security is standardized with reference to IEEE 1609.2.

### 3.3.2 Standards related to congestion control

(1) DSRC

Standards related to congestion control for DSRC have been standardized in USA as SAE J2945/1, and in Europe as ETSI TS 102 687. The various overviews are as follows.

(a) SAE J2945/1

i. Name
- J2945/1: On-Board System Requirements for V2V Safety Communications
- Reference: J2945/1 APR2020

ii. Standardization organization/body
- SAE

iii. Standardization status
- First edition: Mar. 2016, Latest revision: Apr. 2020

iv. Standard positioning
- SAE standards
- System requirements for services using DSRC (WAVE)

v. Scope and standard details
- Specifies the standard profile, functional requirements and performance requirements for V2V safety communication systems
- In DSRC (WAVE), used for BSM transmission

vi. Related standards
- SAE J2735 (defines message sets of BSM, etc.)
- IEEE Std 802.11™, Standard for LAN/MAN - Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
- IEEE Std 1609.2™, IEEE Std 1609.3™, IEEE Std 1609.4™, IEEE Std 1609.12™ (WAVE related standards: cyber security services, networking services, multichannel operations, identifier allocation)

vii. Description

SAE J2945/1 contents structure is shown in Table 3.3.2-1.

**Table 3.3.2-1 SAE J2945/1 contents structure**

| No. | Contents[34] | Remarks |
|---|---|---|
| 1. | SCOPE | ― |
| 2. | REFERENCES | ― |
| 3. | TERMS AND DEFINITIONS | ― |

[34] Source: The table of contents is, SAE, J2945® APR2020, On-Board System Requirements for V2V Safety Communications, Apr. 2020

| No. | Contents[34] | Remarks |
|---|---|---|
| 4. | V2V SAFETY SYSTEMS CONCEPT OF OPERATIONS AND SYSTEM DESCRIPTION | • Explains the concepts of V2V safety operations and system description<br>• Specifically specifies an overview of V2X systems in 4.1 (Fig. 3.3.2-1), and a system description of V2V safety functions in 4.2 (list of important collision scenarios that can be handled by the V2V safety functions, correspondence between the collision scenarios and the six safety applications such as emergency brake lights, etc., respective definitions of the six safety applications, use cases and function system definitions and operations) |
| 5. | INTERFACE DESCRIPTION | • Specifies the V2V wireless data definitions (BSM sending/receiving, positioning, cyber security/privacy, start/stop, mapping), and system interfaces (V2V communications interfaces, SCMS (Security Credential Management System) communications interfaces, positioning subsystem interfaces) |
| 6. | MINIMUM REQUIREMENTS | • Specifies the minimum requirements for conformance standard profile, POSTIM(Positioning and Timing Requirements), BSM sending in the vChannelNumber channel, wireless frequency performance, security and privacy, and cyber security management |
| 7. | PARAMETER SETTINGS | • Specifies the value assigned to parameters in Section 6 Minimum requirements |
| 8. | NOTES | — |
| 9. | APPENDIX A<br>A.1 IMPLEMENTATION CONFORMANCE STATEMENT (NORMATIVE)<br>A.2 COORDINATE TRANSFORMATION (NORMATIVE)<br>A.3 2D POSITION EXTRAPOLATION (NORMATIVE)<br>A.4 CALCULATIONS INTO VEHICLE'S POSITION REFERENCE POINT<br>A.5 PATH HISTORY REFERENCE DESIGN (INFORMATIVE)<br>A.6 PATH PREDICTION REFERENCE DESIGN (INFORMATIVE)<br>A.7 OPEN SKY TEST CONDITIONS (NORMATIVE)<br>A.8 ADDITIONAL CONGESTION CONTROL ALGORITHM DETAILS (NORMATIVE) | — |

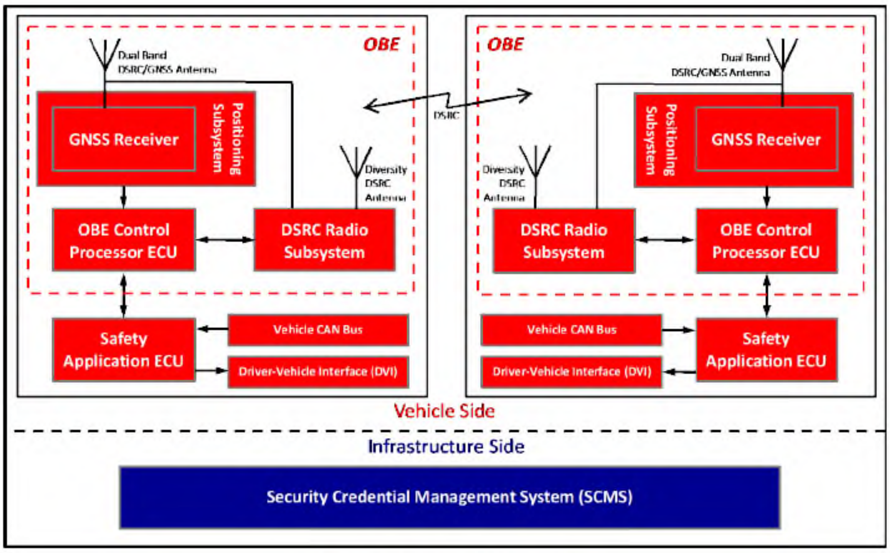



*Figure 1 - On-board V2V system*

**Fig. 3.3.2-1 V2V systems constituent elements and their interfaces (Chapter 4.1)[35]**

(b) ETSI TS 102 687

i. Name
- ETSI TS 102 687 Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part
- Reference: ETSI TS 102 687 V1.2.1

ii. Standardization organization/body
- ETSI

iii. Standardization status
- First edition 2011.7.1, Revised 2018.4.27

iv. Standard positioning
- ETSI TS
- In DSRC, specifies the specification for Congestion Control in ITS-G5

v. Scope and standard details
- Describes the methods of control of data traffic that is inserted in the frequency channel, from the access layer perspective (can be used only in ITS-G5)

vi. Related standards

Normative reference
- ETSI EN 302 571 (V2.1.1): "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band 5
- ETSI TS 103 175 (V1.1.1): "Intelligent Transport Systems (ITS); Cross layer DCC management entity for operation in the ITS G5A and ITS G5B medium

Informative references
- ETSI TS 102 636-4-2, ETSI TR 101 612, ETSI EN 302 663 (V1.2.1)

vii. Description

Specifies Congestion Control in ITS-G5, assuming use in DSRC (ITS-G5)
- Explains the methods of control of data traffic that is injected in the frequency channel, from the access layer perspective

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[35] Source: SAE, J2945®/1 APR2020, On-Board System Requirements for V2V Safety Communications, P13, Apr. 2020

- Defines which component of DCC (Autonomous Decentralized Congestion Control Method) is positioned in which layer of the ITS communication station architecture, and also specifies the mechanisms, etc., in the access layer (DCC access) including transmission power control (TPC) for each packet, transmission rate control (TRC) and transmission data rate control (TDC)
- Does not include mechanisms and management aspects in layers other than the access layer

ETSI TS 102 687 contents structure is shown in Table 3.3.2-2.

**Table 3.3.2-2 ETSI TS 102 687 contents structure**

| No. | Contents[36] | Remarks |
|---|---|---|
| 1. | Scope | ― |
| 2. | References | ― |
| 3. | Definitions, symbols and abbreviations | ― |
| 4. | Overview | ― |
| 5. | Algorithms | • Specifies the congestion control method |
| 6. | Annex A (informative): Parameter setting of reactive approach | ― |
| 7. | Annex B (informative): Packet handling to meet channel occupancy limit δ | ― |
| 8. | Annex C (informative): Bibliography | ― |
| 9. | Annex D (informative): Change | ― |

(2) LTE-V2X

Standards related to congestion control for LTE-V2X have been standardized in USA as SAE J3161/1, and in Europe as ETSI TS 103 574. The various overviews are as follows.

(a) SAE J3161/1

i. Name
- J3161/1: On-Board System Requirements for LTE-V2X V2V Safety Communications
- Reference: J3161/1 MAR2022

ii. Standardization organization/body
- SAE

iii. Standardization status
- First edition: Mar. 2022

iv. Standard positioning
- SAE standards
- System requirements for services using C-V2X PC5

v. Scope and standard details
- Specifies the standard profile, functional requirements and performance requirements for V2V safety communication systems
- Used for BSM sending and receiving in C-V2X PC5 (Release14) mode4

vi. Related standards
- SAE J2735 V2X Communications Message Set Dictionary
- SAE J2945/1 On-Board System Requirements for V2V Safety Communications

[36] Source: The table of contents is, ETSI, ETSI TS 102 687 V1.2.1 (2018-04), Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part, Apr. 2018

- SAE J2945/5 Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
- ETSI TS 136 201, ETSI TS 136 213, ETSI TS 136 321, ETSI TS 136 322, ETSI TS 136 331, (E-UTRA related standard specification: definition of physical layer, physical layer processing, MAC protocol specification, wireless link control specification, radio resource control (RRC) protocol specification)
- ETSI TS 123 285, Architecture enhancements for V2X services, V14.9.0 (Release 14) [3GPP TS 23.285]
- ETSI TS 123 303 Proximity-based services (ProSe); Stage 2, V14.1.0 (Release 14) [3GPP TS 23.303]
- IEEE Std 1609.2™, IEEE Std 1609.3™, IEEE Std 1609.12™ (WAVE related standards: cyber security services, networking services, identifier allocation)

vii. Description

SAE J3161/1 contents structure is shown in Table 3.3.2-3.

**Table 3.3.2-3 SAE J3161/1 contents structure**

| No. | Contents[37] | Remarks |
|---|---|---|
| 1. | SCOPE | — |
| 2. | REFERENCES | — |
| 3. | TERMS AND DEFINITIONS | — |
| 4. | V2V SAFETY SYSTEMS CONCEPT OF OPERATIONS AND SYSTEM DESCRIPTION | • Explanation of the concepts of V2V safety operations and system description<br>• Specifically, gives the system outline in 4.1 (Fig. 3.3.2-2) and a system description of the V2V safety functions (with reference to SAE J2945/1) in 4.2<br>• Also, this document adds the handling of the information sent by public safety vehicles (police vehicles, fire engines and ambulances) engaged in response to emergencies |
| 5. | INTERFACE DESCRIPTION | • Specifies the V2V wireless data definitions (up to BSM sending and receiving, positioning, cyber security/privacy, start/stop are described with reference to SAE J2945/1, while mapping specifies the data frames and elements that support the public safety vehicles equipped with the SAE J2945/1 reference + emergency handling, and in addition specifies PC5 wireless configuration), and system interfaces (V2V communications interfaces, SCMS (Security Credential Management System) communication interfaces *1and positioning subsystem interfaces *1) |

[37] Source: The table of contents is, SAE, J3161™/1 MAR2022, On-Board System Requirements for LTE-V2X V2V Safety Communications, Mar. 2022

| No. | Contents[37] | Remarks |
|---|---|---|
| 6. | MINIMUM REQUIREMENTS | • Specifies the minimum requirements for conformance standard profile, POSTIM (Positioning and Timing Requirements)*1, BSM sending, wireless frequency performance, cyber security and privacy, and cyber security management*1 |
| 7. | PARAMETER SETTINGS | • In Section 6 Minimum requirements, specifies the values allocated to parameters (basically, references SAE J2945/1, and only exception parameters are described) |
| 8. | NOTES | – |
| 9. | APPENDIX A<br>A.1 IMPLEMENTATION CONFORMANCE STATEMENT (NORMATIVE)<br>A.2 COORDINATE TRANSFORMATION (NORMATIVE)<br>A.3 2D POSITION EXTRAPOLATION (NORMATIVE)<br>A.4 REFER TO SAE J2945/1 A.3.CALCULATIONS INTO VEHICLE'S POSITION REFERENCE POINT<br>A.5 PATH HISTORY REFERENCE DESIGN (INFORMATIVE)<br>A.6 PATH PREDICTION REFERENCE DESIGN (INFORMATIVE)<br>A.7 OPEN SKY TEST CONDITIONS (NORMATIVE)<br>A.8 ADDITIONAL CONGESTION CONTROL ALGORITHM DETAILS (NORMATIVE)<br>A.9 EXAMPLE SIGNED MESSAGE WITH CERTIFICATE AND CORRESPONDING ASN.1 (INFORMATIVE)<br>A.10 RRC PRE-CONFIGURATION PARAMETERS | – |
| 10. | APPENDIX B CHANGES TO SAE J2735 TO ADD TIME CONFIDENCE TO VEHICLE SAFETY EXTENSIONS | – |
| 11. | APPENDIX C SSP DESIGN FOR EMERGENCY VEHICLES (REFER TO J2945/5) | – |

*1 Described with respective reference to SAE J2945/1.

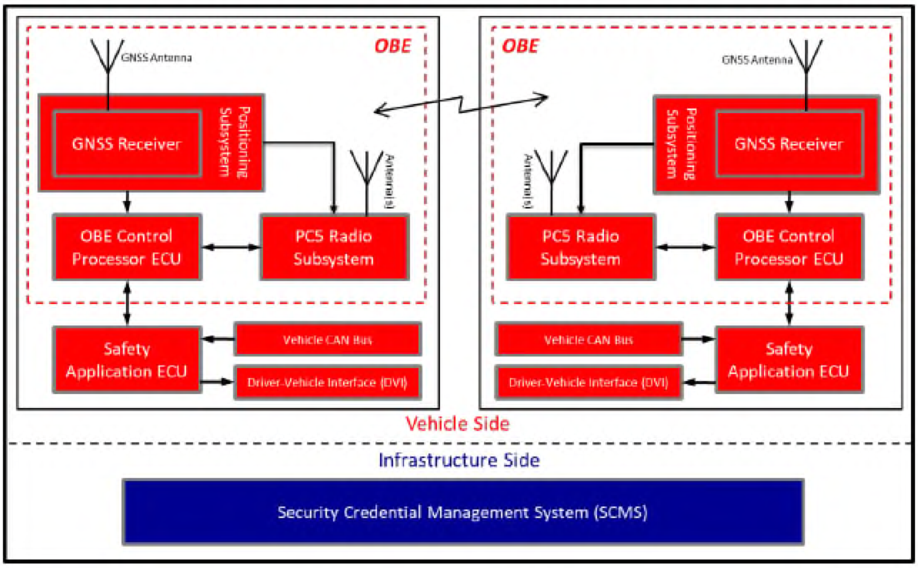


*Figure 1 - On-board V2V system*

**Fig. 3.3.2-2 V2V systems constituent elements and their interfaces (Chapter 4.1)[38]**

(b) ETSI TS 103 574

i. Name
- Intelligent Transport Systems (ITS); Congestion Control Mechanisms for C-V2X PC5 interface; Access layer part
- Reference: ETSI TS 103 574 V1.1.1

ii. Standardization organization/body
- ETSI

iii. Standardization status
- Revised: 2018-11, 1.1.1 (Active)

iv. Standard positioning
- Technical specification (TS)
- Specifies the congestion control mechanism involved in C-V2X communication, used in ITS communication cyber security with a security layer (ETSI TS 102 940 to 943)

v. Scope and standard details
- Specifies the congestion control technology in the LTE-V2X access layer
- The description includes the interface to the entities that perform congestion control
- This TS conforms to the 3GPP Release14 RAN specification

vi. Related standards
- ETSI TS 136 300 (V14.7.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 version 14.7.0 Release 14)."
- ETSI TS 136 321 (V14.7.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (3GPP TS 36.321 version 14.7.0 Release 14)."
- ETSI TS 136 331 (V14.6.2): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (3GPP TS 36.331 version 14.6.2 Release 14)."

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[38] Source: SAE, J3161™/1 MAR2022, On-Board System Requirements for LTE-V2X V2V Safety Communications, P11, Mar. 2022

- ETSI TS 136 214 (V14.4.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements (3GPP TS 36.214 version 14.4.0 Release 14)."

vii. Description
ETSI TS 103 574 contents structure is shown in Table 3.3.2-4.

**Table 3.3.2-4 ETSI TS 103 574 contents structure**

| No. | Contents[39] | Remarks |
|---|---|---|
| 1. | Scope | ― |
| 2. | Reference | ― |
| 3. | Definition of terms and abbreviations | ― |
| 4. | Congestion Control Overview<br>4.1 Introduction<br>4.2 Operational requirements<br>4.3 Congestion control architecture<br>4.4 Default parameters for mode 4 | • 4.1: Explains an overview of the position of congestion control in V2X communication (Fig. 3.3.2-3), mechanisms and causes of channel congestion<br>• 4.2: Specifies the channel resource operation requirements depending on the channel load due to congestion<br>• 4.3: Specifies the architecture of congestion control in LTE-V2X (Congestion control management entities have interfaces to the facilities layer, the transport/network layer and the access layer, respectively)<br>• 4.4: Explains an outline of precedence values related to packets sent to the lower layer from the application layer in LTE-V2X, and the reference standards for preference values |
| 5. | Control mechanism<br>5.1 Calculation of CR<br>5.2 Calculation of CBR<br>5.3 Other considerations | • 5.1: Specifies the relational expression between CR (Channel occupancy Ratio) and Crlimit (CR limit value) for packet transmission<br>• 5.2: Specifies CBR (Channel Busy Ratio) calculation method in the access layer<br>• 5.3: Specifies measurements, congestion control and specifications for the case of configurations where the control pool and the data pool are not adjacent in frequency terms |

[39] Source: The table of contents is, ETSI, ETSI TS 103 574 V1.1.1 (2018-11), Intelligent Transport Systems (ITS); Congestion Control Mechanisms for the C-V2X PC5 interface; Access layer part, Nov. 2018

| No. | Contents[39] | Remarks |
|---|---|---|
| 6. | Congestion Control Process and data exchange<br>6.1 Introduction<br>6.2 Algorithm/flowchart(informative)<br>6.3 Data exchange between access layer congestion control and Congestion Control Management Entity<br>6.4 Data exchanged between Congestion Control Management Entity and Facilities and Network/transport Layers | • 6.1: Overview of Chapter 6<br>• 6.2: Specifies processing processes using the various send pools<br>• 6.3: Specifies parameters for exchange between congestion control and congestion control management entities in the access layer<br>• 6.4: Specifies the parameters that the congestion control management entities exchange with the facilities layer and transport/network layer respectively |

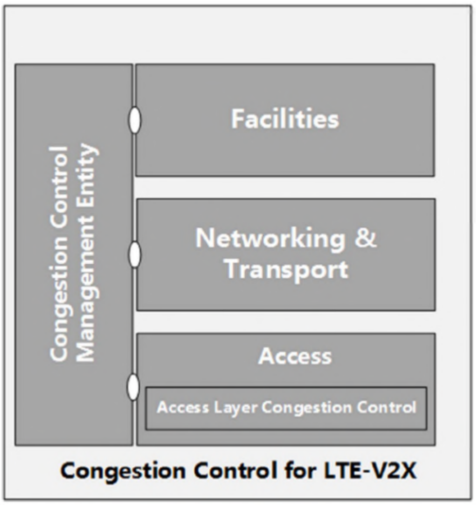


**Fig. 3.3.2-3 Congestion control in ITS station[40]**

[40] Source: ETSI, ETSI TS 103 574 V1.1.1 (2018-11), Intelligent Transport Systems (ITS); Congestion Control Mechanisms for the C-V2X PC5 interface; Access layer part, P7, Nov. 2018

### 3.3.3 Standards relating to interference avoidance

Standards related to interference avoidance with DSRC have been standardized in Europe as ETSI TS 103 724. The overview is as follows.

(a) ETSI TS 103 724

i. Name

ETSI TS 103 724

Intelligent Transport Systems (ITS); Facilities layer function; Interference Management Zone Message (IMZM)

ii. Standardization organization/body

ETSI

iii. Standardization status

- Technical Specification (TS) from ETSI TC ITS (WG1 Application Requirements and Services)
- Drafted in 2019 and published in Aug. 2021 (versions prior to V2.1.1 are not published)

iv. Standard positioning

- Used in Europe to prevent interference between V2X (ITS-G5, C-V2X) and other services

v. Scope and standard details

- Defines the Interference Management Zone Message (IMZM) that identifies the interference avoidance zone
- An interference management zone is established in the ITS station and in the same channel or neighboring channel scenarios of other services, to optimize frequency sharing through dynamic band sharing

vi. Related standards

- ETSI EN 302 636: GeoNetworking
- ETSI TS 102 894: Users and applications requirements
- ETSI TS 103 097: Security header and certificate formats
- ETSI EN 302 637: Basic Set of Applications (CAM)
- ETSI TS 103 300-3: VRU awareness basic service, etc.

vii. References

ETSI TS 103 724 V2.1.1

viii. Description

ETSI TS 103 724 contents structure is shown in Table 3.3.3-1.

**Table 3.3.3-1 ETSI TS 103 724 contents structure**

| No. | Contents[41] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | References | — |
| 3. | Definition of terms, symbols and abbreviations | — |
| 4. | Introduction to Interference Management Zone (IMZ) basic service | • Establishes an Interference Management Zone (IMZ) as a geographical area that can be dynamically shared between the ITS stations and other services and spectrum |
| 5. | IMZ basic service functional description | • IMZ service is positioned as a facilities layer function (Fig. 3.3.3-1) |

[41] Source: The table of contents is, ETSI, ETSI TS 103 724 V2.1.1 (2021-08), Intelligent Transport Systems (ITS); Facilities layer function; Interference Management Zone Message (IMZM); Release 2, Nov. 2018

| No. | Contents[41] | Remarks |
|---|---|---|
| 6. | IMZM dissemination | • Presents the use conditions of wireless resources in the zone as IMZ messages (IMZM) |
| 7. | IMZM Format Specification | • IMZM are sent via CAM format from devices on the infrastructure side, and transmit the channel used in IMZ, service type such as Tolling, etc., and parameters (Fig. 3.3.3-2) |
| 8. | Annex A (normative): ASN.1 specification of IMZM | — |
| 9. | Annex B (informative): Security analysis of IMZ use cases | — |

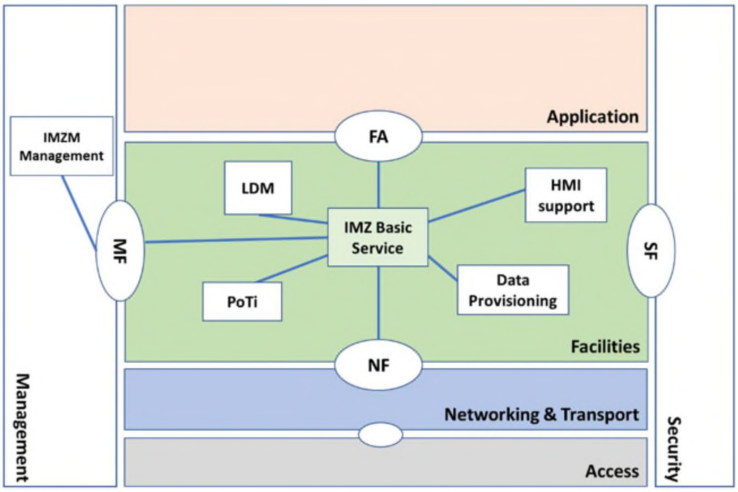


Figure 1: IMZ basic service within the ITS-S architecture

**Fig. 3.3.3-1 IMZ services in ITS stations [42]**

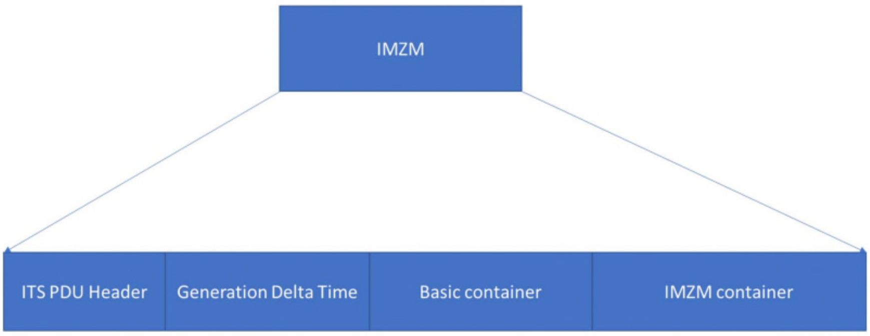


Figure 4: General structure of an IMZM

**Fig. 3.3.3-2 IMZM Structure[43]**

[42] Source: ETSI, ETSI TS 103 724 V2.1.1 (2021-08), Intelligent Transport Systems (ITS); Facilities layer function; Interference Management Zone Message (IMZM); Release 2, P12, Nov. 2018
[43] Source: ETSI, ETSI TS 103 724 V2.1.1 (2021-08), Intelligent Transport Systems (ITS); Facilities layer function; Interference Management Zone Message (IMZM); Release 2, P20, Nov. 2018

### 3.3.4 Cyber security standards

Standards related to V2X communication cyber security have been standardized in the US as IEEE 1609.2, in Europe as ETSI TS 102 940 and others, and in China as YD/T 3594. The various overviews are as follows.

(a) IEEE 1609.2

i. Name
- IEEE Standard for Wireless Access in Vehicular Environments--Security Services for Applications and Management Messages
- Reference: IEEE Std 1609.2-2016

ii. Standardization organization/body
- IEEE

iii. Standardization status
- Revised: 2016-03, Active

iv. Standard positioning
- IEEE standards
- Specifies WAVE security services used at the bottom of the congestion control layer onboard system (DSRC: SAE J2945/1, C-V2X: SAE J3161/1)

v. Scope and standard details
- Specifies safety assurance methods, etc., of application messages, and formats and processing where security of messages used by WAVE devices can be secured
- Also describes the management functions required to support core cyber security functions

vi. Related standards
- Federal Information Processing Standard (FIPS) 180-4, Secure Hash Standard (SHS), Aug. 2015.
- Federal Information Processing Standard (FIPS) 186-4, Digital Signature Standard (DSS), July 2013.
- Federal Information Processing Standard (FIPS) 197, Advanced Encryption Standard (AES), Nov. 2001.
- IEEE Std 1363a™-2004, IEEE Standard Specifications for Public Key Cryptography—Amendment 1: Additional Techniques.
- IEEE Std 1609.0™, IEEE Guide for Wireless Access in Vehicular Environments (WAVE)—Architecture.
- IEEE Std 1609.3™, Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services.
- IEEE Std 1609.12™, Standard for Wireless Access in Vehicular Environments (WAVE)—Identifier Allocations.
- IETF Request for Comments: 3629, UTF-8, A Transformation Format of ISO 10646.5
- IETF Request for Comments: 5639, Elliptic Curve Cryptography (ECC) Brainpool Standard Curves and Curve Generation.
- Standards for Efficient Cryptography Group, “SEC 1: Elliptic Curve Cryptography,” Version 2.0, May 21, 2009.7
- Standards for Efficient Cryptography Group, “SEC 4: Elliptic Curve Qu-Vanstone Implicit Certificate Scheme (ECQV),” Version 1.0, Jan. 24, 2013.
  * While not included as a Reference document, SAE specifies SS V2X 001 (Security Specification through the Systems Engineering Process for SAE V2X Standards) as a guide for system building

vii. Description
- Specifies methods for preventing spoofing or message forgery, such as attachment of a pseudonym certificate to messages exchanged in V2V/V2I

IEEE 1609.2 contents structure is shown in Table 3.3.4-1.

**Table 3.3.4-1 IEEE 1609.2 contents structure**

| No. | Contents[44] | Remarks |
|---|---|---|
| 1. | Overview | — |
| 2. | Normative reference | — |
| 3. | Definitions, abbreviations, and acronyms | — |
| 4. | General description | • Specifies the mechanism for updating the pseudonym certificate on a fixed cycle<br>• Specifies privacy protection methods that assign multiple pseudonym certificates to V2X communications devices, and update them at fixed periods to prevent the tracking of communications content |
| 5. | Cryptographic operations and validity | — |
| 6. | Data structures | — |
| 7. | Certificate revocation lists (CRLs) and the CRL Verification Entity | — |
| 8. | Peer-to-peer certificate distribution (P2PCD) | — |
| 9. | Service primitives and functions | — |
| 10. | Annex A (normative) Protocol Implementation Conformance Statement (PICS) proforma | — |
| 11. | Annex B (normative) ASN.1 modules | — |
| 12. | Annex C (informative) Specifying the use of IEEE Std 1609.2 by SDEEs | — |
| 13. | Annex D (informative) Examples and use cases | — |
| 14. | Annex E (informative) Deployment considerations | — |
| 15. | Annex F (informative) Bibliography | — |

(b) ETSI TS 102 940

i. Name
- ETSI TS 102 940 Intelligent Transport Systems (ITS) Security; ITS communications security architecture and security management Release 2
- Reference: ETSI TS 102 940 V2.1.1

ii. Standardization organization/body
- ETSI

iii. Standardization status
- Revised in 2021 (established in 2012)

iv. Standard positioning
- Specifies the functional entities required for ITS communication and their relationship with the various elements of the ITS reference architecture defined by ETSI EN 302 665, based on the ITS security services defined under the European standard ETSI TS 102 731

[44]Source: The table of contents is, IEEE, IEEE Std 1609.2™-2016, IEEE Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages, Jan. 29, 2016

v. Scope and standard details
- Specifies the functional entities required for cyber security services and their relationship with the entities and elements of the ITS reference architecture, as the ITS communication cyber security architecture
- Specifies the role and positioning of the suite of security services including the management of security identifiers and certificates, PKI processes and interfaces, and basic policies and guidelines

vi. Related standards
- ETSI EN 302 665 ITS Communications Architecture
- ETSI TS 102 731 ITS Security; Security Services and Architecture
- ETSI TS 102 941 ITS Security; Trust and Privacy Management
- ETSI TS 102 942 ITS Security; Access Control
- ETSI TS 102 943 ITS Security; Confidentiality services
- ETSI TS 103 097 ITS Security; Security header and certificate formats
- ETSI EN 302 636-4-1 ITS Vehicular communications; GeoNetworking; Part4

vii. Description

ETSI TS 102 940 contents structure is shown in Table 3.3.4-2.

**Table 3.3.4-2 ETSI TS 102 940 contents structure**

| No. | Contents[45] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | References | — |
| 3. | Definition of terms, symbols, abbreviations and notation | — |
| 4. | ITS reference architecture<br>4.1 Background<br>4.2 ITS applications groups<br>4.3 Security requirements of ITS application groups | • Specifies the reference architecture (Fig. 3.3.4-1) |
| 5. | ITS communications security architecture<br>5.1 ITS station communications security architecture<br>5.2 Security services<br>5.3 ITS security functional model | • Specifies the cyber security architecture |
| 6. | ITS station security management<br>6.1 Basic principles<br>6.2 Guidelines for establishing enrolment trust requirements<br>6.3 Trust and privacy management<br>6.4 Access control<br>6.5 Identity management<br>6.6 Confidentiality | • Specifies the cyber security management in ITS stations |

[45] Source: The table of contents is, ETSI, ETSI TS 102 940 V2.1.1 (2021-07), Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management; Release 2, July 2021

| No. | Contents[45] | Remarks |
|---|---|---|
| 7. | ITS Security management system<br>7.0 General<br>7.1 Certificate Trust List/multiple Root Cas<br>7.2 Root CA<br>7.3 Enrolment Authority<br>7.4 Authorization Authority<br>7.5 Trust List Manager<br>7.6 Misbehaviour Authority | • Specifies cyber security management system (Fig. 3.3.4-2) |

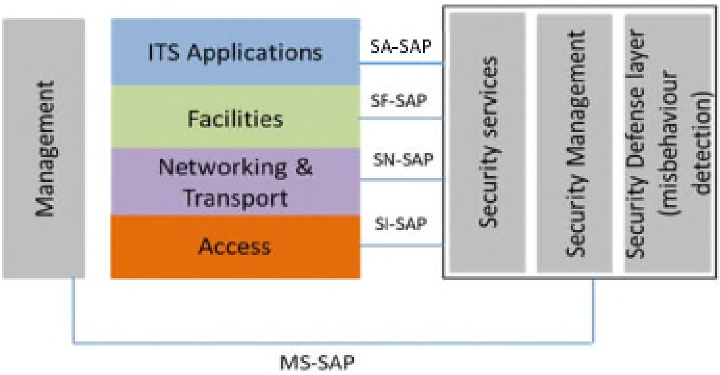


**Fig. 3.3.4-1 Configuration of cyber security in ITS stations[46]**

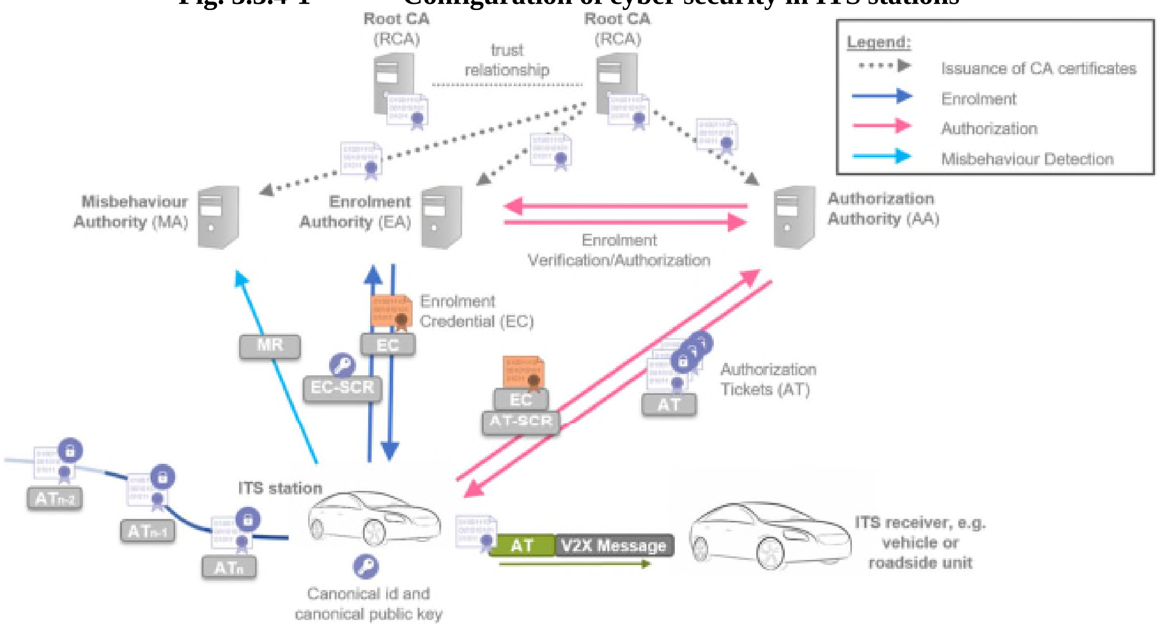


**Fig. 3.3.4-2 PKI architecture[47]**

[46] Source: ETSI, ETSI TS 102 940 V2.1.1 (2021-07), Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management; Release 2, P22, July 2021

[47] Source: ETSI, ETSI TS 102 940 V2.1.1 (2021-07), Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management; Release 2, P35, July 2021

(c) YD/T 3594

i. Name
- YD/T 3594-2019 General technical requirements of security for vehicular communication based on LTE
- Reference: YD/T 3594-2019

ii. Standardization organization/body
- China Communication Standards Association

(Drafting；China Academy of Information and Communications Technology)

iii. Standardization status
- Established in 2019

iv. Standard positioning
- Issued as a standard of the Ministry of Industry and Information Technology

v. Scope and standard details
- Specifies the overall technical requirements, interfaces, cyber security requirements and cyber security procedures for cyber security of vehicular communication using LTE

vi. Related standards
- GB/T 37376-2019 Transportation - Digital certificate format
- GB/T 37374-2019 Intelligent transport - Digital certificate application interface
- 3GPP TS 33.210 3G security; Network Domain Security (NDS); IP network layer security)
- 3GPP TS 33.223 Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA) Push function)
- 3GPP TS 33.246 3G Security; Security of Multimedia Broadcast/Multicast Service (MBMS)
- IEEE Std 1363 IEEE Standard Specifications for Public-Key Cryptography
- IEEE Std 1609.2-2016 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages
- IETF RFC 5639 Elliptic Curve Cryptography (ECC) Brainpool Standard Curves and Curve Generation

vii. Description

YD/T 3594 contents structure is shown in Table 3.3.4-3.

**Table 3.3.4-3 YD/T 3594 contents structure**

| No. | Contents[48] | Remarks |
|---|---|---|
| 1. | Scope | — |
| 2. | Normative References | — |
| 3. | Abbreviations | — |
| 4. | LTE-based vehicular communication architecture<br>4.1 Overview<br>4.2 PC5 and LTE-Uu based V2X communication architecture<br>4.3 MBMS and LTE-Uu based V2X communication architecture<br>4.4 LTE-based vehicular communication security architecture | • Specifies the architecture (Fig. 3.3.4-3) |

[48] Source: The table of contents is, COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE’S REPUBLIC OF CHINA, YD/T 3594-2019, General technical requirements of security for vehicular communication based on LTE, Nov. 11, 2019

| No. | Contents[48] | Remarks |
|---|---|---|
| 5. | Requirements for LTE-based vehicular communication security<br>5.1 General security requirements<br>5.2 Security requirements for network elements | • Specifies cyber security requirements<br>• Requires authentication by network, protection of V2X communication completeness, protection of anonymity and privacy (prevention of device tracking and identification), support for use of encryption algorithms, support of safe communication paths (https, etc.) and support of secure storage of sensitive information |
| 6. | Security process of V5 interface<br>6.1 Overview<br>6.2 Description of security basic elements<br>6.3 General requirements for security data structure<br>6.4 Public key certificate format<br>6.5 Message signing process<br>6.6 Message encryption process<br>6.7 Key negotiation | • Specifies cyber security processes as V5 (reference point between V2X applications in each UE) and other reference points (V3, MB2)<br>• Includes IEEE 1609.2 as a reference standard |
| 7. | Security procedures of other interfaces<br>7.1 V2X communication security process between network elements<br>7.2 Security process of V3 interface<br>7.3 Security process of MB2 interface | |
| 8. | Appendix A (Normative) Algorithm description | — |
| 9. | Appendix B (Informative) Device authorization management | — |
| 10. | Appendix C (Informative) Public key certificate management | — |
| 11. | Appendix D (Informative) Data message of V5 interface | — |
| 12. | Appendix E (Informative) Key negotiation calculation process | — |
| 13. | Appendix F (Informative) Certificate request and response | — |
| 14. | Appendix G (Informative) Recommendations on allocation of security-related AID value | — |

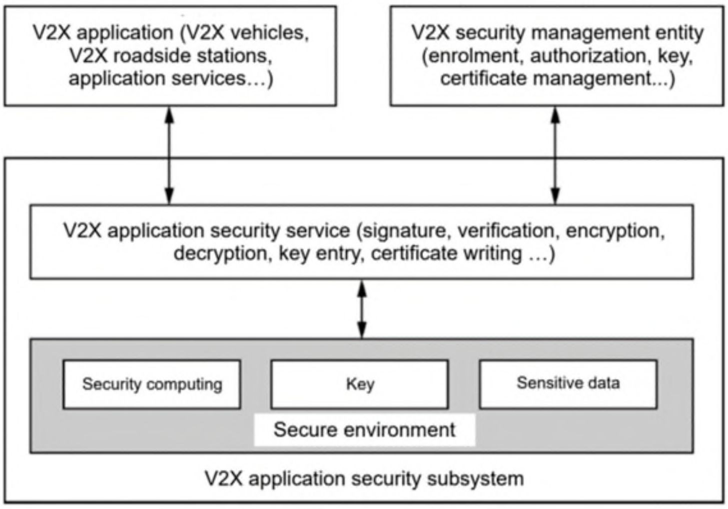


**Fig. 3.3.4-3 Cyber security architecture**[49]

[49] COMMUNICATION INDUSTRY STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA, YD/T 3594-2019, General technical requirements of security for vehicular communication based on LTE, P13, Nov. 11, 2019

## 3.4 Items requiring continued research

### 3.4.1 Consideration for new services

The study and standardization of new services is proceeding in each country. In addition to the services that use basic messages such as BSM and CAM/DENM, which have been considered as the first step, messages that contribute to the safety of pedestrians, etc. (VRU) are also being considered, and SAE and ETSI are progressing their standardization.

Further, advanced services such as the sharing of sensing data as Cooperative Perception Services (CPS/CPM), services that exchange closely data on vehicle status, and services that perform arbitration and negotiation are also under consideration, and the standardization of the messages for these new services is also underway.

While continuing to survey trends in such services, it is also necessary to consider the need to introduce services.

### 3.4.2 Survey of standardization for communications and control

Standardization of communication and control has been established, but many new communication standards are still under consideration.

While standards for LTE-V2X and DSRC (802.11p) have been developed, the use of new communications such as NR-V2X and 802.11bd are still developing, and we must also understand future trends in standardization.

Also, study of control methods and their standardization will continue, with needs changing as a result of new services (for example, added communications traffic due to use in VRU, increases in communication volume due to data sharing, etc.), and we must also focus on these trends.

# 4. Research aimed at developing communication protocol proposals

This chapter describes the details of study for drafting of a communication protocol. Specifically, working towards a communications protocol draft, the communication channel allocation, congestion control technology in upper layers and verification of effectiveness through traffic flow simulation was studied.

## 4.1 Communication channel allocation

The study procedure for allocation of communication channels is shown in Fig. 4.1-1.

First, in the study of study direction regarding allocation, the channel configuration to be studied and the target messages were defined as the study direction, having regard to the results of research into overseas trends. Next, in the study of the proposed allocation of communication channels, the proposed communication channel allocation was studied using the ITS Forum communication requirements and message sets (RC-017). The features and issues for implementation, etc., for each proposed communication channel allocation were discussed.

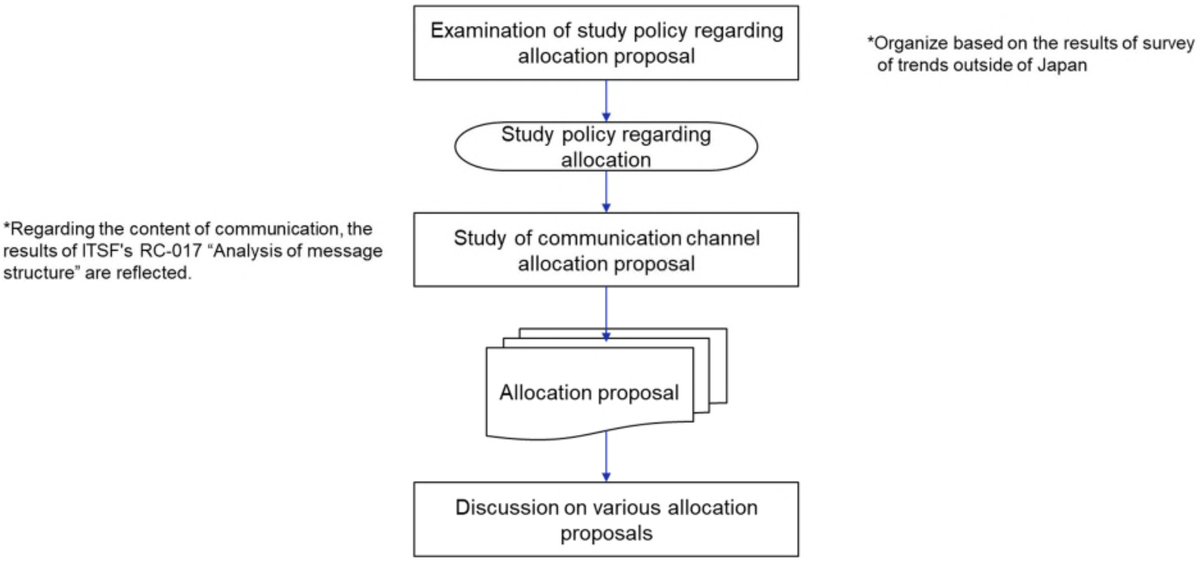


**Fig. 4.1-1 Procedure for the channel allocation study**

For the proposed allocation studied in the above procedure, case studies were conducted based on the use cases for Cooperative Driving Automation, the data traffic for each channel calculated and issues studied to determine the communication channel allocation.

### 4.1.1 Study policy regarding allocation proposal

(1) Channel bandwidth

In this study, the communication channel allocation proposal will be studied, assuming the 5.9 GHz band and 30 MHz band, and also assuming the messages in RC-017.

The bandwidth per channel will be targeted at the 10 MHz band, the 20 MHz band, and the 30 MHz band respectively in line with overseas trends.

Fig. 4.1.1-1 shows the status of frequency allocation in various countries.

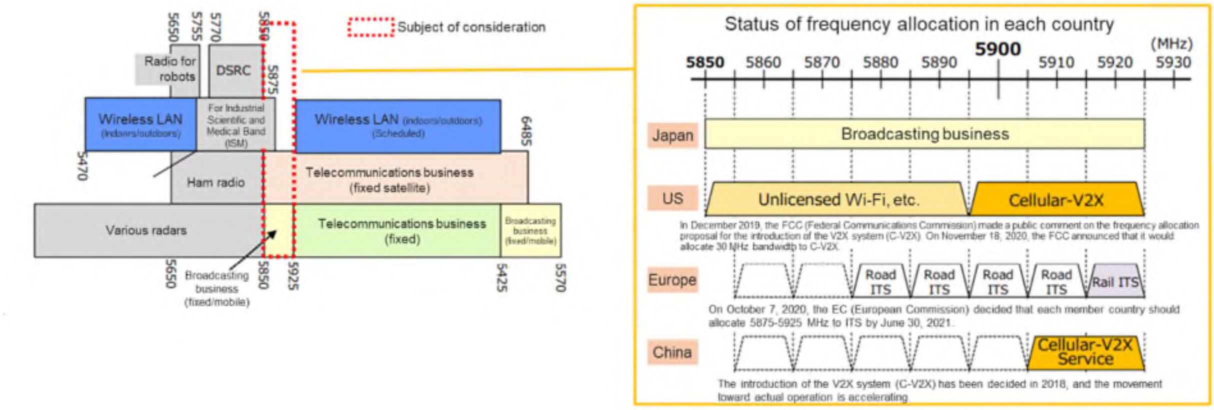


**Fig. 4.1.1-1 Frequency allocation status in various countries[50]**

(2) Message

For messages in RC-017 (total of 12 types related to DSRC (dedicated short range communication)), a communication channel allocation proposal according to communication method (V2I, V2V) and communication content will be studied.

- It is assumed that all use cases will be implemented (in 2040 or later)
- At the current time, messages relating to traffic prediction support information using V2I (d-1 to 5) and platooning (g-1, 2) are not taken into account

### 4.1.2 Study of communication channel allocation proposal

In terms of communication channel allocation concepts, messages in RC-017 were grouped and an allocation proposal based on those groups were studied.

(1) Basic concepts in communication channel allocation

The following shows the message groups and the details of the allocation proposal studied.

(a) Message grouping

The messages defined in RC-017 were grouped using the following 3 perspectives.

1) In principle, because the usage scenarios are different for the V2I use case and the V2V use case, they will be allocated to separate channels.
2) Negotiation with road side units and negotiation between vehicles involve the generation of many exchanges and so in principle will be allocated to separate channels.
3) Incidents that occur in emergencies in the vehicle (sudden hard braking, etc.) should be transmitted accurately, so in principle should be allocated to separate channels.

Those results are shown in Fig. 4.1.2-1.

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[50] Source: Frequency Reorganization Action Plan (FY2022 edition) (Draft) Outline p.11
https://www.soumu.go.jp/main_content/000833366.pdf

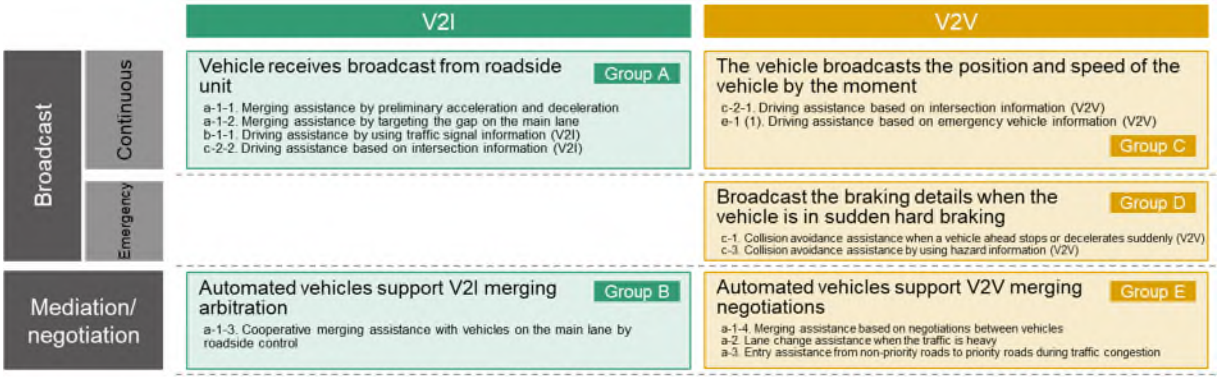


**Fig. 4.1.2-1 Message grouping**

Note that for c-2-1 messages for driving assistance based on intersection information, replacement of the c-2-1 message names with vehicle basic information messages was studied, considering not only around the intersection but also messages that are always sent as in ETSI's CAM and SAE's BSM.

(b) Study of allocation proposal

Groups A-E of Fig. 4.1.2-1 studied the Proposal 1 to 9 allocation according to the following concepts.

- Proposals 1 to 4: Studied allocation proposal of Channel bandwidth 10 MHz × 3ch based on 1) to 3) of 4.1.2(1)(a).
  Note that for Proposals 3 and 4, it is assumed that one of the 4 channels would share the 700 MHz band ITS.
- Proposal 5: Allocation proposal with Channel bandwidth 30 MHz × 1ch was studied.
  (In C-V2X, Channel bandwidth of 30 MHz can be supported as NR-V2X)
- Proposals 6 to 9: Allocation proposal with Channel bandwidths 10 MHz × 1ch, and 20 MHz × 1ch was studied. (Refer to the 5.9 GHz allocation by US FCC, Channel bandwidths 10 MHz × 1ch and 20 MHz × 1ch)

Image of allocation proposals 1 to 9 are shown in Fig. 4.1.2-2.

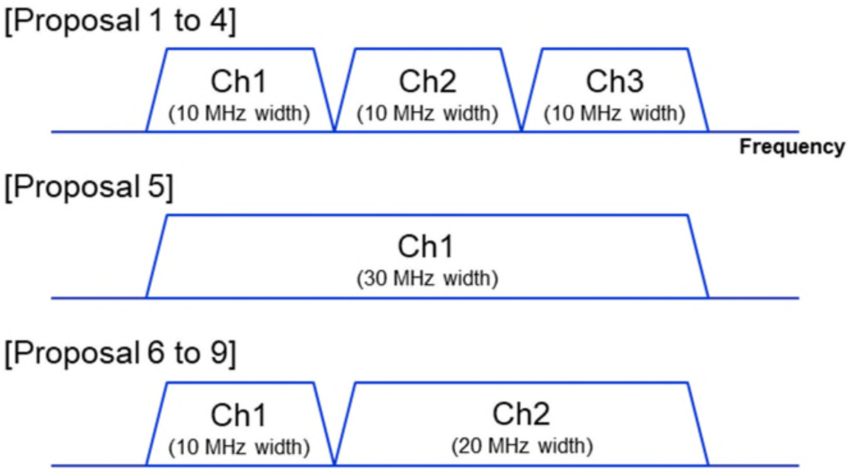


**Fig. 4.1.2-2 Image of allocation proposals 1 to 9**

The channel allocations and bandwidths in the above allocation proposals 1 to 9 are shown in Table 4.1.2-1.

**Table 4.1.2-1 Channel allocation proposal (Proposal 1 to 9)**

<table>
<tr><th>Communication method</th><th>Group</th><th>Proposal 1</th><th>Proposal 2</th><th>Proposal 3</th><th>Proposal 4</th><th>Proposal 5</th><th>Proposal 6</th><th>Proposal 7</th><th>Proposal 8</th><th>Proposal 9</th></tr>
<tr><td rowspan="2">V2I</td><td>Group A<br>Broadcast message from road side units</td><td>Ch1<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch1<br>10 MHz</td><td rowspan="5">Ch1<br>30 MHz</td><td rowspan="2">Ch1<br>10 MHz</td><td>Ch2<br>20 MHz</td><td>Ch2<br>20 MHz</td><td>Ch1<br>10 MHz</td></tr>
<tr><td>Group B<br>Negotiation message from road side units</td><td>Ch1<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch2<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch2<br>20 MHz</td><td>Ch1<br>10 MHz</td></tr>
<tr><td rowspan="3">V2V</td><td>Group C<br>Broadcast (continuous) message from vehicle</td><td>Ch2<br>10 MHz</td><td>Ch2<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch2<br>10 MHz</td><td rowspan="3">Ch2<br>20 MHz</td><td>Ch2<br>20 MHz</td><td>Vehicle basic information messages<br>Ch1<br>10 MHz<br>Other than above<br>Ch2<br>20 MHz</td><td>Vehicle basic information messages<br>Ch2<br>20 MHz<br>Other than above<br>Ch1<br>10 MHz</td></tr>
<tr><td>Group D<br>Broadcast (emergency) message from vehicle</td><td>Ch3<br>10 MHz</td><td>Ch2<br>10 MHz</td><td>Ch3<br>10 MHz</td><td>Ch3<br>10 MHz</td><td>Ch2<br>20 MHz</td><td>Ch2<br>20 MHz</td><td>Ch1<br>10 MHz</td></tr>
<tr><td>Group E<br>Negotiation message between vehicles</td><td>Ch2<br>10 MHz</td><td>Ch3<br>10 MHz</td><td>Ch4<br>10 MHz</td><td>Ch4<br>10 MHz</td><td>Ch1<br>10 MHz</td><td>Ch2<br>20 MHz</td><td>Ch1<br>10 MHz</td></tr>
</table>

The features of the various allocation proposals are shown in Table 4.1.2-2.

**Table 4.1.2-2 Features of channel allocation proposal (Proposal 1 to 9)**

| Proposal | Overview | Features |
|---|---|---|
| Proposal 1 | 10 MHz×3ch | Emergency vehicle message has priority<br>Taking into account the reachability of broadcast (emergency) messages from vehicles during emergencies, the broadcast (emergency) messages from vehicles will be allocated a standalone channel |
| Proposal 2 | 10 MHz×3ch | Negotiation message between vehicles has priority<br>Taking into account the reachability of a negotiation message during a merge, negotiation messages between vehicles will be allocated a standalone channel |
| Proposal 3 | 10 MHz×4ch | Negotiation by road side units, vehicle emergency messages and negotiation messages between vehicles have priority<br>In consideration of the reachability of mediation messages while merging, emergency messages and negotiation messages while merging, negotiation messages between vehicles such as mediation messages with road side units, broadcast (emergency) messages from vehicles and inter-vehicle negotiation messages are allocated to a standalone channel |
| Proposal 4 | 10 MHz×4ch | V2V message has priority<br>Taking into account the reachability of V2V messages, V2V messages will be allocated a standalone channel |
| Proposal 5 | 30 MHz × 1ch | All messages are concentrated in a single channel<br>For increased flexibility and expandability, the maximum bandwidth volume is allocated to a single 30 MHz channel |
| Proposal 6 | 10 MHz×1ch, 20 MHz×1ch | V2I set to 10 MHz and V2V to 20 MHz<br>In order to enhance the independence of V2I and V2V, allocate to different channels according to communication method (V2I, V2V) |
| Proposal 7 | 10 MHz×1ch, 20 MHz×1ch | Negotiation messages will be set to 10 MHz, and broadcast messages to 20 MHz<br>In order to enhance independence in broadcast and mediation/negotiation, allocated to separate channels by communication method (broadcast, mediation/negotiation) |
| Proposal 8 | 10 MHz×1ch, 20 MHz×1ch | Vehicle basic information messages will be set to a 10 MHz standalone channel<br>To enhance the independence of vehicle basic information messages, allocate the vehicle basic information messages to a standalone 10 MHz |
| Proposal 9 | 10 MHz×1ch, 20 MHz×1ch | Vehicle basic information messages will be set to a 20 MHz standalone channel<br>To enhance the independence of vehicle basic information messages, allocate the vehicle basic information messages to a standalone 20 MHz |

### 4.1.3 Discussion on various allocation proposals

The advantages and disadvantages of the various allocation proposals were studied. The advantages and disadvantages of the various proposals are shown in Table 4.1.3-1.

**Table 4.1.3-1 List of advantages and disadvantages of the channel allocation proposals (Proposals 1 to 9)**

| Proposal | Advantages | Disadvantages |
|---|---|---|
| Proposal 1 | • Reduce the impact of delay, etc., due to other messages during emergencies by allocating vehicle emergency messages to a standalone Ch3 | • Ch2 large data traffic<br>• When there is a large number of negotiation vehicles, the data traffic on Ch1 is large |
| Proposal 2 | • Reduce the impact of delay, etc., due to other messages during merging by allocating vehicle negotiation messages between vehicles to a standalone Ch3 | • When there is a large number of negotiation vehicles, the data traffic on Ch1 is large<br>• It is possible that communications in Ch2 groups C and D may impact each other |
| Proposal 3 | • By allocating road side and vehicle mediation, vehicle emergency messages and inter-vehicle negotiation to respective standalone Ch2, 3, 4, the impact of delays, etc., due to messages other than road side and vehicle mediation, vehicle emergency messages and inter-vehicle negotiation is reduced | • Ch1 large data traffic |
| Proposal 4 | • Reduce the impact of delays due to V2I messages, by allocating each V2V message to a standalone Ch2, 3 and 4 | • When there is a large number of negotiation vehicles, the data traffic on Ch1 is large |
| Proposal 5 | • Has flexibility and expandability for future use cases and messages<br>• More efficient spectrum use can be anticipated | • Complexity of congestion control in upper layers<br>• The 30 MHz band of C-V2X requires the use of NR-V2X |
| Proposal 6 | • Channel separation by V2I, V2V<br>• Allocate 20 MHz for V2V, that is assumed to have a large and also a fluctuating data traffic<br>• More efficient spectrum use as Ch2 can be anticipated | • Complexity of congestion control in Ch2 upper layers<br>• When there is a large number of negotiation vehicles, the data traffic on Ch1 is large |
| Proposal 7 | • Allocate broadcast and negotiation separately to Ch1 and Ch2<br>• More efficient spectrum use as Ch2 can be anticipated | • Complexity of congestion control in Ch1 and Ch2 upper layers |
| Proposal 8 | • Easy to accommodate migration between use cases (e.g., a-1-3 -> a-1-4)<br>• Allocate to event-type messages with some spare capacity<br>• More efficient spectrum use as Ch2 can be anticipated | • Complexity of congestion control in Ch2 upper layers |
| Proposal 9 | • Easy to accommodate migration between use cases (e.g., a-1-3 -> a-1-4)<br>• More efficient spectrum use as Ch2 can be anticipated | • Complexity of congestion control in Ch1 upper layers<br>• When there is a large number of negotiation vehicles, the data traffic on Ch1 is large |

### 4.1.4 Data traffic calculation in line with case studies

For the allocation proposal, the case study conditions were defined based on the Use cases for Cooperative Driving Automation, and the communication volume calculated for each channel.

(1) Case study conditions

The following shows the case study conditions.

(a) Target case studies

The candidates for use case appearance location are shown in Table 4.1.4-1.

In terms of appearance location, use cases related to “around intersection” are the target, through selection of “around intersection” where various use cases are congested and the likelihood of much communication is high.

**Table 4.1.4-1 Use case location of appearance candidates**

| Use case location of appearance | a-1-3<br>(Merging assistance: V2I) | a-1-4<br>(Merging assistance: V2V) | a-2<br>(Lane change: V2V) | b-1-1<br>(Traffic signal information: V2V) | c-1<br>(Collision avoidance: V2V) | c-2-1<br>(Intersection Information: V2V) | c-2-2<br>(Intersection information: V2I) | c-3<br>(Hazard information: V2V) | e-1<br>(Emergency vehicle: V2I, V2V) |
|---|---|---|---|---|---|---|---|---|---|
| Around merge point | ○ | △*1 | ○ | - | ○ | - | - | ○ | - |
| Around intersection | - | - | ○ | ○ | ○ | ×*2 | ○ | ○ | ○ |
| Communication path | • Infrastructure -> Merging vehicle | • Merging vehicle -> Mainline vehicle<br>• Mainline vehicle -> Merging vehicle | • Changing vehicle -> Receiving vehicle<br>• Receiving vehicle -> Changing vehicle | • Infrastructure -> Surrounding vehicle | • Infrastructure -> Surrounding vehicle | • Detected vehicle -> Surrounding vehicle | • Oncoming vehicle -> Right-turn vehicle | • Detected vehicle -> Surrounding vehicle | • Emergency vehicle -> Surrounding vehicle<br>• Emergency vehicle -> Infrastructure<br>• Infrastructure -> Surrounding vehicle |

*○: Generated, -: Not generated

*1 △: Generated, but excluded from data traffic calculation (because merging assistance employs the a-1-3 use case)

*2 ×: Generated, but excluded from data traffic calculation (because considered the same as the vehicle basic information message)

(b) Road environment and vehicle conditions in the case study

The road environment and vehicle conditions are shown below.

- A total of 5 lanes, two through lanes, and one right-turn lane, for both horizontal and vertical directions of the intersection.
- Vehicles in the vertical direction are stopped.
- The right turn lane is 250 m and the right turn vehicles are stopped.
- Vehicle length is 5 m.
- Inter-vehicle distance targets vehicle distances 20 km/h@1-second vehicle interval, 40 km/h@1-second vehicle interval and 40 km/h@2-second vehicle interval, and at stopped status the vehicle interval is 2 m.

(c) Communication conditions in the case study

The communication conditions are shown below.

- Communication range: Radius of 250 m from the intersection center point.
- Vehicle basic information messages (same as c-2-1 message): Assumed to be always transmitted in a fixed cycle (travelling vehicle 100 ms cycle, stopped vehicle 1s cycle)
- c-1: Assumes simultaneous transmission from 10 vehicles.
- e-1: Assumes simultaneous transmission from 1 vehicle.
- a-2: Assumes a lane change occurs with the generation of c-1, and 5% of traveling vehicles make a lane change.

(d) Data traffic calculation formula

The calculation formula for the data traffic is shown below.

Data traffic [bps] = (message size × cycle × number terminals within communication range) [bps]

The required message size and transmission interval for finding the data traffic uses the values listed in RC-017.

(e) Individual conditions by use case

The individual conditions for each use case are shown below.

- c-1 and c-3 are considered a set. In this study, it is assumed that 5 vehicles detect hazard information, and 5 vehicles simultaneously transmit use case c-1 and c-3 messages, with a total of 10 vehicles issuing c-1/c-3 messages.
- The relay transmission in c-1 and c-3 will be studied here assuming that there is no relay to the following vehicle.
- The e-1 emergency vehicle is considered to be 1 vehicle.
- In a-2, automated vehicles are assumed not to change lanes immediately before the intersection but a lane change may occur due to the generation of c-1 and c-3. (Tentatively) 5% of all vehicles are assumed to change lane.
- Event trigger use cases are considered to occur simultaneously (when data traffic is at maximum)

(f) Vehicle placement

The vehicle placement for 20 km/h@1-second vehicle interval, 40 km/h@1-second vehicle interval and 40 km/h@2-second vehicle interval is shown below.

i. 20 km/h@1-second vehicle interval

The result of intersection vehicle placement in the case of 20 km/h@1-second vehicle interval (inter-vehicle distance of 5.56 m) is 460 vehicles. An image of the intersection is shown below in Fig. 4.1.4-1.

Below, data traffic was calculated based on the vehicle basic information messages.

Horizontal direction straight through vehicles: 47 vehicles × 4 lanes
Horizontal direction right-turn vehicles: 34 vehicles × 2 lanes
All vertical direction lanes: 34 vehicles × 6 lanes
Packet size per message: 2,256 bits[51]

[51] Reference: https://itsforum.gr.jp/Public/J7Database/p70/ITS_FORUM_RC-017_v10.pdf

Number of traveling vehicles (horizontal direction straight-through vehicles) (sending at 100 ms cycle): 188 vehicles

Number of stopped vehicles (horizontal direction right-turn vehicles + vertical direction all vehicles) (sending at 1s cycle): 272 vehicles

Data traffic calculation: (data traffic of travelling + data traffic of stopped) × 1/1,000
(2,256 bits × 10 Hz × 188 vehicles + 2,256 bits × 1 Hz × 272 vehicles) × 1/1,000 = 4,854.91 Kbps

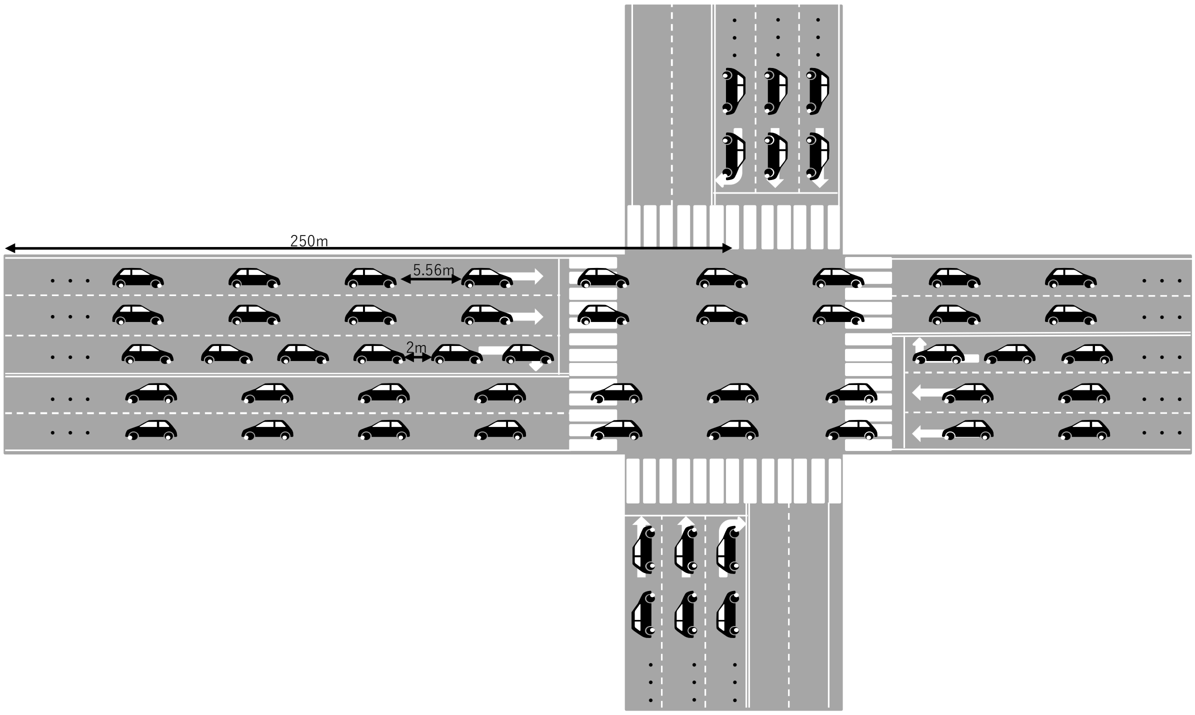


**Fig. 4.1.4-1 Vehicle placement image in 20 km/h@1-second vehicle interval**

ii. 40 km/h@1-second vehicle interval

The result of intersection vehicle placement in the case of 40 km/h@1-second vehicle interval (inter-vehicle distance of 11.11 m) is 396 vehicles. An image of the intersection is shown below in Fig. 4.1.4-2.

Below, data traffic was calculated based on the vehicle basic information messages.

Horizontal direction straight through vehicles: 31 vehicles × 4 lanes
Horizontal direction right-turn vehicles: 34 vehicles × 2 lanes
All vertical direction lanes: 34 vehicles × 6 lanes
Packet size per message: 2,256 bits

Number of traveling vehicles (horizontal direction straight-through vehicles) (sending at 100 ms cycle): 124 vehicles

Number of stopped vehicles (horizontal direction right-turn vehicles + vertical direction all vehicles) (1s cycle): 272 vehicles

Data traffic calculation: (data traffic of travelling + data traffic of stopped) × 1/1,000
(2,256 bits × 10 Hz × 124 vehicles + 2,256 bits × 1 Hz × 272 vehicles) × 1/1,000 = 3,411.07 Kbps

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Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation"
Maximum data size of c-2-1 on P.256

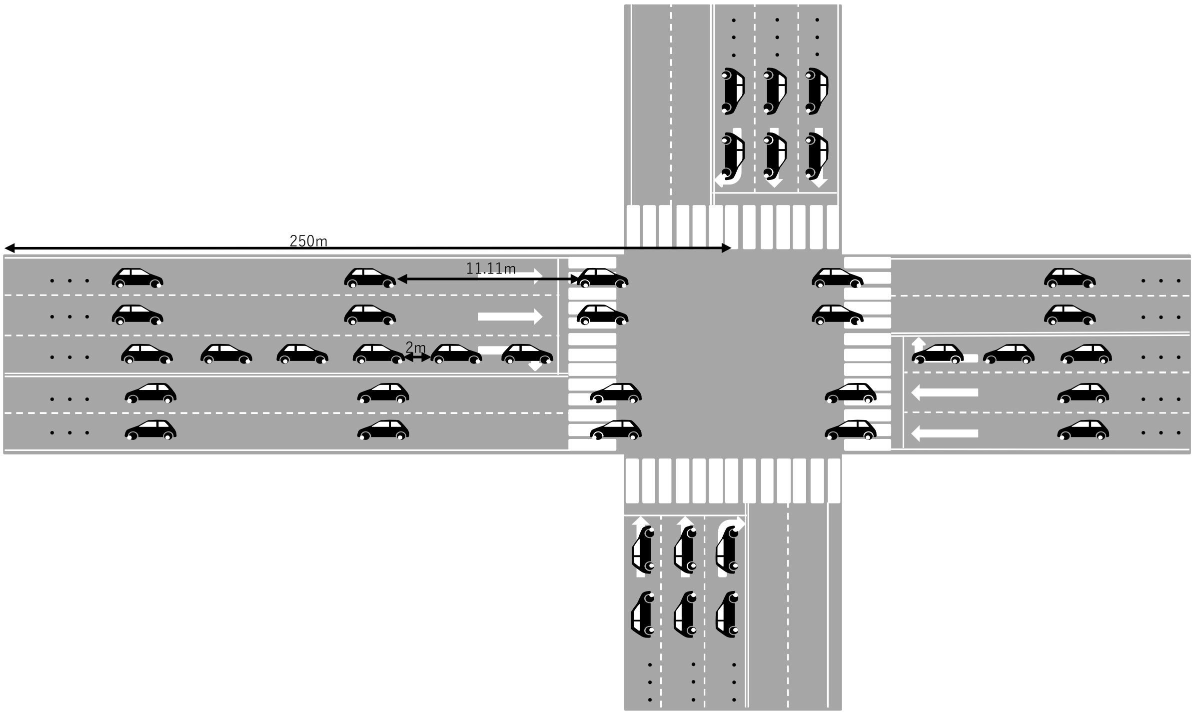


**Fig. 4.1.4-2 Vehicle placement image in 40 km/h@1-second vehicle interval**

iii. 40 km/h@2-second vehicle interval

The result of intersection vehicle placement in the case of 40 km/h@2-second vehicle interval (inter-vehicle distance of 22.22 m) is 348 vehicles. An image of the intersection is shown below in Fig. 4.1.4-3.

Below, data traffic was calculated based on the vehicle basic information messages.

Horizontal direction straight through vehicles: 19 vehicles × 4 lanes
Horizontal direction right-turn vehicles: 34 vehicles × 2 lanes
All vertical direction lanes: 34 vehicles × 6 lanes
Packet size per message: 2,256 bits

Number of traveling vehicles (horizontal direction straight-through vehicles) (100 ms cycle): 76 vehicles

Number of stopped vehicles (horizontal direction right-turn vehicles + vertical direction all vehicles) (1s cycle): 272 vehicles

Data traffic calculation: (data traffic of travelling + data traffic of stopped) × 1/1,000
(2,256 bits × 10 Hz × 76 vehicles + 2,256 bits × 1 Hz × 272 vehicles) × 1/1,000= 2,328.19 Kbps

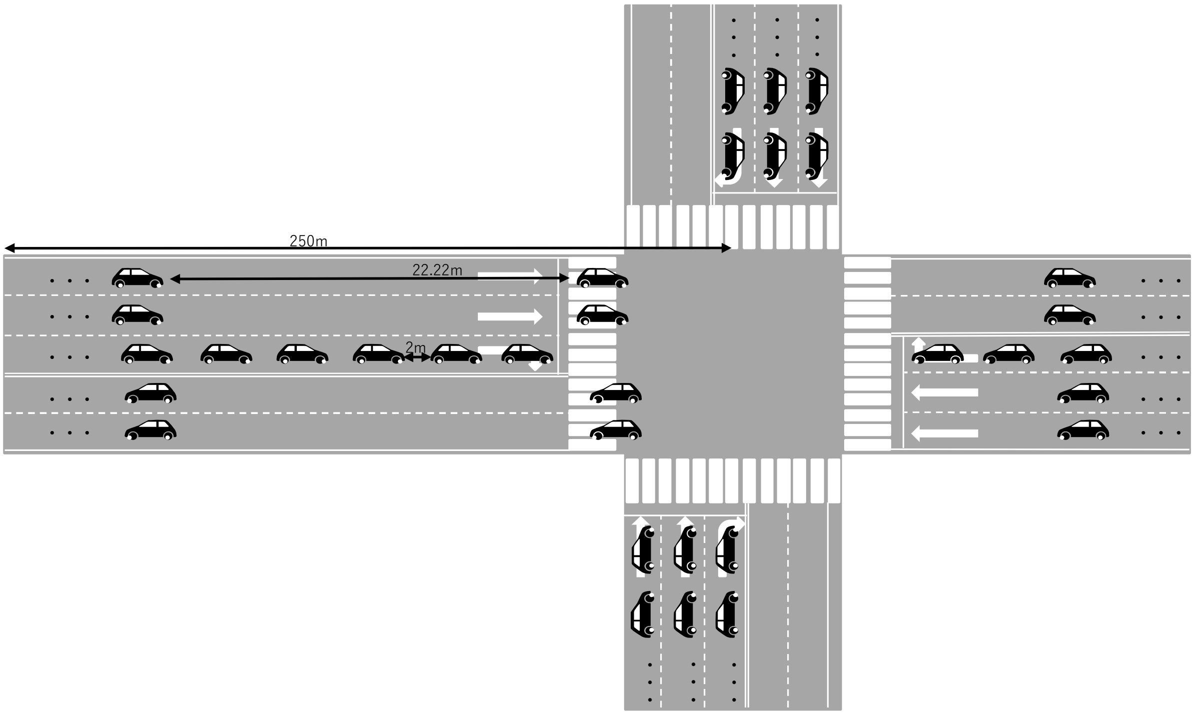


**Fig. 4.1.4-3 Vehicle placement image in 40 km/h@2-second vehicle interval**

(2) Calculation results in the case study

Calculation results from the case studies are shown below.

(a) Calculation of data traffic in each use case

Lists the result of data traffic calculation for each vehicle layout use case described above.

i. 20 km/h@1-second vehicle interval

The results of vehicle placement calculation for 20 km/h@1-second vehicle interval is shown in Table 4.1.4-2.

**Table 4.1.4-2 Data traffic for each use case at 20 km/h@1-second vehicle interval**

| Use case | Message ID | Transmitting Number of terminals | Packet size per message [bit] | Transmission interval [ms] | Data traffic [Kbps] |
|---|---|---|---|---|---|
| - | Vehicle basic information messages | 460 | 2,256 | 10 | 4,854.9 |
| a-2 | Agreement/update request message | 9 | 2,328 | 10 | 1,288.6 |
| | Agreement/update response message | 47 | 2,296 | 10 | |
| b-1-1 | Traffic signal information messages | 1 | 8,000 | 10 | 80.0 |
| c-1/c-3 | Messages in use case c-3 | 5 | 2,496 | 10 | 249.6 |
| c-2-2 | Messages in use case c-2-2 | 1 | 9,200 | 10 | 92.0 |
| e-1 | Messages in use case e-1 | 1 | 2,416 | 10 | 24.2 |

ii. 40 km/h@1-second vehicle interval

The results of vehicle placement calculation for 40 km/h@1-second vehicle interval is shown in Table 4.1.4-3.

**Table 4.1.4-3 Data traffic for each use case at 40 km/h@1-second vehicle interval**

| Use case | Message ID | Transmitting Number of terminals | Packet size per message [bit] | Transmission interval [ms] | Data traffic [Kbps] |
|---|---|---|---|---|---|
| - | Vehicle basic information messages | 396 | 2,256 | 10 | 3,411.1 |
| a-2 | Agreement/update request message | 6 | 2,328 | 10 | 851.4 |
| | Agreement/update response message | 31 | 2,296 | 10 | |
| b-1-1 | Traffic signal information messages | 1 | 8,000 | 10 | 80.0 |
| c-1/c-3 | Messages in use case c-3 | 5 | 2,496 | 10 | 249.6 |
| c-2-2 | Messages in use case c-2-2 | 1 | 9,200 | 10 | 92.0 |
| e-1 | Messages in use case e-1 | 1 | 2,416 | 10 | 24.2 |

iii. 40 km/h@2-second vehicle interval

The results of vehicle placement calculation for 40 km/h@2-second vehicle interval is shown in Table 4.1.4-4.

**Table 4.1.4-4 Data traffic for each use case at 40 km/h@2-second vehicle interval**

| Use case | Message ID | Transmitting Number of terminals | Packet size per message [bit] | Transmission interval [ms] | Data traffic [Kbps] |
|---|---|---|---|---|---|
| - | Vehicle basic information messages | 348 | 2,256 | 10 | 2,328.2 |
| a-2 | Agreement/update request message | 4 | 2,328 | 10 | 529.4 |
| | Agreement/update response message | 19 | 2,296 | 10 | |
| b-1-1 | Traffic signal information messages | 1 | 8,000 | 10 | 80.0 |
| c-1/c-3 | Messages in use case c-3 | 5 | 2,496 | 10 | 249.6 |
| c-2-2 | Messages in use case c-2-2 | 1 | 9,200 | 10 | 92.0 |
| e-1 | Messages in use case e-1 | 1 | 2,416 | 10 | 24.2 |

(a) Calculation results in channel allocation proposal

For Proposals 1 to 9, the results of data traffic calculation in each channel in the channel allocation proposal for vehicle placement in each case of 20 km/h@1-second vehicle interval, 40 km/h@1-second vehicle interval, and 40 km/h@2-second vehicle interval, are shown in Table 4.1.4-5.

**Table 4.1.4-5 Calculation results in channel allocation proposal**

Unit: Data traffic (Kbps)

| Channel | Proposal 1 | | | Proposal 2 | | | Proposal 3 | | | Proposal 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval |
| Ch.1 | 172.0 | 172.0 | 172.0 | 172.0 | 172.0 | 172.0 | 5051.1 | 3607.2 | 2524.4 | 172.0 | 172.0 | 172.0 |
| Ch.2 | 6167.7 | 4286.6 | 2881.7 | 5128.7 | 3684.8 | 2602.0 | 0 | 0 | 0 | 4879.1 | 3435.2 | 2352.4 |
| Ch.3 | 249.6 | 249.6 | 249.6 | 1288.6 | 851.4 | 529.4 | 249.6 | 249.6 | 249.6 | 249.6 | 249.6 | 249.6 |
| Ch.4 | - | - | - | - | - | - | 1288.6 | 851.4 | 529.4 | 1288.6 | 851.4 | 529.4 |

| Channel | Proposal 5 | | | Proposal 6 | | | Proposal 7 | | | Proposal 8 | | | Proposal 9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval | 20 km/h @1-second vehicle interval | 40 km/h @1-second vehicle interval | 40 km/h @2-second vehicle interval |
| Ch.1 | 6589.3 (2196.4) | 4708.3 (1569.4) | 3303.3 (1101.1) | 172.0 | 172.0 | 172.0 | 1288.6 | 851.4 | 529.4 | 4854.9 | 3411.1 | 2328.2 | 1734.4 | 1297.2 | 975.1 |
| Ch.2 | - | - | - | 6417.3 (3208.7) | 4536.3 (2268.2) | 3131.3 (1565.7) | 5300.7 (2650.4) | 3856.8 (1928.4) | 2774.0 (1387.0) | 1734.4 (867.2) | 1297.2 (648.6) | 975.1 (487.6) | 4854.9 (2427.5) | 3411.1 (1705.6) | 2328.2 (1164.1) |
| Ch. 3,4 | No allocation | | | | | | | | | | | | | | |

* (xxxx.x): For values in brackets in the table, value converted to 10 MHz band

* Pink-filled area: Channel maximum data traffic including Group C Broadcast (continuous) from vehicles
Currently the vehicle basic information messages have a 100 ms cycle for traveling vehicles and 1s cycle for stopped vehicles, but depending on conditions, the congestion control must be considered

* Blue-filled area: Dependent on number of vehicles in a-2, as group E (negotiation between vehicles themselves) (in this case, 5% of traveling vehicles)

(b) Discussion regarding data traffic calculation results

Data traffic in channels that include vehicle basic information messages and inter-vehicle messages about negotiation is proportional to the number of vehicles, so when data traffic increases, the volume is in the Mbps range. Regarding other messages, even when the vehicle interval is short and traffic is high, the data traffic decreased relatively.

Where the data traffic is considered to increase in proportion to the number of vehicles, as in this case study, (in particular in a real environment, where the upper limit on the number of vehicles cannot be estimated), suppression of channel data traffic using congestion control, etc., must be studied even when there is communication load in the channels.

### 4.1.5 Issues for study in each allocation proposal

The procedure for identification of issues for consideration and validation for the channel allocation proposals is shown below.

1） Identifies issues for study from the following 2 perspectives
- Issue identification from ideal channel allocation (top down)
- Identification of issues in channel allocation proposals 1 to 9 from a technology perspective (bottom-up)

2） Run a cross-matching linking of issues from the two perspectives identified in 1） to check that there are no omissions

3） The issues linked in 2） are categorized in the following 4 categories
- Check of bandwidth use volume in each channel allocation proposal
- Message multiplexing
- Check of bandwidth usage (20 MHz and 30 MHz band channel allocation)
- Check whether or not multichannel support can be supported

4） Summary of issues

(1) Identification of study issues

Mining and study of issues in each allocation proposal was conducted, both top-down and bottom up.

(a) Issue identification from top-down

The result of issue identification from the following perspectives is shown in Fig. 4.1.5-1.
- Averaging of channel data traffic
- Co-ordination between use cases
- Future flexibility, expandability
- Sharing of 5.9 GHz band and 700 MHz band ITS

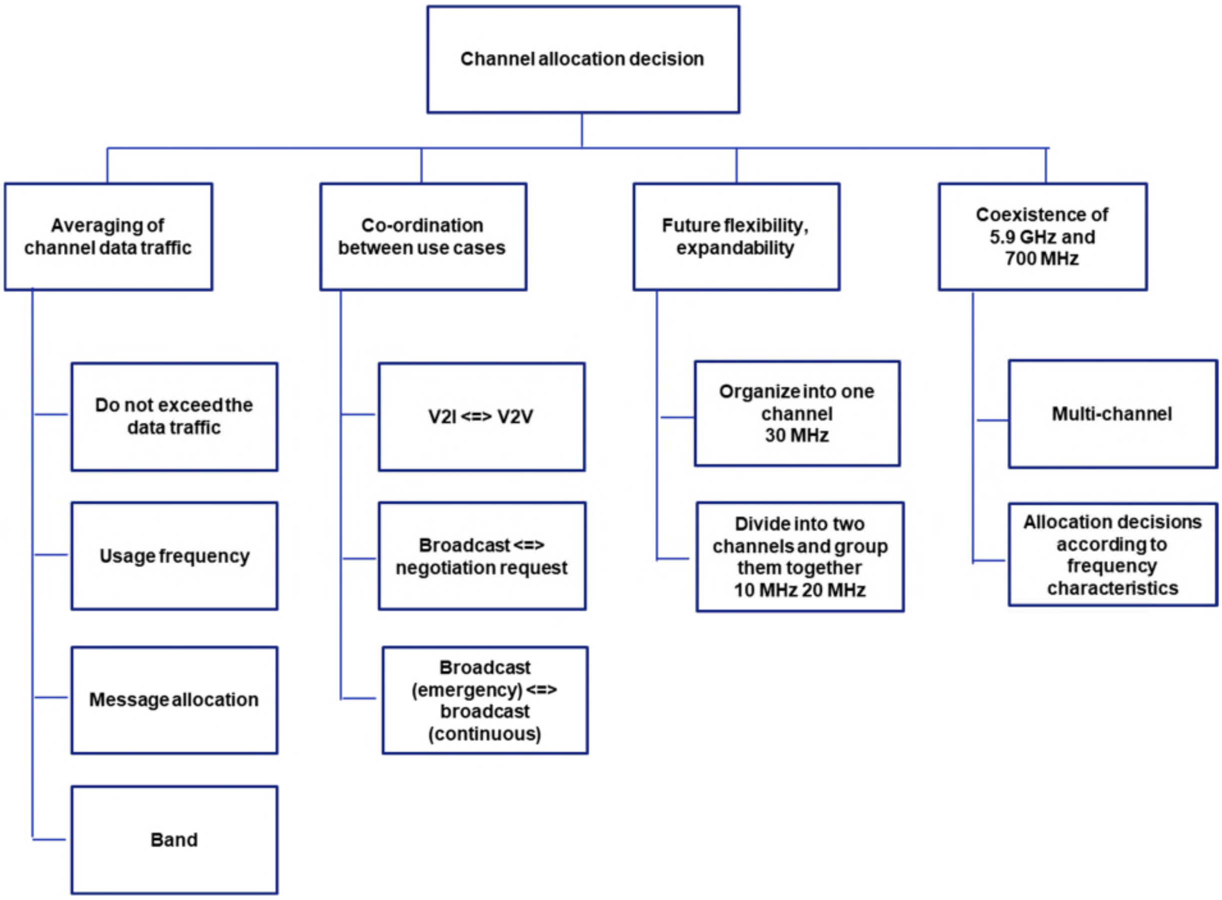


**Fig. 4.1.5-1 Issue identification from top-down**

Further, specific issue details and study and validation items studied in the Fig. 4.1.5-1 tree structure are shown in Table 4.1.5-1.

**Table 4.1.5-1 List of issues from top-down perspective (1/2)**

| No | Major item | Medium item | Minor item | Issues |
|---|---|---|---|---|
| 1 | Channel allocation decision | Averaging of channel data traffic | Data traffic exceeded (congestion control) | Study of congestion control when transmission interval is short and channel load is high |
| 2 | | | Data traffic exceeded (transmission delay) | Check of influence on use case implementation due to transmission delay for messages with low priority |
| 3 | | | Usage frequency | Study of reduction in channel load caused by messages with high transmission frequency and receiving frequency being concentrated in the same channel |
| 4 | | | Message allocation (V2I broadcast) | Study of congestion control due to large data traffic when there are many vehicles |
| 5 | | | Message allocation (V2I negotiation) | Validation of impact due to multiplexing of messages due to large data traffic when there are many vehicles |
| 6 | | | Message allocation (V2V broadcast) | Study of congestion control due to large data traffic (may exceed 10 MHz) when there are many vehicles |
| 7 | | | Message allocation (V2V negotiation) | Study of congestion control due to large data traffic when there are many vehicles |
| 8 | | | Bandwidth (size) | Study of congestion control for bandwidth excess |
| 9 | | Co-ordination between use cases | V2I <=> V2V co-ordination (message delay) | Check impact of message transmission delay caused by linking between use cases on subsequent use cases |
| 10 | | | Broadcast <=> Negotiation co-ordination (message delay) | |
| 11 | | | Broadcast (emergency) <=> Broadcast (continuous) co-ordination | |

**Table 4.1.5-1 List of issues from top-down perspective (2/2)**

| No | Major item | Medium item | Minor item | Issues |
|---|---|---|---|---|
| 12 | | Future flexibility, expandability | Complexity of congestion control in upper layers (30 MHz) | Study of optimization of radio wave resources in 30 MHz band |
| 13 | | | In the 30 MHz band, C-V2X cannot be used (30 MHz) | |
| 14 | | | Optimization of 30 MHz resources (30 MHz) | |
| 15 | | | Complexity of congestion control in upper layers (10 MHz, 20 MHz) | Study of optimization of radio wave resources in 20 MHz band |
| 16 | | | Optimization of 10 MHz and 20 MHz resources (10 MHz and 20 MHz) | |
| 17 | | Sharing of 5.9 GHz band and 700 MHz band ITS | Frequency characteristics (message allocation) | Validation of effect due to message allocation taking into account frequency characteristics |
| 18 | | | Multi-channel (hardware limitation) | Reduction in cost increases due to installation of multiple radio units as a hardware limitation in multi-channel |
| 19 | | | Multi-channel (interference) | Check of impact of interference and blocking from neighboring channels in multi-channel setups |
| 20 | | | Multi-channel (chip performance) | Study of implementation possibility according to chip performance (channel switching limitations, processing specs) in multi-channel |
| 21 | | | Multi-channel (shared) | Study of terminals that support multi-channel for sharing 5.9 GHz and 700 MHz band ITS |

(b) Issue identification from bottom-up

The results of identification of issues identified in Proposals 1 to 9 of Table 4.1.2-1 which is the Communication channel allocation proposal, is shown in Table 4.1.5-2.

**Table 4.1.5-2 List of issues from bottom-up perspective**

| No | Proposal | Issue details |
|---|---|---|
| 1 | Proposal 1 | Optimization of congestion control for Groups C and E |
| 2 | | Study of sending/receiving sequence at road side units with a large number of negotiating vehicles |
| 3 | Proposal 2 | Optimization of congestion control for Groups C and D |
| 4 | | Study of sending/receiving sequence at road side units with a large number of negotiating vehicles |
| 5 | Proposal 3 | Optimization of congestion control for Groups A and C |
| 6 | | Multi-channelization including 700 MHz band ITS |
| 7 | Proposal 4 | Study of sending/receiving sequence at road side units with a large number of negotiating vehicles |
| 8 | | Multi-channelization including 700 MHz band ITS |
| 9 | Proposal 5 | Congestion control specification definition and sharing in road side systems and on board systems |
| 10 | | Study of maximum channel usage |
| 11 | Proposal 6 | Congestion control specification definition and sharing for V2I and V2V |
| 12 | | Study of sending/receiving sequence at road side units with a large number of negotiating vehicles |
| 13 | Proposal 7 | Congestion control specification definition and sharing for V2I and V2V |
| 14 | | Study of mediation/negotiation sending/receiving sequence when the number of mediation/negotiation vehicles is large |
| 15 | Proposal 8 | Congestion control specification definition and sharing for V2I and V2V |
| 16 | | Study of mediation/negotiation sending/receiving sequence when the number of mediation/negotiation vehicles is large |
| 17 | Proposal 9 | Congestion control specification definition and sharing for V2I and V2V |
| 18 | | Study of sending/receiving sequences in road side units or negotiation |

(c) Cross-matching of issues identified from a top-down and bottom-up perspective

As a result of running a cross-matching of issues identified from the top-down and bottom-up perspectives described above, top-down issues can be broadly linked with bottom-up issues. Thanks to that, an overall picture of the issues can be summarized, based on top-down issues identified.

The linking relationships of the bottom-up issues to the top-down issues in Table 4.1.5-3 are shown in the linking table based on Table 4.1.5-1.

**Table 4.1.5-3 Linking of issues from a top-down and bottom-up perspective (1/3)**

| No | Issue item identified from a top-down perspective | | | | Bottom-up perspective issue number | Types of issues |
|---|---|---|---|---|---|---|
| | Major item | Medium item | Minor item | Issues | | |
| 1 | Channel allocation decision | Averaging of channel data traffic | Data traffic exceeded (congestion control) | Study of congestion control when transmission interval is short and channel load is high | 1,2,3,4,5,7,9,11,12,13,14,15,16,17,18 | Check of bandwidth use volume in each channel allocation proposal |
| 2 | | | Data traffic exceeded (transmission delay) | Check of influence on use case implementation due to transmission delay for messages with low priority | 1,2,3,4,5,7,9,11,12,13,14,15,16,17,18 | Check of bandwidth use volume in each channel allocation proposal |
| 3 | | | Usage frequency | Study of reduction in channel load caused by messages with high transmission frequency and receiving frequency being concentrated in the same channel | 1, 2, 3, 4,5, 7 | Check of bandwidth use volume in each channel allocation proposal |
| 4 | | | Message allocation (V2I broadcast) | Study of congestion control due to large data traffic when there are many vehicles | 5 | Check of bandwidth use volume in each channel allocation proposal |
| 5 | | | Message allocation (V2I negotiation) | Validation of impact due to multiplexing of messages due to large data traffic when there are many vehicles | 2,4,7,12,14,16,18 | Check of bandwidth use volume in each channel allocation proposal |
| 6 | | | Message allocation (V2V broadcast) | Study of congestion control due to large data traffic (may exceed 10 MHz) when there are many vehicles | 1,2,3,4,5,7,15,16 | Check of bandwidth use volume in each channel allocation proposal |
| 7 | | | Message allocation (V2V negotiation) | Study of congestion control due to large data traffic when there are many vehicles | 14,16,18 | Check of bandwidth use volume in each channel allocation proposal |
| 8 | | | Bandwidth (size) | Study of congestion control for excess bandwidth | 1,2,3,4,5,7,15,16 | Check of bandwidth use volume in each channel allocation proposal |

**Table 4.1.5-3 Linking of issues from a top-down and bottom-up perspective (2/3)**

| No | Issue item identified from a top-down perspective | | | | Bottom-up perspective issue number | Types of issues |
|---|---|---|---|---|---|---|
| | Major item | Medium item | Minor item | Issues | | |
| 9 | | Co-ordination between use cases | V2I <=> V2V co-ordination (message delay) | Check impact of message transmission delay caused by linking between use cases on subsequent use cases | — | Check of bandwidth use volume in each channel allocation proposal |
| 10 | | | Broadcast <=> Negotiation co-ordination (message delay) | | — | Check of bandwidth use volume in each channel allocation proposal |
| 11 | | | Broadcast (emergency) <=> Broadcast (continuous) co-ordination | | — | Check of bandwidth use volume in each channel allocation proposal |
| 12 | | Future flexibility, expandability | Complexity of congestion control in upper layers (30 MHz) | Study of optimization of radio wave resources in 30 MHz band | 9,10 | Study of flexibility, expandability |
| 13 | | | In the 30 MHz band, NR-V2X cannot be used (30 MHz) | | | |
| 14 | | | Optimization of 30 MHz resources (30 MHz) | | | |
| 15 | | | Complexity of congestion control in upper layers (10 MHz, 20 MHz) | Study of optimization of radio wave resources in 20 MHz band | 11,13,15,17 | Study of issues in 20 MHz and 30 MHz band channel allocation |
| 16 | | | Optimization of 10 MHz and 20 MHz resources (10 MHz and 20 MHz) | | | |

**Table 4.1.5-3 Linking of issues from a top-down and bottom-up perspective (3/3)**

| No | Issue item identified from a top-down perspective | | | | Bottom-up perspective issue number | Types of issues |
|---|---|---|---|---|---|---|
| | Major item | Medium item | Minor item | Issues | | |
| 17 | | Sharing of 5.9 GHz band and 700 MHz band ITS | Frequency characteristics (message allocation) | Validation of effect due to message allocation taking into account frequency characteristics | — | Check whether or not multichannel support can be supported |
| 18 | | | Multi-channel (hardware limitation) | Reduction in cost increases due to installation of multiple radio units as a hardware limitation in multi-channel | — | Check whether or not multichannel support can be supported |
| 19 | | | Multi-channel (interference) | Check of impact of interference and blocking from neighboring channels in multi-channel setups | — | Check whether or not multichannel support can be supported |
| 20 | | | Multi-channel (chip performance) | Study of implementation possibility according to chip performance (channel switching limitations, processing specs) in multi-channel | — | Check whether or not multichannel support can be supported |
| 21 | | | Multi-channel (shared) | Study of terminals that support multi-channel for sharing check of 5.9 GHz and 700 MHz band ITS | 6,8 | Check whether or not multichannel support can be supported |
| 22 | Bottom-up only<br>Study of sending/receiving sequences in road side units or mediation/negotiation | | | | 2,4,7,12,14,16,18 | Message multiplexing |
| 23 | Bottom-up only<br>Congestion control specification definition and sharing in road side systems and on board systems | | | | 9,11,13,15,17 | Check of bandwidth use volume in each channel allocation proposal |

(2) Summary of allocation proposal issues

By summarizing the top-down and bottom-up issues, the issues listed in Table 4.1.5-3 were aggregated into 4 types and the details for future study and validation examples were organized.

The 4 types are shown below.

- Check of bandwidth use volume in each channel allocation proposal
- Message multiplexing
- Study of issues in 20 MHz and 30 MHz band channel allocation
- Check whether or not multichannel support is provided

A list summarizing the issues and study details, as well as validation examples, is shown in Table 4.1.5-4.

**Table 4.1.5-4 List of communication channel allocation issues (1/3)**

| No | Issues for study | Study content | Validation example |
|---|---|---|---|
| 1 | Check of bandwidth use volume in each channel allocation proposal<br>• Decision on data traffic standard values<br>• Check impact of measures for data traffic increase<br>• Study of communication requirements considering multiple use cases<br>• Decision on congestion control technology (transmission control, priorities) | Study the decision criteria for bandwidth usage volume in each channel and check whether or not the decision criteria are exceeded by channel allocation proposals. | With reference to the overseas specifications, determine the basis for the decision criteria, run simulations to decide conditions, and check whether or not the decision criteria are satisfied.<br><br>Decision criteria candidates<br>• Band usage in each channel<br>• All channel efficiency (check channel balance depending on driving environment, etc.)<br><br>Simulation<br>Implementation condition<br>• Incorporate the congestion control technology derived from congestion control, run communication simulations on Proposals 1 to 9, and measure the data traffic.<br><br>Validation method<br>• Check whether the data traffic in each of the channels in Proposals 1 through 9 derived from simulation validation satisfies the decision criteria. |

**Table 4.1.5-4 List of communication channel allocation issues (2/3)**

| No | Issues for study | Study content | Validation example |
|---|---|---|---|
| 2 | Message multiplexing<br>• Study of measures that can suppress the sending/receiving sequence data traffic related to mediation<br>• Additional study regarding RC-017 (Communication requirements/MSG specifications, etc.) | Regarding messages studied in RC-017, study the reduction in bandwidth usage by message multiplexing, taking into account the change in message specification and communication requirements. | Check whether the decision criteria in issue No. 1 are satisfied by message multiplexing.<br><br>Message multiplexing method:<br>(1) Messages are multiplexed when multiple information elements/messages of different types occur on the send side in the same use case.<br>(2) Messages are multiplexed when multiple information elements/messages with different destinations occur on the send side in the same use case.<br>(3) Messages are multiplexed when multiple information elements/messages for different use cases occur on the send side.<br><br>Run simulation:<br>In use cases with the respective conditions (1), (2), (3), check whether the sequence operates normally even when the messages are multiplexed by running a communication simulation.<br><br>Decision conditions:<br>Run simulations (1), (2), and (3), and check whether the decision criteria in issue No. 1 are satisfied.<br>• Also, check the impact using the difference between the before and after of (1), (2), (3) implementation, to demonstrate the effect of multiplexing. |

**Table 4.1.5-4 List of communication channel allocation issues (3/3)**

| No | Issues for study | Study content | Validation example |
|---|---|---|---|
| 3 | Study of flexibility, expandability<br>• Study of issues in 20 MHz and 30 MHz band channel allocation | Checks whether or not there is an issue with the channel allocation proposal, including 20 MHz, 30 MHz bandwidth.<br>• Addition or change of use cases, etc.<br>• More efficient channel use<br>Existence of issues in upper layer when 20 MHz or 30 MHz is allocated | Addition of use cases, study:<br>• Study whether or not UC additions or changes (integration) are possible by extending to a wider area than 10 MHz.<br>Decision on specifications for more efficient channel use: Candidate efficiency specifications (in C-V2X case):<br>• Change the source block size in line with the packet size as in the table in SAE[52].<br>• Optimization of resource blocks is considered to be a method of optimizing channel use efficiency. For running optimization, the optimization method must be studied because the optimum resource block must be determined from MCS or the message size, and the message size varies for each use case. (in case of C-V2X) |
| 4 | Check whether or not multichannel support can be supported<br>• 5.9 GHz band multi-channel implementation method<br>• Shared with 700 MHz | Study of issues for making the 5.9 GHz band multi-channel and sharing with 700 MHz<br>• Introduction of channel switching control<br>• Impact of interference and blocking from neighboring channels<br>• Cost to install multiple radio units<br>• Securing terminals that support multi-channel | Validation conducted using actual equipment:<br>• Evaluates channel switching performance.<br>• Using equipment that can send and receive on multiple channels, evaluate the impact of interference in neighboring channels.<br>Study from a hardware perspective:<br>• Study in order to reduce hardware implementation costs |

52 Reference: https://www.sae.org/standards/content/j3161/1_202203/
P.29 Table 11 20 MHz low speed (<120 km/h), Table 12 20 MHz high speed (≥120 km/h)

Continued study of the following items is required in order to make the final decision on communication channel allocation through the study of issues listed in Table 4.1.5-4. Proposals for study procedures are shown in Fig. 4.1.5-2.

- Taking into account the coordination between use cases and the simultaneous occurrence of multiple use cases, study (additional study regarding RC-017) based on additional study results of communication requirements (cycle, quality, etc.)
- Study based on congestion control specifications (transmission control, priorities)
- 5.9 GHz band multichannel implementation method in radio unit
- Sharing with 700 MHz band ITS

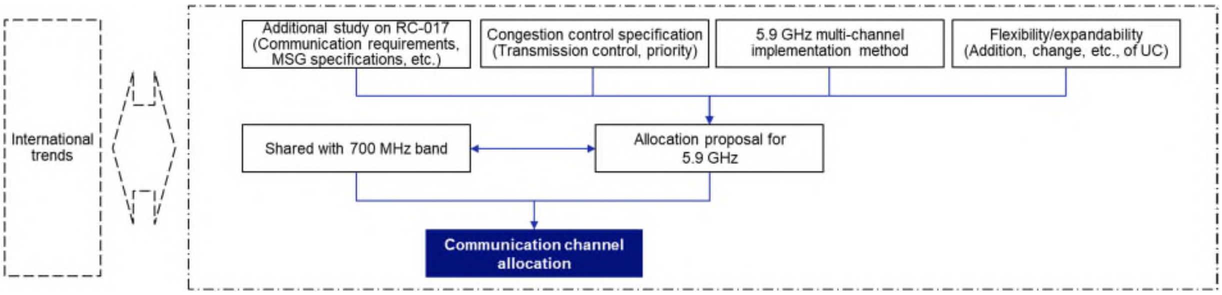


**Fig. 4.1.5-2 Procedure for the communication channel allocation study**

### 4.2 **Congestion control methods in upper layers**

This section discusses the results of study of the congestion control methods in upper layers.

The study procedure for upper layer congestion control methods is shown in Fig. 4.2-1.

Examples of the US (SAE) and EU (ETSI) congestion control methods were researched and a congestion control methods proposal was devised based on the details. The functional requirements in the congestion control methods proposal have been validated through case studies and an image of its implementation and the studied and validated items have been summarized.

The results of this consideration were provided as feedback to study of operational item (c) and operational item (d).

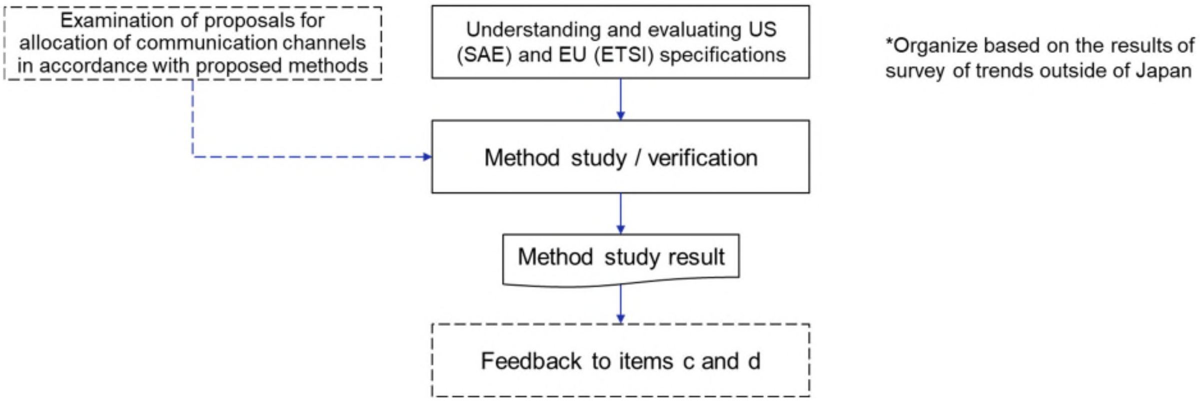


**Fig. 4.2-1 Study procedure for congestion control methods in upper layers**

#### 4.2.1 **Examples of congestion control methods**

Examples of congestion control methods in SAE and ETSI have been researched and the resulting comparison has been summarized.

(1) SAE[53]

The SAE congestion control methods are shown below.

(a) Image diagram of congestion control

An image of the SAE congestion control methods is shown in Fig. 4.2.1-1. The congestion control in upper layers makes transmission timing decisions, sets priorities and makes transmission power decisions.

The details of congestion control in the lower layers vary according to the methods used (LTE-V2X or DSRC). Since this section describes the congestion control methods in the upper layers, only an overview for the lower layers, rather than details, will be described.

[53] Overview based on SAE J2945/1_202004 Ch.6.3.8, SAE J3161/1_202203 Ch.6.1.1, Ch.6.3.8.
https://www.sae.org/standards/content/j2945/1_202004/
https://www.sae.org/standards/content/j3161/1_202203/

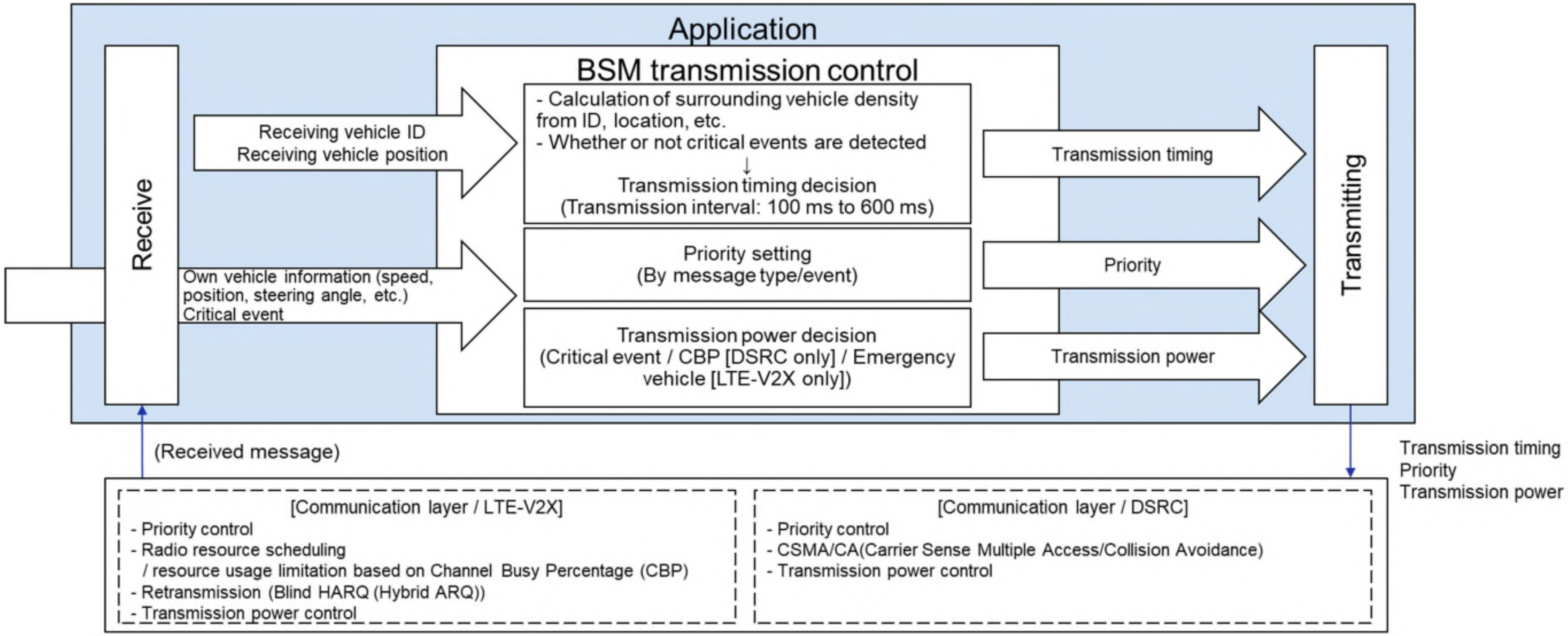


**Fig. 4.2.1-1 Image diagram of the SAE congestion control methods**

(b) Transmission timing decision

The decision item for the transmission timing decision and the input, processing content and output are shown in Table 4.2.1-1.

**Table 4.2.1-1 SAE congestion control methods: Transmission timing decision**

| Decision requirement | Input | Processing details | Output |
|---|---|---|---|
| Surrounding vehicle density | Received BSM<br>(Basic Safety Message) | The number of Vehicle IDs in the received vehicle basic information is calculated and used as Surrounding vehicle density, and transmission timing is calculated on that basis:<br>• Less than lower limit value specified by vehicle density: Transmission timing is fixed using the lower limit value<br>• Greater than upper limit value specified by vehicle density: Transmission timing is fixed to the upper limit value<br>• Vehicle density other than above: Transmission timing is changed in proportion to the vehicle density | Transmission timing |
| Critical event | Critical event decision information | When a new critical event is detected, a BSM is sent immediately*1 | |

*1 In the description of the SAE J2735 BSM message structure, there are data elements indicating a vehicular event as part of BSM, and a critical event can be notified.
https://www.sae.org/standards/content/j2735_202007/

(c) Priority setting

The decision item for priority setting and the corresponding input, processing content and output are shown in Table 4.2.1-2.

**Table 4.2.1-2 SAE congestion control methods: Priority setting**

| Decision requirement | Input | Processing details | Output |
|---|---|---|---|
| Message type | Message type | Changes priority according to message type | Priority |
| Whether a critical event or emergency vehicle or not | Own vehicle information | Changes priority according to own vehicle information (whether emergency vehicle or not, existence of critical event) | |

(d) Transmission power decision

The decision item in decision on the transmission power and the input, processing content and output are shown in Table 4.2.1-3.

**Table 4.2.1-3 SAE congestion control methods: Transmission power decision**

| Decision requirement | Input | Processing details | Output |
|---|---|---|---|
| Critical event | Critical event decision information | Changes the setting of Transmission power, according to whether there is a critical event (where there is a critical event flag, the transmission power is set to the upper limit) | Transmission power |
| (For DSRC) Surrounding communication status | Channel load calculated at lower layers (CBP-Channel Busy Percentage) | Transmission power calculated in accordance with CBP:<br>• Less than lower limit value specified by CBP: Transmission power is fixed by the upper limit value<br>• Greater than upper limit value specified by CBP: Transmission power is fixed by the lower limit value<br>• CBP other than the above: Transmission power changes linearly between the upper limit value and lower limit value | |
| (For LTE-V2X) BSM information | Own vehicle information | Transmission power changes to either of 20 dBm/33 dBm according to own vehicle information (whether emergency vehicle or not) | |

(2) ETSI[54]

The ETSI congestion control methods are shown below.

(a) Image diagram of congestion control

An image of the ETSI congestion control methods is shown in Fig. 4.2.1-2. Congestion control in the upper layers performs transmission timing decisions, and priority setting.

The details of congestion control in the lower layers vary according to the methods used (LTE-V2X or DSRC). Since this section describes the congestion control methods in the upper layers, only an overview for the lower layers, rather than details, will be described.

[54] Overview based on ETSI EN 302 637-2 V1.4.1 Ch.6.1.3, ETSI TS 103 613 V1.1.1 Ch. Annex B Table B.7, ETSI TS 102 636-4-2 V1.2.1 Ch.8 Table 4.
https://www.etsi.org/deliver/etsi_en/302600_302699/30263702/01.04.01_30/en_30263702v010401v.pdf
https://www.etsi.org/deliver/etsi_ts/103600_103699/103613/01.01.01_60/ts_103613v010101p.pdf
https://www.etsi.org/deliver/etsi_ts/102600_102699/1026360402/01.02.01_60/ts_1026360402v010201p.pdf

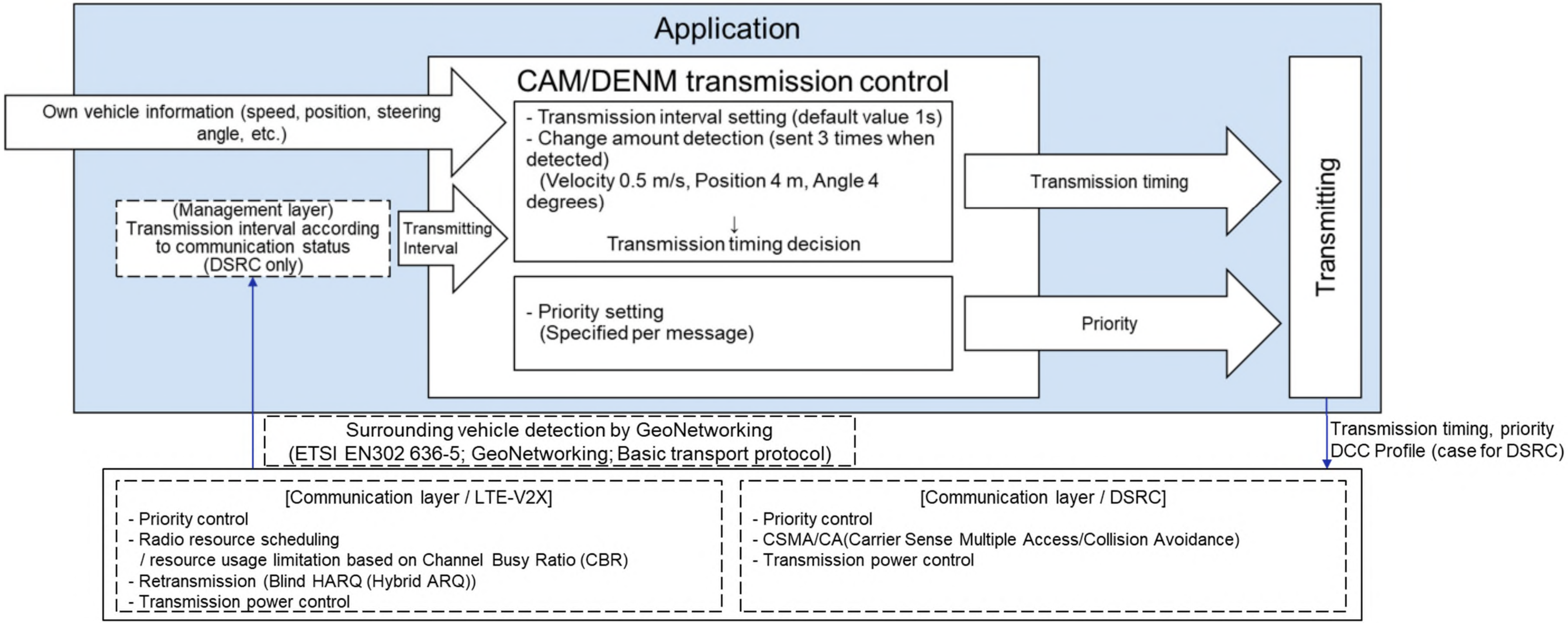


**Fig. 4.2.1-2 Image diagram of the ETSI congestion control methods**

(b) Transmission timing decision

The decision item for the transmission timing decision and the input, processing content and output are shown in Table 4.2.1-4.

**Table 4.2.1-4 ETSI congestion control methods: Transmission timing decision**

| Decision requirement | Input | Processing details | Output |
|---|---|---|---|
| Surrounding communication status (DSRC only) | Channel load calculated in the lower layer | Transmission timing minimum value is calculated according to the channel load passed from the lower layer<br>• Where the channel load is high, the transmission timing is slowed<br>• Where the channel load is low, the transmission timing is accelerated | Transmission timing |
| Own vehicle information (Speed, position, heading) | Own vehicle information acquired from the measurement system (sensors) on board own vehicle | Own vehicle information (speed, position, heading) from the last time a basic vehicle information message was sent is compared, the change value calculated. If that change amount exceeds a certain threshold, transmission is executed immediately, and for a set number of times after that, at the same transmission timing | |

(c) Priority setting

The decision item for priority setting and the corresponding input, processing content and output are shown in Table 4.2.1-5.

**Table 4.2.1-5 ETSI congestion control methods: Priority setting**

| Decision requirement | Input | Processing details | Output |
|---|---|---|---|
| Message type | Message type | Changes priority according to message type | Priority |
| Event emergency level | Event type | The level of emergency is determined by the event type, with different priorities of DENM (Decentralized Environmental Notification Message) according to the level of emergency | |

(3) Comparison of SAE congestion control methods and ETSI congestion control methods

An outline of the respective specifications and main features of the SAE congestion control methods and ETSI congestion control methods are shown in Table 4.2.1-6.

**Table 4.2.1-6 Outline specifications and main features of the SAE and ETSI congestion control methods**

| Items | SAE | ETSI |
|---|---|---|
| Transmission interval | • - (Transmission timing is calculated for each transmission; there is no transmission interval) | • The default transmission interval depends on the application set value<br>CAM: Setting range 100 ms-1s, default 1s<br>• Changes the minimum values for transmission timing according to the communication status (Only DSRC controls the upper layer) |
| Transmission timing decision | • Makes a transmission timing decision according to the surrounding vehicle density (With BSM transmission timing of 100 ms to 600 ms, surrounding vehicle cycle is 100 ms)<br>• Sent immediately when a new critical event is detected | • Sent when change in own vehicle is detected<br>• Change: Speed 0.5 m/s, position 4 m, heading 4 degrees |
| Priority control | • Specifies a priority for each message in advance<br>Changes BSM priority according to own vehicle information (whether emergency vehicle or not, existence of critical event) | • Specifies a priority for each message in advance<br>Changes DENM priority according to details of the event that occurs |
| Transmission power control | • Changes transmission power according to own vehicle information (whether emergency vehicle or not, existence of critical event) (emergency vehicles LTE-V2X only)<br>• Changes transmission power according to surrounding communication status (DRSC only) | • (Transmission power control is implemented in lower layer) |
| Main characteristics | • Controls transmission timing depending on surrounding environment (vehicle density, communication environment)<br>○ Control effects that suit the surrounding environment (vehicle density, communication environment) can be expected<br>△ Influenced by the accuracy of the surrounding environment measurement, requires validation depending on the scenario<br>• Flexible in terms of priority control according to own vehicle information, transmitted message type, etc. | • Controls transmission timing autonomously, primarily according to own vehicle behavior<br>○ Simple logic, that is not easily impacted by the surrounding environment<br>△ Control effect requires validation according to scenario<br>• Flexible in terms of priority control according to own vehicle information, transmitted message type, etc. |

Legend: ○ (Advantages) △ (Disadvantages)

### 4.2.2 Concepts of congestion control methods

This section describes concepts concerning the methods of studying congestion control methods proposals for Japan.

As shown in Table 4.2.1-6, the congestion control methods in SAE and ETSI consists, respectively, of control according to the surrounding environment and control according to own vehicle behavior. When considering the congestion control specifications for Japan, we generally study the decision items used in SAE and ETSI, but also consider Japanese situations and status, for example the differences between the Japanese and the US/European road traffic environments.

The assumptions for the study are shown in 1) to 4) below.

1) Defines the functions to be implemented as congestion control methods in the upper layers, for the following two points.

- Transmission timing decision: Has a function to control the next transmission timing according to status.

- Priority setting: Has a function for setting priority according to message type and status.

2) The policy for division of functions between the application (upper layers) and the communication layer in the congestion control methods proposal is as follows.
- Applications: Has application requirements for communication functions (priority setting, transmission timing decision) and functions for transmission instructions based on the driving vehicle environment.
- Communications layer: Has congestion control functions based on instructions from the application and the wireless communications environment. (according to standards specification specified by 3GPP, IEEE, etc.)

3) The target messages in transmission timing control and priority control are as follows.

(i) Transmission timing control

Targets the following messages which increase according to number of vehicles.

- Vehicle basic information messages

  *Vehicle basic information messages are basic information about the vehicle that is always transmitted, in the same way as BSM in SAE, and CAM in ETSI, and are defined in this study within the ITS Forum communication requirements and the message set (RC-017)by changing the name of the driving assistance message based on c-2-1 intersection information.
- Messages for exchange of negotiation information between vehicles and road-vehicle mediation information (control request/response message, agreement request/response message, update request/response message)

(ii) Priority control

- Vehicle basic information messages
- All other messages defined in RC-017

4) In this study, re-transmission or continuous transmission control by the application (upper layers) or the communication layer is not taken into account.

### 4.2.3 Study of congestion control specifications in upper layers

The results of study of the congestion control specifications related to the transmission timing decision and priority setting are shown below.

(1) Congestion control methods proposal

(a) Image diagram of congestion control methods proposal

An image of the congestion control methods proposal is shown in Fig. 4.2.3-1. Congestion control in the upper layers makes transmission timing decisions, and sets priorities.

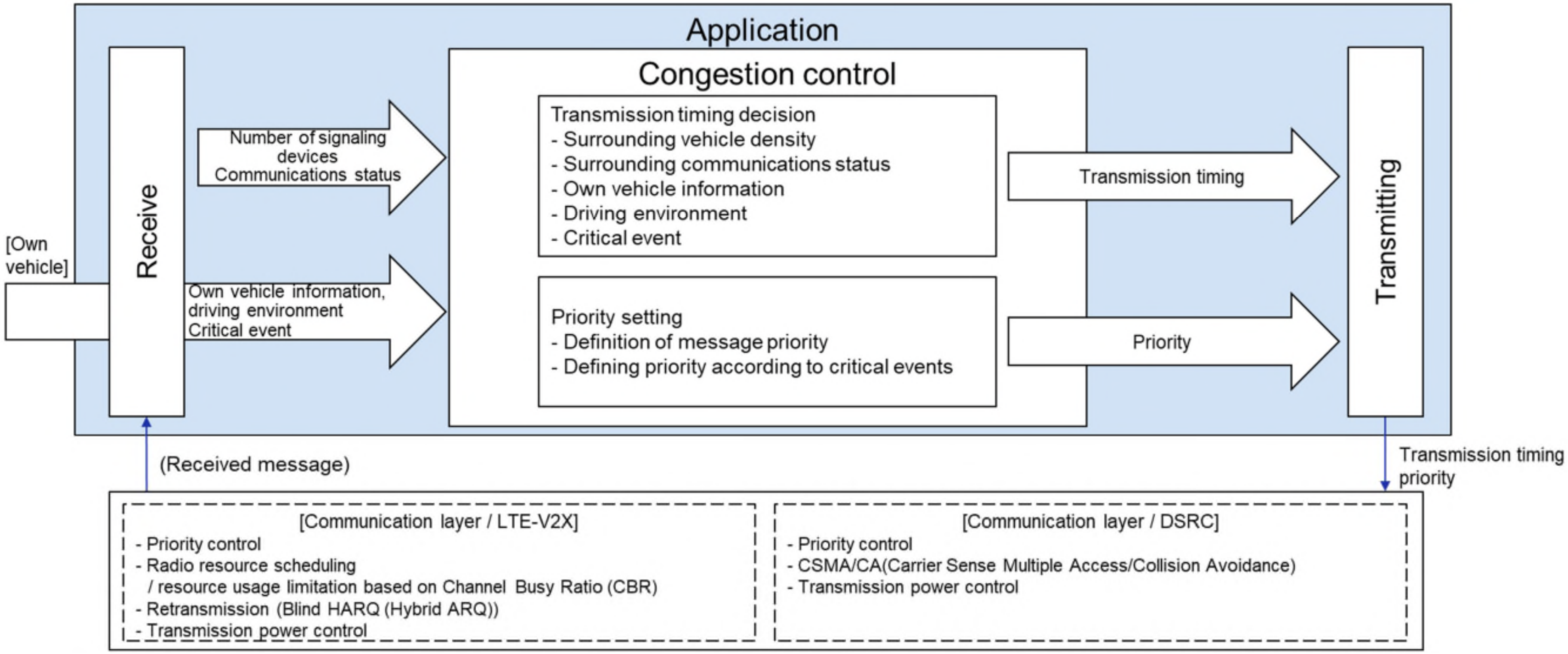


**Fig. 4.2.3-1 Image diagram of congestion control methods proposal**

(b) Decision items in congestion control methods proposal

The decision item for the transmission timing decision and priority setting, and a list of the input, processing content and output are shown in Table 4.2.3-1.

The processing for each decision item in Table 4.2.3-1 is shown in Clauses (2) and (3).

**Table 4.2.3-1 List of decision items in the congestion control methods proposal**

| Decision requirement | Input | Processing outline | Output |
|---|---|---|---|
| Surrounding vehicle density | Received vehicle basic information message | Obtains the surrounding number of vehicles from the number of vehicle IDs in the received vehicle basic information message, and calculates the surrounding vehicle density. Calculates the transmission timing accordingly.<br>• Where the surrounding vehicle density is high, the transmission timing is slowed<br>• Where the surrounding vehicle density is low, the transmission timing is accelerated | Transmission timing |
| Surrounding communications status | Channel load calculated in the lower layer | Transmission timing in order to avoid communication congestion is calculated according to the channel load passed from the lower layer.<br>• Where the surrounding communication status is congested, the transmission timing is slowed<br>• Where the surrounding communication status is quiet, the transmission timing is accelerated | |
| Own vehicle information | Own vehicle information acquired from the measurement system (sensors) on board own vehicle | Own vehicle information (speed, position, heading) from the last time a basic vehicle information message was sent is compared, and the change value calculated. If that change value exceeds a certain threshold, transmission is executed immediately and for a specified number of times after that, at the same transmission timing.<br>• Where own vehicle speed is low, the transmission timing is slowed<br>• Where own vehicle speed is high, the transmission timing is accelerated<br>• When the change value exceeds a threshold, will be sent at that timing | |
| Driving environment | • Map information (highways/prefectural and municipal roads)<br>• Surrounding status acquired from the measurement system (cameras) on board own vehicle | Decision on driving environment according to map information and the surrounding status acquired by the measurement system on board own vehicle.<br>• In a safe driving environment, the transmission timing is slowed<br>• In an environment where communication is easily congested, the transmission timing is slowed<br>• In the case of bad weather and a decline in sensing performance, the transmission timing is accelerated | |
| Critical event | Event information | Determines the existence of a critical event, according to the acquired event information. If a critical event has occurred, transmission occurs instantly and the transmission timing during the critical event is accelerated. | |
| Message type | Message type | Changes the priority according to the message type. | Priority |
| Critical event | Event information | When a critical event occurs, increases the priority of the corresponding messages. | |

(2) Congestion control methods proposal: Transmission timing decision

The items related to transmission timing decisions are shown below, and include, in addition to application requirements, reference items from SAE and ETSI congestion control technologies, and additional items.

- Application requirement: Default transmission interval, transmission timing
- Surrounding vehicle density: Calculates vehicle density based on the number of communicating vehicles
- Surrounding communications status: Wireless resource occupancy, channel load
- Own vehicle information: Speed, location, heading
- Driving environment: Driving environment such as prefectural and municipal roads/limited highways
- Critical event: Exists or not. If exists, event details

The basic processing flow for the transmission timing decision taking into account the above decision items is shown in Fig. 4.2.3-2.

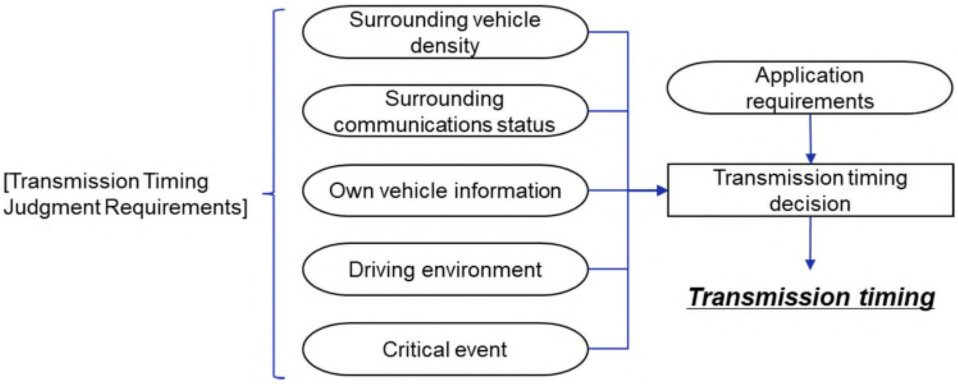


**Fig. 4.2.3-2 Congestion control methods proposal: Transmission timing decision**

The following shows the draft decision item specifications and sample references.

(a) Surrounding vehicle density

i. Surrounding vehicle density calculation method[55]

1） Specifications overview

Surrounding vehicle density means the number of vehicles within a specified radius of the vehicle being measured; it is measured by counting the number of unique vehicle IDs positioned within a target range, from the vehicle basic information messages that the measuring vehicle has received.

Smoothing is performed for the measured vehicle density.

2） Sample specification

The number of unique vehicle IDs positioned within a specified range is counted from the received BSM, and this is the surrounding vehicle density. When calculating the surrounding vehicle density, the formula used and the specified parameter values are shown below.

- Calculation formula for vehicle density smoothing[56]

Smoothed vehicle density ＝ Measured vehicle density ×
weighted coefficient of measured vehicle density ＋ previously calculated smoothed vehicle density ×
(1 － weighted coefficient of measured vehicle density)

- Parameter specified values[57]

Specified range for measuring vehicle density: 100 m
Weighted coefficient of measured vehicle density: 0.05

55 Created with reference to SAE J2945/1_202004 Ch.6.3.8.
https://www.sae.org/standards/content/j2945/1_202004/

56 Source: SAE J2945/1_202004 Ch.6.3.8.4

57 Source: AE J2945/1_202004 Ch.7 Table 21

ii. How to calculate transmission timing using vehicle density[58]

1） Specifications overview

Using the surrounding vehicle density found in i above, the transmission timing for the next vehicle basic information message is calculated.

Regarding the method of calculating transmission timing, where the surrounding vehicle density is high, the transmission timing is delayed, while if the surrounding vehicle density is low, the transmission timing is accelerated. The high and low values for surrounding vehicle density are determined by comparing with a predetermined surrounding vehicle density criteria value. The transmission timing calculation specification is as follows.

- Where the calculated surrounding vehicle density is greater than the upper limit value, the transmission timing is the upper limit value
- Where the calculated surrounding vehicle density is below the lower limit value, the transmission timing is the lower limit value
- Where the calculated surrounding vehicle density is between the upper limit and lower limit value, the transmission timing varies linearly

2） Sample specification

The calculation formula used and the specified parameter values are shown below.

- Calculation formula for the next transmission timing[59]

$$\text{Next transmission timing} = \begin{cases} \textit{Lower limit of transmission timing, vehicle density is below the lower limit value} \\ \textit{Varies proportionally with vehicle density, between the upper and lower limits for vehicle density} \\ \textit{Transmission timing upper limit, vehicle density is above upper limit value} \end{cases}$$

- Parameter specified values[60]

Lower limit value of transmission timing: 100 ms

Transmission timing upper limit value: 600 ms

Vehicle density criteria lower limit value: 25 vehicles

Vehicle density criteria upper limit value: (600/100) × 25 = 150 vehicles (The ratio of the upper and lower limit of vehicle density criteria is the same as the ratio of the transmission timing upper and lower limit, and the vehicle density criteria upper limit value is calculated from the lower limit value)

(b) Surrounding communications status

i. How to calculate transmission timing using channel load[61]

1） Specifications overview

Determined by channel load as surrounding communication status Channel load is an indicator of channel use provided by the wireless hardware. In this study Channel Busy Ratio (CBR) is used as a channel load parameter, and the following description assumes that “Channel load = CBR.”

CBR is found using the percentage of resources where the channel was busy (Received Signal Strength Indicator (RSSI) was above the threshold), during a fixed time period.

In this study, the target messages are primarily vehicle basic information messages, with fixed packet sizes, so a simple reactive approach is adopted for the control mode. Under the reactive approach, the minimum value possible for the transmission timing is determined according to the channel load value, achieving a channel load suppression effect. Further, to avoid frequent changes in transmission timing, the channel load must be smoothed.

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[58] Created with reference to SAE J2945/1_202004 Ch.6.3.8. https://www.sae.org/standards/content/j2945/1_202004/

[59] Source for calculation formula: SAE J2945/1_202004 Ch.6.3.8.4

[60] Source for parameter specified values: SAE J2945/1_202004 Ch.7 Table 21

[61] Created with reference to ETSI TS 102 687 V1.2.1 Ch.5. https://www.etsi.org/deliver/etsi_ts/102600_102699/102687/01.02.01_60/ts_102687v010201p.pdf

The method of determining transmission timing according to channel load is described in Section 4.2.4 as an issue for future consideration.

- Sample specification

The transmission rate, transmission power, and transmission data rate are determined according to channel load. Calculation method used for transmission rate (lookup table) Table 4.2.3-2 is shown in[62].

**Table 4.2.3-2 Example of the relation between channel load and transmission rate**

| Channel load | Channel status | Transmission timing | Transmission rate |
|---|---|---|---|
| < 30% | RELAXED | 100 ms | 10 Hz |
| 30% to 39% | ACTIVE1 | 200 ms | 5 Hz |
| 40% to 49% | ACTIVE2 | 300 ms | 3.33 Hz |
| 50% to 59% | ACTIVE3 | 400 ms | 2.5 Hz |
| ≥ 60% | RESTRICTED | 500 ms | 2 Hz |

(c) Own vehicle information

i. Method of calculating transmission timing according to own vehicle information (Speed, position, heading)[63]

1） Specifications overview

Once a specified time has elapsed since the previous vehicle basic information message transmission, the vehicle starts monitoring its Own vehicle information (speed, position, heading). Once the change in own vehicle information exceeds a standard value, a vehicle basic information message is sent.

When the transmission of a vehicle basic information message has been generated by the change in own vehicle information, the transmission timing of the next vehicle basic information message is set to be accelerated to ensure safety. Where transmission is not generated for a fixed continuous number of times as a result of changes in own vehicle information, the transmission timing returns to the default value.

2） Sample specification

In ETSI, the following two patterns are defined as CAM transmission conditions.[64]

- Condition (1): CAM is sent when the criteria value for change in own vehicle information is exceeded.
  Speed change: 0.5 m/s
  Position change: 4 m
  Heading change: 4 degrees
- Condition (2): Once the time from the previous CAM transmission to the calculated following CAM transmission has elapsed (for DSRC, the communication status in the upper layers must be taken into account in addition to measuring the above times), CAM will be sent.

In CAM transmission under Condition (1), own vehicle information changes start to be monitored after a specified time has elapsed since the previous CAM transmission. In LTE-V2X the specified time is the lower limit value of the transmission timing (fixed at 100 ms), while in DSRC the specified time is variable depending on channel load. The method of calculating the specified time for DSRC uses a lookup table for the reactive approach. As an example, Table 4.2.3-2[62] is used for ETSI validation.

Further, when a CAM transmission is generated according to Condition (1), the maximum

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62 Source for lookup table: ETSI TR 101 613 V1.1.1 Ch. 5.2.3.3 Table 12
https://www.etsi.org/deliver/etsi_tr/101600_101699/101613/01.01.01_60/tr_101613v010101p.pdf

63 Created with reference to ETSI EN 302 637-2 V1.4.1 Ch. 6.1.3.
https://www.etsi.org/deliver/etsi_en/302600_302699/30263702/01.04.01_30/en_30263702v010401v.pdf

64 Source for transmission condition: ETSI EN 302 637-2 V1.4.1 Ch. 6.1.3

transmission timing until the next CAM is sent is set to the time from the previous transmission to this transmission. The maximum transmission timing of the next CAM generation after CAM has been sent three times under Condition (2), is set as the default transmission timing (1,000 ms, the upper limit value for transmission timing).

(d) Driving environment

i. Concept of transmission timing decision according to the driving environment

1） Specifications overview

The concept of congestion control according to the driving environment does not exist in SAE or ETSI, but its effect can be expected in the context of road traffic in Japan.

The candidate items that are specific to Japan’s circumstances and status such as differences in road width and speed regulations compared to US and Europe are shown in Table 4.2.3-3. The concepts of transmission timing decisions according to the following ideas for these candidates were considered.

When considering the specific specifications, the following must be identified: Whether or not information on the item candidates can be collected in the driving environment, the collection method and the information accuracy and quality.

- In a driving environment where safety is relatively assured (for example, a limited highway or road with pedestrian-vehicle separation), the transmission timing is slowed.
- In the case of bad weather (e.g., for rain, snow, fog), other anticipated decline in own vehicle or infrastructure sensing performance, the transmission timing is accelerated.
- With a surrounding environment that is easily congested with vehicles (for example, a daytime shopping area), the transmission timing is slowed.
- For intersections between prefectural and municipal roads and expressways, the transmission timing in expressways is slowed to give priority to prefectural and municipal roads.

**Table 4.2.3-3 Item candidates in driving environment**

| Category | Items | Main details | Information gathering process (Assumed) | Issues/Practicality | (Proposed) Concept of transmission timing decision |
|---|---|---|---|---|---|
| Road | Type | Prefectural and municipal roads, and limited highways | • Own vehicle position<br>• Map data | • Existence of map data items | For road types that are guaranteed to be relatively safe, own vehicle transmission timing is slowed. |
| | Structure | Number of lanes, wide/narrow width, grade mitigation, curvature, presence/absence of road shoulder, presence/absence of footpath | • Map data<br>• Own vehicle sensors | • Existence of map data items<br>• Whether own vehicle sensors supported or not | For road structures that are guaranteed to be relatively safe, the own vehicle transmission timing is slowed. |
| | Intersection | Existence of signals, number of lanes, multi-level intersections, number of crossroads, multi-level intersections between prefectural and municipal roads and expressways | • Map data<br>• Own vehicle sensors | • Existence of map data items<br>• Whether own vehicle sensors supported or not | In locations requiring attention to safety, the transmission timing is accelerated. |
| | Partial merge | Split, merge | • Map data<br>• Own vehicle sensors | • Existence of map data items<br>• Whether own vehicle sensors supported or not | In locations requiring attention to safety, the transmission timing is accelerated. |
| | Special locations | Tunnels, level crossings, parking stations, multi-level parking stations, construction zones, accident locations | • Map data<br>• Infrastructure cooperation | • Existence of map data items<br>• Infrastructure cooperation support possible or not | In locations requiring attention to safety, the transmission timing is accelerated. |
| External factors | Weather | Sunny, cloudy, rain, snow, fog<br>*Generation of warnings and emergency broadcasts | • Map data<br>• Own vehicle sensors<br>• Infrastructure cooperation | • Accuracy/reliability of weather data<br>• Whether own vehicle sensors supported or not<br>• Infrastructure cooperation support possible or not | Where low sensing performance is predicted, the own vehicle transmission timing is accelerated. |
| | Ambient light intensity | Ambient brightness depending on time of day, daytime, evening (twilight) or night | • Own vehicle sensors | • Accuracy/reliability of light intensity data<br>• Whether own vehicle sensors supported or not | When ambient light intensity is a brightness that requires attention to safety, the own vehicle transmission timing is accelerated. |
| | Emergency vehicle | Presence of emergency vehicles (police, fire truck, ambulance, etc.) | • Map data | — | Where there are emergency vehicles, own vehicle transmission timing is delayed. |
| | Surrounding environment | Central city area, shopping area, school zone, suburbs, mountainous area | • Map data | • Accuracy/reliability of surrounding environment data<br>• Existence of map data items | Places that quickly become congested, or where attention to safety is required.<br>In the case of surrounding environment, the transmission timing is accelerated. |

(e) Critical event

i. Concept of transmission timing decisions due to critical event generation[65]

1） Specifications overview

Where a critical event has occurred, since the emergency situation and vehicle information (for example, speed, position, heading, etc.) must be notified to the surrounds as quickly as possible, the transmission timing of the vehicle basic information message is accelerated.

The critical event occurrence status (still occurring or not, if so whether a new occurrence or not) is checked, and the transmission timing of the Basic vehicle information messages is set according to that occurrence status.

Note that the setting of the transmission timing according to the occurrence of a critical event is targeted at the vehicle basic information messages, and the need for a field in the vehicle basic information message for placement of the vehicle event information must be considered.

2） Sample specification

In SAE, the next BSM transmission schedule is set to any of the following times. When setting the transmission schedule, check the critical event generation status.

- After calculation of the next BSM transmission timing according to vehicle density
- When a new critical event is generated

Also, the decision on the BSM transmission timing according to the critical event is made as follows.

- When a new critical event is generated: Sent immediately.
- During the occurrence of a critical event (not a new one): Sent immediately when the next transmission timing is 100 ms (± random offset).

ii. Examples of critical event definition for Japan

1） Congestion control specification proposal

Examples of critical event definition including unique events under the ETSI and SAE specifications and SIP case studies are shown in Table 4.2.3-4. The legend used is defined in Table 4.2.3-5.

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[65] Created with reference to SAE J2945/1_202004 Ch.6.3.8.
https://www.sae.org/standards/content/j2945/1_202004/

**Table 4.2.3-4 Example of critical event definition**

| Category | Proposed item | ETSI[66] | SAE[67] | SIP<br>Use case | Example of critical event definition/comment | |
|---|---|---|---|---|---|---|
| Own vehicle status | Emergency braking generated | ○ | ○ | c-1, c-3 | ○ | Emergency |
| | Emergency event occurrence (emergency vehicle, etc.) | - | - | e-1 | ○ | Emergency |
| | Accident/incident occurrence | ○ | ○ | f-1 (V2N) | △ | Current SIP use case V2N only |
| | Driver abnormal incident (driver illness, etc.) | ○ | - | - | △ | Study of whether Automated driving Level 3 required or not |
| | Carrying dangerous goods | - | △ | - | ○ | Mainly for logistics or commercial vehicles |
| | Under teleoperation | - | - | h-1 (V2N) | △ | Current SIP use case V2N only |
| Surrounding status | Abnormal surroundings detected (obstruction ahead, etc.) | - | - | c-3 | △ | C-3 assumes sudden braking |
| | Road environment detection (traffic jam, accident, traffic control, etc.) | ○ | - | - | - | No emergency |
| | Wrong-way driving detection | ○ | - | d-2 | △ | Current SIP use case V2N only |
| Use case status | Merging/lane change/entry intention | - | - | a-1-x,<br>a-2, a-3 | - | No emergency |
| | Straight through intersection intention | - | - | c-2-x | △ | Study required or not |
| | Intersection right-turn intention | - | - | c-2-x | - | No emergency |

**Table 4.2.3-5 Legend**

| Symbol | ETSI | SAE | Example of critical event definition |
|---|---|---|---|
| ○ | Defined as DENM event | Defined as critical event | Recommended |
| △ | - (No relevant listing) | Defined as non-critical vehicle event | Item requires study |
| - | Not defined as DENM event | Not defined as vehicle event | Not recommended |

66 Source: ETSI EN 302 637-3 V1.3.1 Ch.7.1.4 Table 10.
https://www.etsi.org/deliver/etsi_en/302600_302699/30263703/01.03.01_60/en_30263703v010301p.pdf

67 Source: SAE J2735_202007 Ch.7.208.
https://www.sae.org/standards/content/j2735_202007/
Source: SAE J2945/1_202004 Ch. 3.1.2.
https://www.sae.org/standards/content/j2945/1_202004/

(3) Congestion control methods proposal: Priority setting

The decision items in the priority setting are defined as follows.

- Message content (message type)
- Existence of critical event, content

The message priority is set taking into account the above decision items.
The basic processing flow of priority setting is shown in Fig. 4.2.3-3.

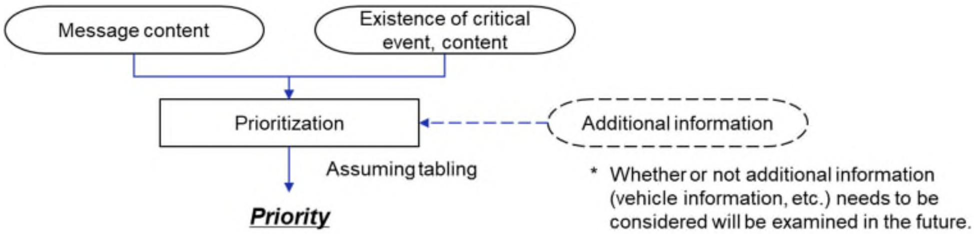


**Fig. 4.2.3-3 Congestion control methods proposal: Priority setting**

(a) Definition of message priority according to message content

i. Concepts in SAE and ETSI

In SAE J2945/0, the recommended priority for Enhanced distributed channel access (EDCA) is different for each message.[68]

In ETSI TS 103 613, the PPPP priority is different for each message, and in ETSI TS 102 636-4-2 the EDCA priority is different for each message[69].

ii. Policy for priority setting according to message content

Examples of the priority definition for messages defined in RC-017 are shown in Table 4.2.3-6.

[68] Refer to SAE J2945/0_201712 Table 3.
https://www.sae.org/standards/content/j2945_201712/

[69] Refer to ETSI TS 103 613 V1.1.1 Table B.7, ETSI TS 102 636-4-2 V1.2.1 Table 4.
https://www.etsi.org/deliver/etsi_ts/103600_103699/103613/01.01.01_60/ts_103613v010101p.pdf
https://www.etsi.org/deliver/etsi_ts/102600_102699/1026360402/01.02.01_60/ts_1026360402v010201p.pdf

**Table 4.2.3-6 Example of message priority definition (at normal times)**

| SIP use case | Policy | Message | Example of priority definition<br><br>(Normal times) |
|---|---|---|---|
| -[*1] | Treated as medium priority as periodic message | Vehicle basic information messages | Medium |
| Driving assistance that uses traffic signal information<br><br>(b-1-1) | Handling of low priority since unrelated to vehicle behavior control | Traffic signal information messages | Low |
| Driving assistance based on intersection information<br><br>(c-2-x) | Handling of high + priorities as messages concerning vehicle behavior control, in particular safety | Messages in use case c-2-1<br><br>Messages in use case c-2-2 | High+ |
| Collision avoidance (c-1, c-3) | | Messages in use case c-3 | |
| Emergency vehicle avoidance (e-1) | | Messages in use case e-1 | |
| Merging assistance (a-1-x)<br><br>Lane change assistance (a-2)<br><br>Priority road entry assistance (a-3) | Handling of high priorities as messages concerning vehicle behavior control | Position information message<br><br>Control request/response message<br><br>Agreement request/response message<br><br>Update request/response message | High |

*1 In RC-017, the use case column contains “-” since there is no definition of a use case that handles vehicle basic information messages.

(b) Definition of message priority according to critical event

i. Concepts in SAE and ETSI

In SAE J2945/1 and SAE J3161/1, BSM priority varies depending on whether a critical event exists or whether it is an emergency vehicle[70].

In ETSI TS 101 539-1, the priority of the DENM message varies depending on the emergency level of the incident[71].

ii. Policy on priority setting according to critical event

For messages defined in RC-017, when a critical event occurs, the priority level of the corresponding messages increases, with reference to the policies in SAE and ETSI.

Future detailed study is required of the message types that correspond to the various critical events, and how to change priorities when a critical event occurs.

Examples of priority definition when a critical event occurs are shown in Table 4.2.3-7.

[70] Refer to SAE J2945/1_202004 Ch.6.3.4, SAE J3161/1_202203 Ch.6.3.4.
https://www.sae.org/standards/content/j2945/1_202004/
https://www.sae.org/standards/content/j3161/1_202203/

[71] Refer to ETSI TS 101 539-1 V1.1.1 Ch.5.1 Table 5.1.1.
https://www.etsi.org/deliver/etsi_ts/101500_101599/10153901/01.01.01_60/ts_10153901v010101p.pdf

**Table 4.2.3-7 Example definition of message priority (When critical event occurred)**

| SIP use case | Policy | Message | Example of priority definition (When critical event occurred) |
|---|---|---|---|
| -*1 | Handling in priorities as a cyclic message | Vehicle basic information messages | Medium+ |
| Driving assistance that uses traffic signal information (b-1-1) | Handling of low priority since unrelated to vehicle behavior control | Traffic signal information messages | - (Due to having no relevant critical event) |
| Driving assistance based on intersection information (c-2-x) | Handling of high + priorities as messages concerning vehicle behavior control, in particular safety | Messages in use case c-2-1<br>Messages in use case c-2-2 | High++ |
| Collision avoidance (c-1, c-3) | | Messages in use case c-3 | |
| Emergency vehicle avoidance (e-1) | | Messages in use case e-1 | |
| Merging assistance (a-1-x)<br>Lane change assistance (a-2)<br>Priority road entry assistance (a-3) | Handling of high priorities as messages concerning vehicle behavior control | Position information message<br>Control request/response message<br>Agreement request/response message<br>Update request/response message | High+ |

*1 In RC-017, the use case column contains "-" since there is no definition of a use case that handles vehicle basic information messages.

(4) Overall image of congestion control methods

Taking into account the results of consideration of (2) and (3) for each decision item shown in Table 4.2.3-1, a congestion control implementation image (functional block diagram) in the application (upper layers) is shown in Fig. 4.2.3-4.

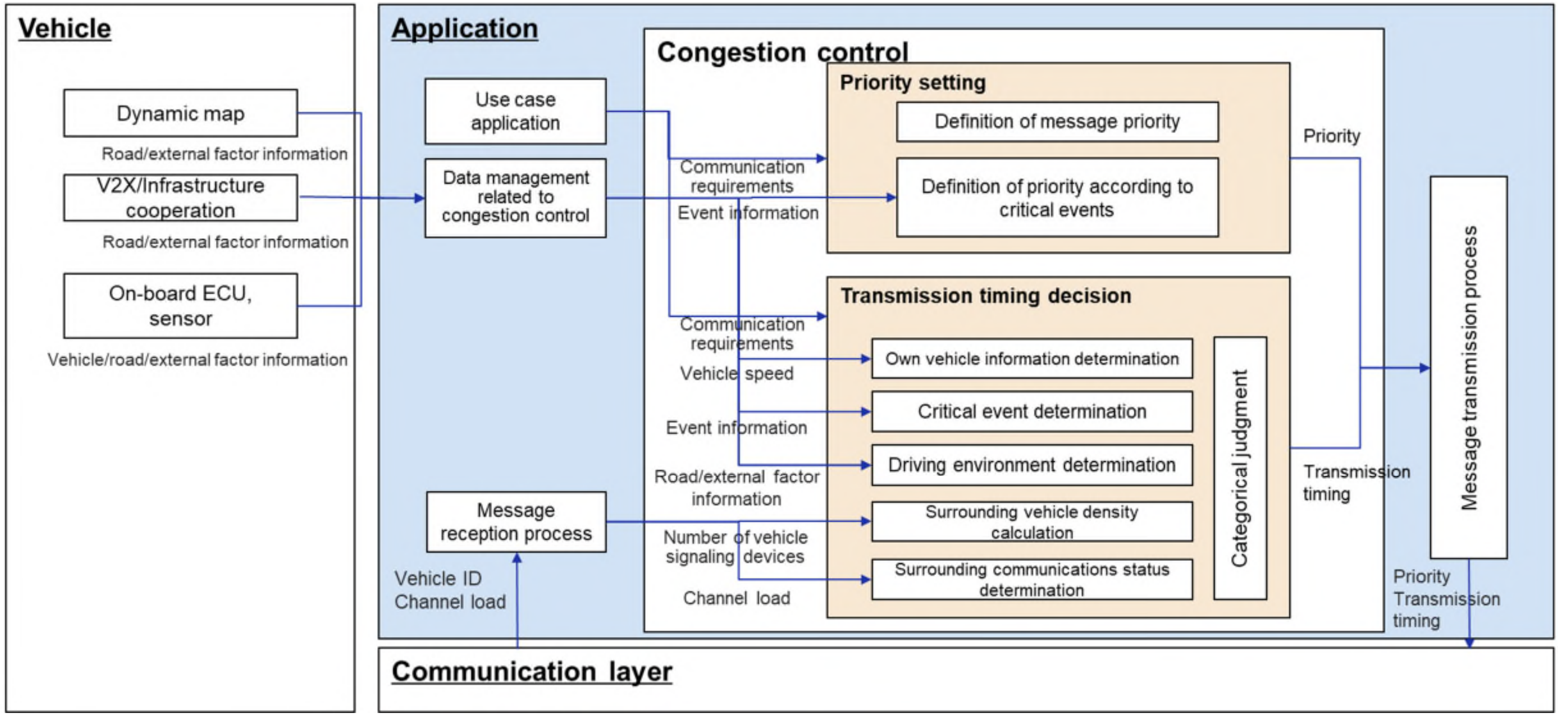


**Fig. 4.2.3-4 Implementation diagram of congestion control**

(5) Case study of the various decision items in transmission timing decisions

For the various decision items for transmission timing decision shown in Table 4.2.3-1, the control content characteristics undergo desktop validation through case studies. The parameter values set as SAE and ETSI congestion control specifications were adopted and validated[72]. Further, regarding the decision item on surrounding communications status, in ETSI, specific parameter values set as congestion control specifications are not defined. For that reason, in this study, the values used in the ETSI validation were adopted and validated[73].

Note that in this validation, the resending/successive transmission control are not considered, and for the communication channels, one channel in the 10 MHz bandwidth was validated.

(a) Case study assumptions

In these case studies, the effect of congestion control through the decision items will be verified for vehicle basic information messages sent by each vehicle. The case study assumptions are shown in the following i to v.

i. Data traffic calculation formula

When verifying the effect of congestion control, calculate the data traffic required when congestion control exists, or when implementing congestion control according to each of the decision items, and confirm the effect through comparison.

The following formula is used as a calculation formula for required data traffic.

Data traffic = packet size × cycle × number of terminals in communication range

ii. Target use cases and decision items

- Use case (messages): Vehicle basic information messages
  The vehicle basic information messages are the target of study as messages whose data traffic fluctuates greatly depending on the number of vehicles.
- Decision items: Surrounding vehicle density, surrounding communications status, own vehicle information

In the transmission timing decision, at the current time, desktop validation of the driving environment and the critical events are difficult and are excluded from desktop validation. The reasons that desktop validation is judged to be difficult may be described as follows.

- Driving environment: Because parameters related to congestion control in line with driving environment have not been designed yet.
- Critical events: Because validation is required for traffic flow simulation including vehicle movements.

iii. Transmission timing upper limit and lower limit values

When validating the congestion control effect, the lower and upper limit values for the transmission timing (transmission interval) of the vehicle basic information message must be determined. Since there is no specification in RC-017, in this validation the lower and upper limit value for transmission timing was set as follows, as a control variable for comparing the effect of congestion control.

- Lower limit value: 100 ms
- Upper limit value: 1,000 ms

iv. Transmission timing when no congestion control

The comparison target when validating the effect of congestion control was set to the transmission timing of vehicle basic information messages when there was no congestion control, as follows.

- Travelling vehicle: 100 ms
- Stationary vehicle: 1,000 ms

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72 For details of the parameters used in the decision item case studies, refer to “Specifications and parameters used in validation” in 4.2.3(5)(d)i, 4.2.3(5)(d)iii.

73 For details of the parameters used in the decision item case studies, refer to “Specifications and parameters used in validation” in 4.2.3(5)(d)ii.

v. Target road environment and vehicle positioning

The assumptions for cases other than above define the road environment (target locations, vehicle positioning methods) for the case study.

- Target locations: A range of 250 m radius around the intersection[74].
- A total of 5 lanes in the intersection were considered: Two through lanes, and one right-turn lane, for both horizontal and vertical directions of the intersection.
- The vehicle length of the vehicles studied was 5 m, and the vehicle gap distance when stopped was 2 m[75].
- Vehicle positioning was as shown below, with examples of specific layout diagrams listed in Fig. 4.2.3-5.
  - No vehicles are positioned in the intersection vertical direction.
  - The right-turn lane in the intersection horizontal direction is 250 m, and the right-turn vehicles are stopped (two lanes, total of 68 vehicles)
  - The through lane vehicles in the intersection horizontal direction are positioned in the following pattern.

(i) 20 km/h@1-second vehicle interval (4 lanes, total 188 vehicles)
(ii) 30 km/h@1-second vehicle interval (4 lanes, total 152 vehicles)
(iii) 40 km/h@1-second vehicle interval (4 lanes, total 124 vehicles)
(iv) 50 km/h@1-second vehicle interval (4 lanes, total 108 vehicles)
(v) 60 km/h@1-second vehicle interval (4 lanes, total 92 vehicles)
(vi) 70 km/h@1-second vehicle interval (4 lanes, total 84 vehicles)

(b) Detailed setting of road environment based on above assumptions

Based on the assumptions of the case study defined in (a) above, a sample vehicle layout diagram in the intersection vicinity of the target locations is described.

The position of all vehicles in the vertical intersection direction, and the vehicles in the horizontal direction right-turn lane, have the same layout in all cases. An example vehicle layout diagram for the case of (iii) 40 km/h@1-second vehicle interval is shown in Fig. 4.2.3-5.

74 In RC-017, refers to the distance assumed possible for direct communication. https://itsforum.gr.jp/Public/J7Database/p70/ITS_FORUM_RC-017_v10.pdf

75 In RC-017, refer to the estimated vehicle length and the vehicle gap distance when stopped. https://itsforum.gr.jp/Public/J7Database/p70/ITS_FORUM_RC-017_v10.pdf

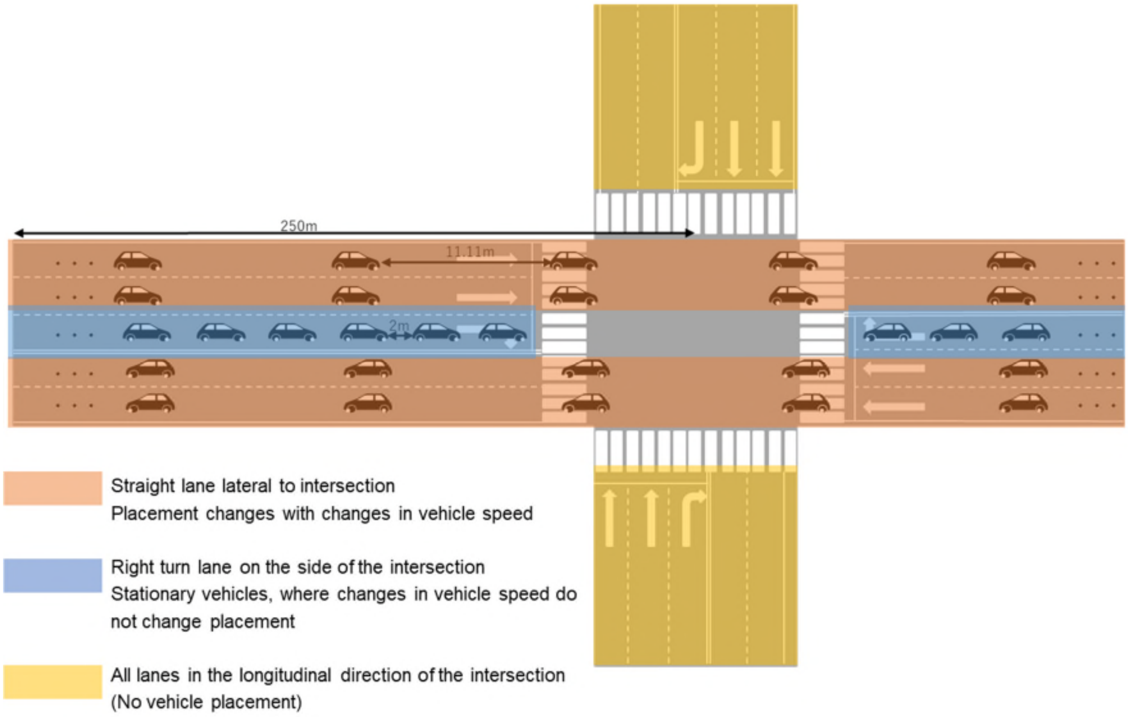



**Fig. 4.2.3-5 Sample vehicle layout diagram for the congestion control case study**

In cases other than layout condition (iii), only the position of vehicles in the through lanes in the intersection horizontal direction will change; there is no change to the position of any vehicle in the vertical direction of the intersection or of vehicles in the right-turn lane in the horizontal direction.

(c) Calculation of data traffic without congestion control

As a comparison for validating the congestion control effect, the results of calculation of the required data traffic when there is no congestion control are shown below. The transmission timing of the vehicle basic information messages used here is according to clause 4.2.3(5)(a).

**Table 4.2.3-8 Result of data traffic calculation with no congestion control**

| Traveling vehicle speed [km/h] | Number of vehicles | | | Data traffic [Kbps] *1 |
|---|---|---|---|---|
| | Traveling vehicles | Stationary vehicle | Total vehicles | |
| 20 | 188 | 68 | 256 | 4,394.7 |
| 30 | 152 | 68 | 220 | 3,582.5 |
| 40 | 124 | 68 | 192 | 2,950.9 |
| 50 | 108 | 68 | 176 | 2,589.9 |
| 60 | 92 | 68 | 160 | 2,228.9 |
| 70 | 84 | 68 | 152 | 2,048.5 |

*1 The packet size of the vehicle basic information message is 282 bytes, identical to the messages in use case c-2-1 defined in RC-017, and the calculation result is rounded off to 2 decimal places.

(d) Results of desktop validation

As validation results for each of the decision items, we will discuss data traffic calculation results, trends in data traffic change, and data traffic effect.

i. Surrounding vehicle density

In this case study, the surrounding vehicle density decision item was the target of validation. The transmission control specification according to surrounding vehicle density is based on SAE J2945/1[76]. However, for standard values for vehicle density range, upper limit value for transmission timing, and standard upper limit value for vehicle density, 4.2.3(5)(a) assumed values were used.

1） Specifications and parameters used in validation

- Surrounding vehicle density standard values
  Vehicle density criteria lower limit value: 25 vehicles
  Upper limit value of vehicle density standard: (1,000/100) × 25 = 250 vehicles
  Range: 250 m radius
- Calculation formula for transmission timing of the next vehicle basic information message

$$\text{Next transmission timing} = \begin{cases} Lower\ limit\ is\ 100ms, vehicle\ density\ is\ 25\ or\ less \\ Linear\ change\ between\ upper\ and\ lower\ limits, vehicle\ density\ of\ 25\ to\ 250\ vehicles \\ Upper\ limit\ of\ 1{,}000\ ms, vehicle\ density\ of\ 250\ or\ more \end{cases}$$

2） Data traffic calculation results

The results of data traffic calculation required for congestion control according to surrounding vehicle density are shown in Table 4.2.3-9

**Table 4.2.3-9 Results of data traffic calculation required for congestion control according to surrounding vehicle density**

| Traveling vehicle speed [km/h] | Number of vehicles | | | Transmission timing (transmission interval) [ms] | | Data traffic [Kbps] *1*2 |
|---|---|---|---|---|---|---|
| | Traveling vehicles | Stationary vehicle | Total vehicles | Stationary vehicle | Traveling vehicles | |
| 20 | 188 | 68 | 256 | 1,000 | 1,000 | 577.5 |
| 30 | 152 | 68 | 220 | 880 | 880 | 564 |
| 40 | 124 | 68 | 192 | 768 | 768 | 564 |
| 50 | 108 | 68 | 176 | 704 | 704 | 564 |
| 60 | 92 | 68 | 160 | 640 | 640 | 564 |
| 70 | 84 | 68 | 152 | 608 | 608 | 564 |

*1 The packet size of the vehicle basic information message is 282 bytes, identical to the messages in use case c-2-1 defined in RC-017, and the calculation result is rounded off to 2 decimal places.

*2 Originally each vehicle should calculate its own surrounding vehicle density, but since this is impossible to do in desktop calculations, the surrounding vehicle density in intersections is used for all vehicles. A comparative result of data traffic calculation with no congestion control is shown in Fig. 4.2.3-6.

[76] For details of control technology, refer to examples of communication control technology in 4.2.3(2)(a).

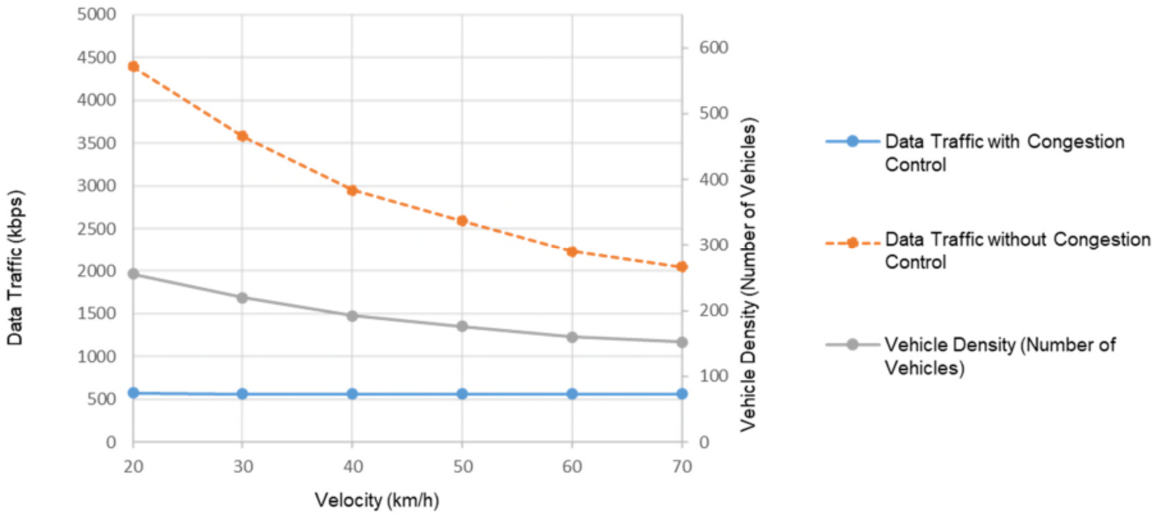



**Fig. 4.2.3-6 Effect of congestion control according to the surrounding vehicle density**

3) Effect of congestion control

In the specified surrounding vehicle density variation range (in this validation, 25 to 250 vehicles), sensitive control according to surrounding vehicle density is possible with linear suppression of data traffic achieved.

- If surrounding vehicle density is B (= 25 vehicles) < N < 10*B where surrounding vehicle density is N and the lower limit of surrounding vehicle density standard is B, transmission timing varies linearly in the range 100 ms to 1,000 ms and data traffic is a constant value
- Since transmission timing is fixed at 100 ms where N ≤ 25, and fixed at 1000 ms where N ≥ 10*25, data traffic in these respective cases is directly proportional to vehicle density

The conditions where the congestion control effect due to surrounding vehicle density is more fully demonstrated are as follows.

- When vehicle basic information messages are an independent channel
- When there is minor difference in data traffic between the vehicle basic information messages and messages in the same channel

However, regarding the surrounding vehicle density standard values, appropriate values must be validated through various case studies. Also, the range of variation in transmission timing must be decided as an application requirement to be implemented.

ii. Surrounding communications status

In this case study, the surrounding communication status decision item is subject to validation. The communication control specification according to the surrounding communications status, is compliant with the validation conducted in ETSI TR 101 613[77].

1) Parameters used in validation

- Resource occupancy calculation formula

  When calculating Surrounding communications status as channel load (CBR), it was calculated using resource occupancy.

  Resource occupancy = number of subframes required for transmission ÷ total number of subframes

[77] For details of control technology, refer to examples of communication control technology in 4.2.3(2)(b).

The concept of parameters in the calculation formula above is indicated below.

- Concept of number of subframes required for transmission

In this case study, the physical resource block capacity (109 bytes) for the Modulation and Coding Scheme (MCS) 5 defined in the LTE-V2X specification, 3GPP TS 36.213 (Table 7.1.7.2.1-1) is used. Also, the relation between the resource block and the subframe are as follows.

1 subframe = 5 sub-channels = 50 RB (Resource Blocks)

According to the above, to send one 282-byte message requires around 2.59 subframes. The required number of subframes for sending can be calculated by multiplying this by the number of vehicles.

- Concept of total number of sub-frames

In calculating resource occupancy, since 1 ms corresponds to one sub-frame, where all vehicles are thought to have the same transmission interval, the total number of sub-frames can be replaced with transmission interval.

Originally, each vehicle should calculate the channel load around its own vehicle, but since this cannot be realized on paper, the channel load at the center of the intersection is applied to all vehicles. For this reason, all vehicles transmit at the same transmission interval.

The calculation method Table 4.2.3-2 for the next vehicle basic information message transmission timing is used, and the transmission timing that corresponds to the calculated resource occupancy is applied.

2) Data traffic calculation results

The results of data traffic calculation required for congestion control according to surrounding communication status are shown in Table 4.2.3-10.

**Table 4.2.3-10 Results of data traffic calculation required for congestion control according to surrounding communication status**

| Traveling vehicle speed [km/h] | Number of vehicles | | | Transmission timing (transmission interval) [ms] | | Data traffic [Kbps] *1*2 |
|---|---|---|---|---|---|---|
| | Traveling vehicles | Stationary vehicle | Total vehicles | Stationary vehicle | Traveling vehicles | |
| 20 | 188 | 68 | 256 | 300 | 300 | 1,925.1 |
| 30 | 152 | 68 | 220 | 300 | 300 | 1,654.4 |
| 40 | 124 | 68 | 192 | 300 | 300 | 1,443.8 |
| 50 | 108 | 68 | 176 | 300 | 300 | 1,323.5 |
| 60 | 92 | 68 | 160 | 300 | 300 | 1,203.2 |
| 70 | 84 | 68 | 152 | 200 | 200 | 1,714.6 |

*1 The packet size of the vehicle basic information message is 282 bytes, identical to the messages in use case c-2-1 defined in RC-017, and the calculation result is rounded off to 2 decimal places.
*2 Originally each vehicle should calculate its own surrounding communication status, but since this is impossible to do in desktop calculations, the surrounding communication status in intersections is used for all vehicles.

A comparative result of data traffic calculation with no congestion control is shown in Fig. 4.2.3-7.

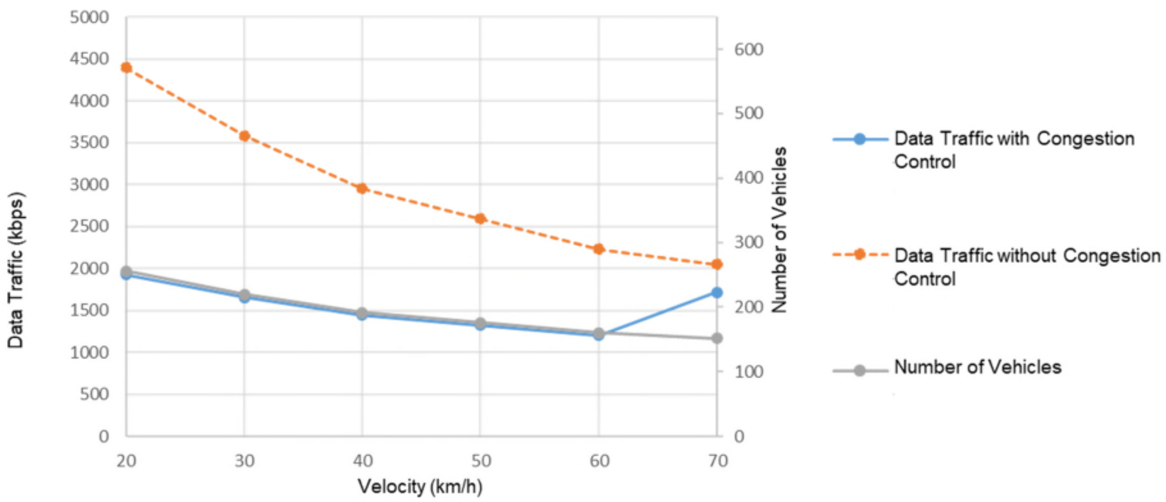



**Fig. 4.2.3-7 Effect of congestion control according to the surrounding communication status**

3) Effect of congestion control

Staged data traffic suppression is implemented according to changes in the resource occupancy (channel load).

In Fig. 4.2.3-7, when the vehicle speed changes from 60 km/h to 70 km/h, because the number of vehicles decreases and the transmission timing (transmission interval) is shortened (refer to Table 4.2.3-10), the data traffic increases for speeds 20 km/h to 60 km/h.

Since the influence not just of the vehicle basic information messages, but of all messages of the channel, must be considered in congestion control due to surrounding communications status, it is believed that there is an overall effect regardless of actual use cases and messages, etc.

However, note that the specifications and parameters for transmission timing decisions based on channel load require the validation of appropriate values through various case studies. Also, since the detection accuracy and quality of channel load vary according to the communication methods (DSRC or LTE-V2X), for the use of channel load values, the detection accuracy and quality of channel load must be ascertained for each communication methods. To avoid status changes due to frequent changes in surrounding communications status, it is thought that smoothing (movement averaging) of the measured channel load is also required.

iii. Own vehicle information

In this case study, the own vehicle information decision item was validated. The transmission control specification for own vehicle information (position) conforms to ETSI EN 302 637-2[78]. The change amount in own vehicle information (speed, heading) is excluded from validation.

1) Specifications and parameters used in validation

- Standard value for own vehicle information (position) change: 4 m
- Method of calculating transmission timing of the next vehicle basic information message: The time required for the vehicle to move the standard value (4 m) according to the vehicle speed is used as the transmission timing.

2) Data traffic calculation results

The results of data traffic calculation required for congestion control according to own vehicle information are shown in Table 4.2.3-11.

**Table 4.2.3-11 The results of the data traffic calculation required for congestion control according to own vehicle information**

| Traveling vehicle speed [km/h] | Number of vehicles | | | Transmission timing (transmission interval) [ms] | | Data traffic [Kbps] *1 |
|---|---|---|---|---|---|---|
| | Traveling vehicles | Stationary vehicle | Total vehicles | Stationary vehicle | Traveling vehicles | |
| 20 | 188 | 68 | 256 | 1,000 | 720 | 793.8 |
| 30 | 152 | 68 | 220 | 1,000 | 480 | 742.5 |
| 40 | 124 | 68 | 192 | 1,000 | 360 | 867.8 |
| 50 | 108 | 68 | 176 | 1,000 | 288 | 930.5 |
| 60 | 92 | 68 | 160 | 1,000 | 240 | 999.4 |
| 70 | 84 | 68 | 152 | 1,000 | 205.71 | 1,018.2 |

*1 The packet size of the vehicle basic information message is 282 bytes, identical to the messages in use case c-2-1 defined in RC-017, and the calculation result is rounded off to 2 decimal places.

A comparative result of data traffic calculation with no congestion control is shown in Fig. 4.2.3-8.

[78] For details of control technology, refer to examples of communication control technology in 4.2.3(2)(c)4.2.3(2)(a).

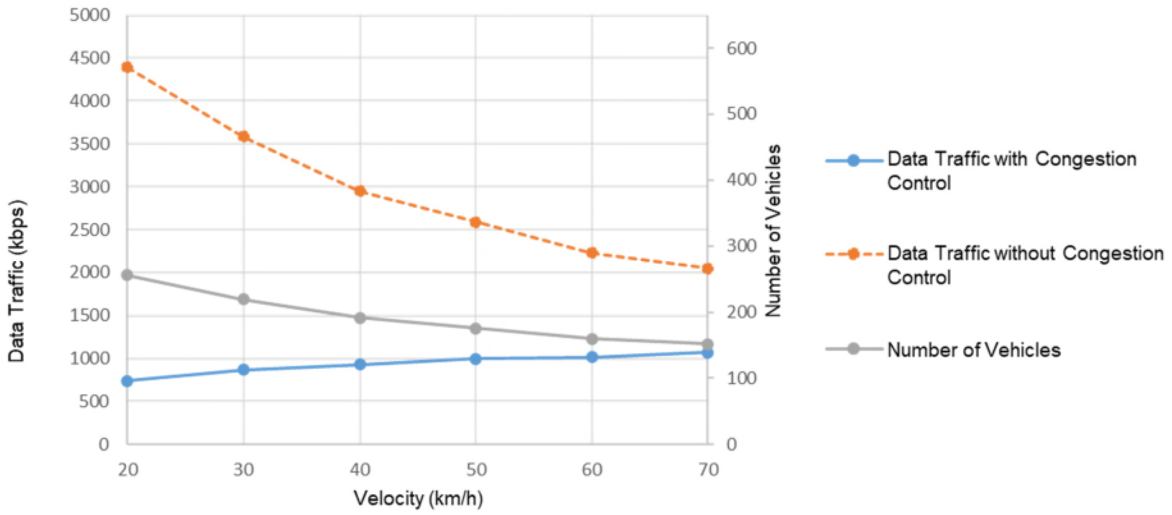



**Fig. 4.2.3-8 Effect of congestion control according to the own vehicle information**

3) Effect of congestion control

A data traffic suppression effect can be achieved according to the specified position change.

The transmission control according to own vehicle information is not very affected by the surrounding environment because the transmission timing is controlled autonomously in accordance with own vehicle behavior, but has an overall effect regardless of the actual use cases and messages generated.

However, regarding the standard value for own vehicle information change, appropriate values must be validated through case studies.

iv. Summary of validation results

Through desktop studies, suppression of the data traffic could be confirmed when the traveling vehicle speed varied in the range 20 km/h to 70 km/h, for each of the following transmission timing decision items.

- Surrounding vehicle density
- Surrounding communications status
- Own vehicle information

The validation results according to the decision items shown in i through iii are indicated in Fig. 4.2.3-9.

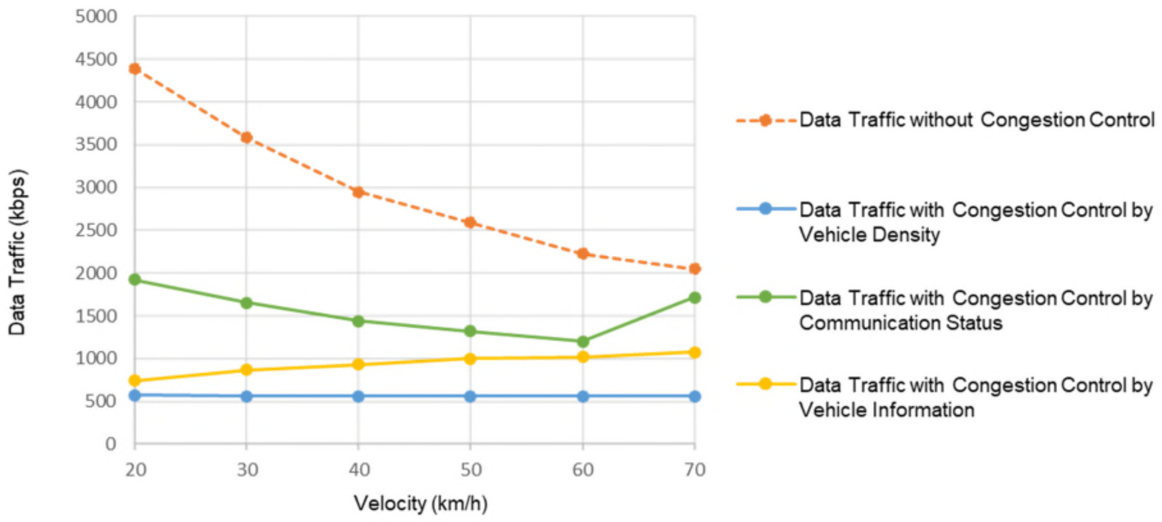



**Fig. 4.2.3-9 Effect of congestion control according to respective decision items**

### 4.2.4 **Summary of issues to consider in congestion control methods proposal**

In this section, the issues for future consideration and validation are listed, for the congestion control methods proposal considered and validated in 4.2.3.

The procedure for identification of issues for consideration and validation for the congestion control methods proposal is shown below.

1) Identification of issues from top-down perspective
Issues are identified from a top-down perspective for realizing use cases.
2) Identification of issues from a bottom-up perspective
Identifies technical issues in various decision items from a bottom-up perspective.
3) Cross-matching of issues identified from a top-down and bottom-up perspective
Issues identified from the above perspectives are cross-matched and the overall issues to be considered are defined.
4) Issue aggregation and mining
All issues are categorized and aggregated. For the aggregated issues, mining is conducted on decision criteria proposals, etc., when validating from a specifications study perspective or a validation perspective.

(1) Consideration and identification of validation issues

In order to comprehensively pick up the issues to be considered and validated for the congestion control methods proposal, issues are identified from both a top-down and bottom-up perspective, and the results from these two perspectives are cross-matched and an overall view of the issues determined.

(a) Identification of issues from a top-down perspective

The issues identified in use case realization are shown in the tree structure in Fig. 4.2.4-1.

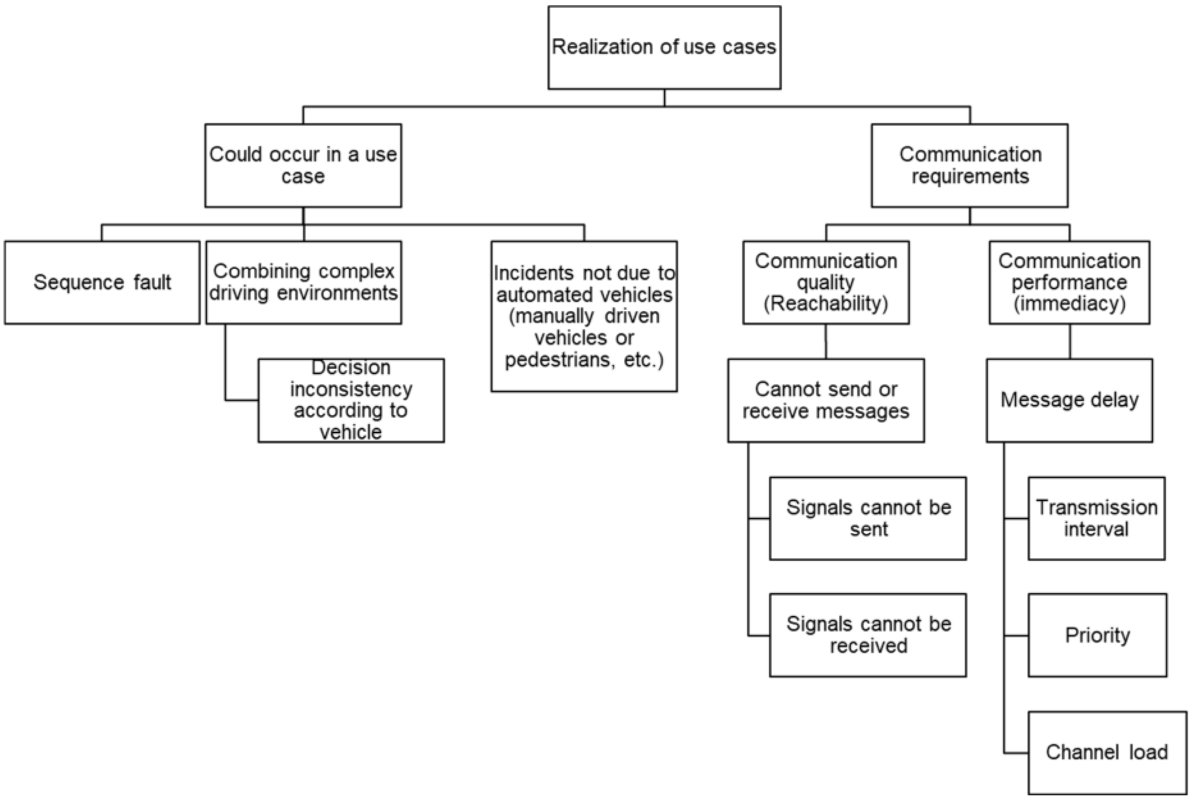



**Fig. 4.2.4-1 Issue identification from top-down**

Further, for the tree structure above, clarified issues and points for study and validation are shown in Table 4.2.4-1.

**Table 4.2.4-1 List of issues from top-down perspective**

| No | Major item | Medium item | Minor item | Issues |
|---|---|---|---|---|
| 1 | Could occur in a use case | Sequence fault | - | Sequence faults due to messages delayed or not able to be received/sent are issues of message reachability and immediacy, identical to issues in No. 5 to 13, so are outside of this study since they were considered under No.5 to 13. |
| 2 | | Complex driving environment | Decision inconsistency according to vehicle | In complex driving environments of 4.2.3(2)(d) study, a decision on calculation method and effect validation for transmission timing where various elements are taken into account and depending on the vehicle, a decision inconsistency can be avoided |
| 3 | | | Co-existence of many use cases | When many use cases co-exist, checks the interference and influence of use cases |
| 4 | | Incidents not due to automated vehicles (manually driven vehicles or pedestrians, etc.) | - | While response to incidents caused by non-automated vehicles must be considered, this is not a congestion control study issue since this problem is unrelated to automated vehicles or congestion control specifications. |
| 5 | Communication requirements | Communication quality (reachability) | Signals cannot be sent | The impossibility of transmission due to traffic increase, is the same issue as No. 13, and is excluded from study since it is studied in No. 13 |
| 6 | | | | Terminal processing resources performance check and load high suppression |
| 7 | | | | Terminal processing speed performance checks in sending and receiving processing |
| 8 | | | | While inability to send signals due to a problem inside the application must be taken into account, this is excluded from congestion control issue study since this is a problem unrelated to congestion control specifications |
| 9 | | | Signals cannot be received | Not being able to receive signals due to increases in traffic, is the same issue as No. 13, and is not subject to study since it is studied in No. 13 |
| 10 | | | | While unstable radio wave quality or radio wave attenuation or outside of receiving range issues due to obstacles must be taken into account, this is excluded from study of congestion control since they are elements that cannot be controlled at the terminal. |
| 11 | | Communication performance (immediacy) | Transmission timing | Study of the transmission timing calculation method for immediacy guarantee, and effect validation |
| 12 | | | Priority | Check of influence on use case implementation due to transmission delay for messages with low priority |
| 13 | | | Channel load | Decision on specifications and effect validation when transmission delay occurs due to increased channel load<br>• Congestion control specification relating to driving environment during high vehicle density or critical event occurrence<br>• Specification of congestion control related to communication environment when channel load is high |

* Gray shading area: Lists reasons for study or validation item being excluded from issue study

(b) Identification of issues from a bottom-up perspective

Under the specifications proposal for each decision item in the congestion control methods proposal, the check items are divided into the following 5 major categories, with the results of respective issue identification shown in Table 4.2.4-2.

1） Challenges for each judgment requirement

The values to be used for specific specifications and parameters in the decision items are issues for study, and the issues in the various decision items are identified by summarizing in Table 4.2.3-1 the input, processing and output of challenges for each judgment requirement in the congestion control specification proposal, and using those results.

2） Combination of multiple decision items

Identifying the issues for decisions on the congestion control proposal by combining various decision items.

3） Common issues in the combination of various decision items and multiple decision items

Identifies common specifications issues for 1）, 2） (retransmission control and transmission power control)

4） Co-existence of multiple use cases

Identifies issues when multiple use cases co-exist.

5） Implementation issues

Presents issues from an implementation issue perspective (hardware control, etc.).

**Table 4.2.4-2 List of issues from bottom-up perspective (1/3)**

| No | Major item | Medium item | Minor item | Issue details |
|---|---|---|---|---|
| 1 | Challenges for each judgment requirement (1/2) | Transmission timing decision | Application requirements related to transmission timing | Excluded from study of congestion control since this is information that must be decided by the implementing application. |
| 2 | | | Surrounding vehicle density | Decision on following parameters<br>• Surrounding vehicle density criteria values (number of vehicles)<br>• Surrounding vehicle density criteria (range) |
| 3 | | | Surrounding communications status | Decision on following parameters and specifications<br>• Selection of channel load parameters (CBR, or other)<br>• Layer where smoothing processing of channel load is implemented and processing details<br>• Upper and lower threshold values for channel load<br>• Method of calculating minimum value for transmission timing according to channel load (Calculated using mapping table/linear relationship) |
| 4 | | | Own vehicle information | Decision on following parameters<br>• Trigger for immediate transmission (speed, position, heading)<br>• Number of times transmitted in the same transmission timing where multiple transmissions are required in the same transmission timing after the immediate transmission trigger |
| 5 | | | Driving environment | Decision on following specifications<br>• Method of combining various conditions relating to the specific control content and driving environment for transmission timing decisions, following the sample congestion control concepts according to the driving environment in clause 4.2.3(2)(d) |
| 6 | | | Critical event | Decision on following specifications<br>• Where a specification that accelerates the transmission timing when a critical event occurs is required, study of the specific specification (how many transmissions at what interval?) |

**Table 4.2.4-2 List of issues from bottom-up perspective (2/3)**

| No | Major item | Medium item | Minor item | Issue details |
|---|---|---|---|---|
| 7 | Challenges for each judgment requirement<br>(2/2) | Priority setting | Message type | Decision on following specifications<br>• Mapping table for priority order according to message type |
| 8 | | | Critical event | Decision on following parameters and specifications<br>• Types of critical events<br>• Mapping table of priority order according to message type when a critical event is generated, for each type of critical event<br>• Priority order of critical event type |
| 9 | Combination of multiple decision items | Communication requirements | Message immediacy guarantee | The following specifications are decided and their effect validated<br>• Selection of decision item for implementation using immediacy guarantee processing<br>• Specification of control when multiple items are implemented |
| 10 | | Communication environment | Bandwidth relaxation | The following specifications are decided and their effect validated<br>• Selection of decision item for implementation using bandwidth relaxation processing<br>• Specification of control when multiple items are implemented<br>• Decision on threshold value for decision condition during bandwidth relaxation processing (surrounding vehicle density, surrounding communications status) |
| 11 | | Combination of communication requirements and communication environment | Immediacy guarantees and bandwidth relaxation | The following specifications are decided and their effect validated<br>• Congestion control specifications that combine immediacy guarantee and bandwidth relaxation |
| 12 | Common issues in the combination of various decision items and multiple decision items | Definition of vehicle basic information message | Detailed definition of vehicle basic information messages as the target of transmission timing decisions under the Congestion control specification proposal | There was no definition of the vehicle basic information message in ITS FORUM RC-017, so we must consider whether we require a message for vehicle basic information like SAE's BSM and ETSI's CAM. Note that it is necessary to study the need for a field to carry vehicle event information in the vehicle basic information message. From a congestion control only perspective, this is outside a study of congestion control, since the message configuration of the vehicle basic information messages cannot be decided. |
| 13 | | Retransmission control | Definition of congestion control specification proposal that takes into account retransmission control | The following specifications are decided and their effect validated<br>• Retransmission control achieved layers and processing details |
| 14 | | Transmission power | Definition of congestion control specification proposal that takes into account transmission power changes | The following specifications are decided and their effect validated<br>• Need for transmission power change specification<br>• Decision on transmission power value according to conditions |

**Table 4.2.4-2 List of issues from bottom-up perspective (3/3)**

| No | Major item | Medium item | Minor item | Issue details |
|---|---|---|---|---|
| 15 | Co-existence of multiple use cases | Channel allocation | Decision on channel allocation as to whether the vehicle basic information message and the mediation/negotiation message can co-exist in the same channel | Decision on the following items<br>• Which of the vehicle basic information messages, or the mediation/negotiation messages, can be allocated to the same channel (studied in Chapter 4.1, so excluded from the study of congestion control issues) |
| 16 | | Transmission timing decision | When channel load is high, how much can the transmission timing of mediation/negotiation messages be delayed | The following specifications are decided and their effect validated<br>• Decision on the mapping table for the mediation/negotiation message transmission timing according to channel load |
| 17 | Implementation issues | Hardware limitations | Frequent transmission timing changes supported or not | Validation of following items on actual equipment<br>• Validation of whether hardware can support changes in transmission timing |
| 18 | | Transmission power | Support in hardware possible or not when implementing transmission power change specifications | Validation of following items on actual equipment<br>• Check on whether hardware transmission power changes can be supported or not |
| 19 | | Processing resource | Consideration of the required capacity of the receiving and sending buffers | The following specifications are decided and then validated on actual equipment<br>• Decision on details of sending/receiving buffer size (memory/register for sending/receiving)<br>• Validation of whether sending/receiving is supported with the sending/receiving buffer size (memory/register for sending/receiving) from the above study results (clarification of required sending/receiving buffer volume) |
| 20 | | | Validation of whether processing resources are sufficient | Validation of following items on actual equipment<br>• Validation of processing resource support for sending/receiving processing (clarification of required processing resource usage) |
| 21 | | Processing speed | Validation of whether transmission processing speed is fast enough for processing of encoding/decoding, information delivery, etc. | Validation of following items on actual equipment<br>• Validation of whether processing speed is supported in sending/receiving processing (clarification of processing speed) |

* Gray shading area : Lists reasons for study/ validation item being excluded from issue study.

(c) Cross-matching of issues identified from a top-down and bottom-up perspective

Issues identified from a top-down and bottom-up perspective are cross-matched and an overall view of issues is shown in Table 4.2.4-3.

**Table 4.2.4-3 Linking of issues from a top-down and bottom-up perspective (1/3)**

| No | Issue item identified from a top-down perspective | | | | Bottom-up perspective issue number | Types of issues |
|---|---|---|---|---|---|---|
| | Major item | Medium item | Minor item | Issues | | |
| 1 | Could occur in a use case | Sequence fault | - | Sequence faults due to messages delayed or not able to be received/sent are issues of message reachability and immediacy, identical to issues in No. 5 to 13, so are outside of this study since they were considered under No.5 to 13. | Linking is omitted since not subject to study due to duplication with other items | Category is omitted since not subject to study due to duplication with other items |
| 2 | | Complex driving environment | Decision inconsistency according to vehicle | In complex driving environments of 4.2.3(2)(d) study, a decision on calculation method and effect validation for transmission timing where various elements are taken into account and depending on the vehicle, a decision inconsistency can be avoided | 5 | Control specifications/parameter appropriate value validation (vehicle basic message) |
| 3 | | | Co-existence of many use cases | When many use cases co-exist, checks the interference and influence of use cases | 15, 16 | Control specifications/parameter appropriate value validation (mediation/negotiation message) |
| 4 | | Incidents not due to automated vehicles (manually driven vehicles or pedestrians, etc.) | - | While response to incidents caused by non-automated vehicles must be considered, this is not a congestion control study issue since this problem is unrelated to automated vehicles or congestion control specifications. | - | Decision on application requirements and application processing |
| 5 | Communication requirements (1/2) | Communication quality (reachability) (1/2) | Signals cannot be sent | The impossibility of transmission due to traffic increase, is the same issue as No. 13, and is excluded from study since it is studied in No. 13 | Linking is omitted since not subject to study due to duplication with other items | Category is omitted since not subject to study due to duplication with other items |
| 6 | | | | Terminal processing resources performance check and load high suppression | 19, 20 | Optimization consideration including communication layers |
| 7 | | | | Terminal processing speed performance checks in sending and receiving processing | 21 | Optimization consideration including communication layers |
| 8 | | | | While inability to send signals due to a problem inside the application must be taken into account, this is excluded from congestion control issue study since this is a problem unrelated to congestion control specifications | - | Decision on application requirements and application processing |

**Table 4.2.4-3 Linking of issues from a top-down and bottom-up perspective (2/3)**

| No | Issue item identified from a top-down perspective | | | | Bottom-up perspective issue number | Types of issues |
|---|---|---|---|---|---|---|
| | Major item | Medium item | Minor item | Issues | | |
| 9 | Communication requirements (2/2) | Communication quality (reachability) (2/2) | Signals cannot be received | Not being able to receive signals due to increases in traffic, is the same issue as No. 13, and is not subject to study since it is studied in No. 13 | Linking is omitted since not subject to study due to duplication with other items | Category is omitted since not subject to study due to duplication with other items |
| 10 | | | | While unstable radio wave quality or radio wave attenuation or outside of receiving range issues due to obstacles must be taken into account, this is excluded from study of congestion control since they are elements that cannot be controlled at the terminal. | - | Decision on application requirements and application processing |
| 11 | | Communication performance (immediacy) | Transmission timing | Study of the transmission timing calculation method for immediacy guarantee, and effect validation<br>Check of influence on use case implementation due to transmission delay for messages with low priority | 2, 3, 4, 5, 6, 9, 10, 11, 16, 17, 21 | Control specifications/parameter appropriate value validation (vehicle basic message) |
| | | | | | | Consideration of complex transmission timing decision specifications |
| | | | | | | Optimization consideration including communication layers |
| 12 | | | Priority | Not being able to receive signals due to increases in traffic, is the same issue as No. 13, and is not subject to study since it is studied in No. 13 | 7, 8 | Consideration of priority setting |
| 13 | | | Channel load | • While unstable radio wave quality or radio wave attenuation or outside of receiving range issues due to obstacles must be taken into account, this is excluded from study of congestion control since they are elements that cannot be controlled at the terminal. | 2, 3, 5, 6, 10, 11, 16 | Control specifications/parameter appropriate value validation (vehicle basic message) |
| | | | | | | Consideration of complex transmission timing decision specifications |

**Table 4.2.4-3 Linking of issues from a top-down and bottom-up perspective (3/3)**

<table>
<tr><th rowspan="2">No</th><th colspan="4">Issue item identified from a top-down perspective</th><th rowspan="2">Bottom-up perspective issue number</th><th rowspan="2">Types of issues</th></tr>
<tr><th>Major item</th><th>Medium item</th><th>Minor item</th><th>Issues</th></tr>
<tr><td>14</td><td colspan="4">Bottom-up only<br>Application requirements related to transmission timing (Excluded from study of congestion control since this is information that must be decided by the implementing application)</td><td>1</td><td>Decision on application requirements and application processing</td></tr>
<tr><td>15</td><td colspan="4">Bottom-up only<br>Detailed definition of vehicle basic information messages as the target of transmission timing decisions in the congestion control specification proposal (From a congestion control only perspective, excluded from study of congestion control, since the message configuration of the vehicle basic information messages cannot be decided)</td><td>12</td><td>Control specifications/parameter appropriate value validation (vehicle basic message)</td></tr>
<tr><td rowspan="2">16</td><td colspan="4" rowspan="2">Bottom-up only<br>Definition of congestion control specification proposal that takes into account retransmission control</td><td rowspan="2">13</td><td>Control specifications/parameter appropriate value validation (vehicle basic message)</td></tr>
<tr><td>Consideration of complex transmission timing decision specifications</td></tr>
<tr><td rowspan="2">17</td><td colspan="4" rowspan="2">Bottom-up only<br>Definition of congestion control specification proposal that takes into account transmission power changes (including whether hardware support is possible)</td><td rowspan="2">14</td><td>Control specifications/parameter appropriate value validation (vehicle basic message)</td></tr>
<tr><td>Consideration of complex transmission timing decision specifications</td></tr>
<tr><td>18</td><td colspan="4">Bottom-up only<br>Support in hardware possible or not when implementing transmission power change specifications</td><td>18</td><td>Optimization consideration including communication layers</td></tr>
</table>

* * Gray shading area: Linking and categorization are omitted since item is excluded from study due to duplication with other items.

(2) Issue aggregation and mining

This section lists the issue aggregation and mining to be conducted for issues listed for future study or validation for the congestion control methods proposal studied and validated in Section 4.2.4. It also presents future study and validation items as countermeasures.

For the aggregated results of issues by issue type in Table 4.2.4-3, and also for various items in the aggregated issues, mining of decision item proposals is conducted when validating from a specifications study perspective and a validation perspective, and the results are shown in Table 4.2.4-4 for various items.

**Table 4.2.4-4 List of issues for study of the congestion control methods proposal (1/3)**

| No | Issues for study | Description | Validation details |
|---|---|---|---|
| 1 | Decision on application requirements and application processing | The following parameters must be determined by requirement of the implemented application.<br>- Default transmission timing of the vehicle basic information messages<br>- Upper limit value and lower limit value of transmission timing of the vehicle basic information messages<br>- Default transmission timing of messages for mediation/negotiation<br>- Upper and lower limit values for transmission timing of messages for mediation/negotiation<br>- Update frequency of information that the application acquires from own vehicle information, or the lower layer such as CBR<br>Further, the processing details of applications such as systems for handling incidents and radio wave faults must be determined. | Excluded from study of congestion control since this is information that must be decided by the implementing application. |
| 2 | Detailed definition of vehicle basic information messages | In RC-017 there is no vehicle basic information message definition, and consideration is required about whether one is required as an independent message. | From a congestion control only perspective, this is excluded from congestion control consideration, including the need for a vehicle event field, since the message configuration of the vehicle basic information messages cannot be decided. |
| 3 | Control specifications/parameter appropriate value validation (vehicle basic message) | Validation of control specifications and appropriate parameter values through various case studies is required.<br>In order to select the specifications for transmission timing decision of vehicle basic information messages, the method of calculating the transmission timing of the various respective items must be decided and the existence of communication bandwidth compression evaluated.<br>- Surrounding vehicle density<br>- Surrounding communications status<br>- Own vehicle status<br>- Driving environment<br>- Critical event | Determine specifications for transmission timing calculation logic and specific required parameter values in decision items. Using those specifications, run a simulation and evaluate the effect of congestion control.<br><br>[Specifications proposal]<br>The SAE and ETSI congestion control specifications are referenced.<br><br>[Decision criteria proposal]<br>- PAR<br>- CBR, etc.<br><br>However, since the specifications definition background and the basis for the decision criteria in SAE and ETSI are not known, individual decision criteria for Japan must be decided.<br>As items to consider in evaluation, the need for transmission power change specifications and those details, together with the details of retransmission control specifications, must be validated. |

**Table 4.2.4-4 List of issues for study of the congestion control methods proposal (2/3)**

| No | Issues for study | Description | Validation details |
|---|---|---|---|
| 4 | Consideration of complex transmission timing decision specifications | Validation of composite decision specifications concerning multiple transmission timing decision items is required. | Determine specifications for transmission timing calculation logic and specific values of required parameters, combined with decision items in Issue No. 3. Using those specifications, run a simulation and evaluate the effect of congestion control.<br><br>[Specifications proposal]<br>The SAE and ETSI congestion control specifications are referenced.<br>Combination of decision items in Issue No. 2.<br><br>[Decision criteria proposal]<br>- PAR<br>- CBR, etc.<br><br>However, from an evaluation perspective and as a criteria for validation, the PAR, CBR, etc., parameters are used but when deciding on standard values, a basis for judgement is required.<br>As items to consider in evaluation, the need for transmission power change specifications and those details, together with the details of retransmission control specifications, must be validated. |
| 5 | Control specifications/parameter appropriate value validation (mediation/negotiation message) | Validation of control specifications and appropriate parameter values through various case studies is required.<br>The method for calculating transmission timing of mediation/negotiation messages must be decided. | After deciding on the detailed calculation logic and the specifications of the specific value of the required parameters for the mediation/negotiation messages, run a simulation and evaluate the validity of the congestion control effect.<br><br>[Specifications study perspective]<br>The mediation/negotiation message is an event-type, which is transmitted immediately if it can be transmitted immediately. Only in cases where immediate transmission is not possible due to high channel load, the specification must require that it is transmitted after an appropriate interval so as not to impact the use case implementation.<br><br>[Decision criteria proposal]<br>- PAR<br>- CBR, etc.<br><br>However, since the specifications definition and the basis for the decision criteria in SAE and ETSI are not known, individual decision criteria for Japan must be decided.<br>As items to consider in evaluation, the need for transmission power change specifications and those details, together with the details of retransmission control specifications, must be validated. |

**Table 4.2.4-4 List of issues for study of the congestion control methods proposal (3/3)**

| No | Issues for study | Description | Validation details |
|---|---|---|---|
| 6 | Consideration of priority setting | For message sets and vehicle basic information messages defined in RC-017, the priority of messages must be decided according to existence of, and type of, critical event.<br>- Priority order of messages at normal times<br>- Type of critical event<br>- Priority order of critical event type<br>- Priority order of message generated when a critical event is generated for each type of critical event | Simulation or actual evaluation is run by installing priority-setting logic according to the existence of critical events and their event type, the impact of congestion control in the scenarios where critical events are generated is evaluated, and the validity of priority setting logic is evaluated.<br>[Decision criteria proposal]<br>From an evaluation perspective, the perspective should be whether or not the message in response to the generation of the corresponding critical event has actually been delivered with priority.<br>*In the current study, an example of the priority order was presented as to whether or not it directly related to vehicle behavior control, but validation is required.<br><br>[Decision criteria proposal]<br>- Have high priority messages been delivered accurately and with priority? |
| 7 | Optimization consideration including communication layers | The following performance requirements, including communication layers and hardware, must be checked and determined.<br>- Communication timing switching time performance checks<br><br>Further, when actually installed as a product, the following items must also be verified.<br>- Clarification of required processing speed<br>- Clarification of required processing resources usage<br>- Decision on details of required size of buffer (memory/register for sending/receiving) for sending and receiving | Optimization including the communications layer should be considered and hardware limitations for the items at left clarified.<br>Validation of whether the hardware limitations are satisfied or not should be conducted using the actual equipment. |

* Gray shading area: Lists reasons for study/ validation item being excluded from issue study.

Validation by simulation or on the actual equipment is required to validate issues, and the impact of the congestion control specification proposal and the optimization of the layers as a whole must be considered. Further, when conducting validation, the standard values for determining the validation perspective and conformance, and the basis for that, must be decided, and additional research, study and validation are required for the quantitative evaluation of the control effect in the final version of the congestion control methods proposal.

Using the results of consideration to date, we believe continued study of the following items is required.

- Validation of control specifications and appropriate parameter values through various case studies
- Consideration of composite decision specifications concerning multiple transmission timing decision items
- Consideration of overall optimization including congestion control in the transmission layers

Proposals for future study procedures are shown in Fig. 4.2.4-2.

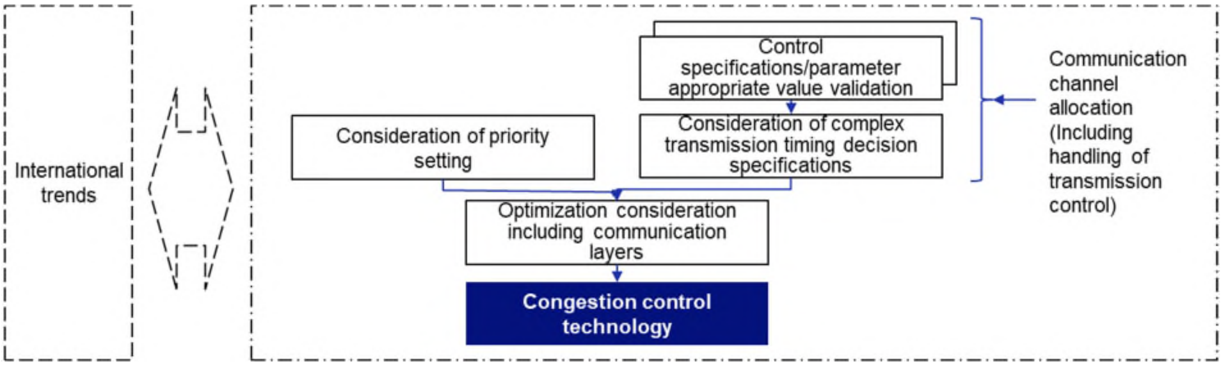



**Fig. 4.2.4-2 Future study procedure proposals**

### 4.3 Verification of communication requirements by simulation

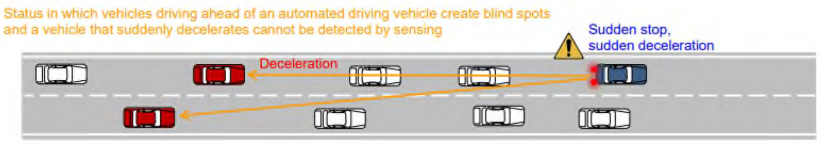
This section verifies the effectiveness of the 5.9 GHz Band V2X Communication Protocol in use cases for Cooperative Driving Automation. Specifically, the effects on vehicle behavior of delays in information transmission between automated vehicles due to differences in communication specifications are verified using traffic simulations.

#### 4.3.1 Selection of use cases for cooperative driving automation to be simulated

The use case for cooperative driving automation handled in the simulation is “c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly” shown in Fig. 4.3.1-1 “c. Lookahead information: Collision avoidance” (hereinafter referred to as the “use case”). This deals with vehicle behavior of notifying the vehicle behind of information on obstacles ahead and encouraging early deceleration, etc. In addition, rapid vehicle control through information transmission is expected, and there is concern about the impact of delay.

**c. Lookahead information: collision avoidance**
**c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly**

| | | | |
|---|---|---|---|
| **Classification by function** | c. Lookahead information: collision avoidance | | |
| **Name of the use case** | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | | |
| **Target areas** | Expressways + General roads | **Target vehicles** | Privately owned vehicles |
| **Overview** | Sudden braking information as well as location and speed information are provided by the vehicle that suddenly decelerates to the following vehicles to prompt them to stop or decelerate in advance and prevent multiple-vehicle collision accidents. | | |
| **Image of the use case** | | | |




| | | | | |
|---|---|---|---|---|
| **Remarks (communication requirements, etc.)** | **Communication** | V2V | **Data category/ content of information** — **Message** | Sudden braking information |
| | **Connection mode** | One-to-many | **Sensor data** | Location, speed |
| | **Control usage** | Speed adjustment, stop | **Rich contents** | – |
| | **Responsiveness** | Required | **Data amount** | Small |

**Fig. 4.3.1-1 Use cases handled in simulation[79]**

Fig. 4.3.1-2 shows a model of communication situations assumed in the simulation. In other words, emergency situations were assumed where the lead vehicle of a group of vehicles comes to a sudden stop in front of an obstacle on a major prefectural or municipal road with relatively high driving speed and that are situations near intersections where various other information needs to be transmitted.

The use cases in this situation are expected to be safer situations by receiving information before the following vehicle begins to slow down in response to deceleration of the vehicle ahead.

[79] SIP Use Cases for Cooperative Driving Automation, Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2019, 2019

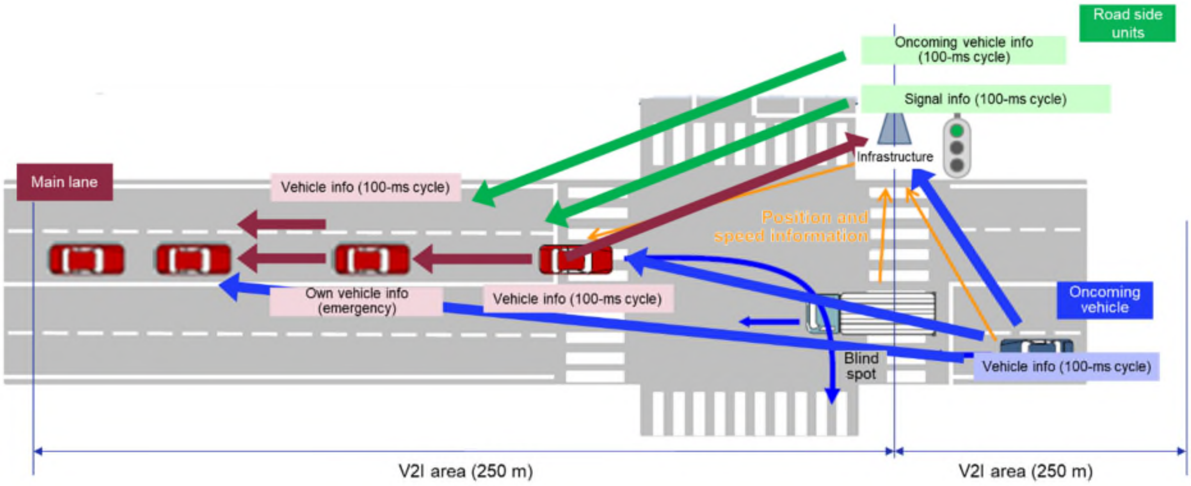



**Fig. 4.3.1-2 Example of communication around an intersection**[80]

Fig. 4.3.1-3 shows a model of information transmission and vehicle behavior expected in the use cases. Here, we assume an automated vehicle traveling at a constant speed (hereinafter called the "lead vehicle of a group of vehicles" or "lead vehicle," Vehicle 0) and a group of vehicles formed by multiple vehicles that follow the automated vehicle (hereinafter called the "vehicles following," Vehicle 1 and Vehicle 2 in the order closest to the lead vehicle). At the same time as the lead vehicle detects an obstacle ahead or other event that requires a sudden stop, the information is reported according to the cycle and number of transmissions specified in the communication requirements. The vehicles following are assumed to be automated vehicles or manually operated vehicles depending on the case in the simulation. If automated vehicles, upon receiving the information, control is performed to widen the gap by preliminary deceleration in order to make the situation safer. At this time, since in actuality various factors may arise that obstruct communication to require multiple reporting for the information to be transmitted to the vehicles following, this is treated as delay time for information transmission, with the communication specifications defined.

Although the use case also assumes a situation where the vehicles following change lanes to avoid a collision, only deceleration behavior in the same lane, which is more restrictive in terms of vehicle control, is assumed here.

[80] Communication requirements in the figure are according to Study report on communication scenarios and requirements for "SIP Use Cases for Cooperative Driving Automation", ITS FORUM RC-017 Ver. 1.0, ITS Info-communications Forum, 2022

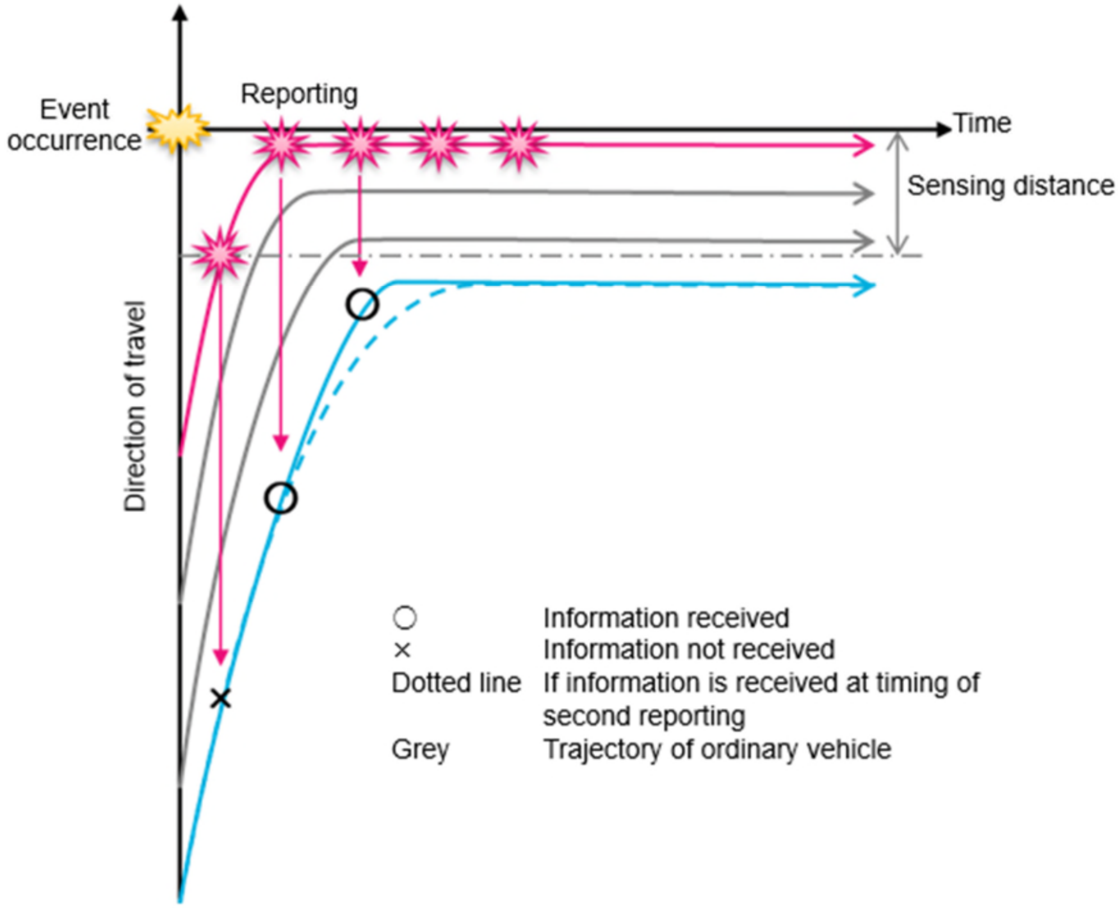



**Fig. 4.3.1-3 Model of information transmission and vehicle behavior expected in the use case**

### 4.3.2 Survey of existing literature on vehicle behavior

Prior to simulation, existing technical literature on vehicle behavior and traffic phenomena to be considered in the assumed use case was surveyed.

(1) Vehicle time gap during steady driving

The simulation generates a group of vehicles driving steadily that follow the vehicle ahead, and the literature was studied for how to set the vehicle time gap then.

(a) Distribution of vehicle time gap on expressways, and major prefectural and municipal roads

The following existing literature was referred to for gap of vehicles during steady driving of manually operated vehicles.

The study by Xing et al.[81] uses sensor pulse data from intercity expressways to analyze traffic conditions before congestion occurs. The results of the analysis are as shown in Fig. 4.3.2-1, with a mode of 1.5 seconds of headway time in the passing lane in the 15 minutes before congestion occurs.

And in the study by Sumida et al.[82], speed and headway time of vehicles traveling on national roads in Fukuoka Prefecture were measured, and it was found that most vehicles traveled in 1 to 1.5 seconds.

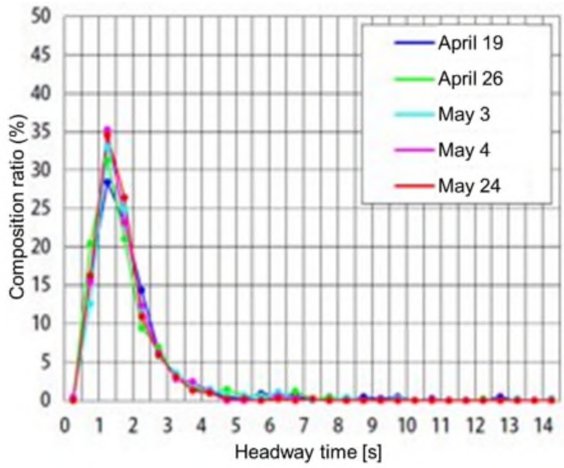



**Fig. 4.3.2-1 Distribution of headway time in the passing lane in the 15 minutes before congestion occurs**

[81] "An Analysis of the Characteristics of Vehicle Platoons Resulting in the Occurrence of Traffic Congestion on Expressways," 2010, Jian Xing, Motofumi Tsuru, Takashi Ishida, Eiji Muramatsu

[82] "Traffic Flow and Accident Prevention Analysis by Traffic Flow Simulation Focusing on Drivers' Headway Holding Time," 2020, Yasuaki Sumida, Masaki Hayashi, Kazuaki Goshi, Katsuya Matsunaga

(b) Setting ACC gap

For setting the gap in steady driving of automated vehicles, information[83] published on the Web was referred to regarding setting of gap for adaptive cruise control (ACC) currently available on the market as existing literature. In this simulation, automated vehicles were assumed to maintain a gap equivalent to “long” of Fig. 4.3.2-2, assuming that safety and comfort are emphasized.

| Vehicle gap distance setting | At vehicle speed of 80 km/h | At vehicle speed of 100 km/h |
|---|---|---|
| Short | Approximately 25 m (Approximately 1.1 sec at vehicle time gap) | Approximately 30 m (Approximately 1.1 sec at vehicle time gap) |
| Medium | Approximately 33 m (Approximately 1.5 sec at vehicle time gap) | Approximately 40 m (Approximately 1.4 sec at vehicle time gap) |
| Long | Approximately 47 m (Approximately 2.1 sec at vehicle time gap) | Approximately 59 m (Approximately 2.1 sec at vehicle time gap) |
| Maximum distance | Approximately 61 m (Approximately 2.7 sec at vehicle time gap) | Approximately 78 m (Approximately 2.8 sec at vehicle time gap) |

**Fig. 4.3.2-2 Example of setting ACC gap[83]**

[83] From Honda FREED Hybrid ACC operation manual https://www.honda.co.jp/ownersmanual/webom/jpn/freedhybrid/2017/details/13686090-53076.html

(2) Deceleration behavior at sudden hard braking

For deceleration behavior of sudden hard braking, the relationship between speed and deceleration is summarized in Fig. 4.3.2-3, based on findings in the technical literature organized in (a) to (f) below. In other words, after organizing the deceleration of the lead vehicle at an emergency stop, the allowable deceleration of the following vehicle at a sudden stop, and the allowable deceleration at a stop when advance information is given, the deceleration in the sudden deceleration behavior of the vehicle ahead was set to 0.5G in this simulation.

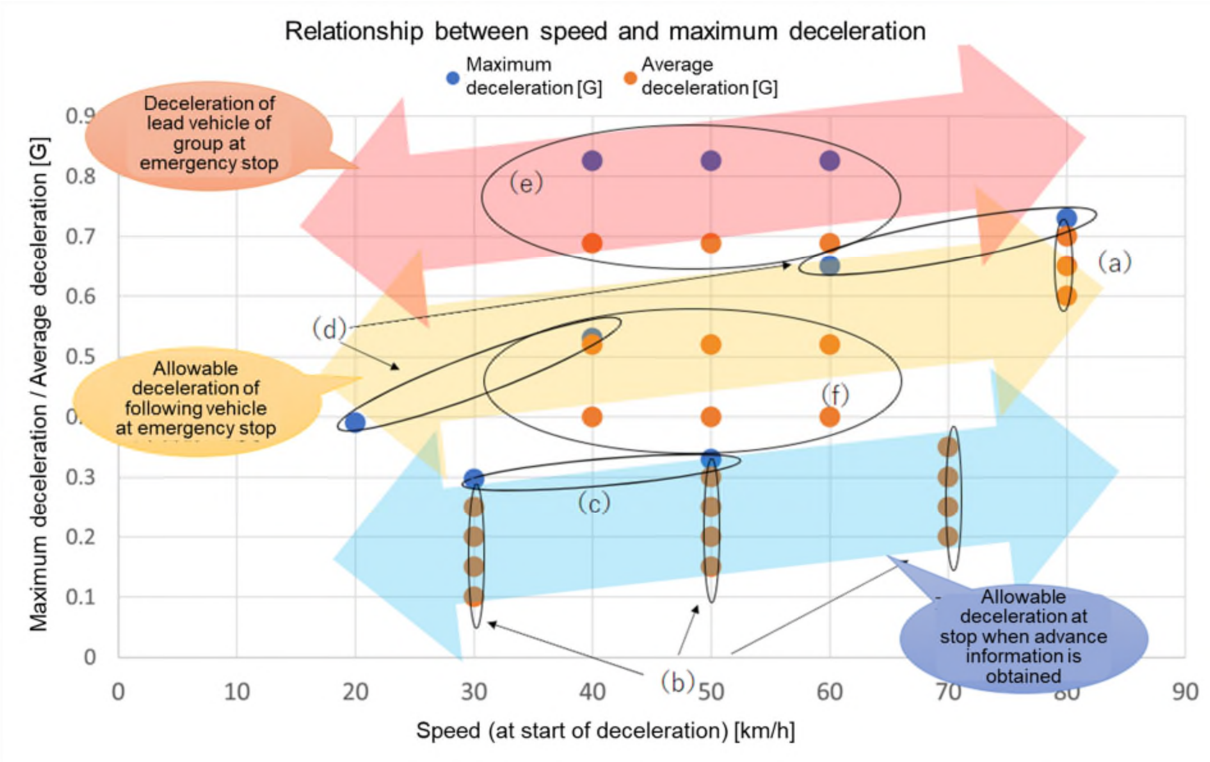



**Fig. 4.3.2-3 Relationship between driving speed and maximum deceleration (Lower case letters in diagram correspond to heading numbers of (a) to (f) below)**

(a) Analysis by driving simulator of driver emergency avoidance action in automatic platooning

In the study by Zheng et al.[84], a driving simulator is used to analyze driver emergency avoidance behavior during automatic platooning. The study was conducted using a driving simulator to measure sudden hard braking behavior of the following vehicle and the vehicle gap distance when the vehicle ahead brakes hard while platooning on an expressway.

In this study, as shown in Fig. 4.3.2-4, sudden deceleration at emergency stop of the lead vehicle is assumed to be 0.6 G. And as shown in Fig. 4.3.2-5, the reaction time from the time the driver confirms the sudden stop of the vehicle ahead to the time the brake pedal is depressed is 0.6 seconds in the sudden hard braking behavior of the following vehicle, so these values are assumed to be usable as findings.

[84] "Analysis of Driver Behaviors for Emergency Avoidance of Automatic Platooning by Using a Driving Simulator," 2012, Rencheng Zheng, Shigeyuki Yamabe, Seungyong Lee, Kimihiko Nakano, Masahiko Aki, Yoshihiro Suda

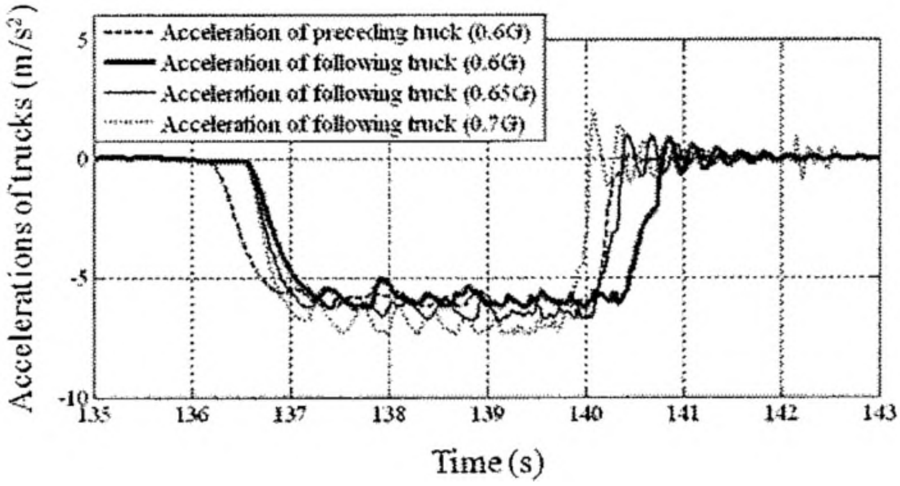



**Fig. 4.3.2-4 Deceleration of vehicle ahead and assumed deceleration of the following vehicle**[84]

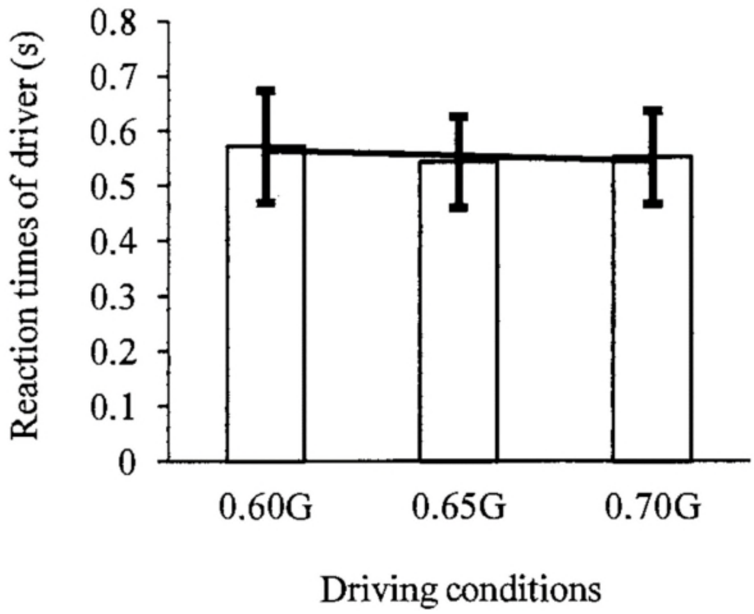



**Fig. 4.3.2-5 Driver reaction times in different decelerations**[84]

(b) Research on driver sense of security during braking

In the study by Tanaka, et al.[85], research is being conducted on driver sense of security during automobile braking. The study involves having subjects drive a passenger car on a straight road, and then having them depress the brake pedal from a specified distance calculated from the average deceleration speed as shown in Table 4.3.2-1 to stop at the desired position. The subjects are asked to rate their sense of security during braking at that time on a 5-point scale with contents similar to Table 4.3.2-2.

Test results are shown in Fig. 4.3.2-6. From Fig. 4.3.2-6, it was found that the smaller the deceleration, the greater the sense of security, and the faster the initial speed, the greater the deceleration at which the driver begins to feel anxiety, suggesting that this study can be used as a sensory interpretation of deceleration behavior.

[85] “The Study on the Scare and Secure for Adaptive Driver Assistant System,” 2016, Hiroaki Tanaka, Daisuke Takemori, Tomohiro Miyachi, Yurie Iribe, Hirotugu Oguri

**Table 4.3.2-1 Setting of deceleration conditions**[85]

| Initial speed [km/h] | Average deceleration [G] | | | | Initial speed [km/h] | Average deceleration [G] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Exp.1 | Exp.2 | Exp.3 | Exp.4 | | Exp.5 | Exp.6 | Exp.7 | Exp.8 |
| 30 | 0.075 | 0.100 | 0.125 | 0.150 | 30 | 0.175 | 0.200 | 0.225 | 0.250 |
| 50 | 0.125 | 0.150 | 0.175 | 0.200 | 50 | 0.225 | 0.250 | 0.275 | 0.300 |
| 70 | 0.175 | 0.200 | 0.225 | 0.250 | 70 | 0.275 | 0.300 | 0.325 | 0.350 |

**Table 4.3.2-2 Five-point-scale evaluation of sense of security**[85]

| Feeling Levels | Perceived Safety |
|---|---|
| 2 | Very secure |
| 1 | Moderately secure |
| 0 | Neutral |
| -1 | Moderately fearful |
| -2 | Very fearful |

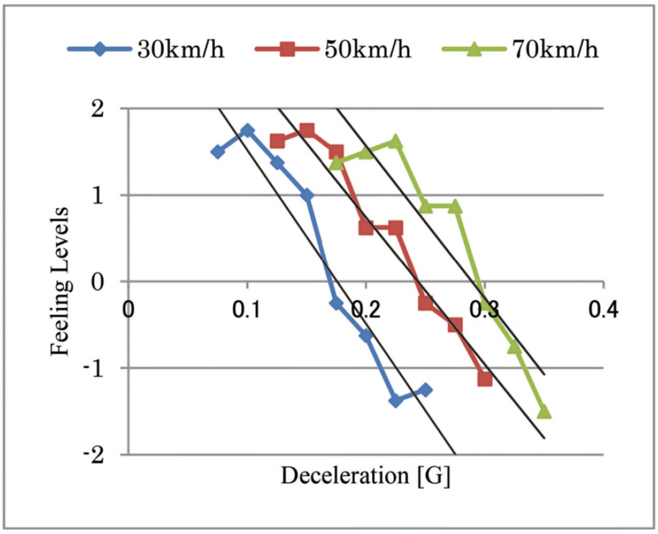



**Fig. 4.3.2-6 Results of questionnaire on sense of security** [85]

(c) Research on sudden deceleration in the dilemma zone when approaching an intersection

In the study by Ichihara et al.[86], ITS wireless technology was studied to reduce sudden deceleration the dilemma zone when approaching intersections by predicting the traffic signal change. The study uses traffic signals that can communicate with the vehicle to obtain traffic prediction support information for the signal ahead and predict in how many seconds the signal will change based on the distance between vehicle and signal and the speed. The traveling vehicle is verified using an actual vehicle for constant speed behavior and using simulation for behavior during acceleration. The results are shown in Table 4.3.2-3. The maximum deceleration at a stop could be reduced by predicting the signal change in advance.

[86] "Reduction of Sudden Deceleration in Dilemma Zone Using ITS Communication," 2021 Naoki Ichihara, Keisuke Yoneda, Naoki Suganuma

**Table 4.3.2-3 Change in deceleration before and after dilemma zone assistance[86]**

| Experimental number | W/ Prediction | W/O Prediction |
|---|---|---|
| ① | $-1.19[m/s^2]$ | $-2.97[m/s^2]$ |
| ② | $-1.09[m/s^2]$ | $-1.78[m/s^2]$ |

(d) Research on detection of hazardous events such as sudden deceleration

In the study by Hatakenaka, et al.[87], research is being conducted on examining methods for detecting hazardous events such as sudden steering and sudden deceleration, and for providing near-miss information. The research analyzes changes in vehicle behavior when small, ordinary, and large vehicles are driven at 20, 40, and 80 km/h on dry and water-film road surfaces, respectively. According to that, as show in Table 4.3.2-4, the influence of changes in sudden deceleration behavior due to road surface conditions and vehicle type is small, indicating that the influence of driving speed is significant.

**Table 4.3.2-4 Deceleration per test roadway item[87]**

| Item | Emergency avoidance behavior (Max. left/right acceleration) | Sudden deceleration behavior (Max. front/rear acceleration) |
|---|---|---|
| Impact per road surface | 0.24 G (dry road surface)<br>0.21 G (water-film road surface)<br>-> Impact is small | • 0.49 G (dry road surface)<br>• 0.51 G (water-film road surface)<br>-> Impact is small |
| Impact per vehicle type | 0.25 G (small vehicle)<br>0.25 G (ordinary vehicle)<br>0.22 G (large vehicle)<br>-> Impact is small | • 0.46 G (small vehicle)<br>• 0.47 G (ordinary vehicle)<br>• 0.45 G (large vehicle)<br>-> Impact is small |
| Impact of driving speed | 0.22G (20km/h)<br>0.22G (40km/h)<br>0.25G (60km/h)<br>0.25G (80km/h)<br>-> Impact is small | -0.39G (20km/h)<br>-0.53G (40km/h)<br>-0.65G (60km/h)<br>-0.73G (80km/h)<br>-> Dependent on speed |
| Impact of individual characteristics | Approximately 0.3 G variation<br>-> Dependent on individual difference | Approximately 0.4 G variation<br>-> Dependent on individual difference |

(e) Research on hard braking behavior according to driver ability

In the study by Makishita, et al.[88], hard braking behavior is considered to be a problem caused by driver ability, and research is being conducted on braking methods and braking distance for different driver abilities. The study covered safe driving instructors and their trainees as well as general drivers. The subjects performed hard braking from the timing when they judged that the speed of the vehicle become stabile, and the acceleration of the vehicle was obtained. The results are as shown in Fig. 4.3.2-7. At maximum acceleration, the average value was 0.966 G for trainees and 0.826 G for general drivers, and a significant difference was seen at a 1% risk rate.

[87] "Study of Driving Safety Assisting Service Using Probe Data," 2007, Hideto Hatakenaka, Takayuki Hirasawa, Yasuyuki Manabe, Yasushi Watanabe, Hiroshi Inoue, Kenro Takenaka, Hirota Kawasaki

[88] "Various drivers' braking behaviors and braking distances," 2001, Hiroshi Makishita, Katsuya Matsunaga

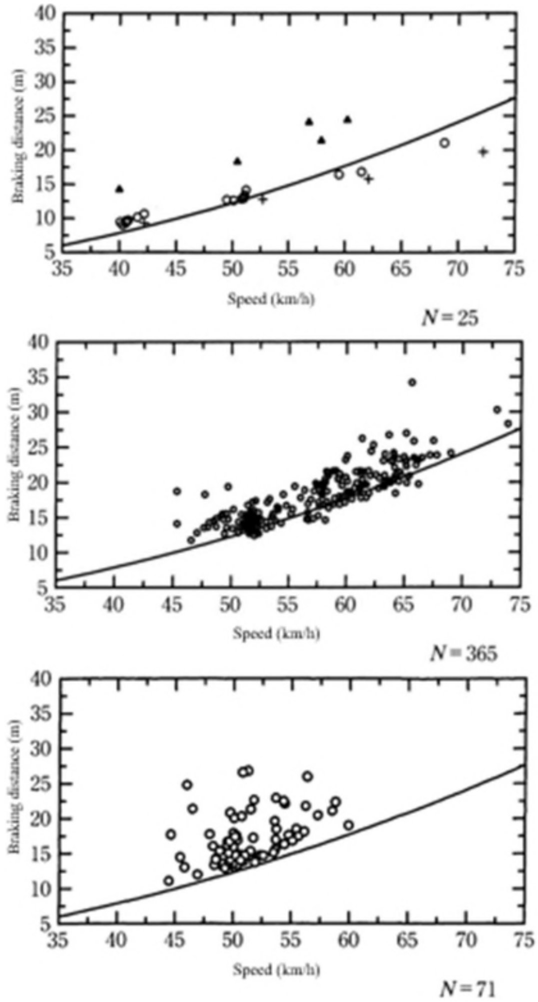



**Fig. 4.3.2-7 Relationship between braking distance and speed (top: instructor, middle: trainee, bottom: general driver)[88]**

(f) Research on detection of sudden deceleration behavior using probe information

In the study by Kikuchi, et al.[89], analysis is performed with 0.3 G as the near-miss threshold in order to propose as near-miss indicators those that can be calculated using probe information, such as sudden deceleration behavior, and to study possibilities for using them. In this study, as shown in Table 4.3.2-5, the intensity of sudden deceleration as an index value for near-misses changed from 0.52 G to 0.46 G before and after countermeasures, and it was believed that the maximum deceleration before countermeasures could be used as a reference value for the simulation.

[89] "STUDY ON THE USABILITY OF HIYARI-HAT DATA TO ROAD-SAFETY PROJECTS," 2012, Harumi Kikuchi, Asao Okada, Hiroaki Mizuno, Yuichi Kinuta, Toshiyuki Nakamura, Go Hagihara, Kazuhiko Makimura

**Table 4.3.2-5 Indicator values for near-miss-related indicators[89]**

| Category | Indicator | Trial indicator | |
|---|---|---|---|
| | | Kikuno-Oshikiri intersection | Oiwake intersection |
| Number of occurrences of sudden deceleration behavior | Number of occurrences of sudden deceleration behavior | 20.8→19.0<br>(9% reduction) | 13.2→6.8<br>(48% reduction) |
| Strength of sudden deceleration | Maximum deceleration | [Oshikiri intersection]<br>0.52G→0.46G<br>[Kikuno intersection]<br>0.40G→0.33G | 0.53G→0.43G |
| | Strength composition at occurrence of sudden deceleration behavior | [Oshikiri intersection]<br>Decrease in ratio with sudden deceleration behavior of 0.5 G or greater<br>[Kikuno intersection]<br>Decrease in ratio with strong sudden deceleration behavior of 0.35 G or greater | Decrease in ratio with strong sudden deceleration behavior of 0.5 G or greater |
| | Average strength at sudden deceleration | 0.34G→0.34G<br>*No statistically significant differences obtained | 0.35G→0.34G<br>*No statistically significant differences obtained |
| Speed immediately before sudden deceleration | Sudden deceleration behavior occurrence point by speed rank | Reduction in sudden deceleration behavior that occurs when traveling at high speed | Reduction in sudden deceleration behavior that occurs when traveling at high speed |

(3) Research on braking start time of vehicles following with the deceleration of the vehicle ahead

Previous literature was also surveyed for time delays in the reaction of a vehicle in ACC driving to the deceleration of the vehicle ahead.

In the study by Makishita, et al.[90], subjects driving passenger cars were asked to drive a circular course set up on a public road, and the time to start braking was measured when hazards such as pedestrians running onto the road and braking behavior of the vehicle ahead occurred. This study showed, as seen from Fig. 4.3.2-8 and Fig. 4.3.2-9, that the majority of reaction times to pedestrians running onto the road ranged from 0.1 to 1.4 seconds, and reaction time to braking by the vehicle ahead is 0.4 to 1.6 seconds.

Referring to this, in the simulation, the parameters were set so that the "deceleration propagation time," which is the time it takes for own vehicle to decelerate in response to the deceleration of the vehicle ahead, would be in the range of 0.4 to 1.6 seconds.

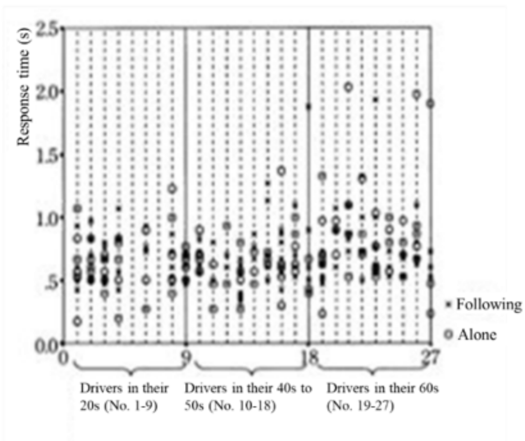



**Fig. 4.3.2-8 Reaction times to pedestrians running onto the road[90]**

[90] "The brake reaction time to a sudden hazard while driving," 2002 Hiroshi Makishita, Katsuya Matsunaga

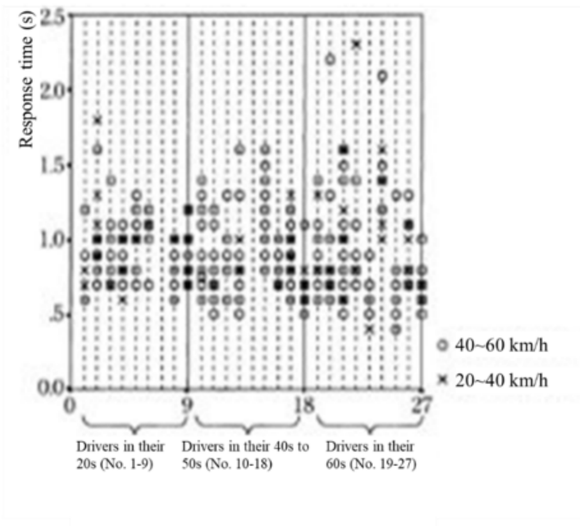



**Fig. 4.3.2-9 Reaction times to braking of vehicle ahead[90]**

(4) Evaluation of ride comfort using jerk

In the simulation, how the behavior at a sudden stop changes depending on the communication specifications is verified. Regarding jerk, which is considered as one of the evaluation indices, the following summarizes previous studies that evaluated vehicle behavior using jerk.

Wang et al.[91] conducted experiments in which subjects seated in passenger seats subjectively evaluated ride comfort by repeatedly starting and stopping the vehicle at various speed ranges in a safe environment. The literature mentions that "...jerking oscillations with an amplitude of about 10 [m/s$^3$] increase the ride comfort score... (i.e., feel uncomfortable)," but ride comfort due to speed variation is considered to be affected by deceleration and jerk.

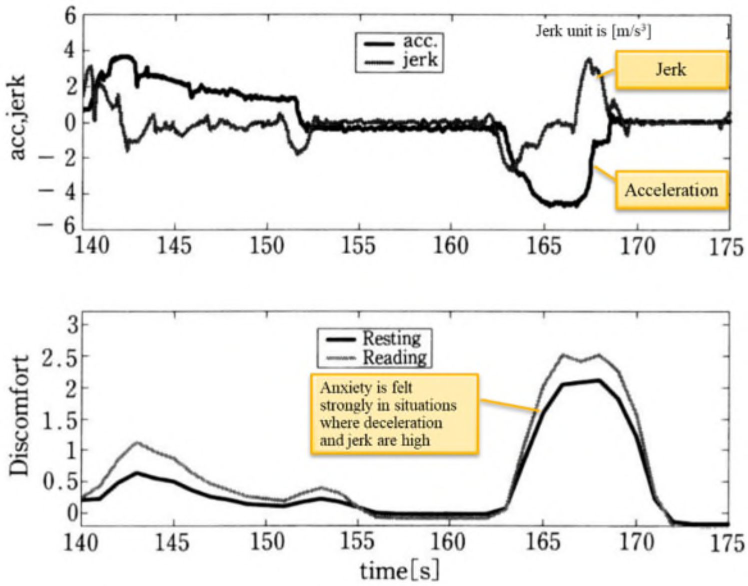



**Fig. 4.3.2-10 Comparison of ride comfort according to riding posture**
**(Top: acceleration and jerk, Bottom: ride comfort in reading and crouched posture)[90]**

[91] Feng Wang, Koichi Sagawa, Hikaru Inooka, "A study of the relationship between the longitudinal acceleration/deceleration of automobiles and ride comfort," The Japanese Journal of Ergonomics Vol. 36, No.4, 2000

In a study with a similar objective, Tanaka et al.[92] had subjects perform sudden hard braking maneuvers from various initial speeds in a safe environment and evaluated the ride comfort using subjective indices. In this study, the average jerk from the start of deceleration to the peak of deceleration is defined as "impression jerk," and as shown in Fig. 4.3.2 11, when impression jerk falls below -3G/sec (≈ -28m/s$^3$)[93], this indicates a tendency to feel anxious.

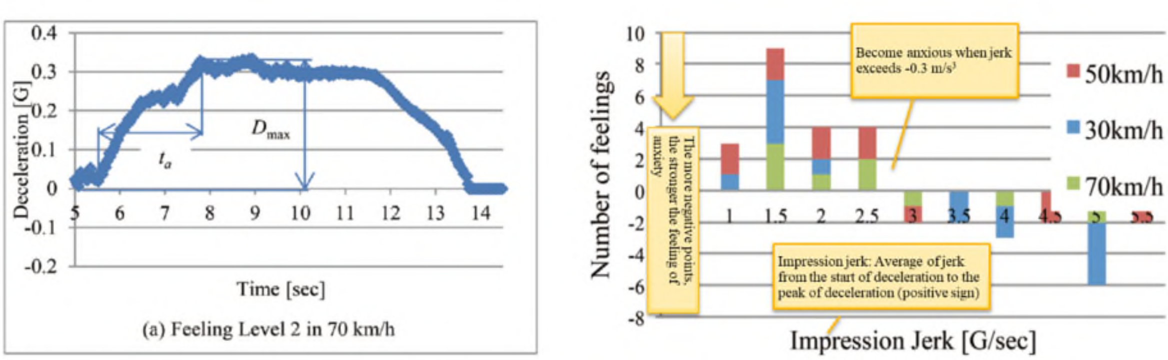



**Fig. 4.3.2-11 Evaluation of anxiety felt by the driver during deceleration**
**(Left: Example of deceleration behavior, Right: Anxiety per driving speed and deceleration)**[91]

[92] Hiroaki Tanaka, Daisuke Takemori, Tomohiro Miyachi, Yurie Iribe, Hirotugu Oguri, "The Study on the Scare and Secure for Adaptive Driver Assistant System," DENSO TECHNICAL REVIEW, Vol. 21, 2016

#### 4.3.3 Vehicle behavior modeling in traffic simulation

This section explains the concept behind the simulations conducted in this study.

(1) Behavior of the lead vehicle of a group of vehicles

For the lead vehicle in a group of vehicles, the behavior of stopping with a specified deceleration after running at a specified speed for a specified period of time was assumed. Here, it was decided to stop at a deceleration level equivalent to a sudden stop in an emergency, where delays caused by the communication method are least tolerated.

(2) Following vehicle following behavior model

The following vehicle drives with AAC behind the vehicle traveling in front of it (hereinafter referred to as the "vehicle ahead" in relation to the "following vehicle"). The IDM+ equation[94], which has been applied in many cases, such as the simulation evaluation of suppression of deceleration wave propagation by ACC at the Netherlands Organisation for Applied Scientific Research (Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek, TNO), is used here as the following behavior model. The IDM+ equation has been used in Japan by the National Institute for Land and Infrastructure Management (NILIM) to study traffic congestion mitigation measures on expressway sag sections when ACC is in widespread use[95] and in simulation evaluations of vehicle-to-infrastructure cooperative merging assistance systems when automated driving is in widespread use[96].

The IDM+ equation uses the following ordinary differential equation to determine acceleration based on driving speed of the following vehicle and the vehicle gap distance from and relative speed to the vehicle ahead. In other words,

$$\frac{dv}{dt} = a \cdot \min\left[1 - \left(\frac{v}{v_d}\right)^2,\ 1 - \left(\frac{s^*(v, \Delta v)}{s}\right)^2\right]$$

$$s^*(v, \Delta v) = s_j + vT + \frac{v\Delta v}{2\sqrt{ab}}$$

Here,

$v$ : Speed [m/s]
$s$ : Headway distance [m]*1
$s^*$ : Desired headway distance[m]
$v_d$ : Desired speed [m/s]
$\Delta v$ : Relative approach speed [m/s]*2
$s_j$ : Headway distance at stop [m]
$T$ : Safe headway time [s]
$a$ : Maximum acceleration [m/s$^2$]
$b$ : Desired deceleration [m/s$^2$]

*1 Calculated in the stimulation as the vehicle tail way distance (vehicle gap distance + own vehicle length)

*2 Positive when approaching vehicle ahead

Note that in the simulation the above differential equation is converted to a difference equation using the fourth-order Runge-Kutta method because the acceleration is updated sequentially in discrete time ($\Delta t = 0.01$[s]).

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94 W. Schakel, B. Arem, Bart Netten：Effects of cooperative adaptive cruise control on traffic flow stability, 13th International IEEE Annual Conference on Intelligent Transportation Systems, Madeira Island, September 19-22, 2010.

95 Kazufumi Suzuki, Kosuke Yamada Ryota Horiguchi, Koichi Iwatake: Impact Assessment of Future Performance of Adaptive Cruise Control for Congestion Mitigation at Expressway Sag Sections, Journal of Traffic Engineering Vol. 1 (2015), No. 2 special edition, pp. B_60-B_67, 2015.

96 Toshimasa Nakagawa, Hirotaka Sekiya, Ryo Nakata, Teruaki Hanamori, Ryota Fujimura, Shinji Itsubo, Yasuyuki IWASATO: Effect Analysis of Merging Support Information Provision System by Traffic Simulation, Journal of Traffic Engineering, Volume 8, Issue 3, pp. 20-29, 2022.

In addition to the above IDM+ equation, an exponential smoothing process is applied here to the acceleration calculated by the IDM+ equation to adjust the propagation delay of the deceleration behavior. In other words,

$$\tilde{a}_{t+1} = \alpha^* \tilde{a}_t + (1 - \alpha^*)\hat{a}_t$$
$$\alpha^* = 1 - \left\{\frac{s_c - s_t}{(1 - \beta)s_c}\right\}^\gamma$$

Here,

$\tilde{a}_t$ : Acceleration after smoothing
$\hat{a}_t$ : Acceleration before smoothing (acceleration obtained by the IDM+ equation from the state at time t)
$s_c$ : Critical headway distance (headway distance that results in a capacitive state at steady-state FD in the IDM+ equation)
$s_t$ : Headway distance ($< s_c$) at time $t$
$\beta \in (0,1)$, $\gamma \in \{1,2,\cdots\}$: Parameter

(3) Setting parameters related to vehicle behavior

The parameters related to vehicle behavior to be employed in the simulation in section 4.3.4 are determined through evaluation by simulation (sensitivity analysis of vehicle behavior). Of the parameters related to vehicle behavior, the initial driving speed, vehicle gap distance, deceleration of the lead vehicle in a vehicle group, and ACC type parameters, all indicated by a ★ in Table 4.3.3-1, were varied and simulations were conducted to evaluate the behavior corresponding to manually operated vehicles (small and large) and automated vehicles (with and without information).

Table 4.3.3-1 Parameters list (sensitivity analysis performed for ★)

| Category | Parameter | Value | Unit | Remarks |
|---|---|---|---|---|
| Basic settings | No. of vehicles | 10 | [vehicles] | |
| | Section length | 4,000 | [m] | |
| | Calculation time | 120 | [s] | |
| | Calculation interval | 0.01 | [s] | |
| | Recording interval | 0.01 | [s] | |
| Behavior of the lead vehicle of a group of vehicles | ★ Initial speed | 15 to 25 | [m/s] | Sensitivity analysis at 5 [m/s] increments (×3) |
| | Deceleration start time | 30 | [s] | |
| | Deceleration at stop | 5.0 | [m/s$^2$] | Deceleration at sudden stop |
| AAC vehicle behavior | ★ Desired speed | 15 to 25 | [m/s] | Sensitivity analysis at 5 [m/s] increments (×3). However, greater than initial speed of the lead car in the group |
| | ★ Safe headway time | 1.0 to 2.5 | [s] | Sensitivity analysis at 0.3 [m/s] increments (×6). Initial vehicle gap distance determined by this value |
| | Headway distance at stop | 7.0 | [m] | Vehicle gap distance at stop is 7-5=2 [m] |
| | ★ Max. acceleration | 1.0 to 2.5 | [m/s$^2$] | Sensitivity analysis at 0.3 [m/s$^2$] increments (×6) |
| | ★ Desired deceleration | 1.0 to 5.0 | [m/s$^2$] | Sensitivity analysis at 0.4 [m/s$^2$] increments (×11) |
| | Vehicle length | 5.0 | [m] | Equivalent to ordinary passenger vehicle |
| Other | ★ Smoothing range (β) | 0.25 to 0.5 | | |
| | ★ Smoothing strength (γ) | 1 to 4 | | |

(a) Vehicle behavior characteristic index confirmed in evaluation by simulation (sensitivity analysis of vehicle behavior)

i. Initial speed and vehicle gap distance

Assuming that automated driving has a longer vehicle gap distance than manual driving, the following policy is used to select parameters based on the summary in section 4.3.2(1). Specifically, parameters were selected in the range of 1.1 to 1.5 seconds vehicle time gap for manual driving and in the range of 1.8 to 2.0 seconds vehicle gap time for automated driving.

ii. Deceleration propagation time

Although the IDM+ equation does not explicitly include a reaction delay time item, deceleration behavior is known to take longer to propagate as a result. Here, the reading is based on the time difference between the start of deceleration of the vehicle ahead and the start of deceleration of the following vehicle, as in Fig. 4.3.3-1. Specifically, the deceleration propagation time was defined as the difference from the vehicle ahead at the time when the deceleration rate exceeded the threshold (0.1 m/s$^2$).

In general, deceleration of the vehicle ahead is sharper the closer it is to the head of the group of vehicles, so more rapid the reaction is required, and the deceleration propagation time becomes shorter. In the parameter sensitivity analysis, based on the findings in section 4.3.2(3), the deceleration propagation time of manually operated vehicles in the vehicle group was selected to fall within the range of 0.4 to 1.6 seconds. In addition, it was believed that automated driving would increase the vehicle gap distance, allowing for gentler deceleration, and that deceleration propagation time would tend to be longer than with manual operation.

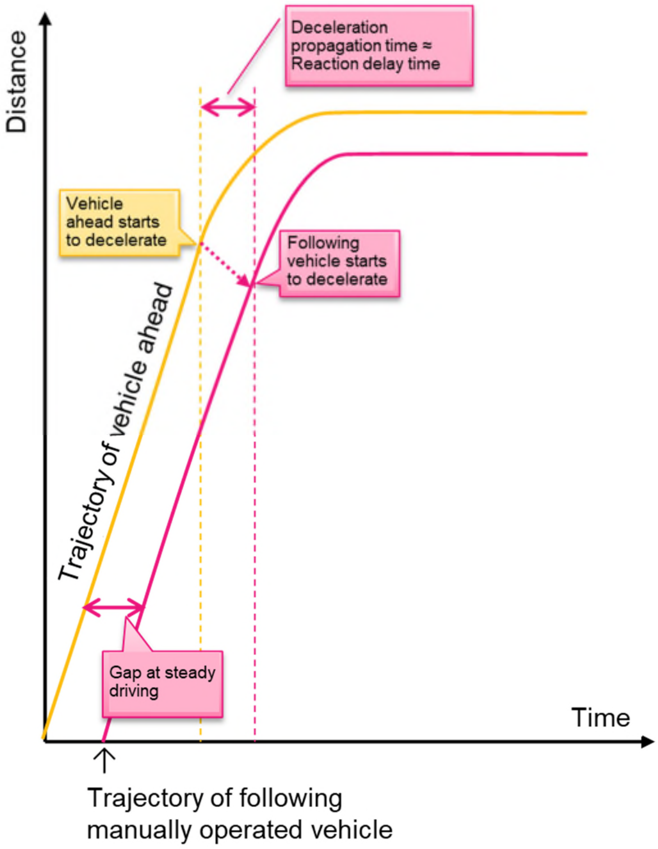


**Fig. 4.3.3-1 Interpretation of deceleration propagation time**

iii. Amplification factor of maximum deceleration

The ratio of the maximum deceleration value of the following vehicle to the maximum deceleration value of the vehicle ahead was examined as an index to characterize vehicle behavior at a stop. If the maximum deceleration value attenuates and propagates, it can be interpreted as behavior that allows safe stopping. If, on the other hand, it amplifies and propagates, deceleration increases towards the rear and finally exceeds the physical frictional resistance between the tire and the road surface, resulting in a collision[97], which is undesirable behavior in terms of safety.

Since the previous literature survey did not provide any findings on the propagation of deceleration during sudden hard braking, it was treated here as an index for understanding the characteristics of manual and automated driving in relative comparison, and it was assumed that the amplification factor is larger for manual driving than for automated driving, and it was thus used as a reference index in parameter sensitivity analysis.

iv. Gap-relative speed sensitivity ratio

In addition, as an index for relative comparison of the characteristics of manual and automated driving, the degree to which the driver responds to both gap and relative speed when following is shown as the vehicle gap-relative speed sensitivity ratio. Specifically, the ratio of the relative speed gain $k\_v$ to the vehicle gap distance gain $k\_s$, estimated by multiple regression analysis is obtained by fitting the relationship between the relative speed and vehicle gap distance to the vehicle ahead for each vehicle obtained from the simulation results to the well-known Helly model in the ACC speed control field (the following formula).

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[97] Note that the IDM+ equation employed here allows for deceleration beyond physical limits so as to be collision free, and it does not address whether or not there will be a collision in later simulations.

$$\dot{v}_t = k_v \Delta v_t + k_s \left( s_t - s_j - v_t T \right)$$

Here,
$\dot{v}_t$: Acceleration,
$v_t$: Speed,
$\Delta v_t$: Relative speed,
$s_t$: Vehicle gap distance,
$s_j$: Vehicle gap distance at stop,
$T$: Safe vehicle time gap

This means response is made with weight placed more on the gap than the relative speed the higher this sensitivity ratio is. Here, automated driving was used as the reference index in parameter sensitivity analysis, as it places more weight on relative speed than manual operation does, resulting in a smaller sensitivity ratio.

(b) Setting parameters list

Table 4.3.3-2 shows the parameter setting values per vehicle model selected through evaluation by simulation (sensitivity analysis of vehicle behavior).

**Table 4.3.3-2 Setting parameters list**

| | Item | Unit | Manually operated vehicle (small) | | Manually operated vehicle (large) | | Automated vehicle (without information) | | Automated vehicle (with information) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Desired speed | [m/s] | 15 to 25 | Match with initial speed of lead vehicle | 15 to 25 | Match with initial speed of lead vehicle | 15.00 | Match with initial speed of lead vehicle | 15.00 | Match with initial speed of lead vehicle |
| | Safe gap | [s] | 1.30 | | 1.60 | Longer than for small | 1.90 | Longer than for manually operated<br>Equivalent to medium to long gap of AAC | 2.20 | Longer than without information<br>Equivalent to long gap of AAC |
| | Stopped vehicle gap | [m] | 2.00 | | 2.00 | | 2.00 | | 2.00 | |
| | Max. acceleration | [m/s$^2$] | 2.20 | | 1.30 | Gentler deceleration than for small | 1.60 | Gentler deceleration than for manually operated | 1.00 | Gentler deceleration than for without information |
| | Desired deceleration | [m/s$^2$] | 5.00 | | 3.40 | | 3.40 | | 2.20 | |
| | Vehicle length | [m] | 5.00 | | 12.00 | | 5.00 | | 5.00 | |
| | Smoothing strength | γ | 2 | | 2 | | 1 | Reaction sharper than for manually operated | 1 | Reaction sharper than for manually operated |
| | Smoothing range | β | 0.5 | | 0.5 | | 0.5 | | 0.5 | |
| Behavior characteristic index (average for 6 vehicles) | Vehicle gap time before deceleration | [s] | 1.38 to 1.43 | | 1.68 to 1.73 | Longer than for small | 1.98 to 2.03 | Longer than for manually operated | 2.28 to 2.33 | Secure margin longer than for without information |
| | Deceleration propagation time | [s] | 0.79 to 0.84 | | 1.01 to 1.08 | Decelerate with margin longer than for small | 1.01 to 1.07 | Decelerate with margin greater than for manually operated | 1.12 to 1.17 | Decelerate with margin greater than for without information |
| | Amplification factor of deceleration | | 0.90 to 0.95 | | 0.90 to 0.96 | Same as for small | 0.84 to 0.89 | Attenuation prorogation greater than for manually operated | 0.82 to 0.87 | Attenuation prorogation greater than for without information |
| | Gap-relative speed sensitivity ratio | | 2.11 to 2.44 | | 0.87 to 1.08 | Emphasize relative speed more than for small | 2.09 to 2.19 | Emphasize relative speed more than with manual operation | 1.70 to (2.86) | Emphasize relative speed more than for without information |

i. Manually operated vehicle (small)

Fig. 4.3.3-2 shows behavior characteristics of manually operated vehicles (small) at the selected parameter values. In each graph, those with the three initial speeds set in sensitivity analysis are shown together.

- In steady driving, approximately 1.4-second vehicle time gap is maintained.
- Deceleration propagation times varied from 0.4 to 1.3 seconds, with an average of approximately 0.82 seconds. As described in (a)ii of this section, Vehicle 1 reacts quickly to the sudden hard braking of the lead vehicle in the group it is following to avoid a collision, but the propagation time increases towards the rear.
- The amplification factor of the deceleration is approximately 0.92 on average, and the deceleration is damped and propagated. Note that Vehicle 1 may exceed 1, suggesting the possibility of a collision as described in (a)iii.
- The average vehicle gap distance-relative speed sensitivity ratio is approximately 2.28, which means that more weight is placed on vehicle gap distance than with automated driving.

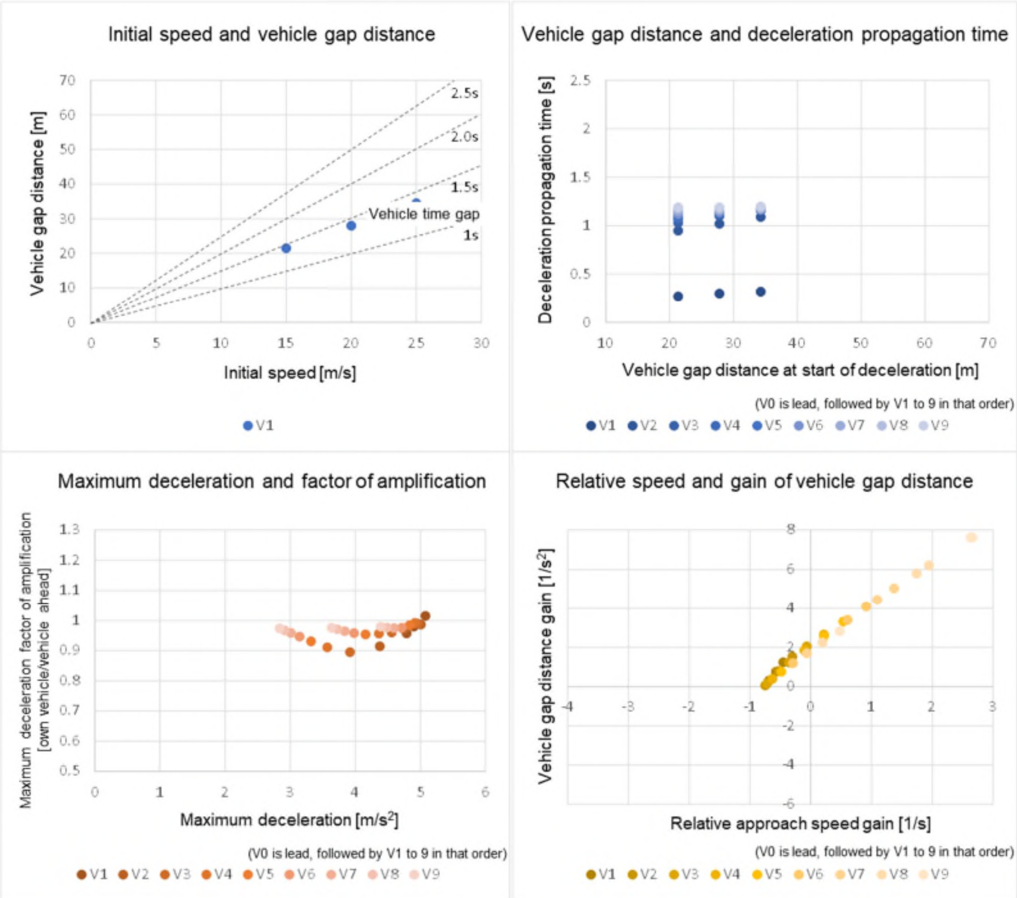



**Fig. 4.3.3-2 Vehicle behavior characteristics for manual operation (small)**

ii. Manually operated vehicle (large)

Fig. 4.3.3-3 shows behavior characteristics of manually operated vehicles (large) at the selected parameter values. For large vehicles, the safe vehicle time gap parameter is set longer than that for small vehicles, resulting in a longer vehicle gap time during steady driving and, accordingly, a longer deceleration propagation time.

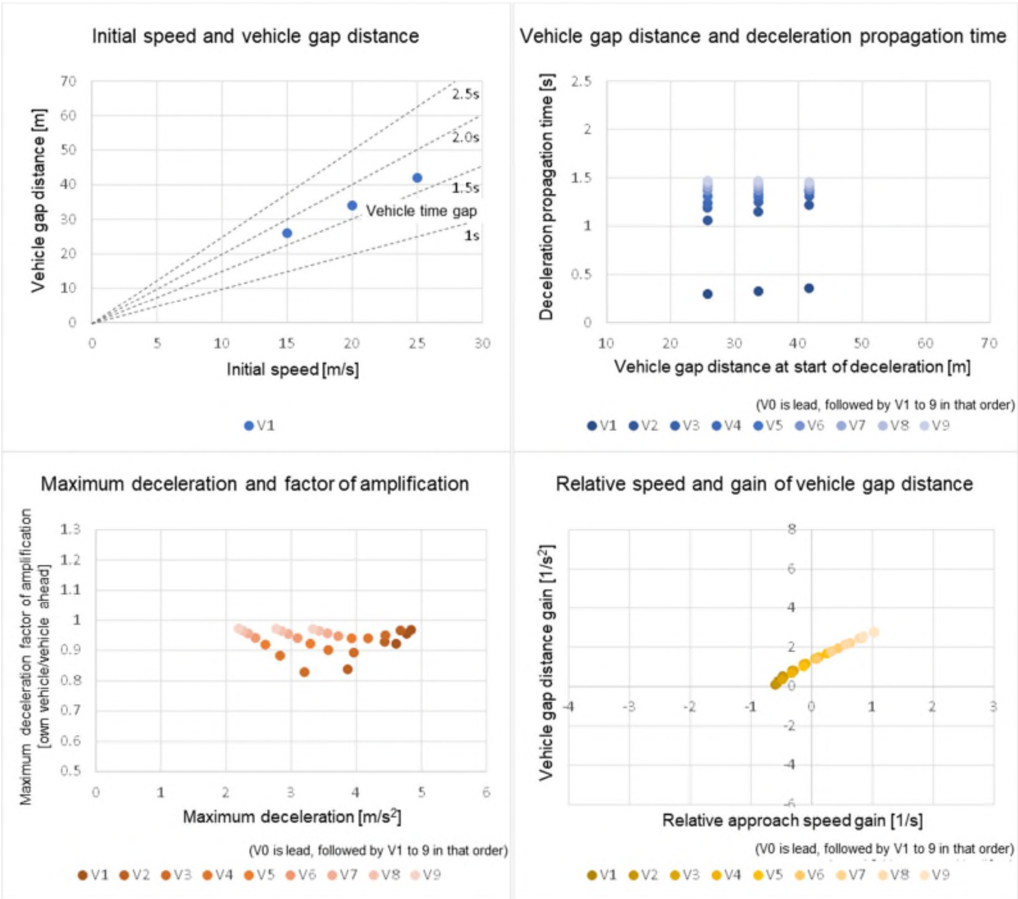



**Fig. 4.3.3-3 Vehicle behavior characteristics for manual operation (large)**

iii. Automated vehicle (without information)

Fig. 4.3.3-4 shows behavior characteristics of automated vehicles (without information) at the selected parameter values. In steady driving in automated driving, the deceleration propagation time is longer than in manual operation due to being set to maintain a longer gap than with manual operation. This is because the desired deceleration parameter in the IDM+ equation is set smaller for automated driving than for manual driving, and when driving at the same vehicle time gap and speed, automated driving shows quicker and more responsive behavior, but because automated driving is done with a longer vehicle time gap, the deceleration propagation time is also longer, as shown in Fig. 4.3.3-5. This also results in a smaller amplification factor of deceleration and safer stopping behavior.

The gap-relative speed sensitivity ratio indicates that the behavior is more focused on relative speed than with manually operated vehicles.

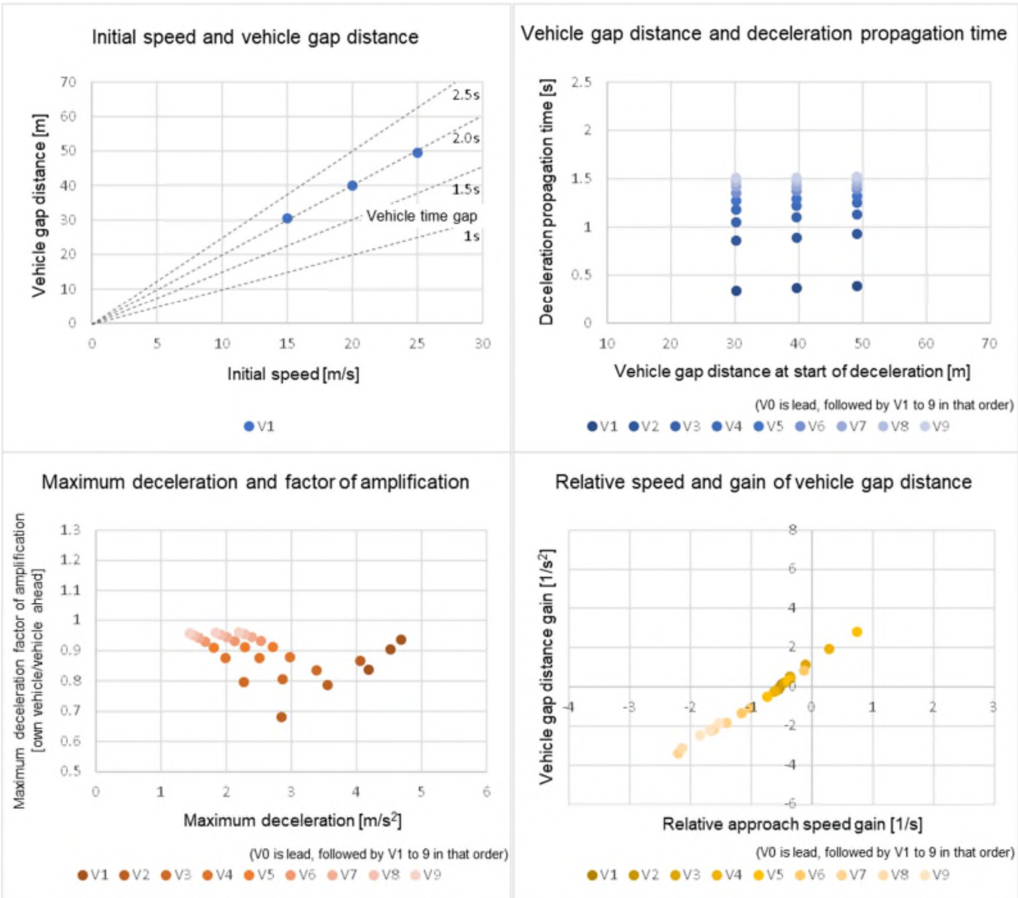



**Fig. 4.3.3-4 Vehicle behavior characteristics for automated driving (without information)**

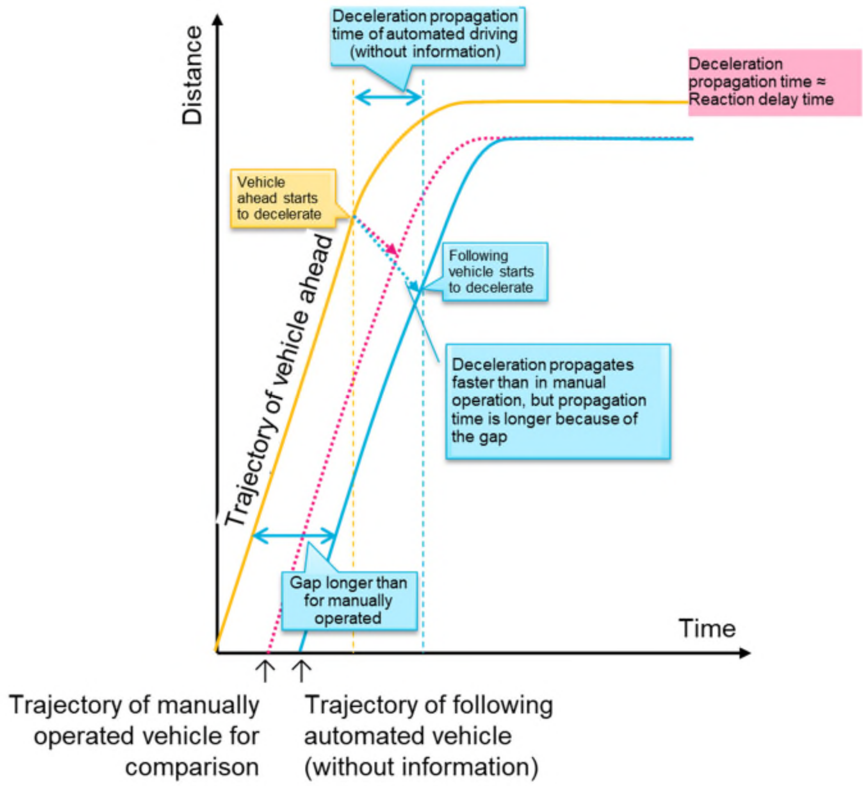



**Fig. 4.3.3-5 Model of comparing deceleration behavior of automated vehicles and manually operated vehicles**

iv. Automated vehicle (with information)

Fig. 4.3.3-6 shows behavior characteristics of automated vehicles (with information) at the selected parameter values. Vehicles were set to maintain a longer gap if with information than without information. Accordingly, the deceleration propagation time is longer and the amplification factor of deceleration is smaller than in behavior without information.

As shown in Fig. 4.3.3-7, in the simulation, automated vehicles first drive in the without information setting, and then switch to the with information setting when obstacle detection information of the lead vehicle of a group of vehicles is transmitted. Therefore, deceleration is done to maintain a longer gap than that at the time information is transmitted. This results in preliminary deceleration if information is transmitted prior to the deceleration propagation time due to following the vehicle ahead.

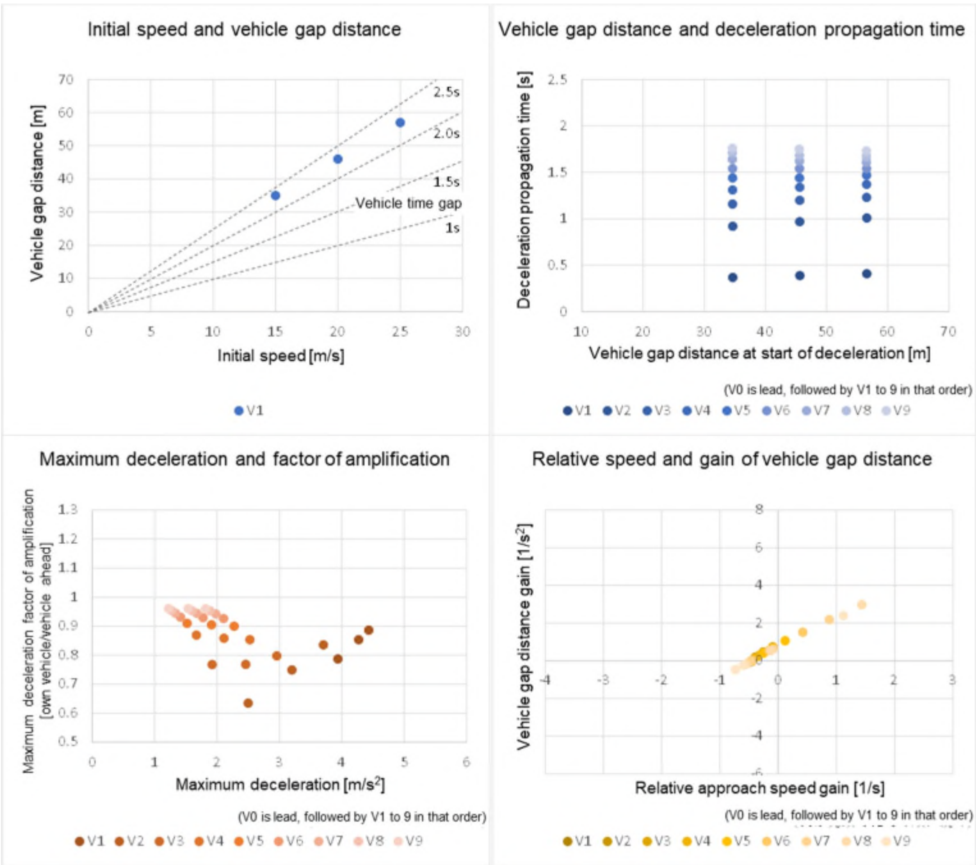



**Fig. 4.3.3-6 Vehicle behavior characteristics for automated driving (with information)**

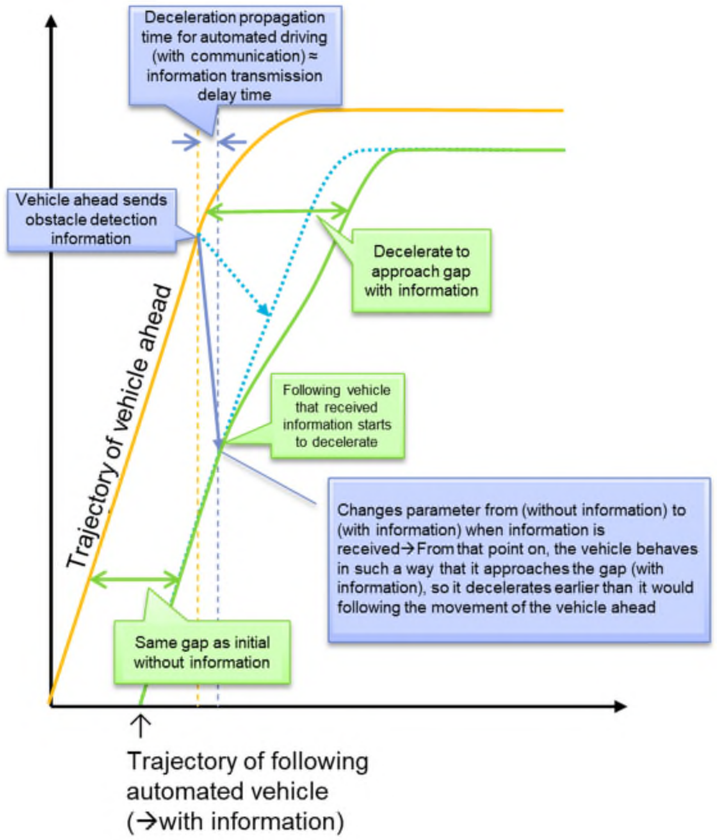



**Fig. 4.3.3-7 Model of preliminary deceleration behavior of automated vehicles by information transfer**

### 4.3.4 Evaluation by simulation

Assuming multiple patterns of communication specifications, simulations were conducted in multiple cases with different conditions for communication specifications, automated vehicles/manually operated vehicles, and small/large vehicles. The simulation results are shown below.

(1) Communication specifications

For the communication specifications in the simulation, multiple patterns were set for the timing of receiving the first message by the vehicles following based on the following assumptions.

- Delay in timing of receiving in vehicles following due to sudden deterioration of the communication environment, such as communication shadowing by large vehicles
- Consideration of the difference between when 700 MHz band intelligent transport system are used and not used

1） Impact on communication quality due to differences in radio wave propagation characteristics between the 700 MHz and 5.9 GHz bands

The 5.9 GHz band is more susceptible to deterioration of communication quality due to shadowing by vehicles, multipath effects, etc. The 5.9 GHz band is more susceptible to shadowing losses due to vehicles in between, increasing the likelihood of non-delivery of messages due to deterioration of the communication environment (vehicles at the rear are more susceptible).

2） Impact on communication congestion due to differences in overall communication capacity with and without the 700 MHz band

With the 700 MHz band, there is a one channel net increase in the number of communication channels, and overall communication volume also increases, which raises concerns about the impact on communication congestion. As a communication requirement for use cases where the impact of communication congestion is small, messages are sent in 100 ms cycles after the occurrence of an event, and conditions were set for timing of receiving between 100 ms and 500 ms to account for the possibility of non-delivery of messages.

Simulations were conducted using the nine different patterns, 1 to 9, shown in Table 4.3.4-1 as communication specifications, varying the delay time from the timing of obstacle detection until the information reaches the following vehicle.

**Table 4.3.4-1 Setting patterns for communication specifications**

**Information transmission delay time**

| | Vehicle1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 | Remarks |
|---|---|---|---|---|---|---|---|
| **Pattern 1** | 100 ms | 100 ms | 100 ms | 200ms | 200ms | 200ms | Assumes (small) deterioration of communication environment for Vehicle 4 subsequent vehicles |
| **Pattern 2** | 100 ms | 100 ms | 100 ms | 200ms | 200ms | 300ms | Assumes (medium) deterioration of communication environment for Vehicle 4 and subsequent vehicles |
| **Pattern 3** | 100 ms | 100 ms | 100 ms | 300ms | 300ms | 300ms | Assumes (large) deterioration of communication environment for Vehicle 4 and subsequent vehicles |
| **Pattern 4** | 100 ms | 100 ms | 200ms | 300ms | 300ms | 400 ms | Assumes (small) deterioration of communication environment for Vehicle 3 subsequent vehicles |
| **Pattern 5** | 100 ms | 100 ms | 200ms | 300ms | 400 ms | 400 ms | Assumes (medium) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | deterioration of communication environment for Vehicle 3 and subsequent vehicles |
| **Pattern 6** | 100 ms | 100 ms | 200ms | 300ms | 400 ms | 500ms | Assumes (large) deterioration of communication environment for Vehicle 3 and subsequent vehicles |
| **Pattern 7** | 100 ms | 100 ms | 100 ms | 100 ms | 100 ms | 100 ms | According to communication requirements |
| **Pattern 8** | 500ms | 500ms | 500ms | 500ms | 500ms | 500ms | Comparison and verification |
| **Pattern 9** | 1s | 1s | 1s | 1s | 1s | 1s | Comparison and verification |
| **Pattern 11** | — | 100 ms | — | — | — | — | |
| **Pattern 12** | — | 300ms | — | — | — | — | |
| **Pattern 13** | — | 500ms | — | — | — | — | |

(2) Evaluation details

In the simulation, based on the communication specifications in (1) above, behavior of the vehicles following is evaluated when the lead vehicle is made to stop at a deceleration of 5 $m/s^2$ (≈0.5 G) with a group of vehicles in steady driving having an automated vehicle as the first (Vehicle 0) and six vehicles following (Vehicle 1 to Vehicle 6). Steady driving is a state in which the vehicle ahead runs at a constant speed and the vehicles following in ACC driving do not change speed. Here, major prefectural and municipal roads are assumed, with the lead automated vehicle traveling at 54 km/h (15 m/s).

As an evaluation index, the time variation of speed, acceleration, and jerk of the vehicles following is shown in a graph and compared between cases. After presenting simulation results for a total of 16 cases in (3) to (5) below, the results of each case are compared and evaluated in (6).

(3) Simulation results: Suddenly stopping from the speed range of major prefectural and municipal roads with all automated vehicles (Cases 0 to 9)

Cases in the simulation are shown in Table 4.3.4-2. In addition, (a) to (j) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case.

**Table 4.3.4-2 Case settings list (Cases 0 to 9)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **0** | | 15 m/s (54 km/h) | All automated driving | Without communication |
| **1** | Pattern 1 | ” | ” | With communication |
| **2** | Pattern 2 | ” | ” | ” |
| **3** | Pattern 3 | ” | ” | ” |
| **4** | Pattern 4 | ” | ” | ” |
| **5** | Pattern 5 | ” | ” | ” |
| **6** | Pattern 6 | ” | ” | ” |
| **7** | Pattern 7 | ” | ” | ” |
| **8** | Pattern 8 | ” | ” | ” |
| **9** | Pattern 9 | ” | ” | ” |

(a) Case 0

**Table 4.3.4-3 Timing of information transmission (Case 0)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

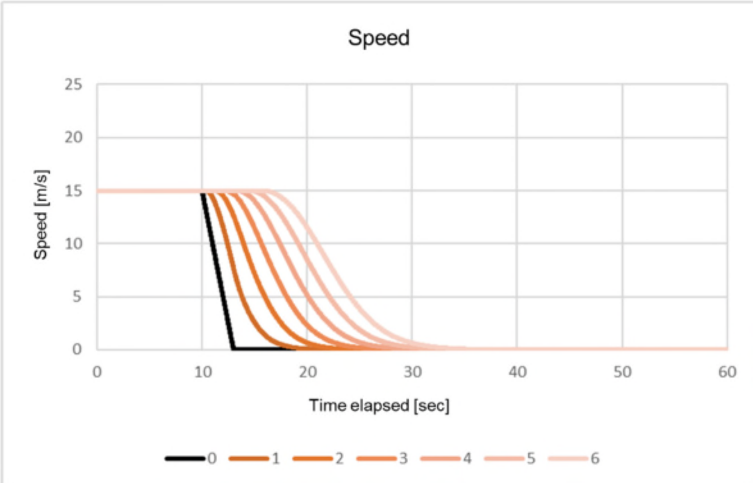



**Fig. 4.3.4-1 Change in speed at sudden stop (Case 0)**

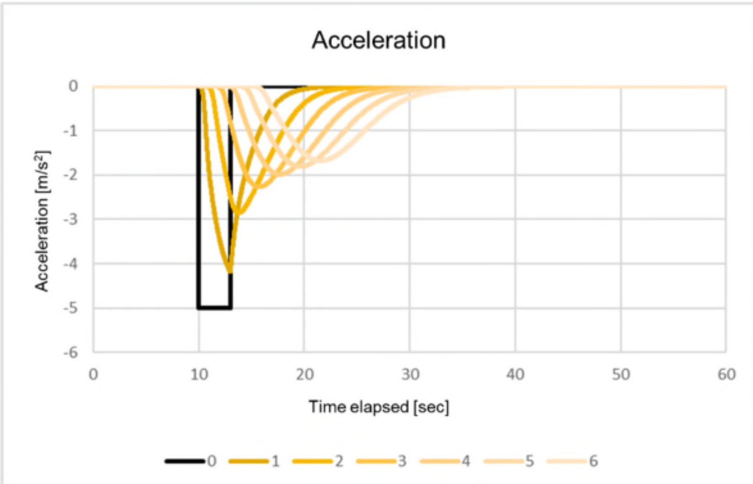



**Fig. 4.3.4-2 Change in acceleration at sudden stop (Case 0)**

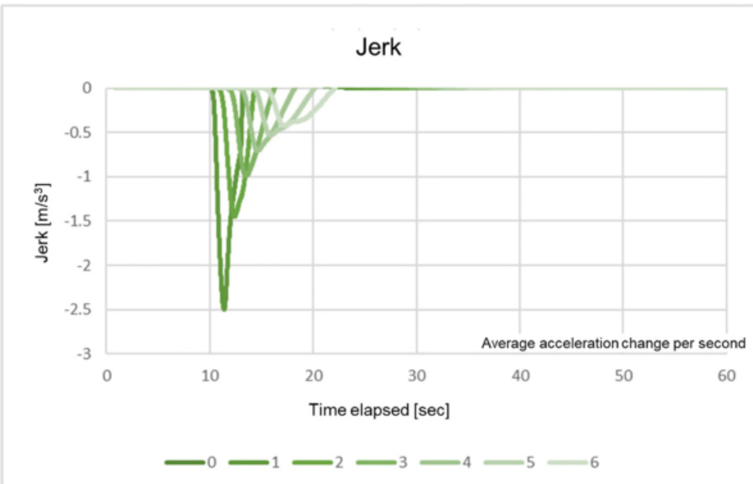



**Fig. 4.3.4-3 Change in jerk at sudden stop (Case 0)**

(b) Case 1

**Table 4.3.4-4 Timing of information transmission (Case 1)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 200 | 200 | 200 |

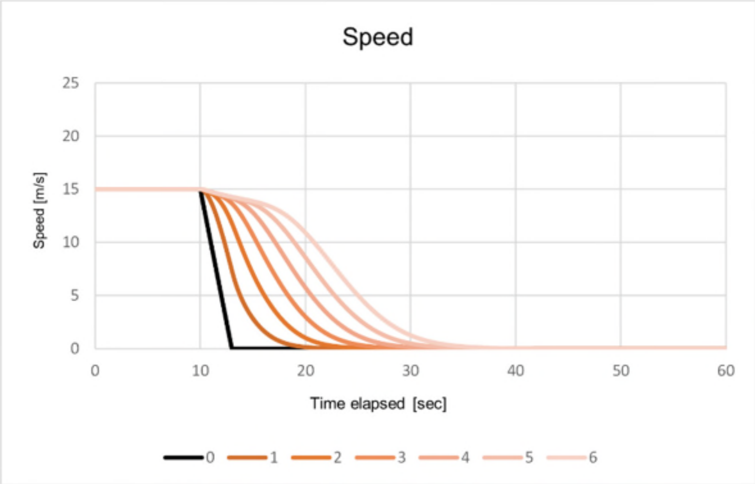



**Fig. 4.3.4-4 Change in speed at sudden stop (Case 1)**

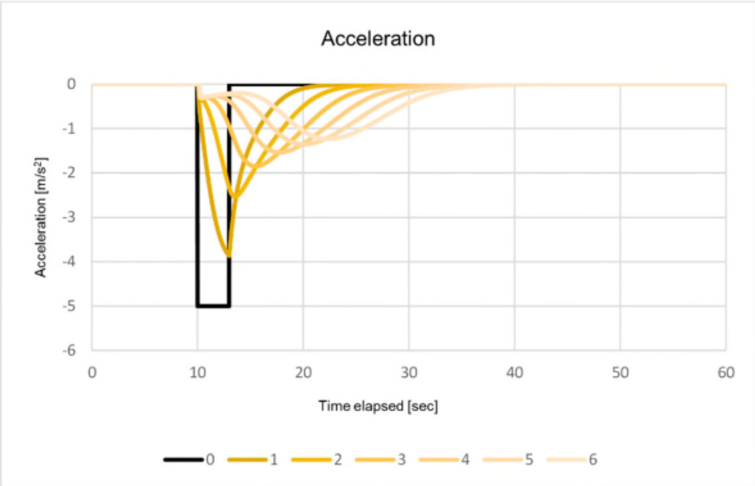



**Fig. 4.3.4-5 Change in acceleration at sudden stop (Case 1)**

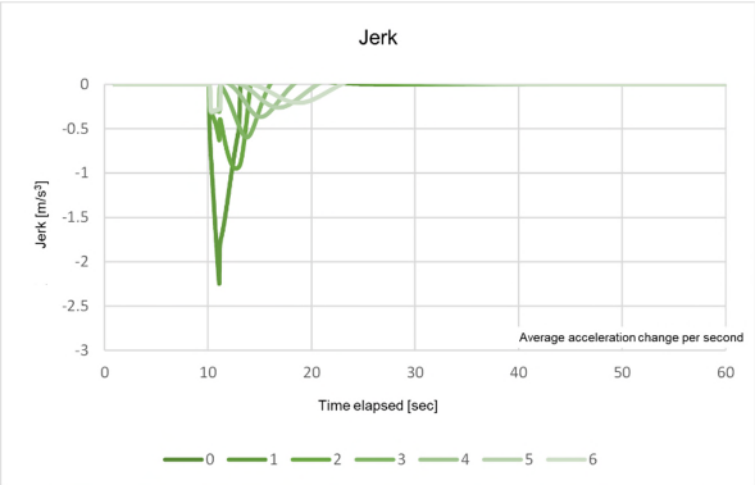



**Fig. 4.3.4-6 Change in jerk at sudden stop (Case 1)**

(c) Case 2

**Table 4.3.4-5 Timing of information transmission (Case 2)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 200 | 200 | 300 |

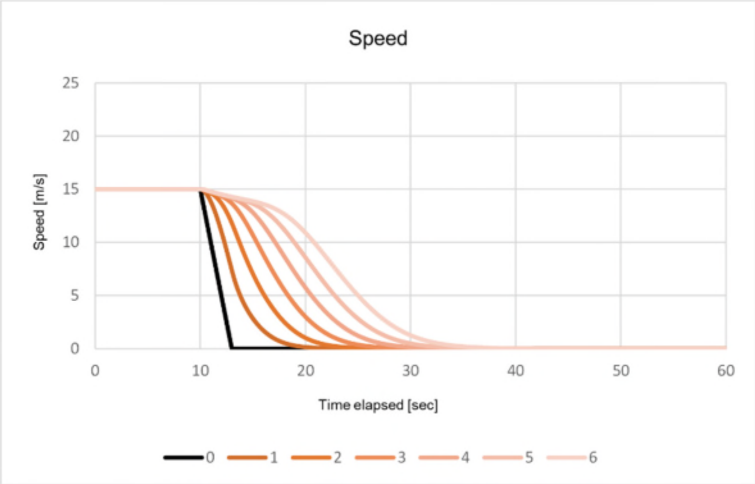



**Fig. 4.3.4-7 Change in speed at sudden stop (Case 2)**

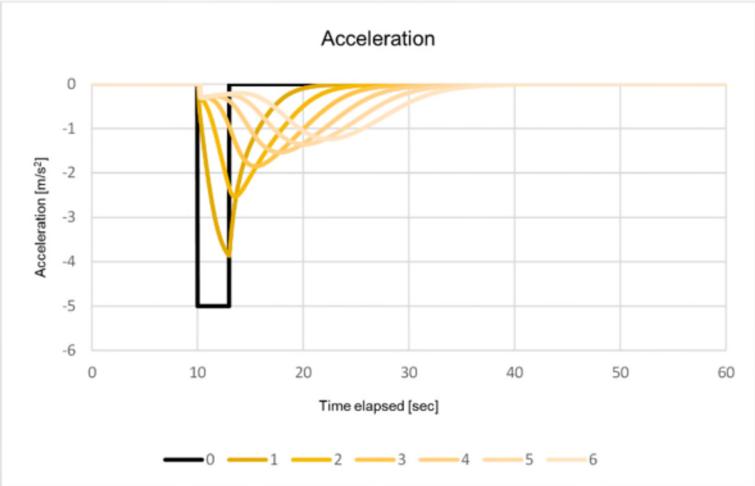



**Fig. 4.3.4-8 Change in acceleration at sudden stop (Case 2)**

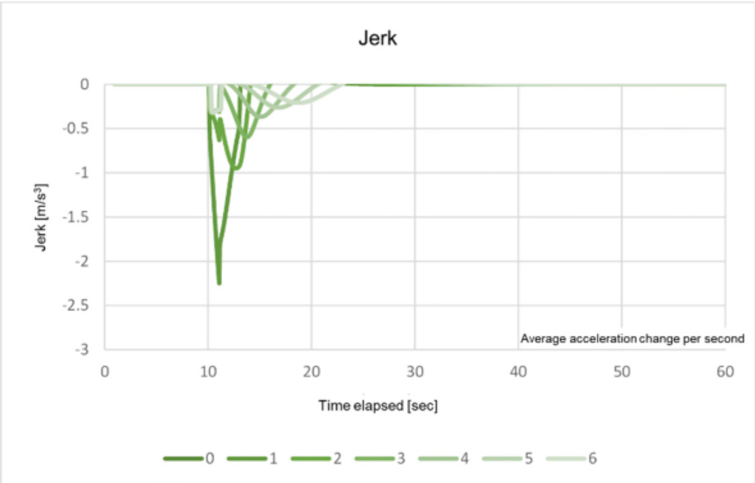



**Fig. 4.3.4-9 Change in jerk at sudden stop (Case 2)**

(d) Case 3

**Table 4.3.4-6 Timing of information transmission (Case 3)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 300 | 300 | 300 |

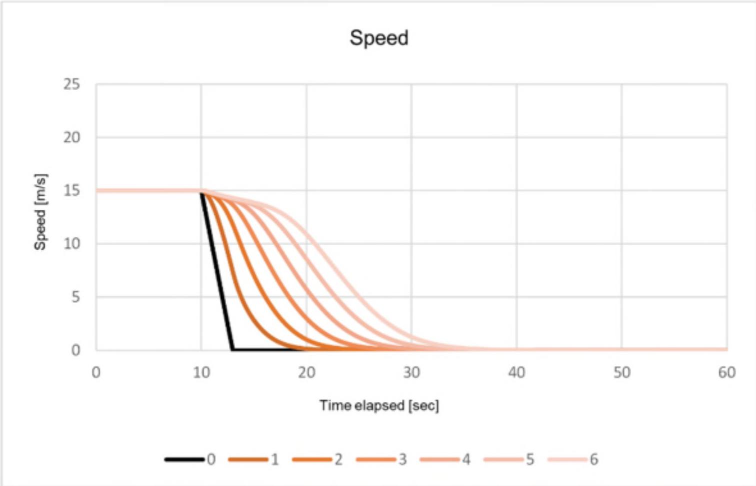



**Fig. 4.3.4-10 Change in speed at sudden stop (Case 3)**

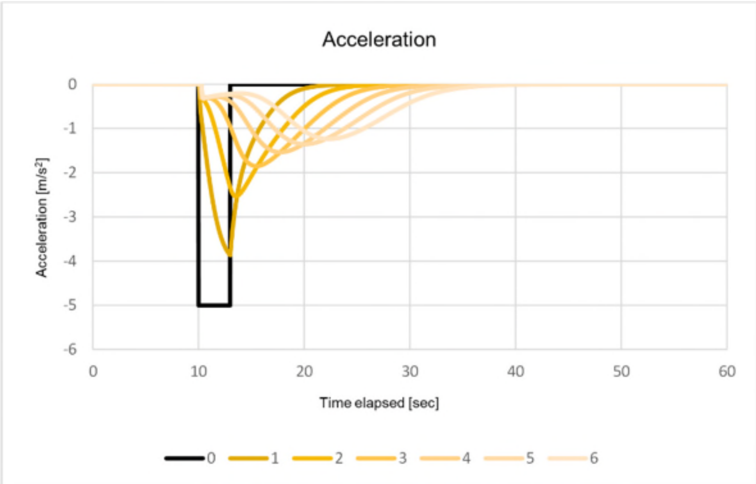



**Fig. 4.3.4-11 Change in acceleration at sudden stop (Case 3)**

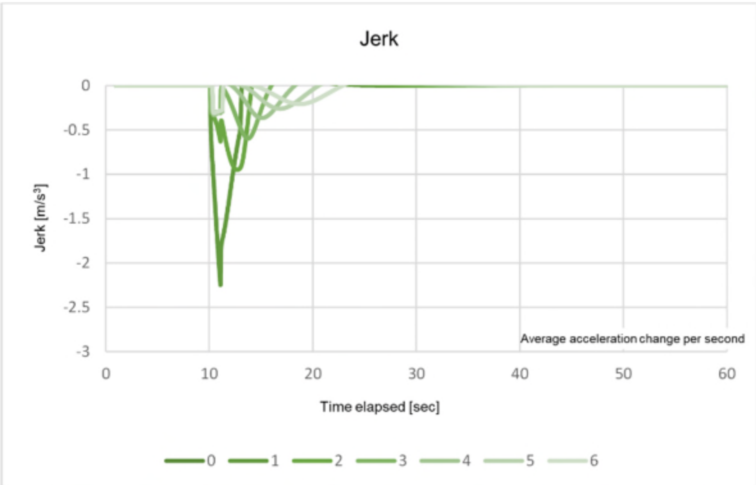



**Fig. 4.3.4-12 Change in jerk at sudden stop (Case 3)**

(e) Case 4

**Table 4.3.4-7 Timing of information transmission (Case 4)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 300 | 400 |

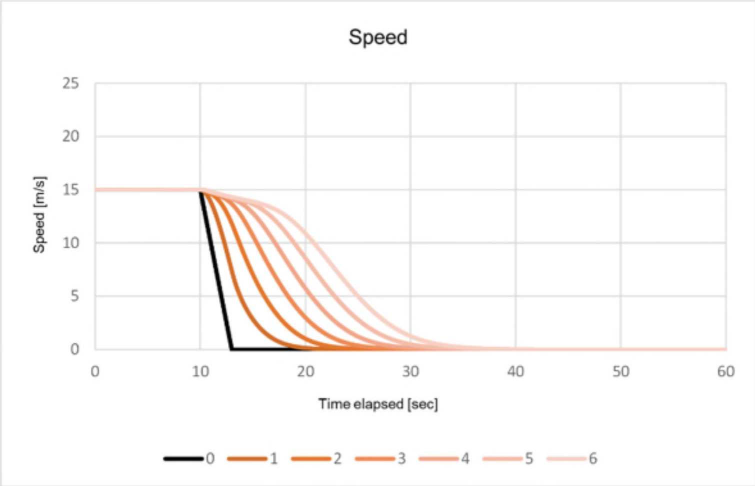



**Fig. 4.3.4-13 Change in speed at sudden stop (Case 4)**

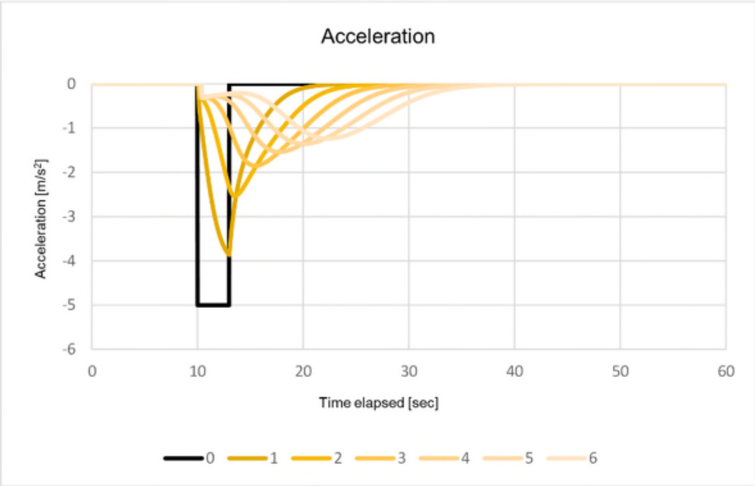



**Fig. 4.3.4-14 Change in acceleration at sudden stop (Case 4)**

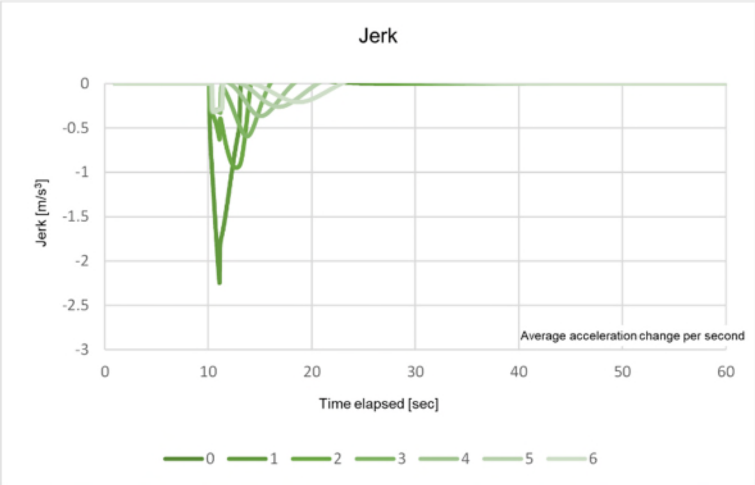



**Fig. 4.3.4-15 Change in jerk at sudden stop (Case 4)**

(f) Case 5

**Table 4.3.4-8 Timing of information transmission (Case 5)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 400 | 400 |

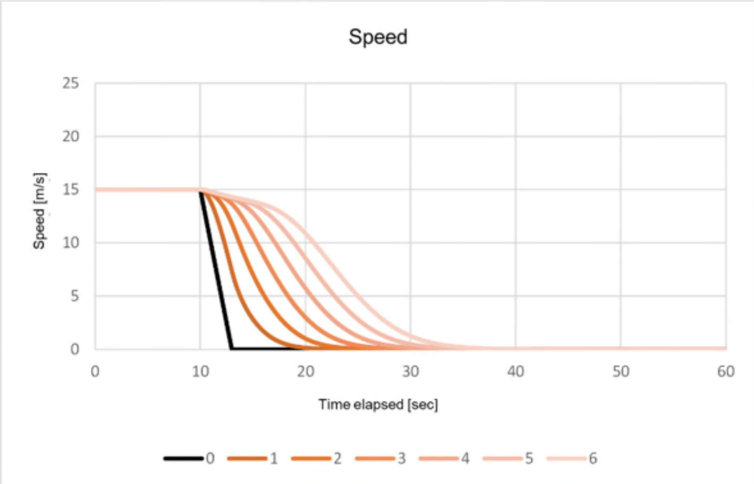



**Fig. 4.3.4-16 Change in speed at sudden stop (Case 5)**

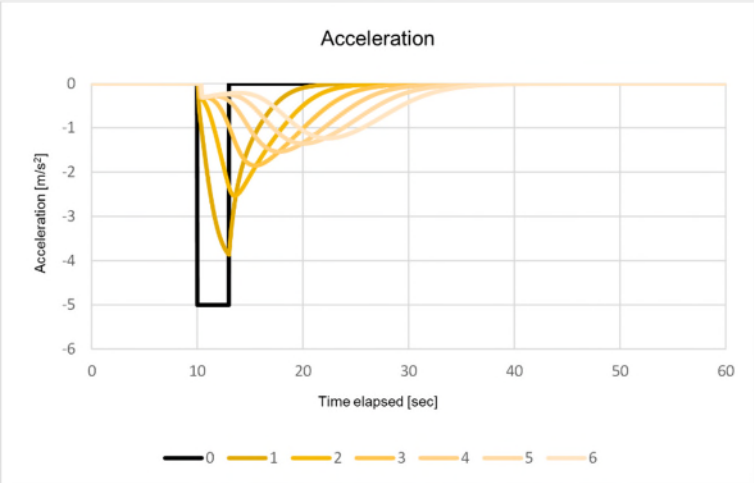



**Fig. 4.3.4-17 Change in acceleration at sudden stop (Case 5)**

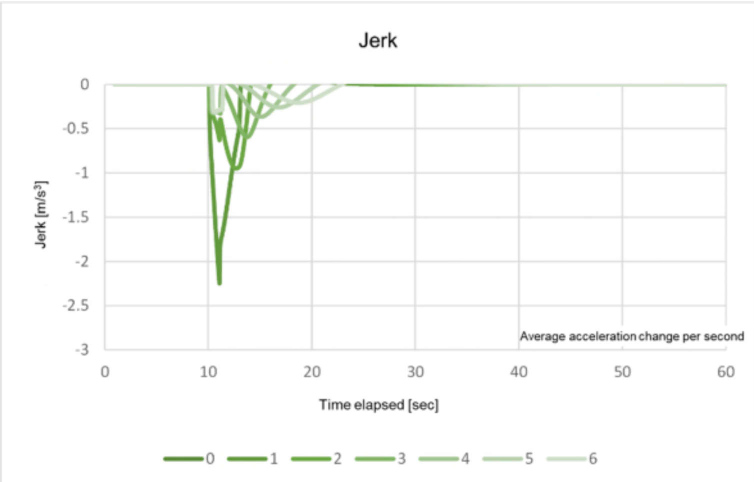



**Fig. 4.3.4-18 Change in jerk at sudden stop (Case 5)**

(g) Case 6

**Table 4.3.4-9 Timing of information transmission (Case 6)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 400 | 500 |

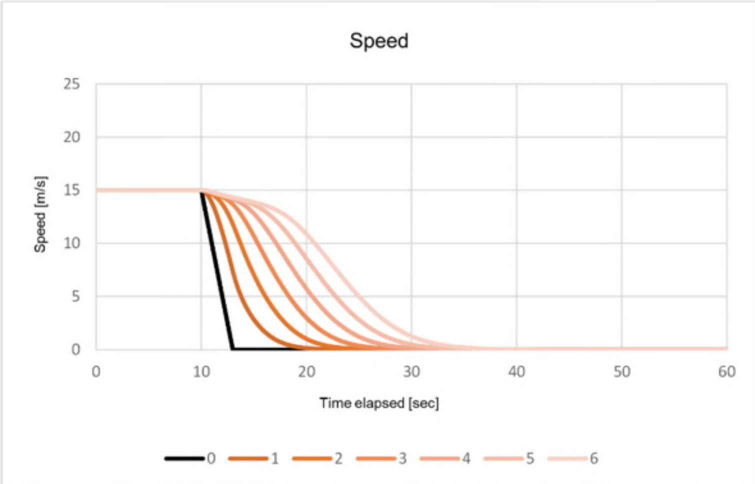



**Fig. 4.3.4-19 Change in speed at sudden stop (Case 6)**

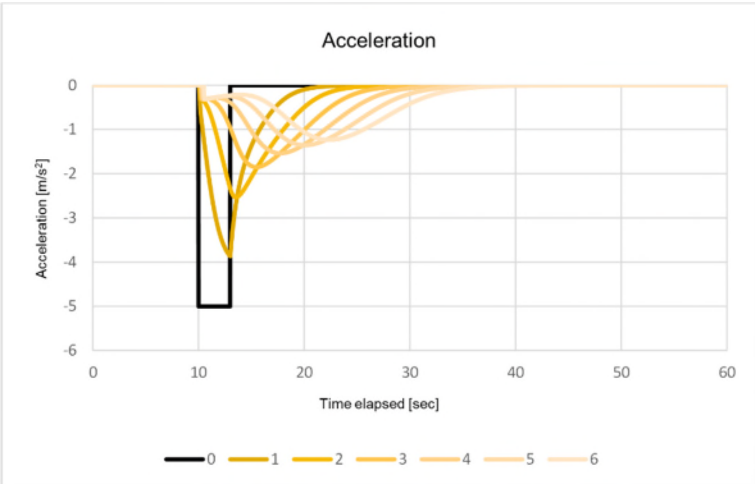



**Fig. 4.3.4-20 Change in acceleration at sudden stop (Case 6)**

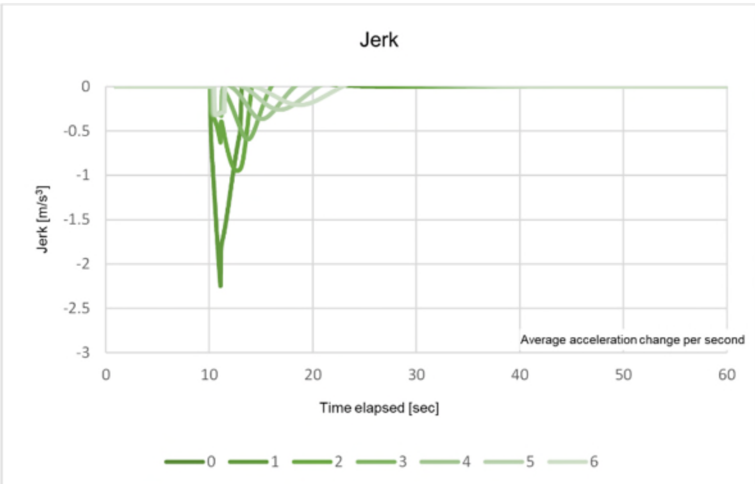



**Fig. 4.3.4-21 Change in jerk at sudden stop (Case 6)**

(h) Case 7

**Table 4.3.4-10 Timing of information transmission (Case 7)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 100 | 100 | 100 |

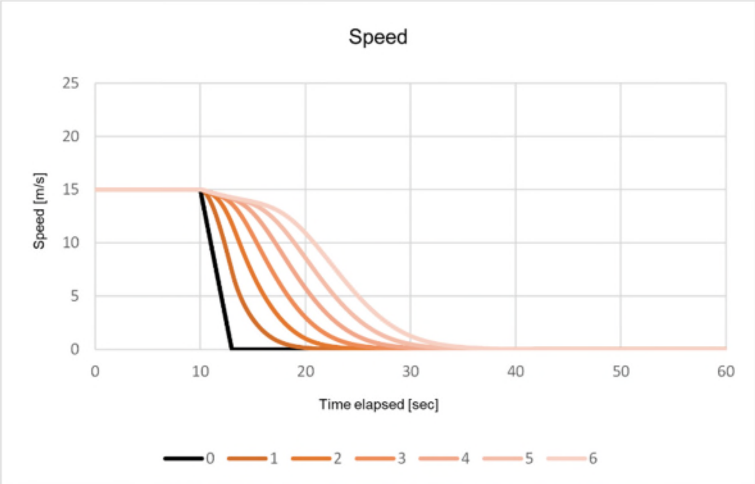



**Fig. 4.3.4-22 Change in speed at sudden stop (Case 7)**

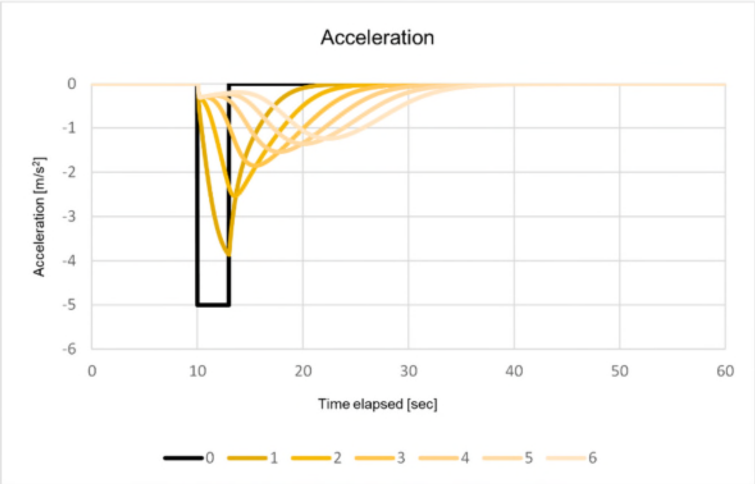



**Fig. 4.3.4-23 Change in acceleration at sudden stop (Case 7)**

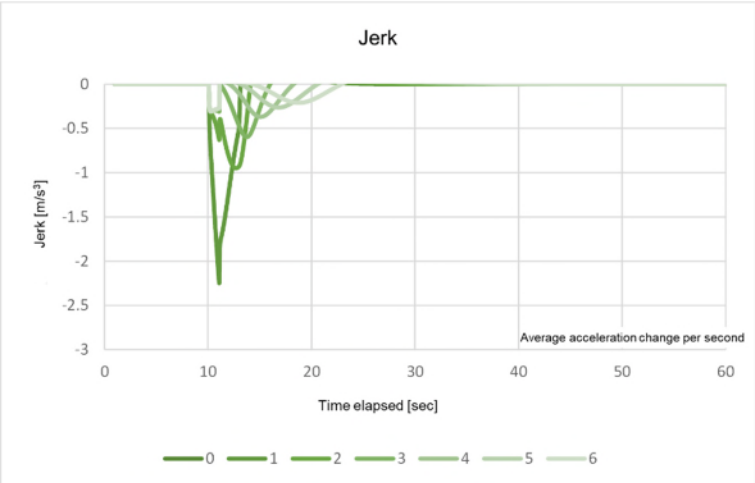



**Fig. 4.3.4-24 Change in jerk at sudden stop (Case 7)**

(i) Case 8

**Table 4.3.4-11 Timing of information transmission (Case 8)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 500 | 500 | 500 | 500 | 500 | 500 |

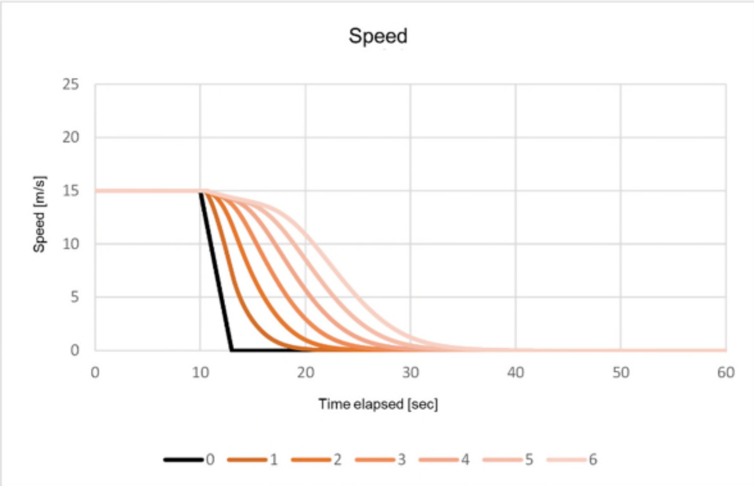



**Fig. 4.3.4-25 Change in speed at sudden stop (Case 8)**

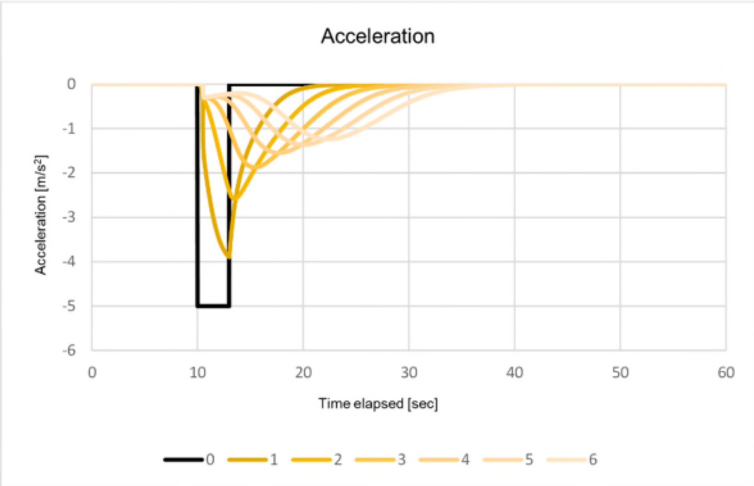



**Fig. 4.3.4-26 Change in acceleration at sudden stop (Case 8)**

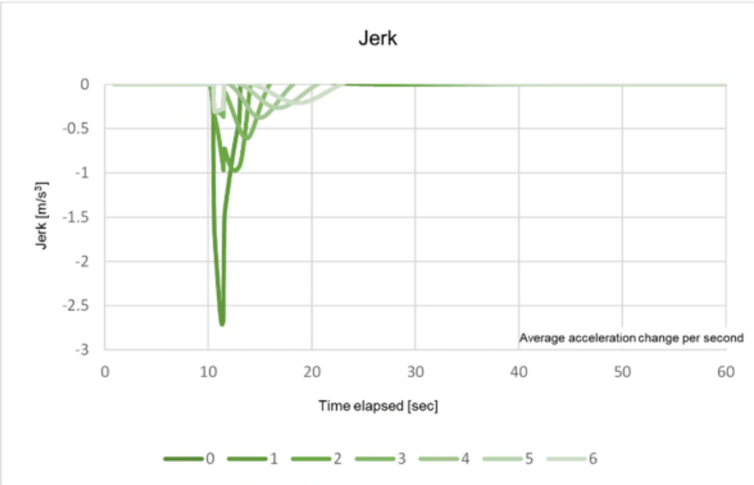



**Fig. 4.3.4-27 Change in jerk at sudden stop (Case 8)**

(j) Case 9

**Table 4.3.4-12 Timing of information transmission (Case 9)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |

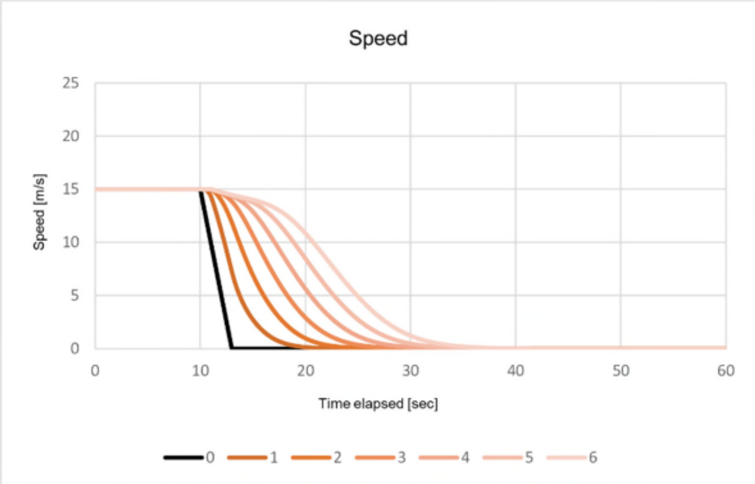



**Fig. 4.3.4-28 Change in speed at sudden stop (Case 9)**

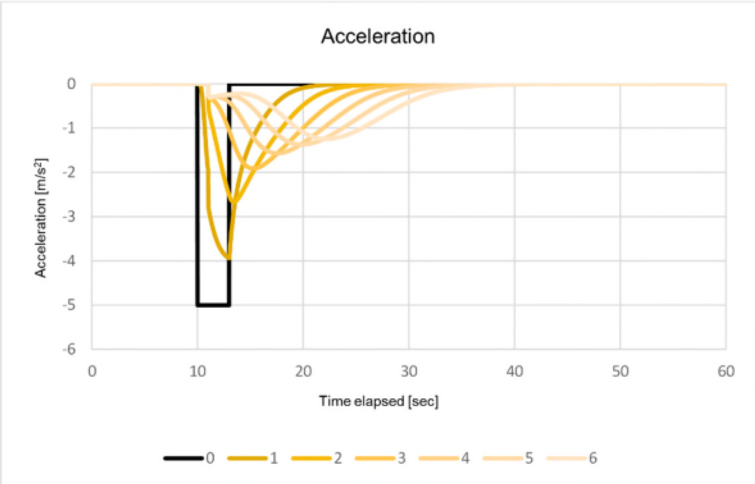



**Fig. 4.3.4-29 Change in acceleration at sudden stop (Case 9)**

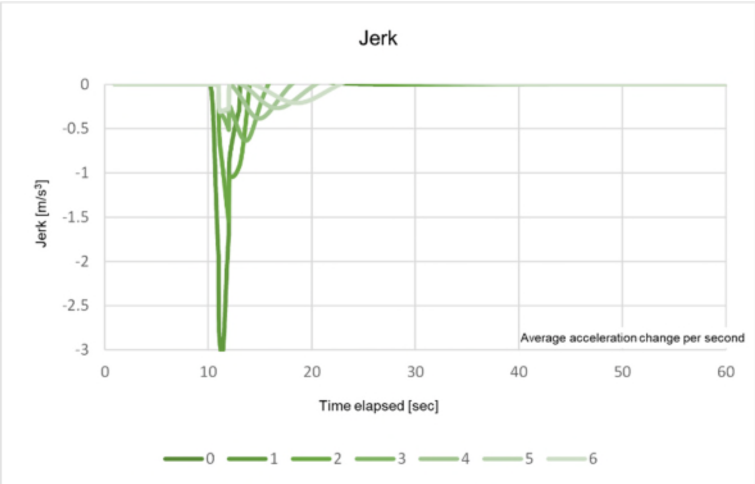



**Fig. 4.3.4-30 Change in jerk at sudden stop (Case 9)**

(4) Simulation results: Suddenly stopping from the speed range of major prefectural and municipal roads with automated vehicles mixed with manually operated vehicles (Cases 10 to 13)

Cases in the simulation are shown in Table 4.3.4-13. In addition, (a) to (d) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case.

**Table 4.3.4-13 Case settings list (Cases 10 to 13)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **10** | | 15 m/s (54 km/h) | Vehicle 2 is automated driving and others are manually operated (small) | Without communication |
| **11** | Pattern 11 | ” | ” | With communication |
| **12** | Pattern 12 | ” | ” | ” |
| **13** | Pattern 13 | ” | ” | ” |

(a) Case 10

**Table 4.3.4-14 Timing of information transmission (Case 10)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

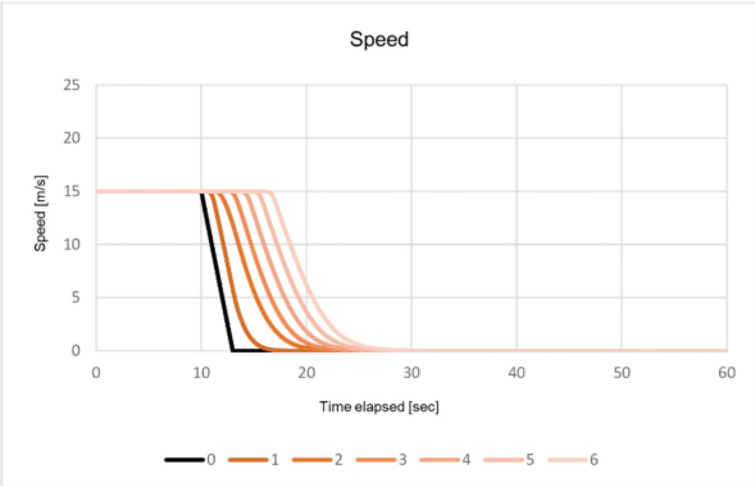



**Fig. 4.3.4-31 Change in speed at sudden stop (Case 10)**

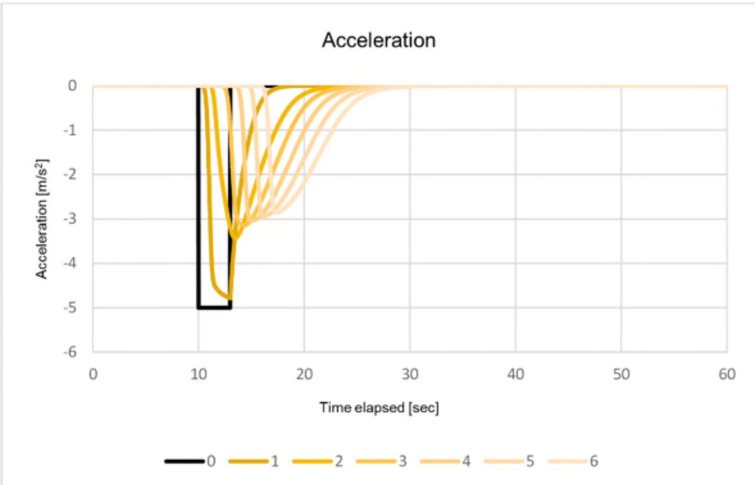



**Fig. 4.3.4-32 Change in acceleration at sudden stop (Case 10)**

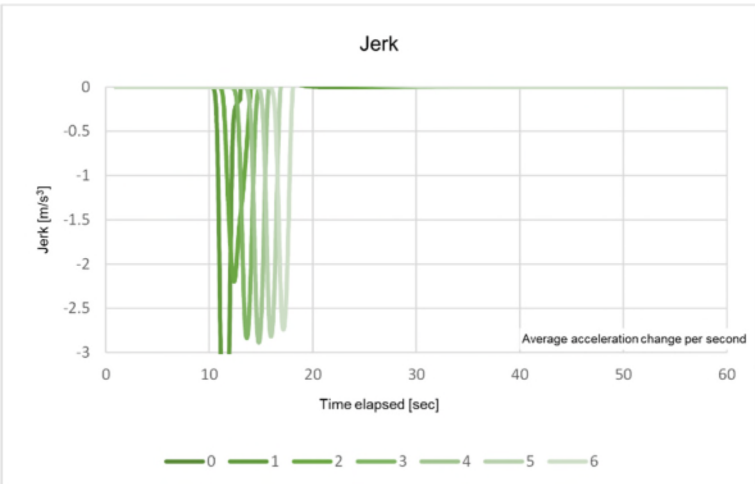



**Fig. 4.3.4-33 Change in jerk at sudden stop (Case 10)**

(b) Case 11

**Table 4.3.4-15 Timing of information transmission (Case 11)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 100 | - | - | - | - |

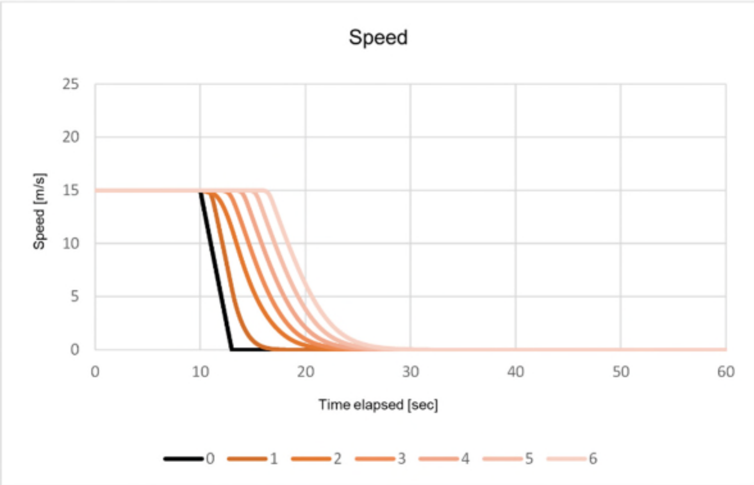



**Fig. 4.3.4-34 Change in speed at sudden stop (Case 11)**

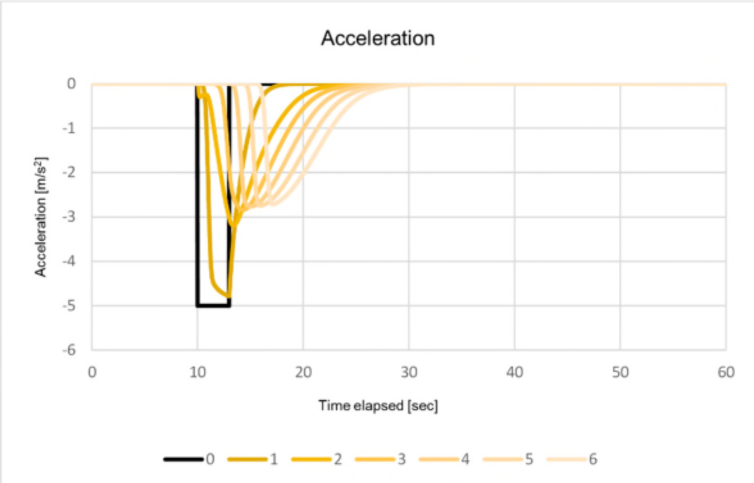



**Fig. 4.3.4-35 Change in acceleration at sudden stop (Case 11)**

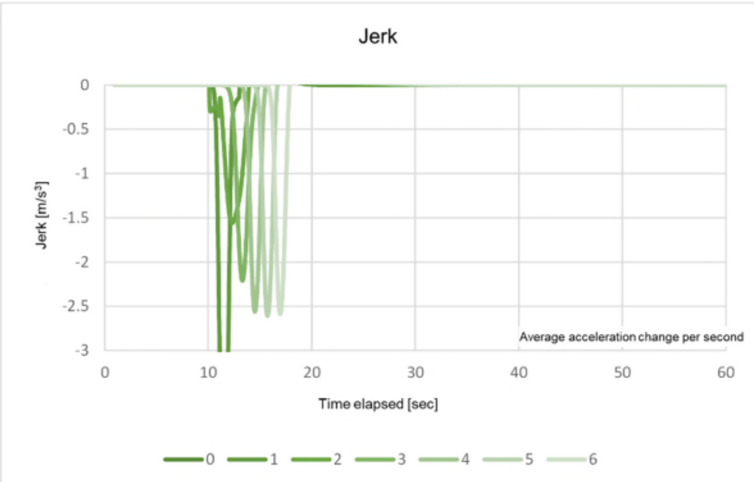



**Fig. 4.3.4-36 Change in jerk at sudden stop (Case 11)**

(c) Case 12

**Table 4.3.4-16 Timing of information transmission (Case 12)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 300 | - | - | - | - |

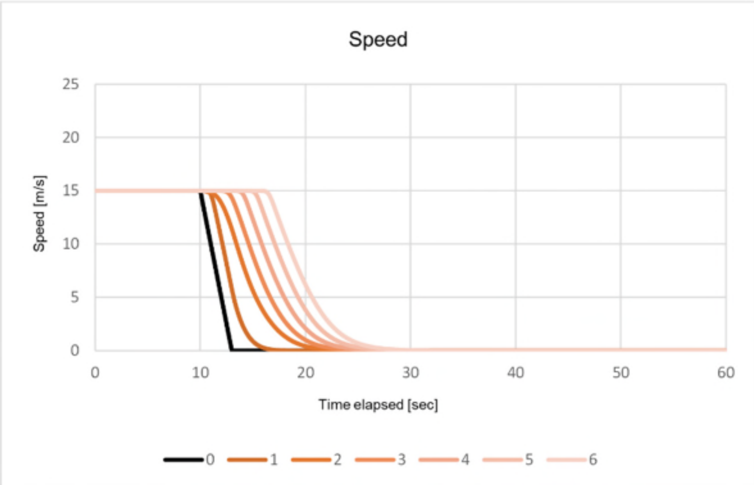



**Fig. 4.3.4-37 Change in speed at sudden stop (Case 12)**

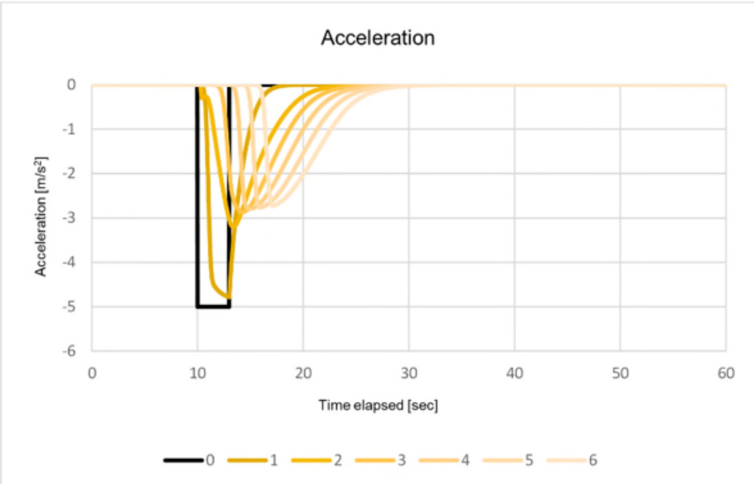



**Fig. 4.3.4-38 Change in acceleration at sudden stop (Case 12)**

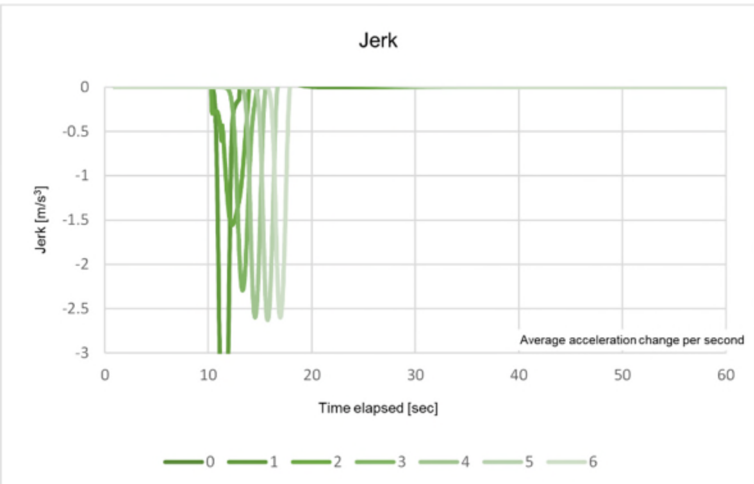



**Fig. 4.3.4-39 Change in jerk at sudden stop (Case 12)**

(d) Case 13

**Table 4.3.4-17 Timing of information transmission (Case 13)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 500 | - | - | - | - |

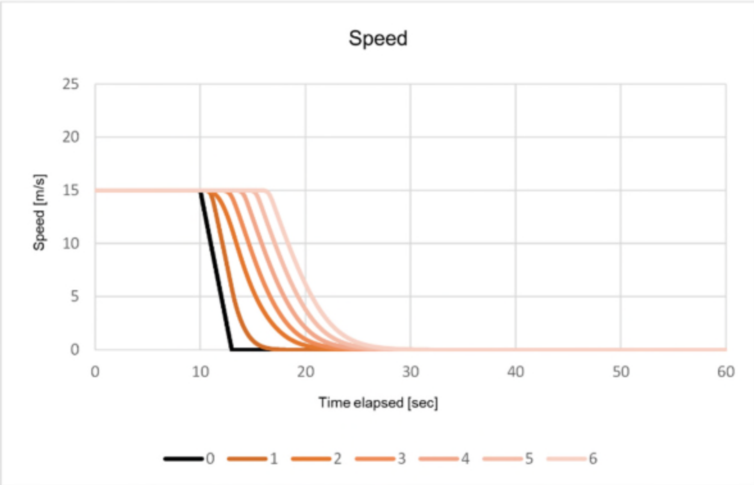



**Fig. 4.3.4-40 Change in speed at sudden stop (Case 13)**

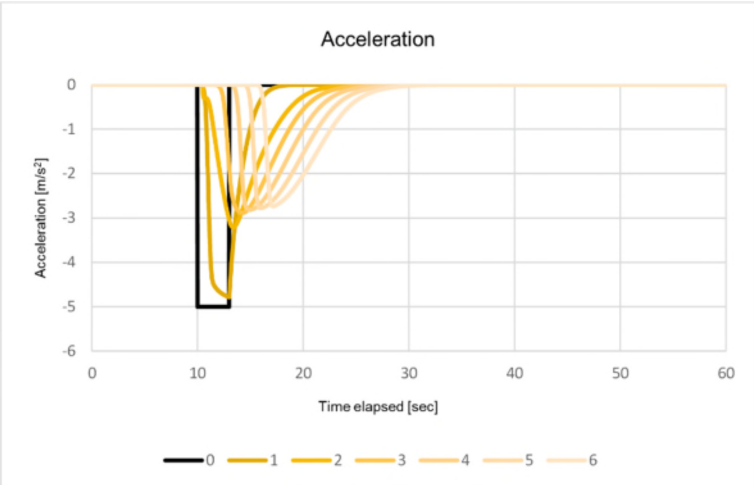



**Fig. 4.3.4-41 Change in acceleration at sudden stop (Case 13)**

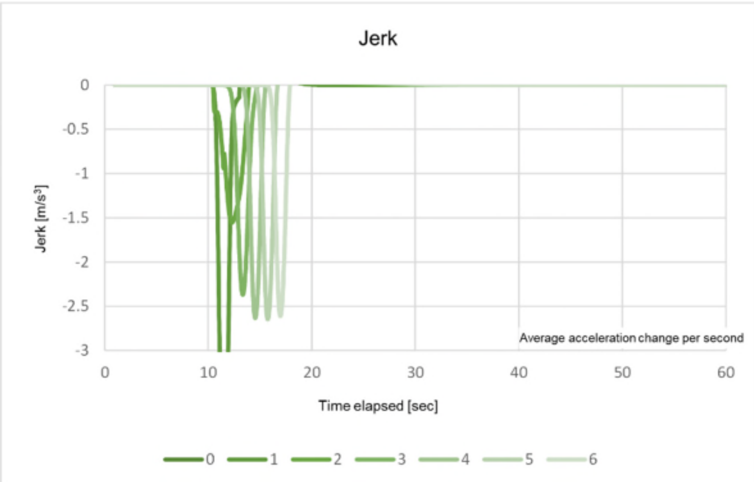



**Fig. 4.3.4-42 Change in jerk at sudden stop (Case 13)**

(5) Simulation results: Suddenly stopping from the speed range of major prefectural and municipal roads with large vehicles mixed in (Cases 30 and 31)

Cases in the simulation are shown in Table 4.3.4-18. In addition, (a) to (b) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case.

**Table 4.3.4-18 Case settings list (Cases 30, 31)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **30** | | 15 m/s (54 km/h) | Vehicle 2 is automated driving and others are manually operated (large) | Without communication |
| **31** | Pattern 11 | ” | ” | With communication |

(a) Case 30

**Table 4.3.4-19 Timing of information transmission (Case 30)**

| | Vehicle 1 (Manually operated, large) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated, large) | Vehicle 4 (Manually operated, large) | Vehicle 5 (Manually operated, large) | Vehicle 6 (Manually operated, large) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

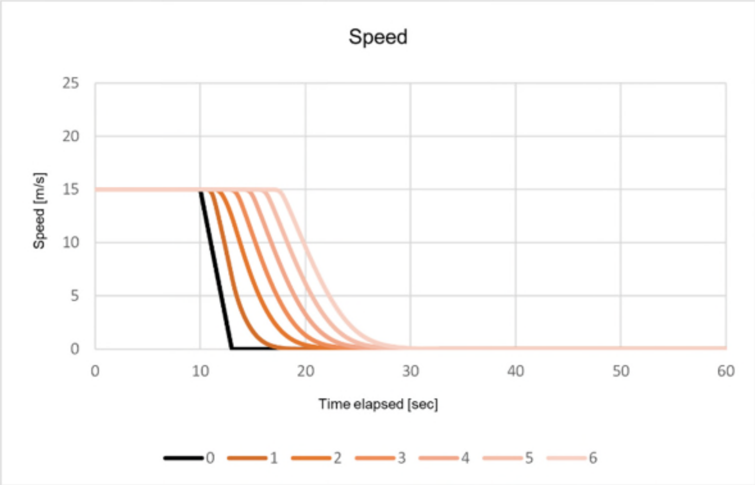



**Fig. 4.3.4-43 Change in speed at sudden stop (Case 30)**

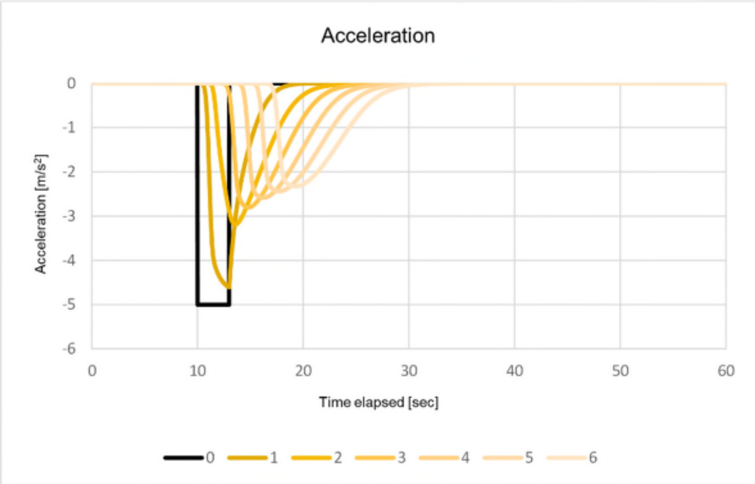



**Fig. 4.3.4-44 Change in acceleration at sudden stop (Case 30)**

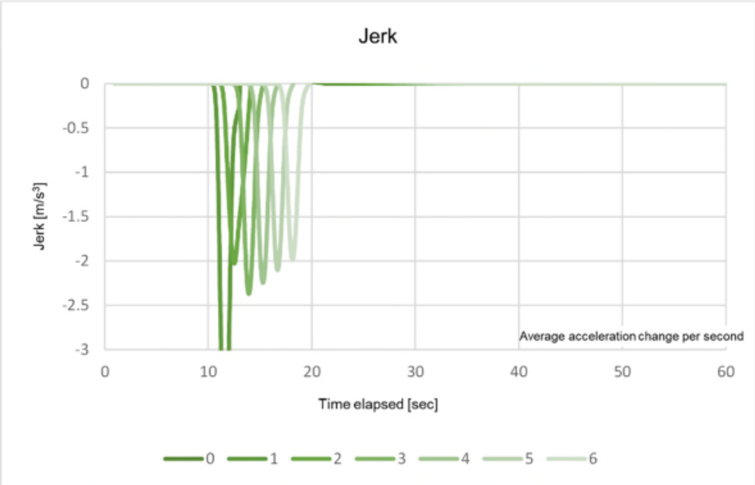



**Fig. 4.3.4-45 Change in jerk at sudden stop (Case 30)**

(b) Case 31

**Table 4.3.4-20 Timing of information transmission (Case 31)**

| | Vehicle 1 (Manually operated, large) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated, large) | Vehicle 4 (Manually operated, large) | Vehicle 5 (Manually operated, large) | Vehicle 6 (Manually operated, large) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 100 | - | - | - | - |

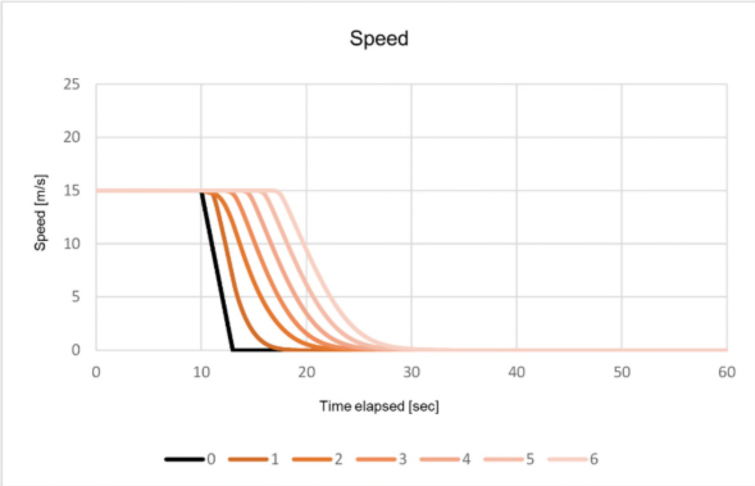



**Fig. 4.3.4-46 Change in speed at sudden stop (Case 31)**

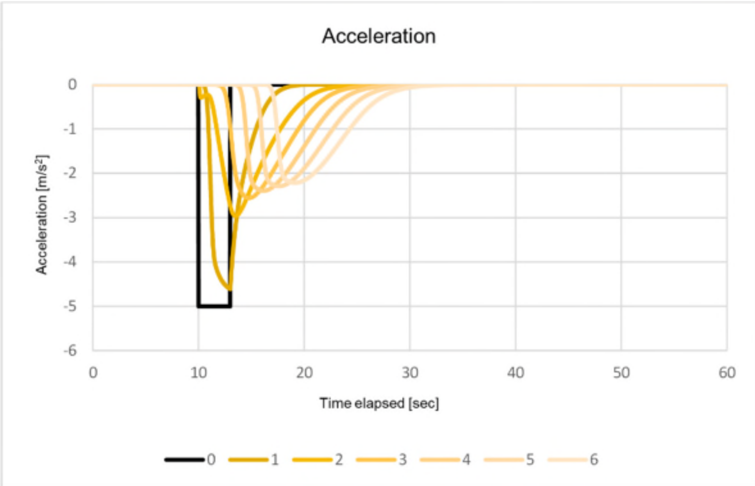



**Fig. 4.3.4-47 Change in acceleration at sudden stop (Case 31)**

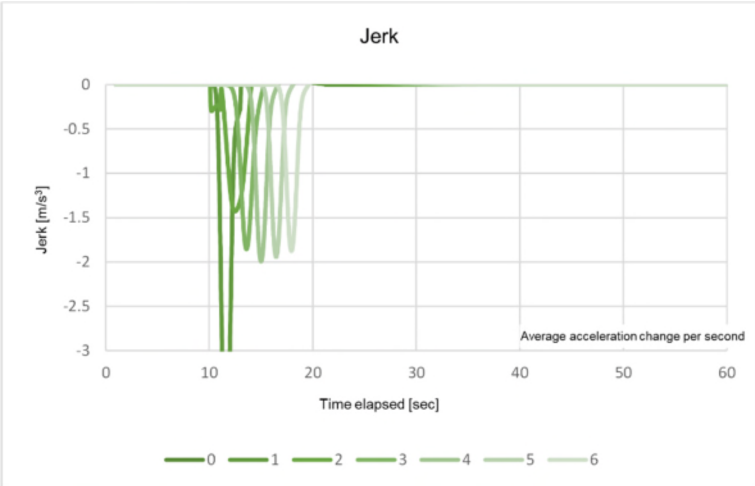



**Fig. 4.3.4-48 Change in jerk at sudden stop (Case 31)**

(6) Simulation results considerations

Simulation results shown in (3) to (5) are considered here.

(a) Effects with and without communication

Differences in changes in the speed and acceleration of the following vehicles were observed with Case 0 without communication and other cases with communication (1 to 9), where all vehicles were automated vehicles. As shown in Fig. 4.3.4-49, the deceleration peak was smaller and the timing was later in cases with communication, indicating safer stopping behavior.

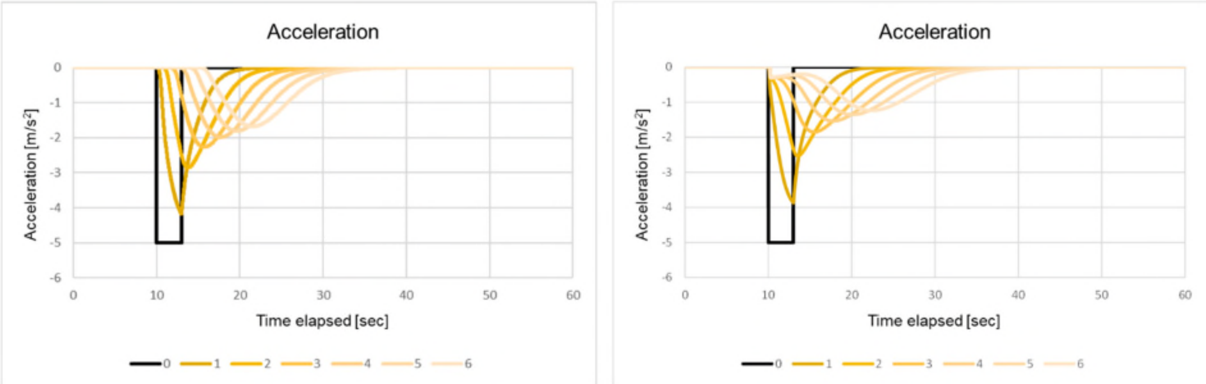



**Fig. 4.3.4-49 Comparison of acceleration changes with (left: Case 0) and without (right: Case 1) communication in a group composed of automated vehicles**

Similarity, difference was also observed in the changes in speed and acceleration of the manually operated vehicles that were following in cases without communication (Cases 10 and 30) and in other cases with communication (Cases 11 to 13 and 31), in which manually operated vehicles and automated vehicles are mixed. As shown in Fig. 4.3.4-50, the deceleration peak was smaller and the timing was later in cases with communication, indicating safer stopping behavior than with manually operated vehicles.

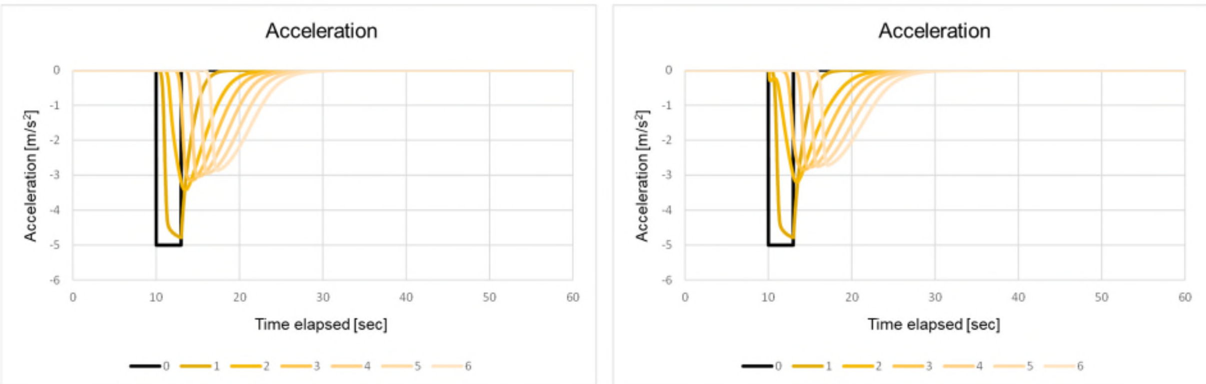



**Fig. 4.3.4-50 Comparison of acceleration changes without (left: Case 10) and with (right: Case 11) communication in a group composed of mixed manually operated vehicles (small) and automated vehicles**

In both cases, jerk peaks were also smaller, suggesting that with communication psychological aspects with the driven vehicle would also result in behavior with greater peace of mind. In particular, in the cases with manual operation mixed, jerk becomes smaller for Vehicle 3 and later manually operated vehicles that follow Vehicle 2 (automated vehicle), as shown in Fig. 4.3.4-51. Since a linear correlation between jerk and ride comfort evaluation values has been observed, this example can be interpreted as a reduction of about 30% in the anxiety with Vehicle 3.

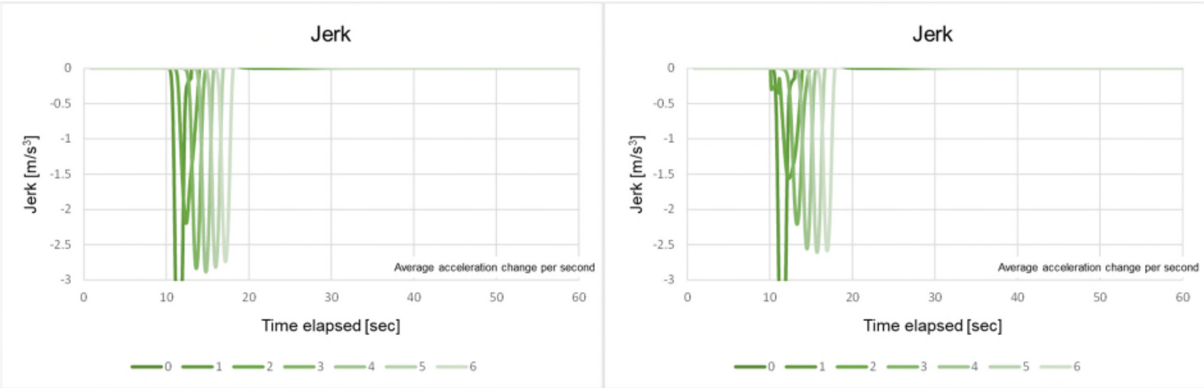



**Fig. 4.3.4-51 Comparison of jerk changes without (Case 10) and with (Case 11) communication in a group composed of mixed manually operated vehicles (small) and automated vehicles**

(b) Evaluation of differences in receiving opportunity in vehicles following

Comparisons of Cases 1-9 and Cases 11-13 with communication where receiving opportunity differs for vehicles following showed no significant impact on changes in speed, acceleration, etc., of the vehicles following, even when comparing changes in speed and acceleration.

This is considered to be because the variability of receiving opportunity (100 ms to 500 ms) was small compared to the propagation time of the deceleration behavior of the vehicles following (Vehicle 2: 850 ms to Vehicle 9: approximately 1.5 s), and thus the impact of the difference in receiving opportunity on deceleration (acceleration) and jerk was not observed with Vehicle 2 and subsequent following vehicles.

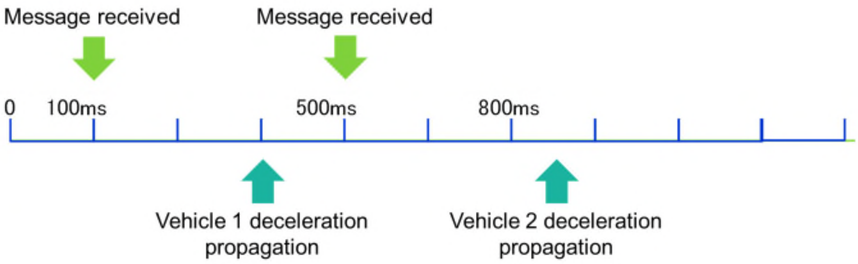



**Fig. 4.3.4-52 Relationship between message receiving opportunity and deceleration propagation opportunity**

When compared in terms of level of jerk, differences were observed depending on the receiving opportunity. Fig. 4.3.4-53 compares the change in jerk between Case 7, which has the fastest communication opportunity at 100 ms for all vehicles, and Case 8, which has the slowest at 500 ms for all vehicles. Case 8 on the right side has a larger peak jerk of Vehicle 1, and a disadvantage is recognized in the evaluation of ride comfort due to a delay in communication opportunity.

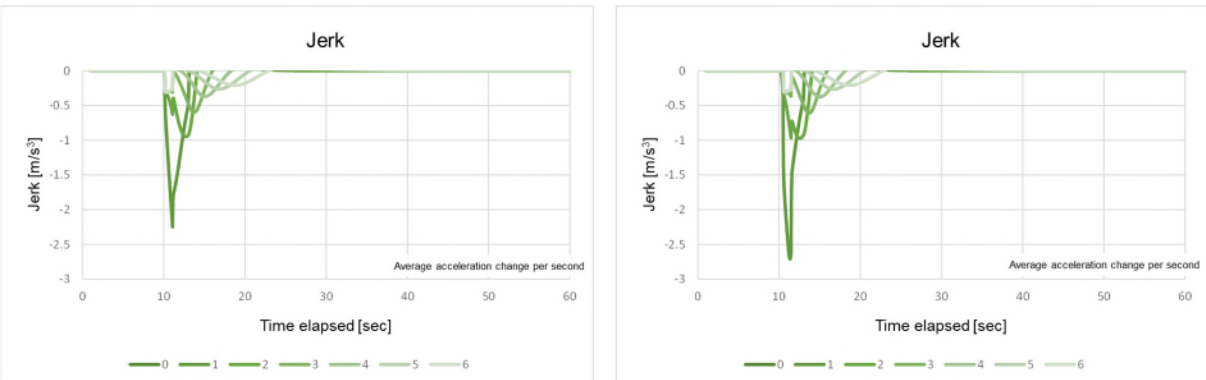



**Fig. 4.3.4-53 Comparison of jerk changes with communication opportunity of 100 ms (left: Case 7) and 500 ms (right: Case 8) in a group composed of automated vehicles**

(c) Impact of mixing with large vehicles

As a difference in traffic conditions, cases 30 and 31 were conducted as case studies when large vehicles are mixed in. In the comparison of acceleration change in Fig. 4.3.4-54, even when large vehicles are mixed in, the deceleration peak is smaller in cases with communication, which provides an advantage in terms of ride comfort. In contrast to Fig. 4.3.4-55, where small vehicles are mixed, the peak jerk is smaller with large vehicles than with small vehicles, but this is because large vehicles are traveling with more greater gap than small vehicles and decelerating with greater margin.

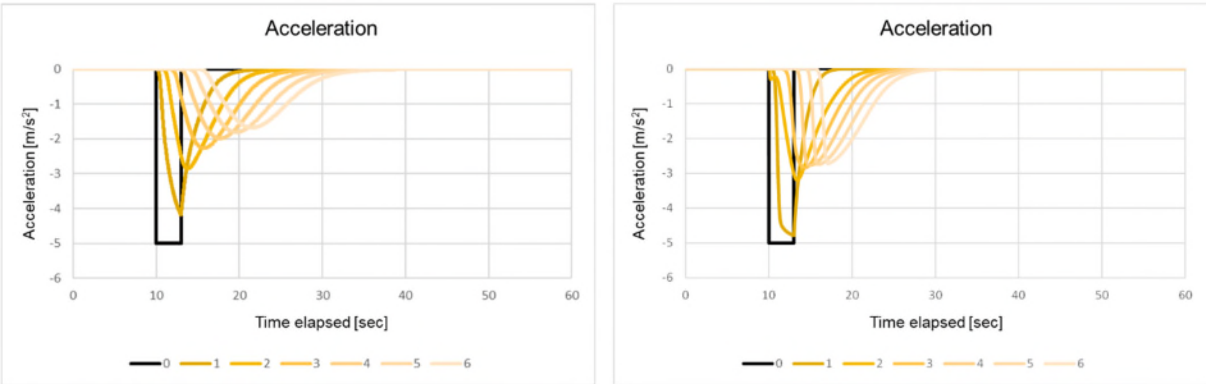



**Fig. 4.3.4-54 Comparison of jerk changes without (Case 30) and with (Case 31) communication in a group composed of mixed manually operated vehicles (small) and automated vehicles**

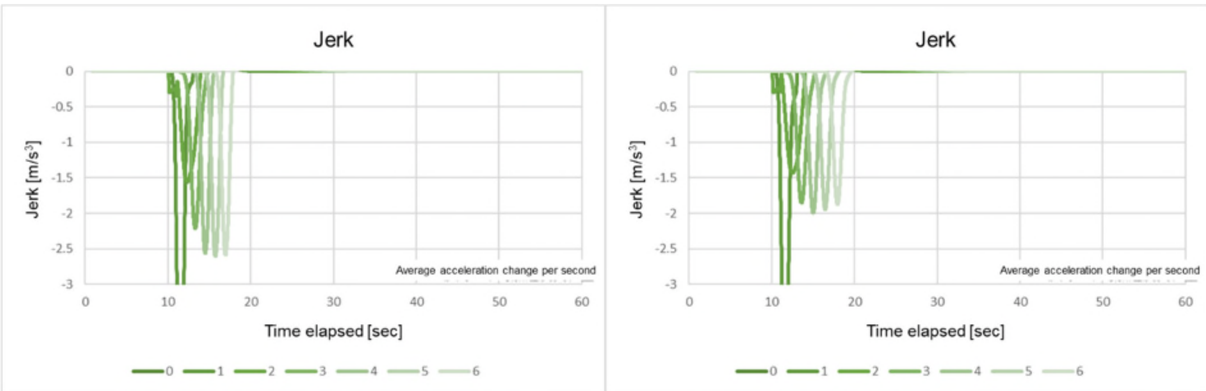



**Fig. 4.3.4-55 Comparison of jerk change with communication in a group with manually operated vehicles (small) mixed (Case 11) and with communication in a group with manually operated vehicles (large) mixed (Case 31)**

### 4.3.5 Considerations and issues regarding verification results

(1) Considerations of verification results

Results of verification are summarized below.

1) Effect of 5.9 GHz band V2X system
- In addition to “deceleration” as a safety, evaluation was conducted from the viewpoint of “jerk” as a ride comfort.
- By detecting the sudden deceleration of the preceding vehicle by communication and the following vehicle preliminarily decelerating, the following vehicle has the effect of mitigating the peak of “deceleration” and stopping safely. The “jerk" peak is reduced, which has the effect of reducing the anxiety felt by occupants.
- In the comparison of with and without communication, a more pronounced difference was observed in “jerk” than “deceleration.”

2) Impact of difference in communication specification
- At the range of receiving opportunity delay (100 to 500 ms) assumed with this simulation, for the vehicle (Vehicle 1) immediately behind the lead vehicle (Vehicle 0) of a group of vehicles, deceleration propagation due to following a vehicle further to the front occurs as delay becomes large up to 500 ms, so the effect of preliminary deceleration is reduced.
- From Vehicle 2 in the group, no change due to differences in reception timing were observed.
- Since it takes several seconds to propagate the deceleration of the preceding vehicle in the case without information, it is considered that even a delay of up to 500ms can be performed preliminarily deceleration sufficiently early.

3) Impact of difference in traffic conditions
- Even in situations where traffic conditions differ due to large vehicles being mixed in, information communication can provide safety benefits to vehicles following.

(2) Issues

This time, differences in communication environments were expressed by constants as information transmission delay times of 100 to 500 ms. In actual communication environments, however, delays are believed to exist depending on the situation, such as reduced certainty of information transmission due to the influence of shadowing, multipath, congestion, and the like. To address these issues, it is desirable to link communication simulators and traffic simulators to create an evaluation tool that is realistic for the surrounding environment.

In reality, there may be various factors such as the delay between the vehicle ahead detecting an obstacle and issuing information, or the delay from the time the following vehicle receives the information until it controls the behavior of the vehicle, etc, How to model these also needs to be discussed.

Since no actual data was presented on deceleration behavior of automated vehicles in this study, parameters that were considered appropriate were set in consultation with a working-level committee after showing qualitative differences with respect to the behavior of manually operated vehicles in sensitivity analysis. It should be mentioned that for more realistic evaluation, it is desirable to model vehicle behavior based on actual behavior data of automated vehicles.

### 4.3.6 Reference materials

Apart from the simulations shown in sections 0 to (5), simulations were conducted using reference cases with variations in traffic condition settings and assumptions. Those reference cases are covered below.

(1) Simulation results: Suddenly stopping from the high speed range with all automated vehicles (Cases 60 to 69)

Cases in the simulation are shown in Table 4.3.6-1. In addition, (a) to (j) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case.

While there was a difference in the speed change of the following vehicle between Case 60 without communication and Cases 61-69 with communication, as in evaluation cases same as case comparison in section 4.3.4 , there was no significant difference in stopping behavior due to difference in communication pattern.

**Table 4.3.6-1 Case settings list (Cases 60 to 69)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **60** | | 25 m/s (90 km/h) | All automated driving | Without communication |
| **61** | Pattern 1 | ” | ” | With communication |
| **62** | Pattern 2 | ” | ” | ” |
| **63** | Pattern 3 | ” | ” | ” |
| **64** | Pattern 4 | ” | ” | ” |
| **65** | Pattern 5 | ” | ” | ” |
| **66** | Pattern 6 | ” | ” | ” |
| **67** | Pattern 7 | ” | ” | ” |
| **68** | Pattern 8 | ” | ” | ” |
| **69** | Pattern 9 | ” | ” | ” |

(a) Case 60

**Table 4.3.6-2 Timing of information transmission (Case 60)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

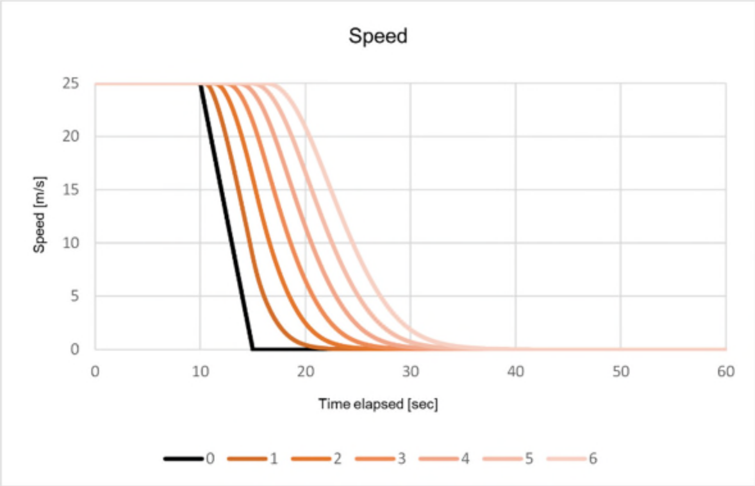



**Fig. 4.3.6-1 Change in speed at sudden stop (Case 60)**

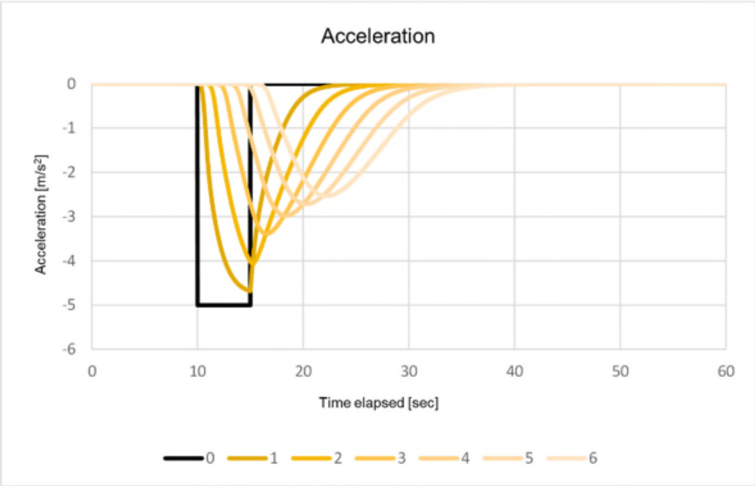



**Fig. 4.3.6-2 Change in acceleration at sudden stop (Case 60)**

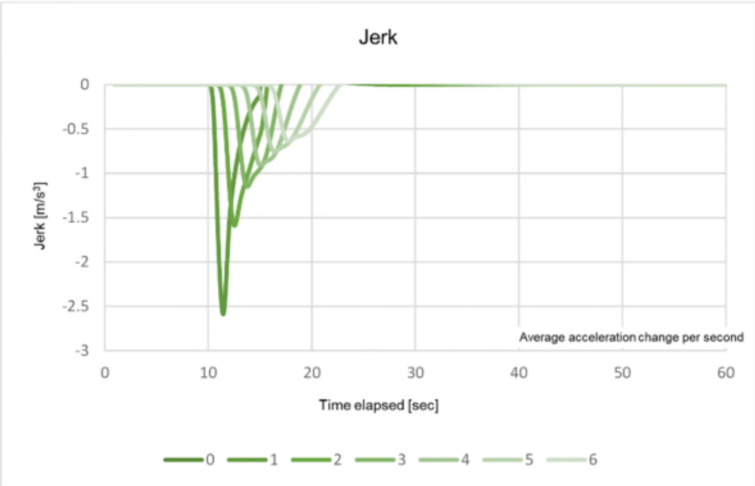



**Fig. 4.3.6-3 Change in jerk at sudden stop (Case 60)**

(b) Case 61

**Table 4.3.6-3 Timing of information transmission (Case 61)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 200 | 200 | 200 |

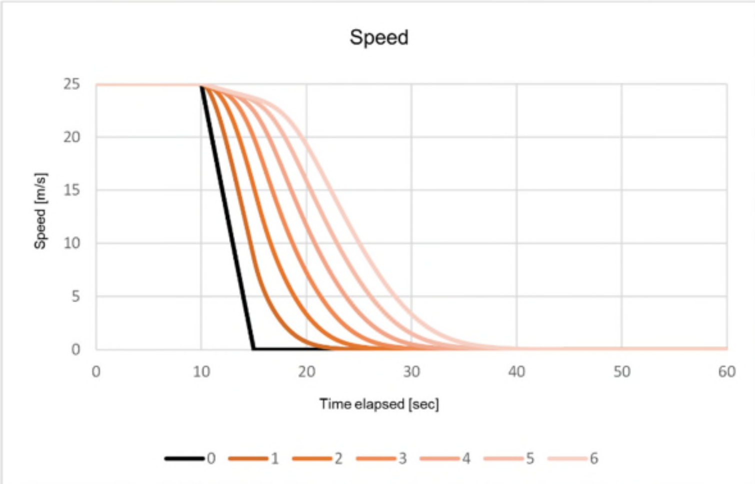



**Fig. 4.3.6-4 Change in speed at sudden stop (Case 61)**

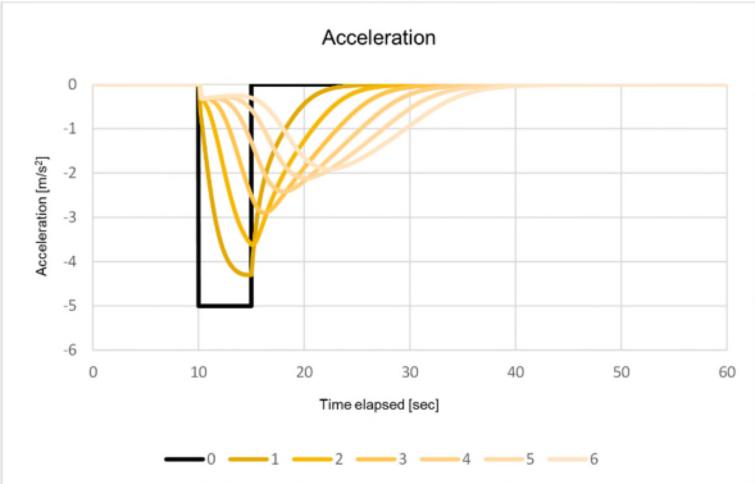



**Fig. 4.3.6-5 Change in acceleration at sudden stop (Case 61)**

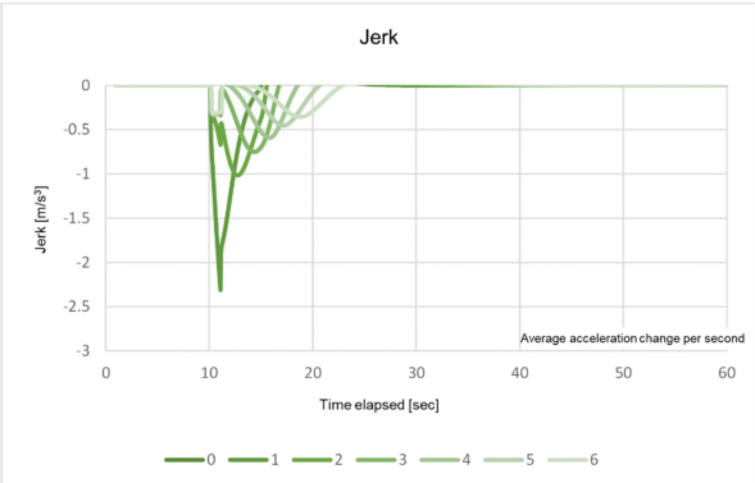



**Fig. 4.3.6-6 Change in jerk at sudden stop (Case 61)**

(c) Case 62

**Table 4.3.6-4 Timing of information transmission (Case 62)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 200 | 200 | 300 |

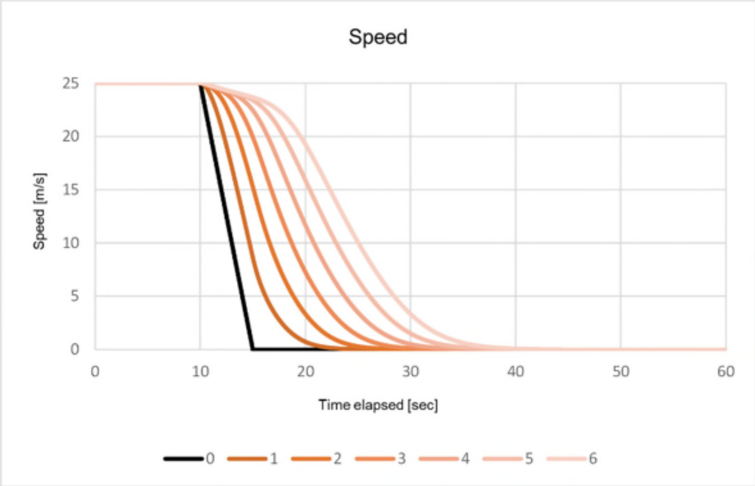



**Fig. 4.3.6-7 Change in speed at sudden stop (Case 62)**

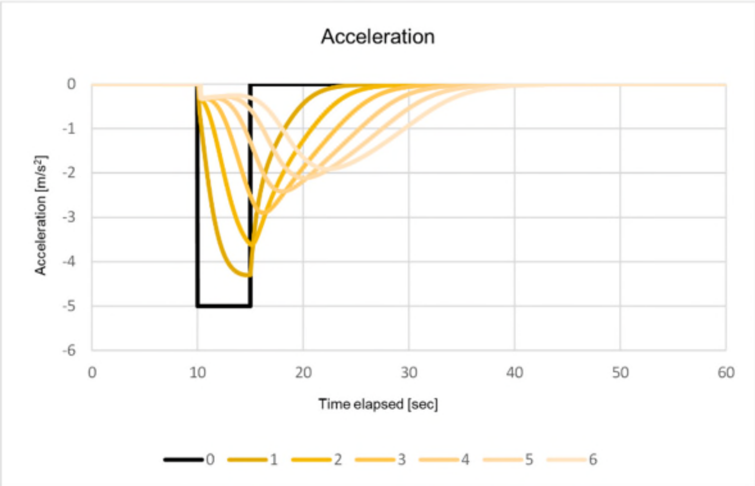



**Fig. 4.3.6-8 Change in acceleration at sudden stop (Case 62)**

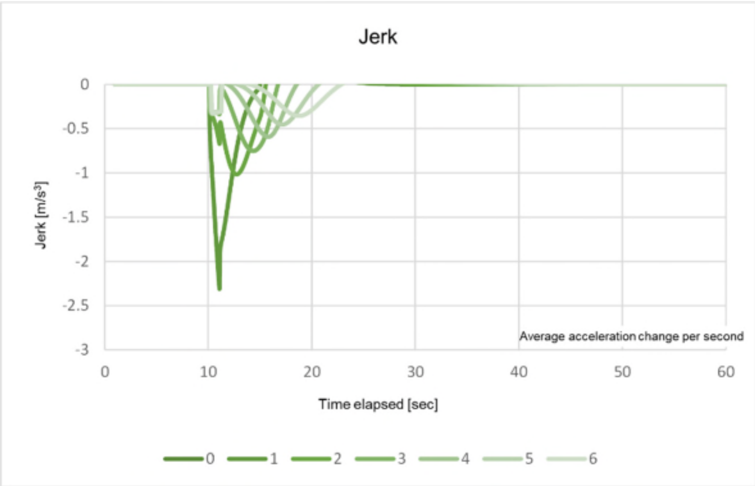



**Fig. 4.3.6-9 Change in jerk at sudden stop (Case 62)**

(d) Case 63

**Table 4.3.6-5 Timing of information transmission (Case 63)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 300 | 300 | 300 |

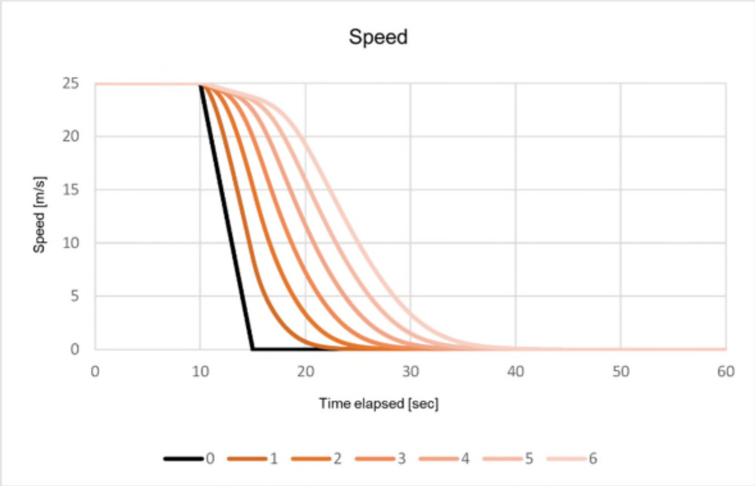



**Fig. 4.3.6-10 Change in speed at sudden stop (Case 63)**

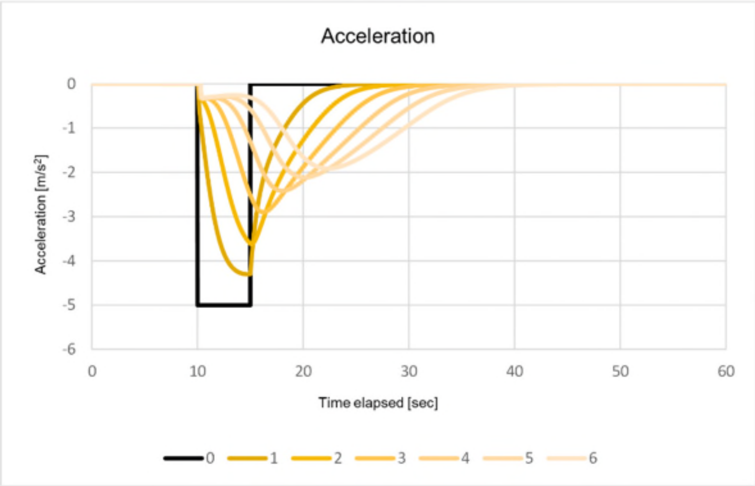



**Fig. 4.3.6-11 Change in acceleration at sudden stop (Case 63)**

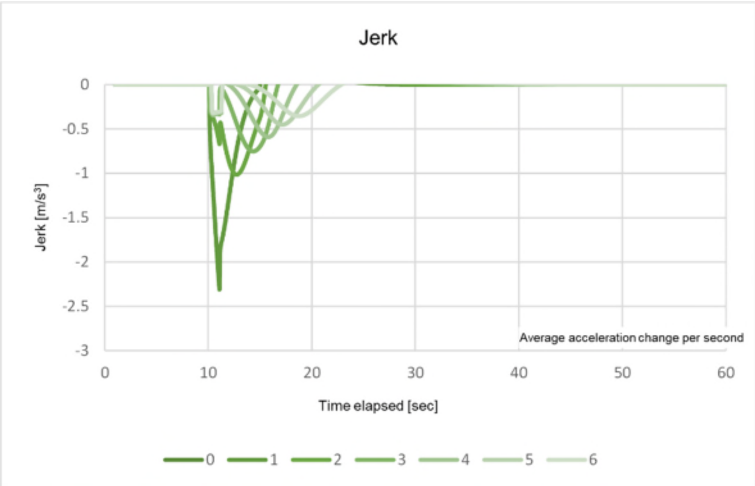



**Fig. 4.3.6-12 Change in jerk at sudden stop (Case 63)**

(e) Case 64

**Table 4.3.6-6 Timing of information transmission (Case 64)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 300 | 400 |

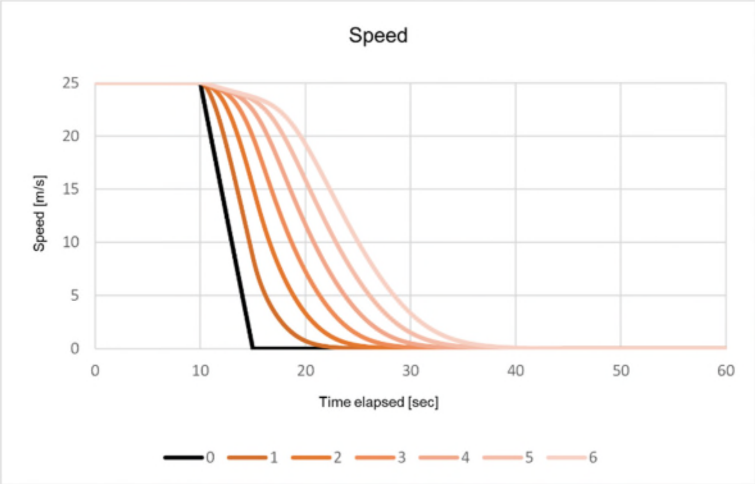



**Fig. 4.3.6-13 Change in speed at sudden stop (Case 64)**

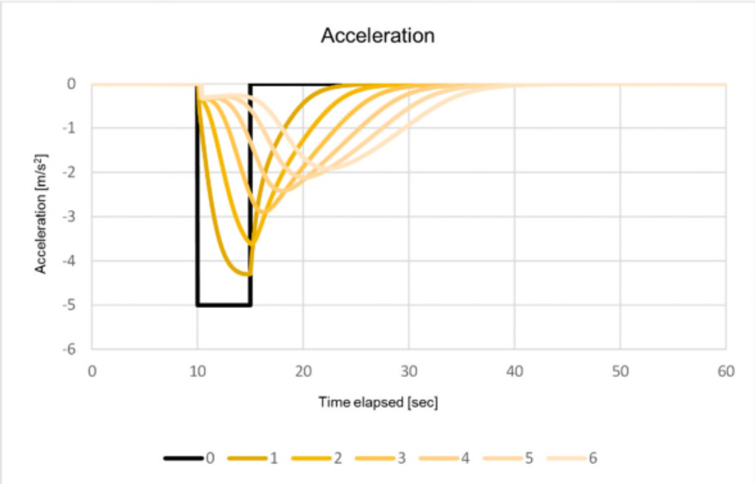



**Fig. 4.3.6-14 Change in acceleration at sudden stop (Case 64)**

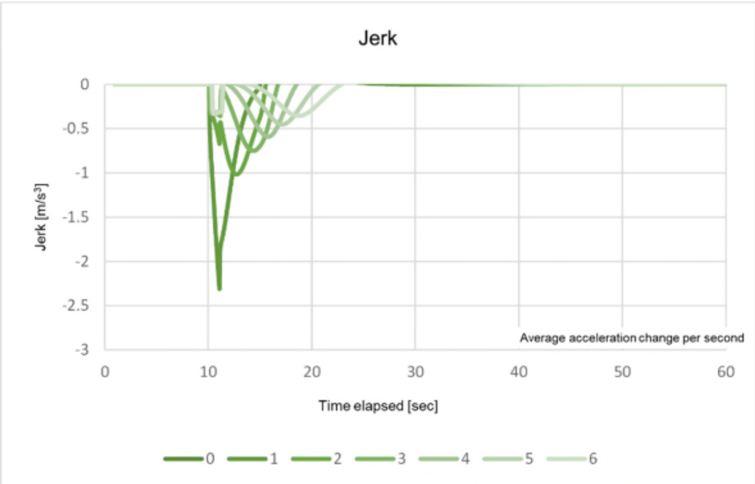



**Fig. 4.3.6-15 Change in jerk at sudden stop (Case 64)**

(f) Case 65

**Table 4.3.6-7 Timing of information transmission (Case 65)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 400 | 400 |

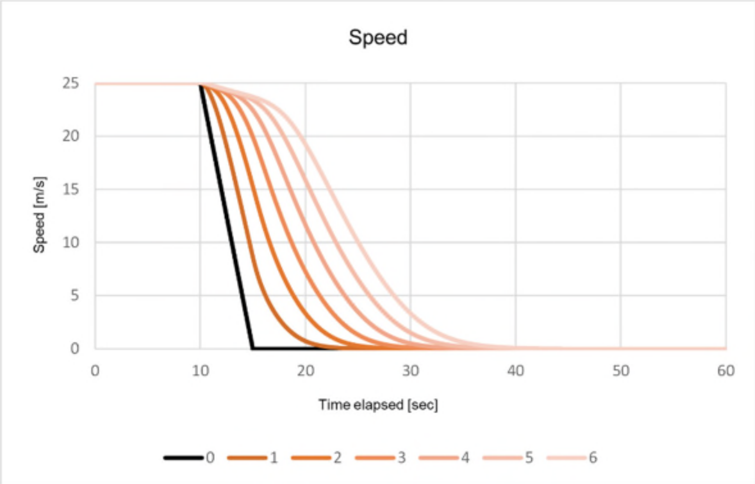



**Fig. 4.3.6-16 Change in speed at sudden stop (Case 65)**

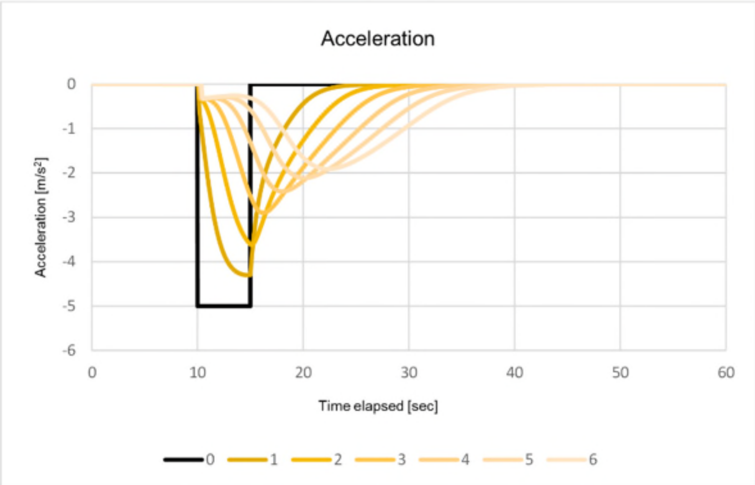



**Fig. 4.3.6-17 Change in acceleration at sudden stop (Case 65)**

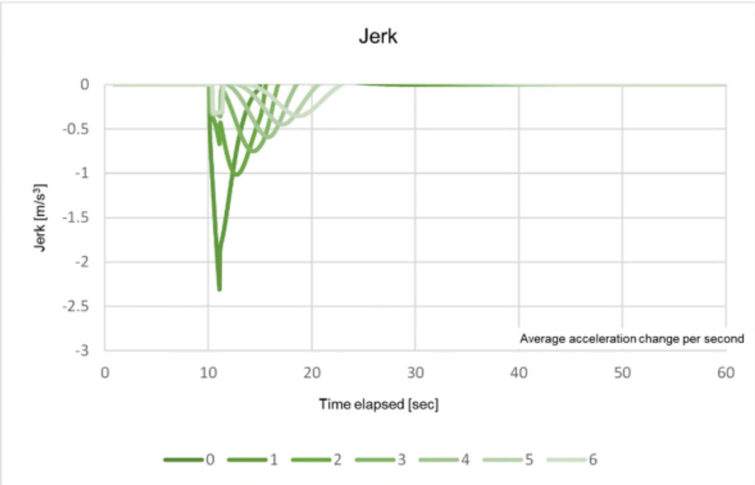



**Fig. 4.3.6-18 Change in jerk at sudden stop (Case 65)**

(g) Case 66

**Table 4.3.6-8 Timing of information transmission (Case 66)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 200 | 300 | 400 | 500 |

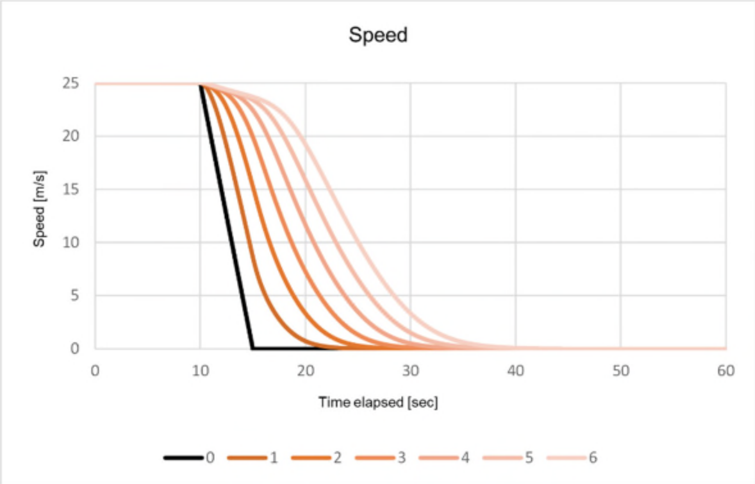



**Fig. 4.3.6-19 Change in speed at sudden stop (Case 66)**

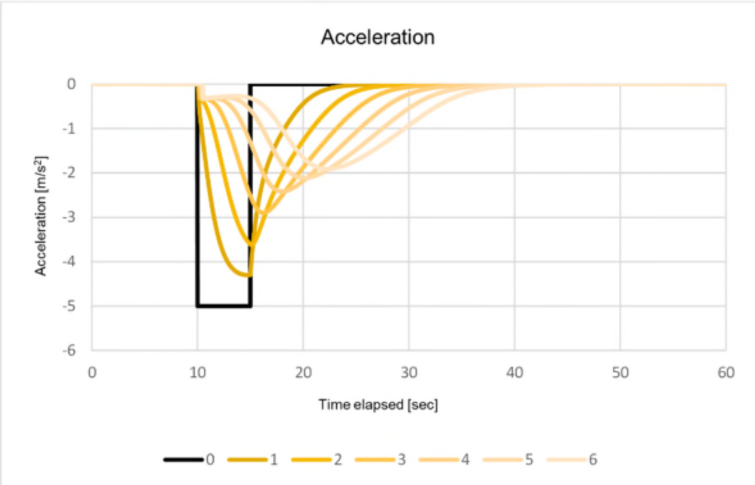



**Fig. 4.3.6-20 Change in acceleration at sudden stop (Case 66)**

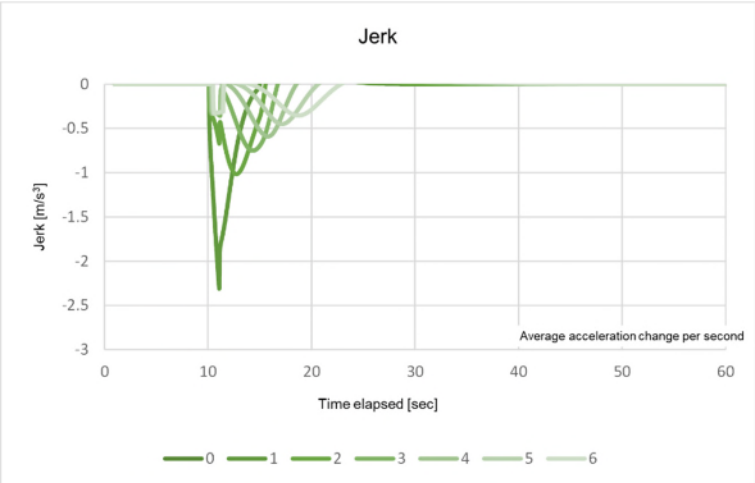



**Fig. 4.3.6-21 Change in jerk at sudden stop (Case 66)**

(h) Case 67

**Table 4.3.6-9 Timing of information transmission (Case 67)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 100 | 100 | 100 |

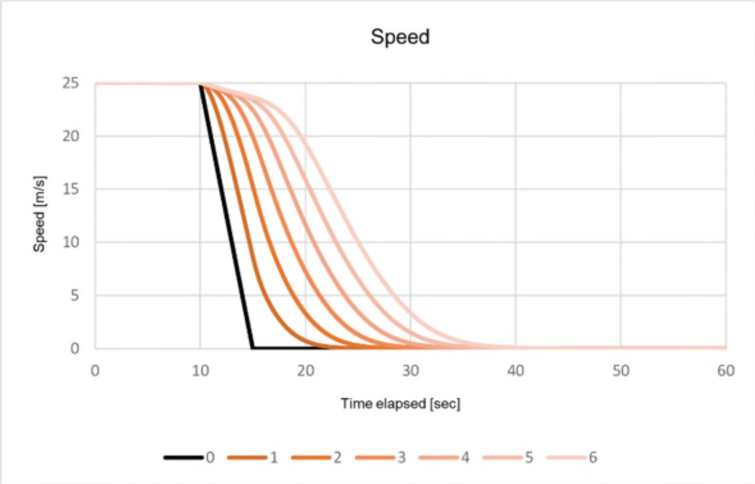



**Fig. 4.3.6-22 Change in speed at sudden stop (Case 67)**

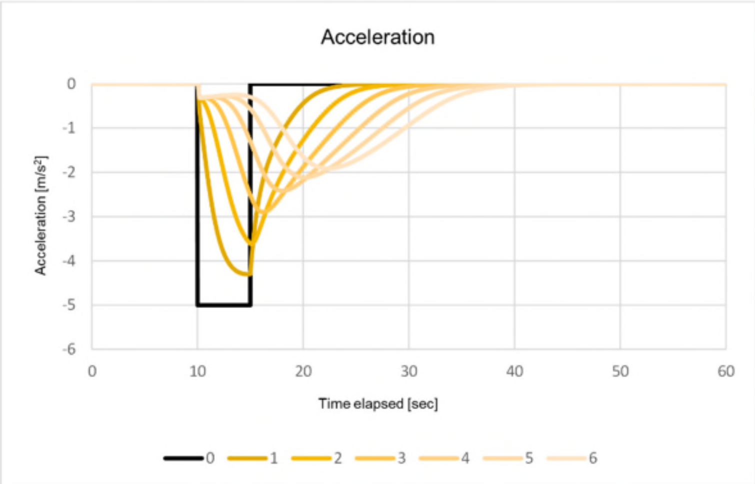



**Fig. 4.3.6-23 Change in acceleration at sudden stop (Case 67)**

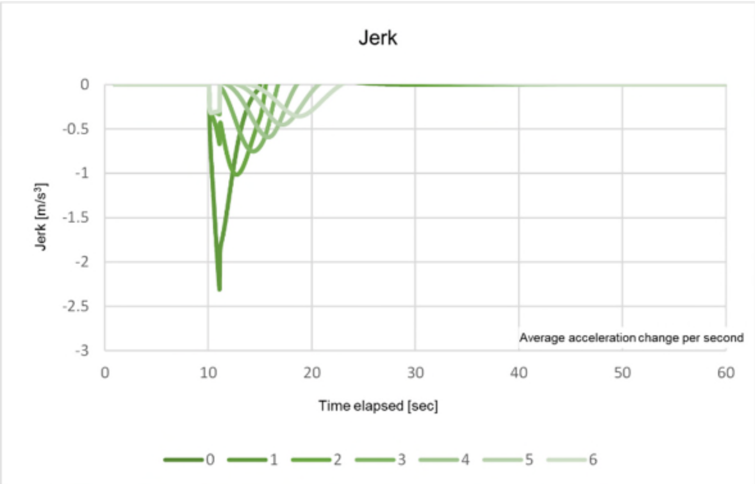



**Fig. 4.3.6-24 Change in jerk at sudden stop (Case 67)**

(i) Case 68

**Table 4.3.6-10 Timing of information transmission (Case 68)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 500 | 500 | 500 | 500 | 500 | 500 |

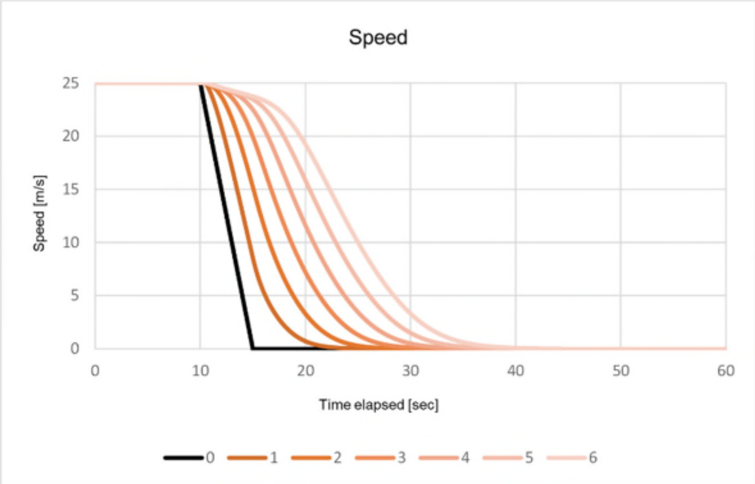



**Fig. 4.3.6-25 Change in speed at sudden stop (Case 68)**

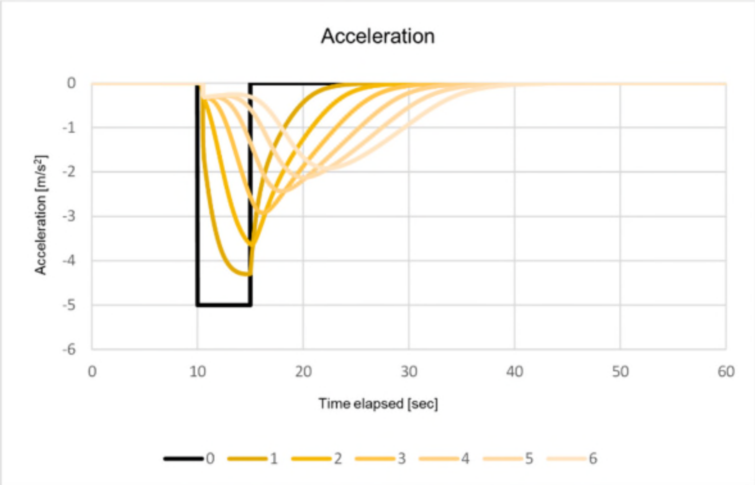



**Fig. 4.3.6-26 Change in acceleration at sudden stop (Case 68)**

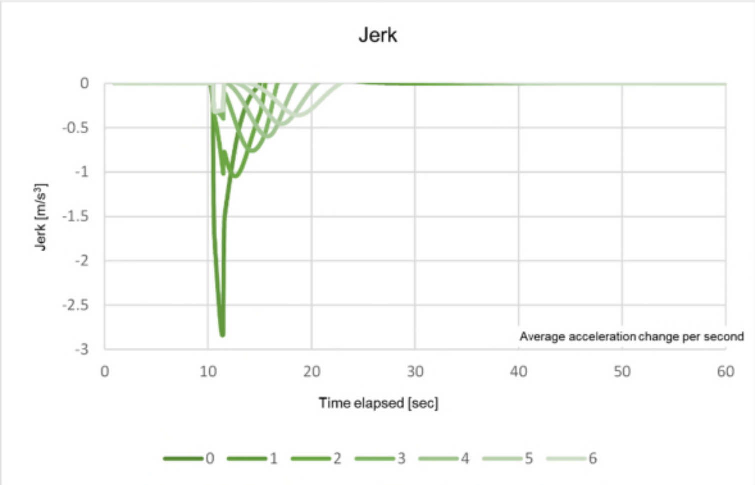



**Fig. 4.3.6-27 Change in jerk at sudden stop (Case 68)**

(j) Case 69

**Table 4.3.6-11 Timing of information transmission (Case 69)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |

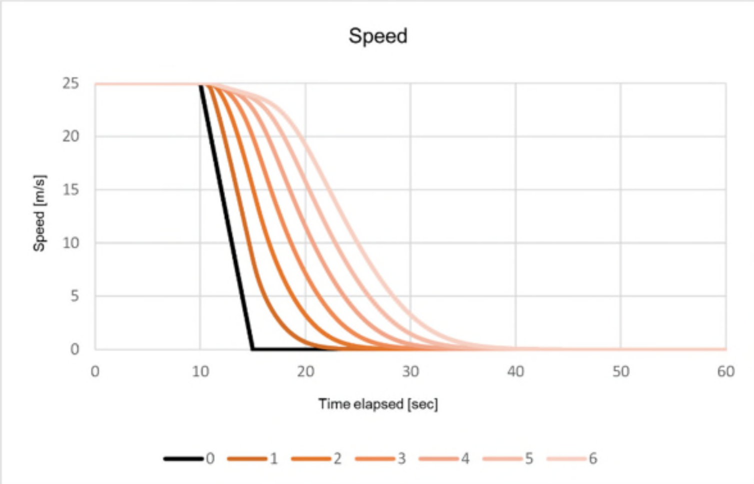



**Fig. 4.3.6-28 Change in speed at sudden stop (Case 69)**

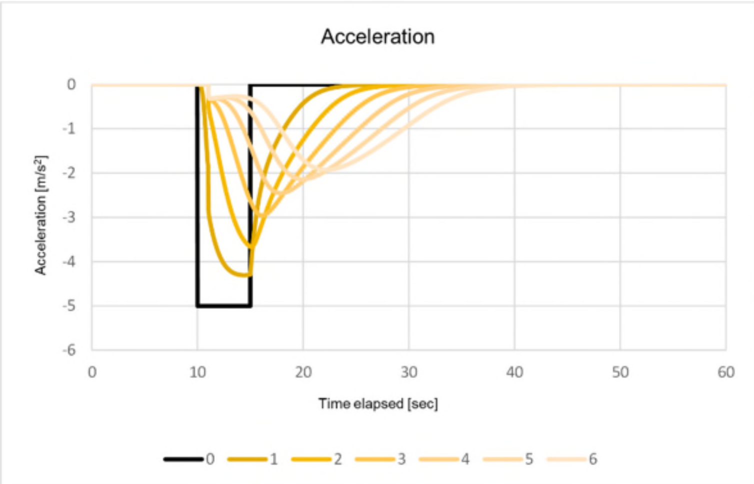



**Fig. 4.3.6-29 Change in acceleration at sudden stop (Case 69)**

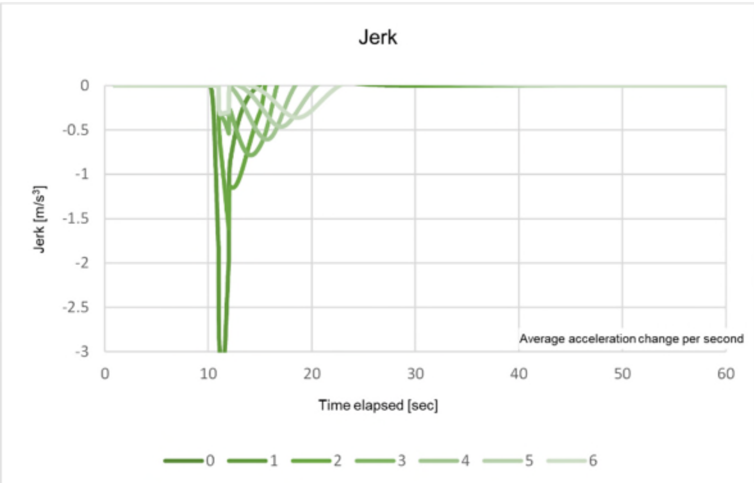



**Fig. 4.3.6-30 Change in jerk at sudden stop (Case 69)**

(2) Simulation results: Suddenly stopping at the high speed range with automated vehicles mixed with manually operated vehicles (Cases 70 to 73)

Cases in the simulation are shown in Table 4.3.6-12. In addition, (a) to (d) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case. .

Here too, while there was a difference in the speed change of the following vehicle between Case 70 without communication and Cases 71-73 with communication, as in (1), there was no significant difference in stopping behavior due to difference in communication pattern.

**Table 4.3.6-12 Case settings list (Cases 70 to 73)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **70** | | 25 m/s (90 km/h) | Vehicle 2 is automated driving and others are manually operated (small) | Without communication |
| **71** | Pattern 11 | ” | ” | With communication |
| **72** | Pattern 12 | ” | ” | ” |
| **73** | Pattern 13 | ” | ” | ” |

(a) Case 70

Table 4.3.6-13 Timing of information transmission (Case 70)

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

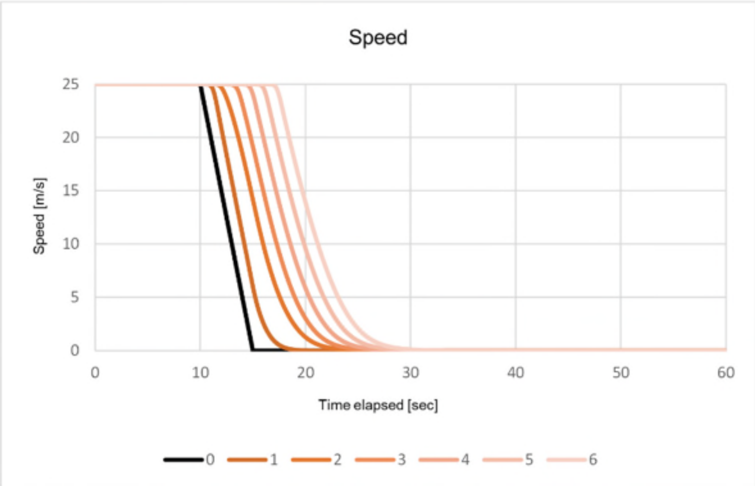



**Fig. 4.3.6-31 Change in speed at sudden stop (Case 70)**

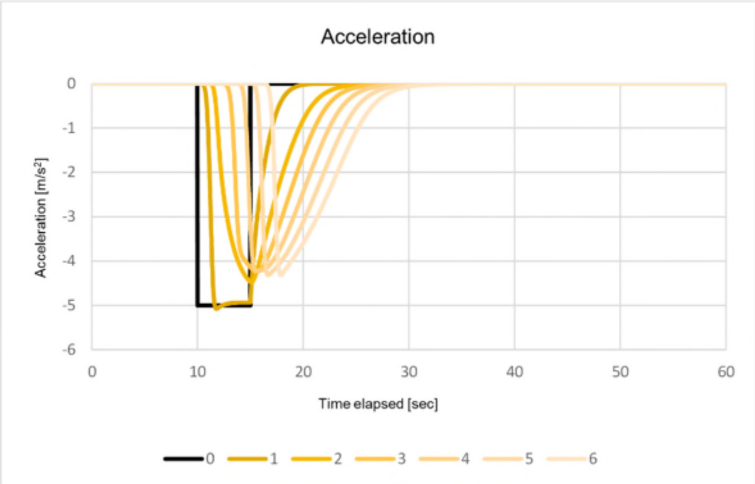



**Fig. 4.3.6-32 Change in acceleration at sudden stop (Case 70)**

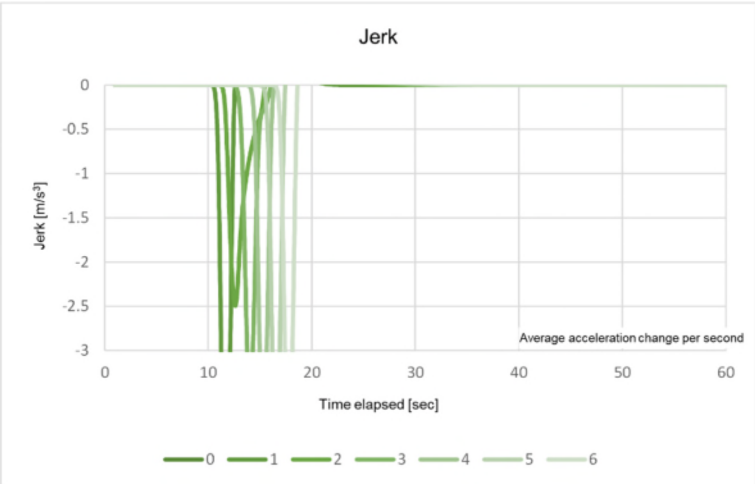



**Fig. 4.3.6-33 Change in jerk at sudden stop (Case 70)**

(b) Case 71

**Table 4.3.6-14 Timing of information transmission (Case 71)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 100 | - | - | - | - |

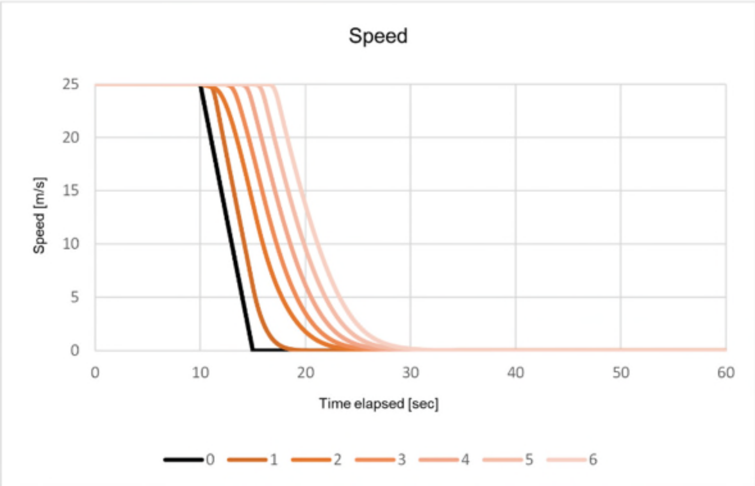



**Fig. 4.3.6-34 Change in speed at sudden stop (Case 71)**

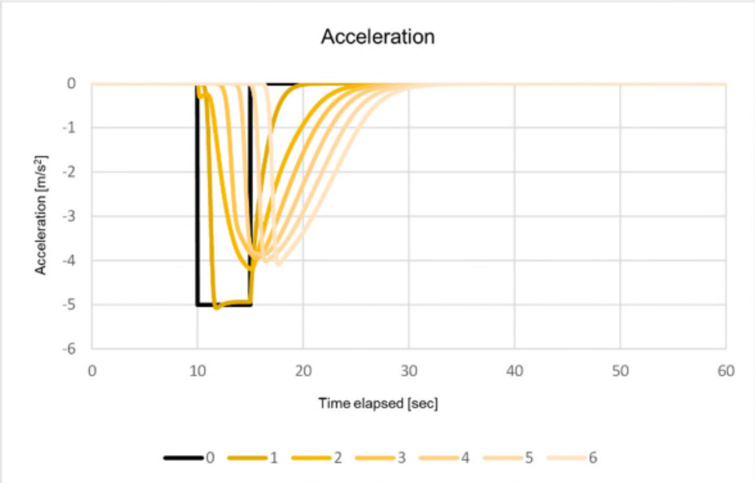



**Fig. 4.3.6-35 Change in acceleration at sudden stop (Case 71)**

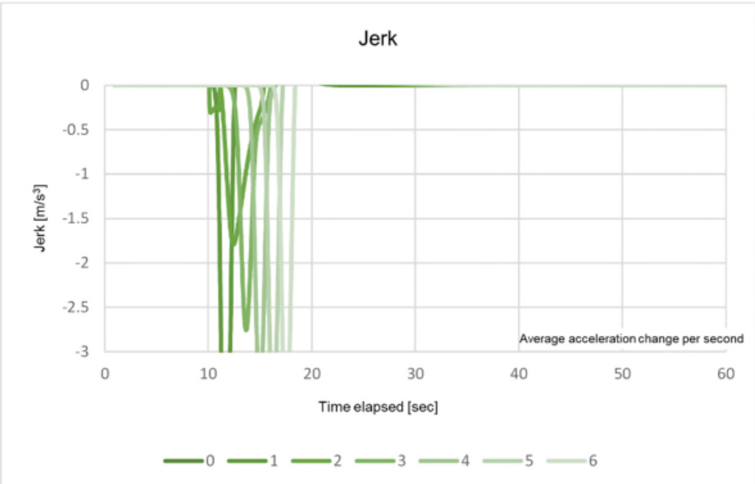



**Fig. 4.3.6-36 Change in jerk at sudden stop (Case 71)**

(c) Case 72

Table 4.3.6-15 Timing of information transmission (Case 72)

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 300 | - | - | - | - |

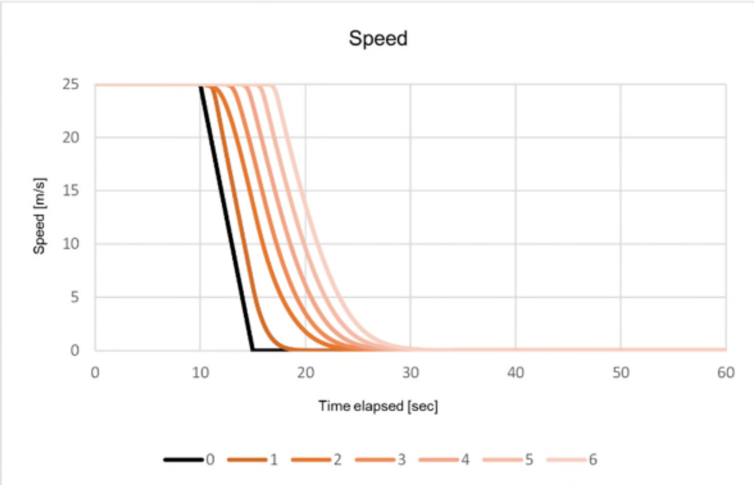



Fig. 4.3.6-37 Change in speed at sudden stop (Case 72)

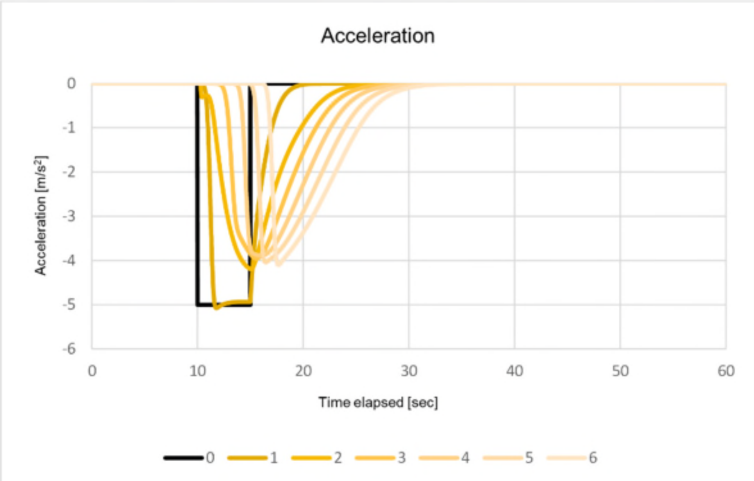



Fig. 4.3.6-38 Change in acceleration at sudden stop (Case 72)

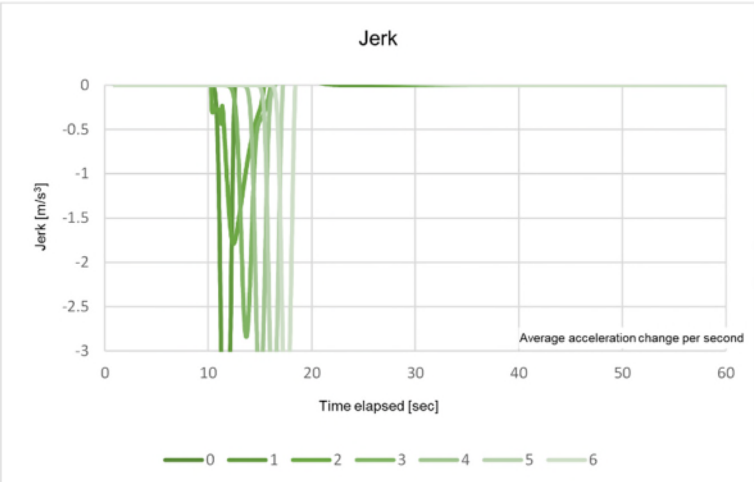



Fig. 4.3.6-39 Change in jerk at sudden stop (Case 72)

(d) Case 73

**Table 4.3.6-16 Timing of information transmission (Case 73)**

| | Vehicle 1 (Manually operated) | Vehicle 2 (Automated) | Vehicle 3 (Manually operated) | Vehicle 4 (Manually operated) | Vehicle 5 (Manually operated) | Vehicle 6 (Manually operated) |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | 500 | - | - | - | - |

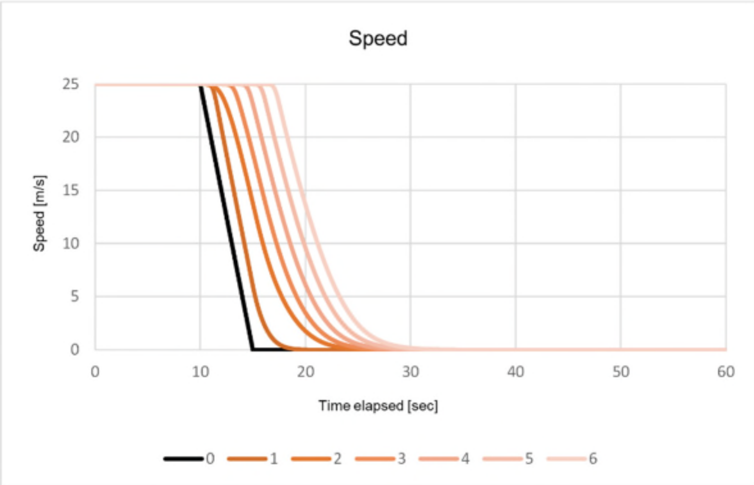



**Fig. 4.3.6-40 Change in speed at sudden stop (Case 73)**

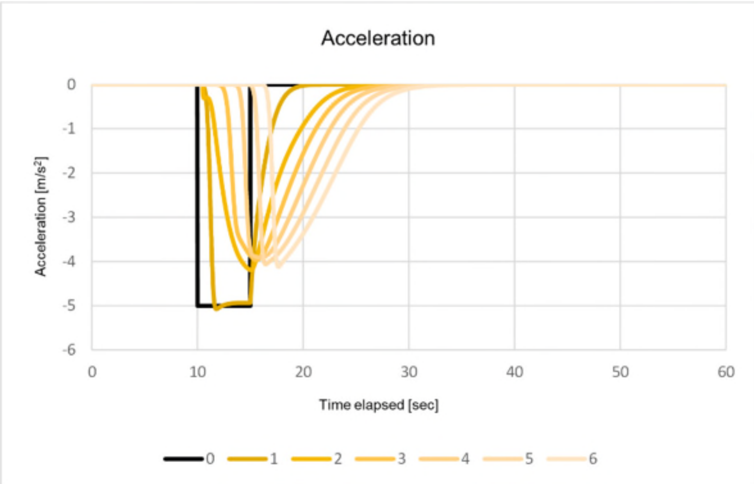



**Fig. 4.3.6-41 Change in acceleration at sudden stop (Case 73)**

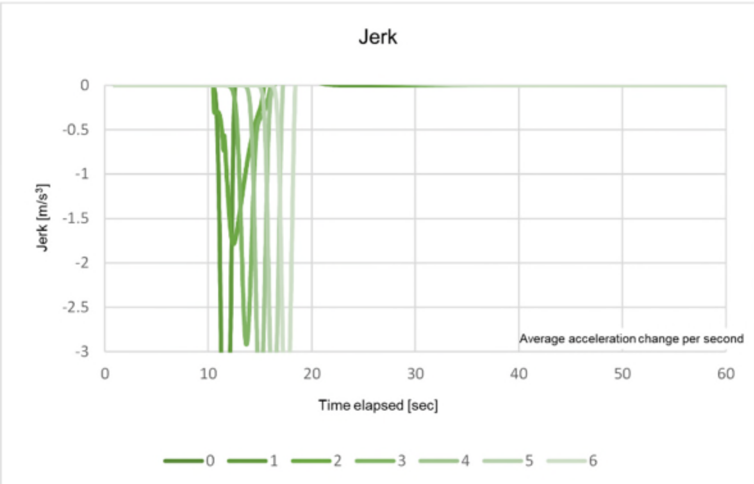



**Fig. 4.3.6-42 Change in jerk at sudden stop (Case 73)**

(3) Simulation results: Suddenly stopping from the speed range of major prefectural and municipal roads with all short gap automated vehicles (Cases 20 to 21)

Cases in the simulation are shown in Table 4.3.6-17. The cases in (a) and (b) below show the time variation of speed, acceleration, and jerk of the vehicles in the group of vehicles in each case.

As the safe gap becomes shorter, there is less leeway for deceleration behavior in response to sudden hard braking. Therefore, comparing cases in Section 4.3.4 , the peak of deceleration and jerk becomes larger, but looking at peak reduction with and without communication, the reduction in short gap is large. In other words, it is suggested that the shorter the gap, the greater the benefit of communication.

**Table 4.3.6-17 Case settings list (Cases 20 to 21)**

| Case | Communication pattern | Initial speed | Model | Remarks |
|---|---|---|---|---|
| **20** | | 15 m/s (54 km/h) | All automated driving (safe gap 1.3 seconds) | Without communication |
| **21** | Pattern 1 | ” | ” | With communication |

(a) Case 20

**Table 4.3.6-18 Timing of information transmission (Case 20)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | - | - | - | - | - | - |

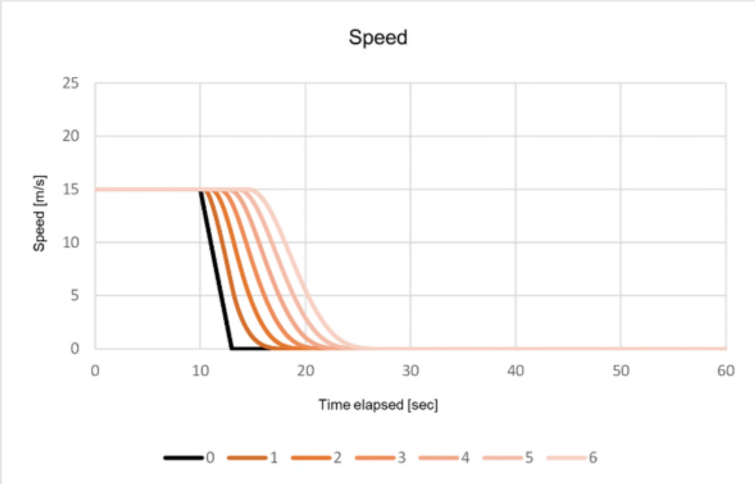



**Fig. 4.3.6-43 Change in speed at sudden stop (Case 20)**

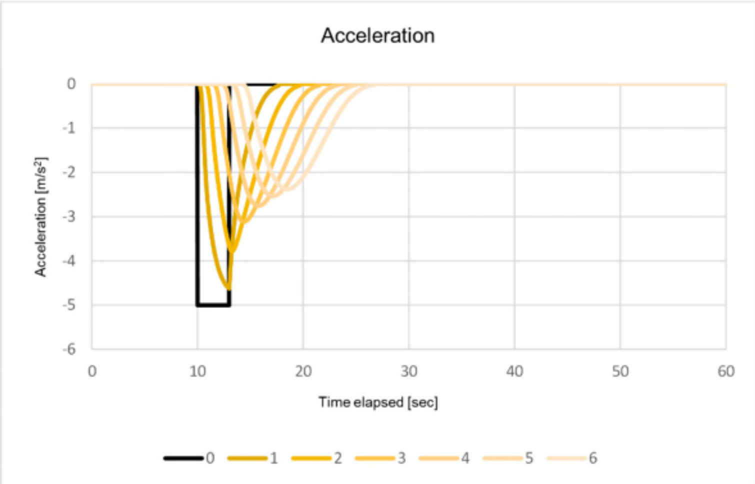



**Fig. 4.3.6-44 Change in acceleration at sudden stop (Case 20)**

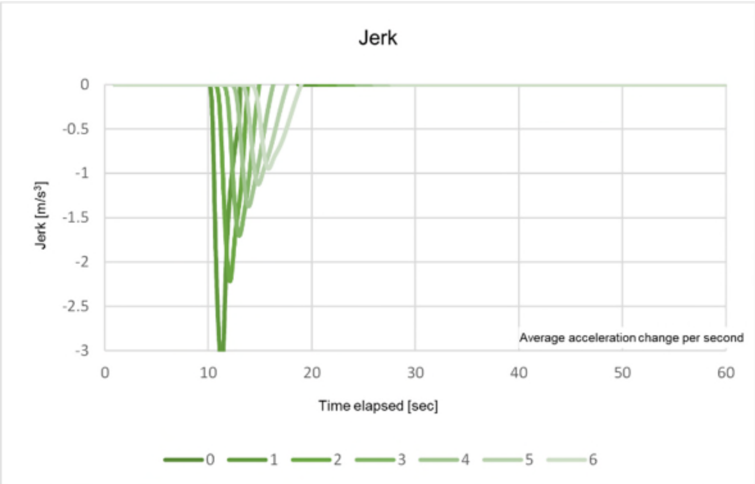



**Fig. 4.3.6-45 Change in jerk at sudden stop (Case 20)**

(b) Case 21

**Table 4.3.6-19 Timing of information transmission (Case 21)**

| | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 | Vehicle 5 | Vehicle 6 |
|---|---|---|---|---|---|---|
| Timing of information transmission [ms] | 100 | 100 | 100 | 200 | 200 | 200 |

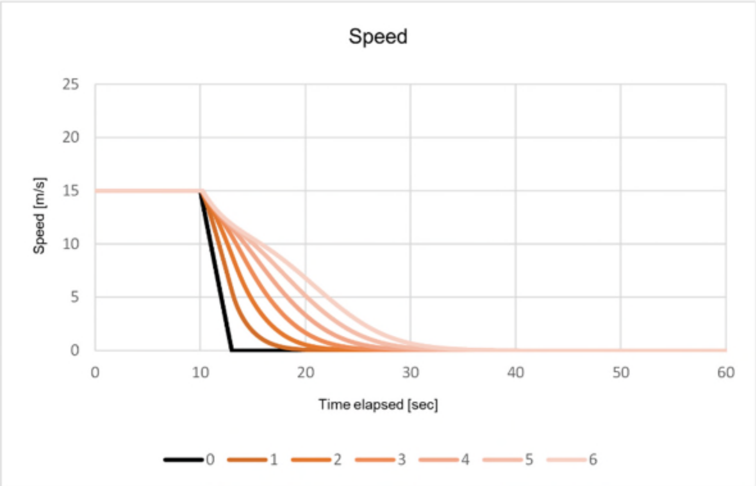



**Fig. 4.3.6-46 Change in speed at sudden stop (Case 21)**

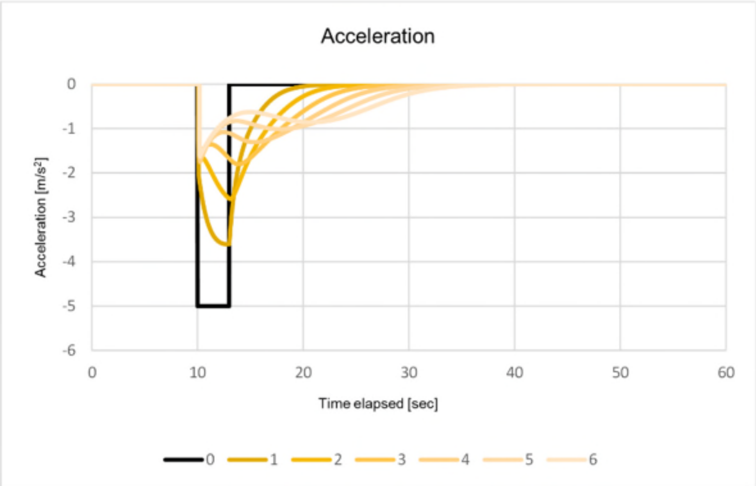



**Fig. 4.3.6-47 Change in acceleration at sudden stop (Case 21)**

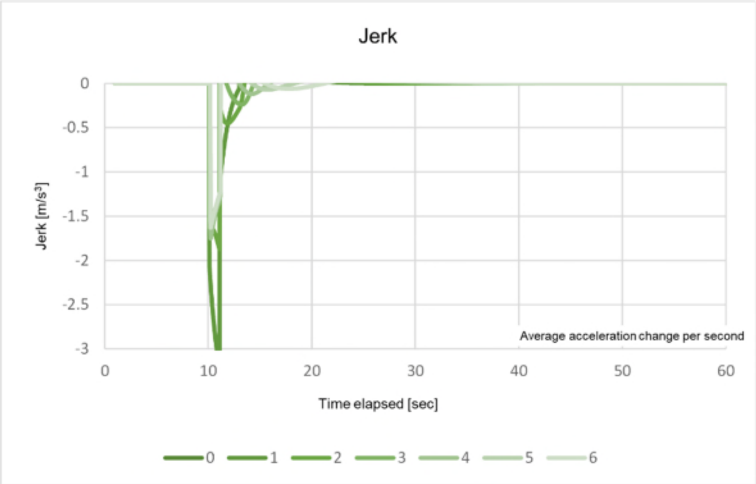



**Fig. 4.3.6-48 Change in jerk at sudden stop (Case 21)**

# 5. Design of communication protocol proposal

This part describes the results of studying a communication protocol proposal and communication message set proposal and organizing the issues (Section 5.1 and 5.2). Additionally, it describes the results of evaluating communication performance by communication simulation, discussion, and organizing the issues (Section 5.3). Finally, it describes references (Section 5.4).

## 5.1 Communication protocol proposal study

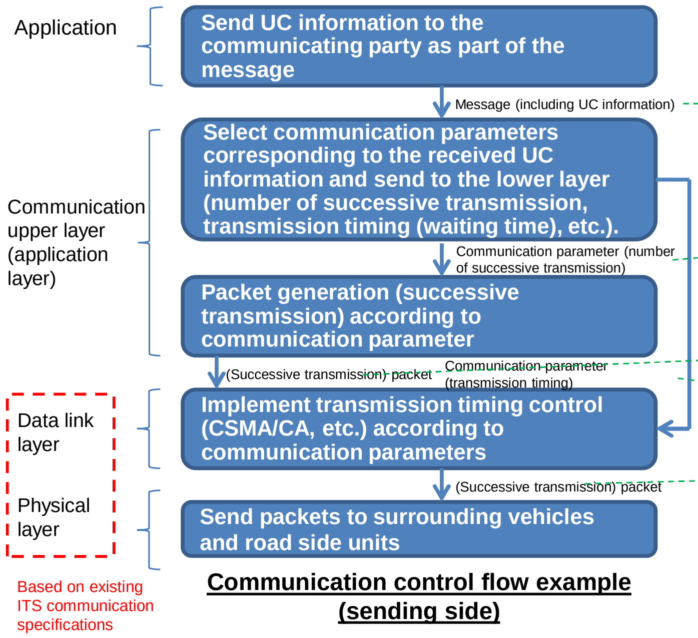
This section describes the results of studying a communication protocol proposal and organizing the issues. The following describes the process of the study (Section 5.1.1), and in accordance with that, the results of organizing the reference standards and studying communication control flows, protocol stacks, functions, operations, and interfaces on each layer, and method of linking to the 700 MHz Band Intelligent Transport Systems (Section 5.1.2 to 5.1.5), and based on these, the results of detailing the communication sequence based on examples of SIP UC communication scenarios and confirming the appropriateness of the study proposals (Section 5.1.6) and organizing the issues (Section 5.1.7).

### 5.1.1 Process of study

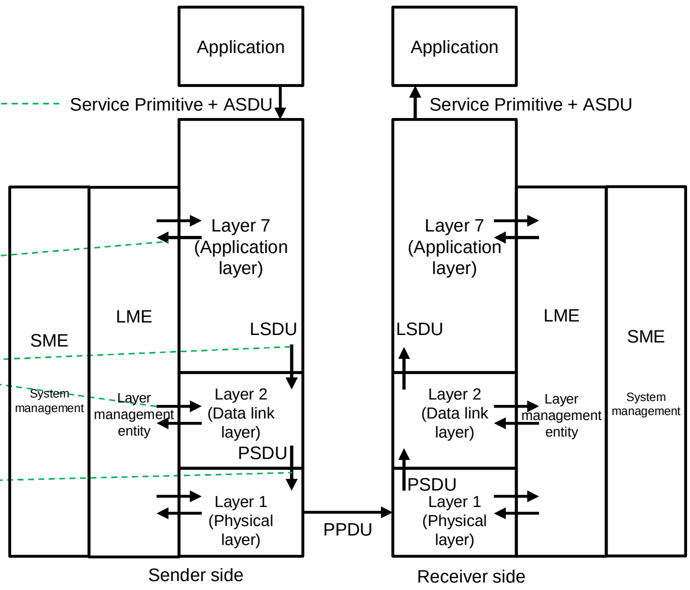
The process of the communication protocol proposal study was as below.

First, based on the results of the survey of trends internationally (Part 3), a study was done of DSRC/CV2X technical specifications of the U.S. and Europe, taking the SAE and IEEE standards of the U.S. and the ETSI standards of Europe (below, "European and American specifications") as candidates for existing 5.9 GHz band ITS wireless communication standards, then the communication control flows, protocol stacks, communication specifications, etc., were organized (Section 5.1.2). Next, the communication control flows, etc., were organized, with reference to the "Study report on communication scenarios and requirements for 'SIP Use Cases for Cooperative Driving Automation'" [2] (below, "ITS FORUM RC-017"), a guideline issued by the ITS Forum, as communication scenarios draft of the SIP use cases for Cooperative Driving Automation [1] (below, "SIP UC"). After a comparison and analysis of the two sets of organization results, a 5.9 GHz band communication protocol proposal was created by adding the unique specifications of the communication scenarios draft to the European and American specifications and summarizing the communication control flows and protocol stacks as an overview draft (Section 5.1.3), after which the functions, operations, and interfaces were summarized as a detailed specifications draft (Section 5.1.4) and a study was done on the method of linking to the ITS wireless communication specification (700 MHz Band Intelligent Transport Systems [3]) already existing in Japan (Section 5.1.5). Taking account of the communication protocol proposal that was created, the communication sequence based on examples of SIP UC communication scenarios (see ITS FORUM RC-017) was detailed based on the layer categories and interlayer interfaces of the communication protocol proposal to confirm the appropriateness of the functions, operations, interfaces, etc. (Section 5.1.6), and finally, study issues were organized (Section 5.1.7). Concerning security, the same system as the European and American specifications (electronic signature) was anticipated. The preconditions necessary to study the communication protocol proposal (interfaces, processing procedures, etc.) were organized, but a study of detailed specifications was outside the scope of this effort.

The flow of the process of study described above is shown in Fig. 5.1.1-2, while a communication protocol proposal summary image is shown in Fig. 5.1.1-1.




**Communication control flow example (sending side)**




**Example of protocol stack (ITS FORUM RC-005 Version 3.0)**

| Items | | Candidate communication method (addition and review of functions based on existing ITS communication) | | |
|---|---|---|---|---|
| | | ITS FORUM RC-005 based **+ additional functions** | ARIB STD-T109 based **+ additional functions** | ARIB STD-T75 based **+ additional functions** |
| Feasible UC | V2I (I -> V) | 1-2-2, 1-2-3, 2-1-1, 2-2 | | 1-2-2, 1-2-3, 2-1-1, 2-2 |
| | V2V | 1-2-1, 2-1-2, 3 | | – |
| | Vehicle-to-Infrastructure/vehicle to vehicle cooperative | 1-2-4 | | – |
| Application | **Relay control** | **Present (UC1-2-1)** | | None |
| | **Transmission control** | **Present (UC2-1-2,UC3)** | **Present (UC2-1-2)** | None |
| L7 (communication upper layer) | **Successive transmission control** | **Present (change the number of times according to UC)** | None/**Present (during automatic driving support)** | None/**Present (during automatic driving support)** |
| L2 (data link layer) | MAC method | CSMA/CA (random backoff control) | | TDMA (Slotted ALOHA) |
| | Retransmission control | None | | Present |
| | Packet segmentation/recombination | Present | None/**Present (during automatic driving support)** | Present |
| L1 (physical layer) | Center frequency | 5.8 GHz band | 760 MHz band | 5.8 GHz band |
| | Antenna power | 10 mW/MHz or less | | Base station: 300 mW or less, Mobile station: 10 mW or less |
| | Occupied bandwidth | 9 MHz | | 4.4 MHz |
| | Modulation method | QPSK/OFDM, 16QAM/OFDM | | π/4 shift QPSK |
| | Error correction | Convolutional code (coding rate 1/2) | | BCH code (63,51) |
| | Diversity control (receiving) | None/Present (during automatic driving support) | | None |

***Blue letters: Additional changes from the existing base ITS communication specifications**

**Example of communication specifications**

**With reference to the existing communication standards (DSRC, CV2X) for ITS (intelligent transport system), add and organize the results of the examination of project item b (communication channel allocation, communication congestion control) and the method of cooperation with the 700 MHz Band Intelligent Transport Systems.**

**Fig. 5.1.1-1 Communication protocol proposal summary image (communication control flows, protocol stacks, communication specifications)**

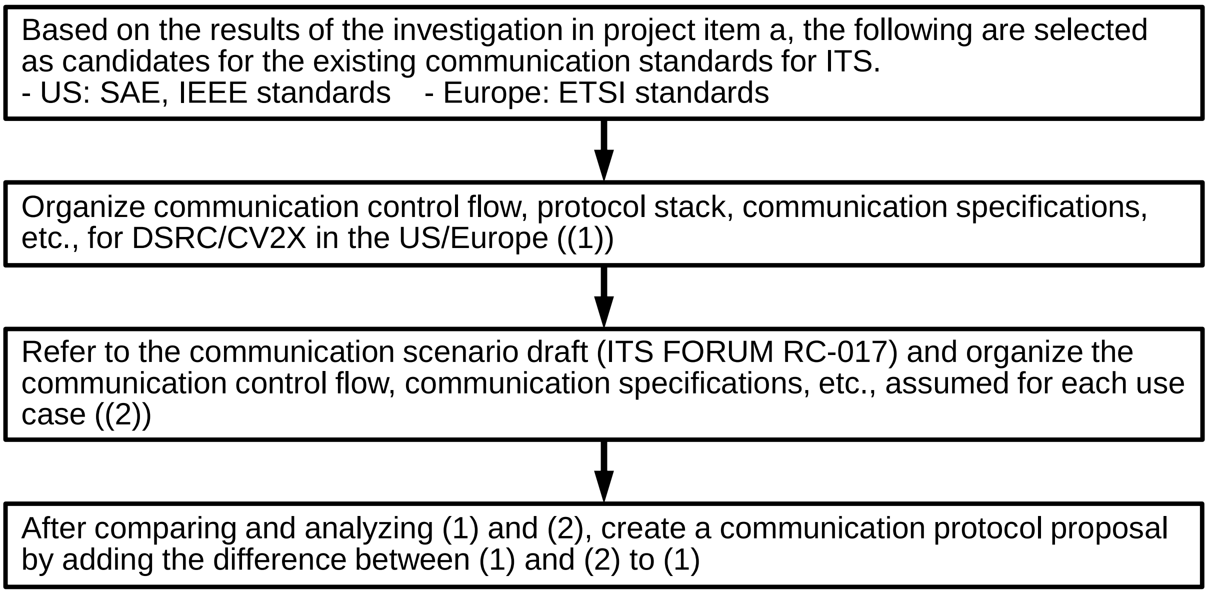



**Fig. 5.1.1-2 Communication protocol proposal study procedure**

### 5.1.2 Organization of reference standards

This section describes the results of organizing the communication control flows and protocol stacks (Section (1)), communication specifications (Section (2)), and interlayer interfaces (Section (3)) after a study was done of DSRC/CV2X technical specifications of the U.S. and Europe, taking the SAE and IEEE standards of the U.S. and the ETSI standards of Europe (below, "European and American specifications") as candidates for existing 5.9 GHz band ITS wireless communication standards, based on the results of the survey of trends internationally (Part 3).

(1) Communication control flows, protocol stacks

An overview of European and the US specifications' communication control flows and protocol stacks is given in Table 5.1.2-1. For convenience, the message sublayer in the US specifications (SAE J2945/1, J3161/1, etc.) and facility layer in European specifications (ETSI TS 102 894-1, etc.) are organized here as "upper layers (Layer 5 to 7 equivalent)" as functions equivalent to Layer 5 to 7.

A comparison of European and the US specifications shows that, in respect to communication control flows, the American specifications do not have a substantial function in Layer 3, but there is no difference in basic functions in other layers. In respect to protocol stacks, there is some deviation between the two in how Layer 3 to 7 are composed, but in the respective specifications, there is a common stack with the two wireless communication methods (DSRC, CV2X) in Layer 1 to 2. Additionally, the composition of Layer 1 to 2 is common to Europe and America in each wireless communication method (DSRC, CV2X), and DSRC provides a multi-channel switching function, unlike CV2X.

Results of organizing details of communication control flows and protocol stacks under American DSRC, American CV2X, European DSRC, and European CV2X are given below in Fig. 5.1.2-1 to Fig. 5.1.2-4.

**Table 5.1.2-1 Overview of reference standards (communication control flows, protocol stacks) [4]-[25]**

<table>
<tr><th rowspan="3">Layer</th><th colspan="4">Communication control flow</th><th colspan="4">Protocol stack</th></tr>
<tr><th colspan="2">US</th><th colspan="2">Europe</th><th colspan="2">US</th><th colspan="2">Europe</th></tr>
<tr><th>DSRC</th><th>CV2X</th><th>DSRC</th><th>CV2X</th><th>DSRC</th><th>CV2X</th><th>DSRC</th><th>CV2X</th></tr>
<tr><td>Application</td><td colspan="4">- Send message periodically<br>- Priority setting, transmission timing determination</td><td colspan="2">EEBL, FCW, etc.<br>(DSRC:SAE J2945/1, etc.,<br>CV2X:SAE J3161/1, etc.)</td><td colspan="2">Co-operative Awareness,<br>Road Hazard Warning, etc.<br>(ETSI TS 102-637-1, etc.)</td></tr>
<tr><td>Upper layer<br>(Layer 5 to 7 equivalent)</td><td colspan="4">- Periodically transmit basic vehicle information (*1)<br>- Congestion control (bandwidth control (*2))<br>- Multiplexing of information elements(*3)<br>- Split message (*4)<br>- Send hazard information periodically (*5)<br>- Transfer hazard information (*5, 6)</td><td colspan="2">Communication service: BSM Exchange, etc.<br>(DSRC:SAE J2945/1, etc.,<br>CV2X:SAE J3161/1, etc.),<br>Message: BSM, etc.<br>(SAE J2735, etc.)</td><td colspan="2">Communication service: CA Basic Service,<br>DEN Basic Service, etc.<br>(ETSI TS 102-894-1, etc.),<br>Message: CAM, DENM, etc.<br>(ETSI TS 102-894-2, etc.)</td></tr>
<tr><td>Transport layer<br>(Layer 4)</td><td colspan="4">Added information identifying upper layer services</td><td colspan="2">WSMP Transport Protocols<br>(IEEE 1609.3)</td><td colspan="2">Basic Transport Protocol<br>(ETSI EN 302 636-5)</td></tr>
<tr><td>Network layer<br>(Layer 3)</td><td colspan="2">No real functionality</td><td colspan="2">- Added information to identify the destination on the network<br>- Send repeatedly (*6)<br>- Forward packet</td><td colspan="2">WSMP Networking Protocols<br>(IEEE 1609.3)</td><td colspan="2">GeoNetworking<br>(ETSI EN 302 636-4-1, etc.)</td></tr>
<tr><td rowspan="4">Data link layer<br>(Layer 2)</td><td colspan="4">Added information identifying the upper layer protocol</td><td>LLC<br>(IEEE 1609.3)</td><td>PDCP<br>(ETSI TS 136 323)</td><td>LLC<br>(ISO/IEC 8802-2)</td><td>PDCP<br>(ETSI TS 136 323)</td></tr>
<tr><td colspan="4">Cannel allocation</td><td>Channel Coordination<br>(IEEE 1609.4)</td><td>–</td><td>Multichannel Operation<br>(ETSI TS 102 724)</td><td>–</td></tr>
<tr><td colspan="4">Split packet</td><td rowspan="2">MAC<br>(IEEE 802.11)</td><td>RLC<br>(ETSI TS 136 322)</td><td rowspan="2">MAC<br>(IEEE 802.11)</td><td>RLC<br>(ETSI TS 136 322)</td></tr>
<tr><td colspan="4">- Added information identifying the transmission source link<br>- Wireless multiplexing - Retransmission control (*7)<br>- Congestion control (priority control (*8))</td><td>MAC<br>(ETSI TS 136 321)</td><td>MAC<br>(ETSI TS 136 321)</td></tr>
<tr><td>Physical layer<br>(Layer 1)</td><td colspan="4">Encode, modulate and transmit</td><td>PHY<br>(IEEE 802.11)</td><td>PHY<br>(ETSI TS 136 201)</td><td>PHY<br>(IEEE 802.11)</td><td>PHY<br>(ETSI TS 136 201)</td></tr>
<tr><td>Security layer</td><td colspan="4">Add information (signature) to ensure the authenticity of the transmission source and the integrity of the message</td><td colspan="4">Electronic signature<br>(US: IEEE 1609.2, Europe: ETSI TS 102 940, etc.)</td></tr>
</table>

(*1) For BSM transmission with US specifications or CAM transmission with European specifications
(*2) For US DSRC, with output control (*3) For European specifications (consideration example based on ETSI TR 103 439)
(*4) For MAPEM transmission with European specifications (*5) For DENM transmission with European specifications
(*6) Option (*7) For CV2X (*8) In the case of European DSRC, there is band control and output control

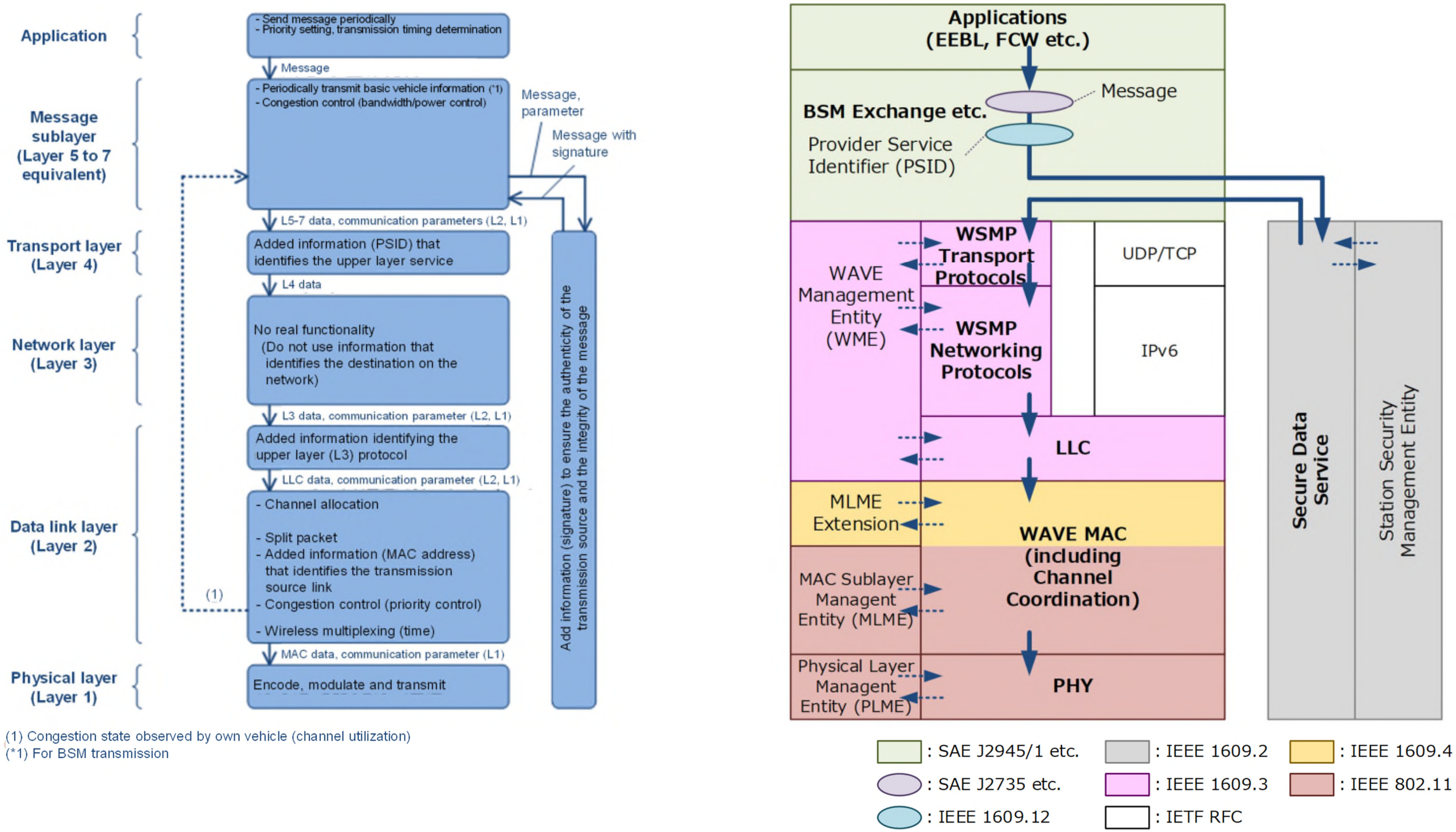



**Fig. 5.1.2-1 Communication control flows, protocol stacks (American DSRC) [4], [6]-[10], [26]**

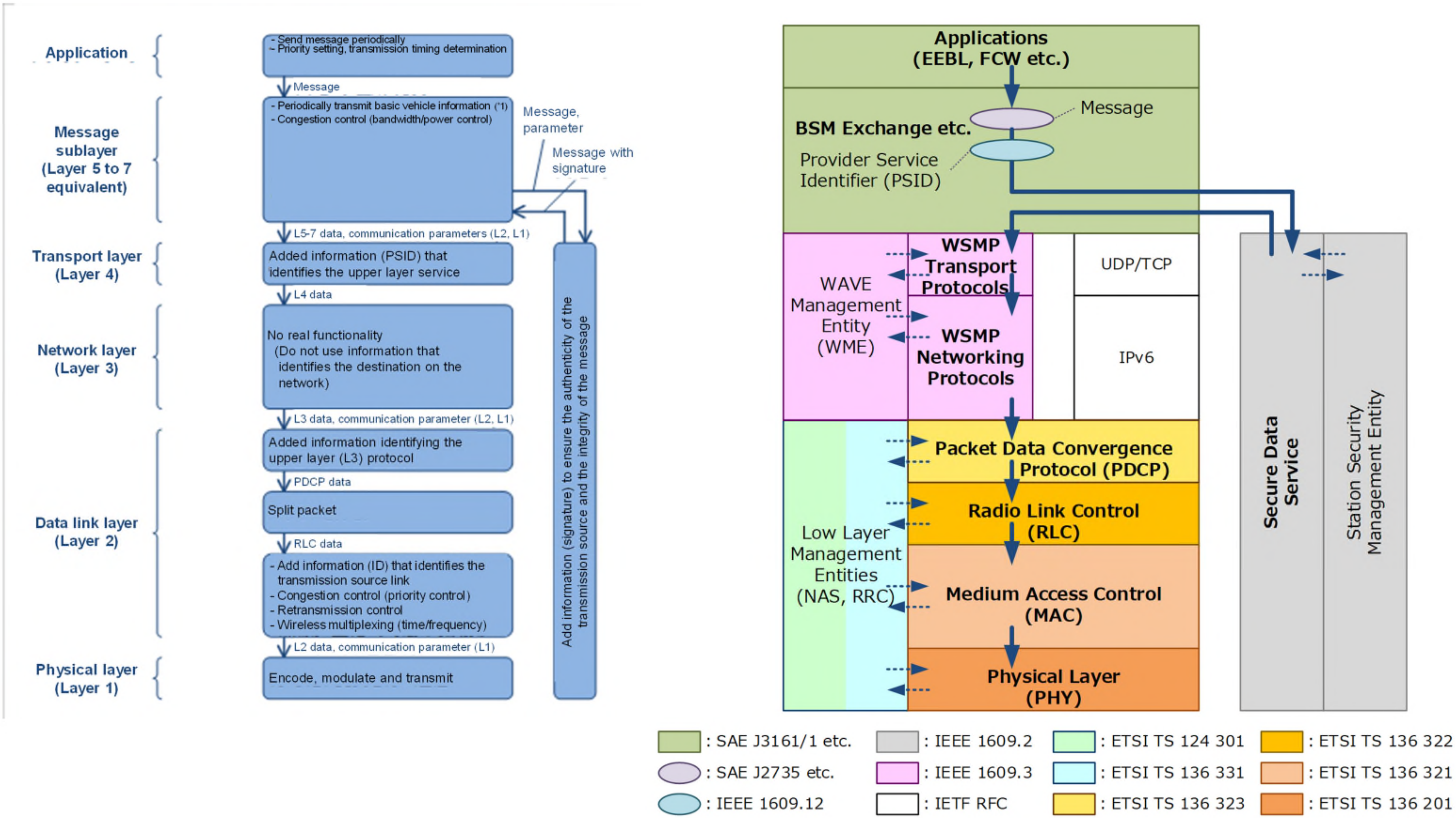



**Fig. 5.1.2-2 Communication control flows, protocol stacks (American CV2X) [5]-[9], [11]-[14], [26]-[28]**

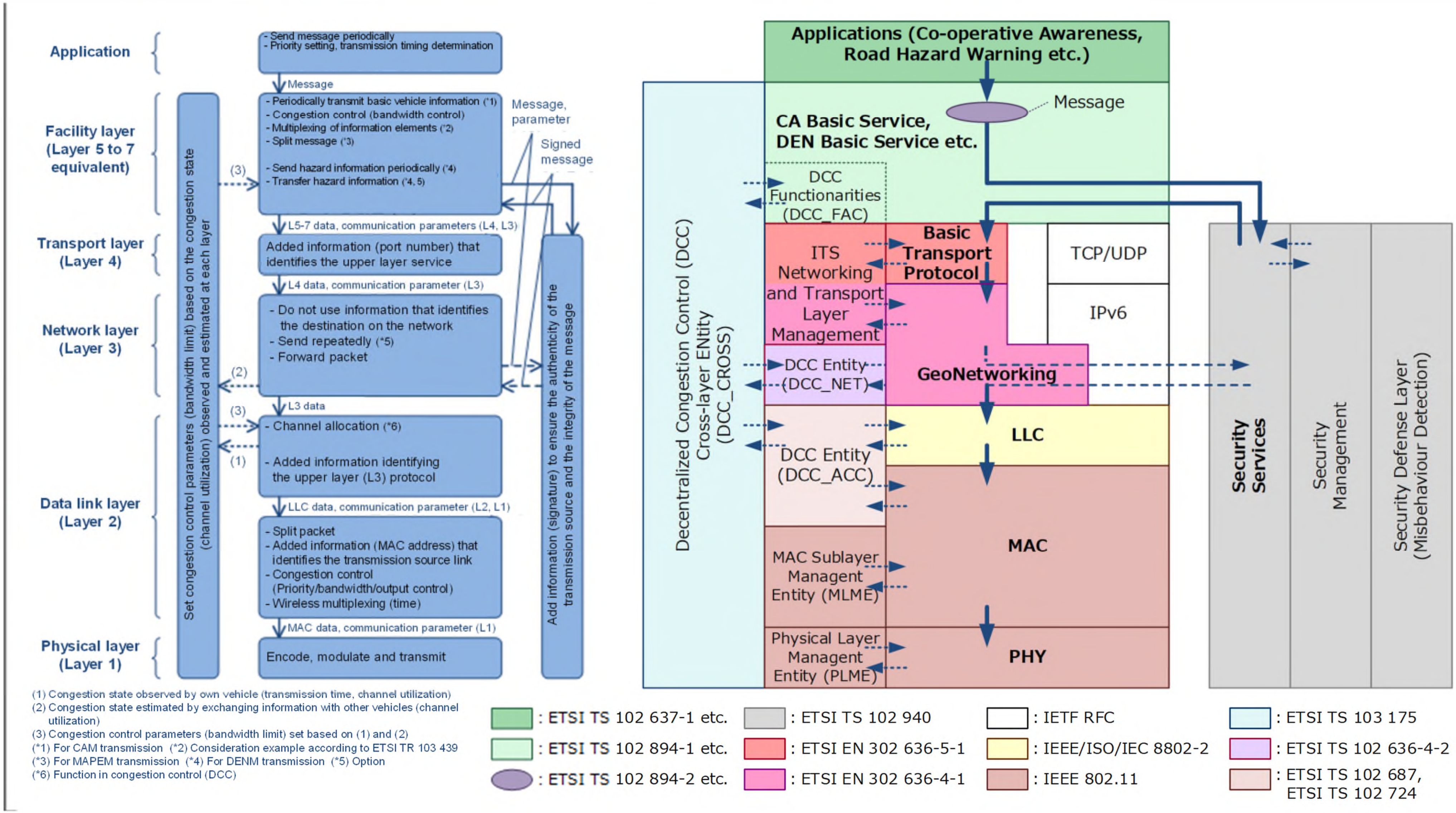



**Fig. 5.1.2-3 Communication control flows, protocol stacks (European DSRC) [15]-[23], [29]-[31]**

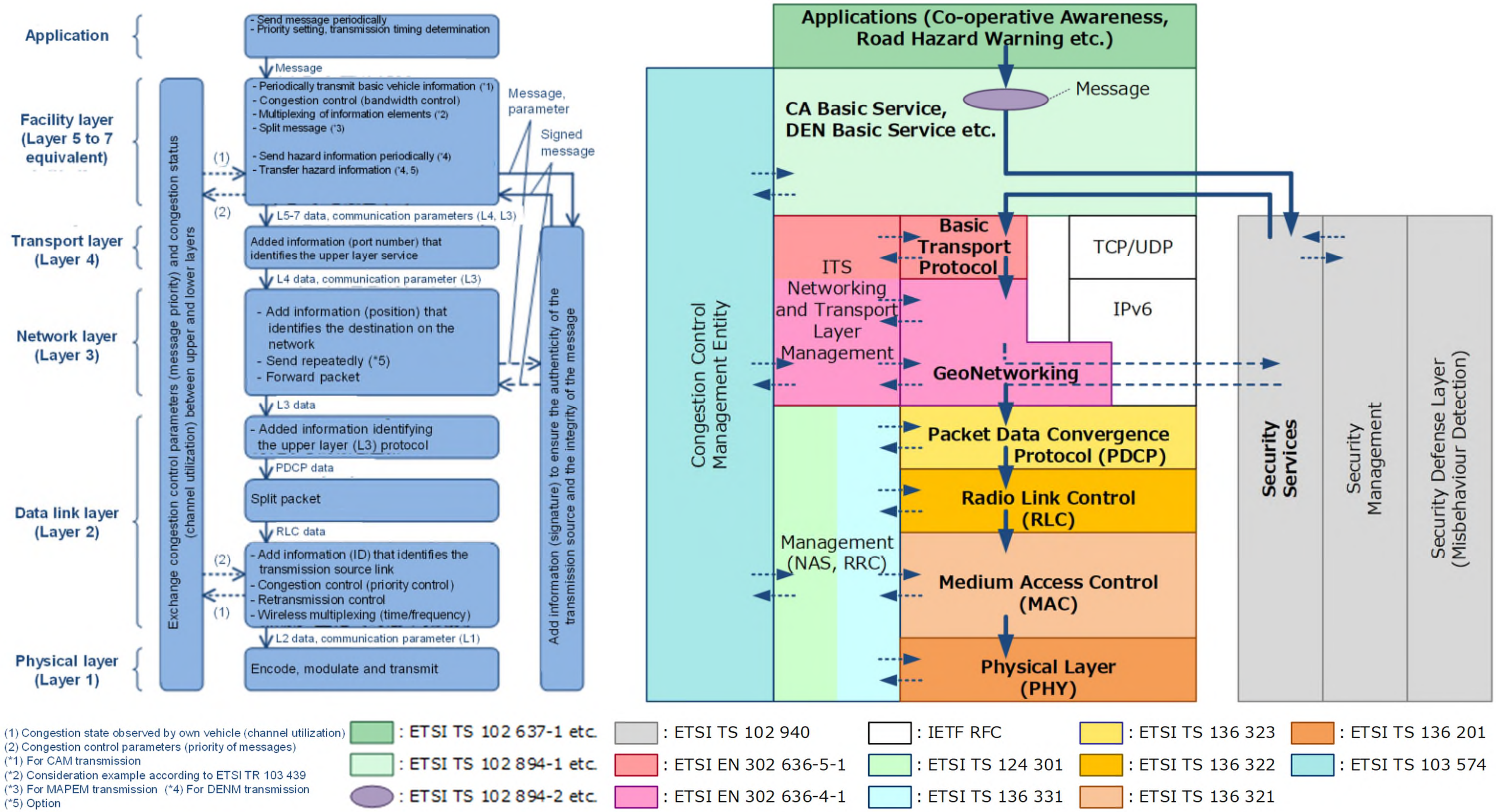



**Fig. 5.1.2-4 Communication control flows, protocol stacks (European CV2X) [15]-[20], [24], [27]-[28], [32]**

(2) Communication specifications

This section describes results of organizing communication specifications in European and the US specifications, breaking the description down to the upper layers (Layer 5 to 7 equivalent) (Section (a)), network and transport layers (Layer 3 to 4) (Section (b)), congestion control (Section (c)), and multi-channel operation (d).

(a) Upper layers (Layer 5 to 7 equivalent)

First, the upper layer specifications of the European specifications are described in Table 5.1.2-2.

Communication services in the upper layers (equivalent to the facility layer under the European specifications) are determined for each message, but services in Day 2 and beyond (CPS, which shares sensor information; MCS, which does negotiation; platooning; etc.) are currently being standardized and future trends will need to be confirmed.

Next, the upper layer specifications of the US specifications are described in Table 5.1.2-3. Communication services other than BSM are currently being standardized (and together with that, message set specifications are scheduled to be reviewed) and future trends will need to be confirmed. A comparison of European and the US specifications shows that communication services that transmit BSM under the US specifications do not have very different specifications from communication services that transmit similar messages (CAM, DENM) under the European specifications.

**Table 5.1.2-2 Communication specifications (upper layers of European specifications) [15], [25], [33]-[39]**

■ **Application example (reference)**

| Phase (*1) | Day 1 (Awareness Driving) | | | | Day 2 (Sensing Driving) | Day 3+ (Co-operative Driving) | |
|---|---|---|---|---|---|---|---|
| Name | Co-operative Awareness | Road Hazard Warning | Intersection Collision Risk Warning | Traffic Light Prioritisation | Overtaking Vehicle Warning | Co-operative Lane Change | Platooning |
| Source (*2) | ETSI TS 102 637-1 | | ETSI TS 101 539-2 | ETSI TS 103 301 | ETSI TR 102 638 | | *ETSI TR 103 298* |

■ **Upper layer (L5-7 equivalent)**

| Communication service | CA Basic Service | DEN Basic Service | RLT Service | TLM Service | IVI Service | TLC Service | CP Basic Service | MC Service | – | |
|---|---|---|---|---|---|---|---|---|---|---|
| Message name | CAM | DENM | MAPEM | SPATM | IVIM | SREM, SSEM | CPM | MCM | PAM | PCM |
| Standard specifications (*2) | ETSI EN 302 637-2 | ETSI EN 302 637-3 | ETSI TS 103 301 | | | | ETSI TR 103 562 | *ETSI TS 103 561* | *ETSI TR 103 298* | |
| Communication method | V2V, V2I, I2V | | I2V | | | V2I, I2V | V2V, V2I, I2V | | V2V | V2V |
| Message destination | Non-specific vehicles (*3) | | | | | | | | | Specific vehicles (*4) |
| Periodic/aperiodic | Periodic | Aperiodic | Periodic | | | Aperiodic | Periodic | Aperiodic | Periodic | Periodic |
| Transmission interval | 0.1 to 1.0 | | 1.0 | | | – | 0.1 to 1.0 | | 0.05 to 0.1 | 0.02 to 1.0 |
| Transmission | None | None/Present | | | | | | None | | |
| Similar US specs (Reference) (*2) | SAE J2945/1, SAE J3161/1 | SAE J2945/2 | *SAE J2945/B* | | *SAE J2945/4* | – | *SAE J2945/8*, SAE J3224 | *SAE J3186* | *SAE J2945/6* | |

(*1) Refer to "Guidance for day 2 and beyond roadmap, July 2021" (C2C-CC) for correspondence between phases and applications
(*2) Italics have not yet been published, so for European specifications see the relevant document (ETSI TR 103 439)
(*3) MC Service may be for specific vehicles (*4) Non-specific vehicles are also possible

**Table 5.1.2-3 Communication specifications (upper layers of the US specifications) [4]-[5], [40]-[41]**

■ **Application example (reference)**

| Name | Emergency Electronic Brake Lights | Emergency Vehicle Alert | Road Weather Applications | Signalized Intersection Applications | Road Safety Applications | Cooperative Perception System | Sensor Sharing Service | Maneuver Sharing and Coordinating Service | Platooning |
|---|---|---|---|---|---|---|---|---|---|
| Source (*1) | SAE J2945/1, SAE J3161/1 | SAE J2945/2 | SAE J2945/3 | *SAE J2945/B* | *SAE J2945/4* | *SAE J2945/8* | SAE J3224 | *SAE J3186* | *SAE J2945/6* |

■ **Upper layer (L5-7 equivalent)**

| Message name | BSM | BSM | RWM | MAP, SPaT | TIM | PSM | SDSM | | |
|---|---|---|---|---|---|---|---|---|---|
| Standard specifications (*1) | SAE J2945/1, SAE J3161/1 | SAE J2945/2 | SAE J2945/3 | *SAE J2945/B* | *SAE J2945/4* | *SAE J2945/8* | SAE J3224 | *SAE J3186* | *SAE J2945/6* |
| Communication method | V2V, V2I | | I2V | V2I | | V2V, V2I, I2V | | | V2V |
| Message destination | Unspecified vehicle | | | | | | | | |
| Periodic/aperiodic | Periodic (*2) | Aperiodic | Aperiodic | | | | | | |
| Transmission interval | | 0.1 to 0.6 | 0.5 to 1.0 | | | | | | |
| Transmission | None | | | | | | | | |
| European similar specifications (Reference) (*1) | ETSI EN 302 637-2 | ETSI EN 302 637-3 | | ETSI TS 103 301 | | ETSI TR 103 562 | | *ETSI TS 103 561* | *ETSI TR 103 298* |

(*1) Italics have not yet been published, so please refer to the summary on the SAE website for US specifications
(*2) Send timing reset due to event occurrence

(b) Network and transport layers (Layer 3 to 4)

The communication specifications of the network and transport layers (Layer 3 to 4) are given in Table 5.1.2-4.

Under both the European and the US specifications, the transport layer (Layer 4) is anticipated to have broadcasting capabilities and to work in real time; the specifications are similar to UDP in the Internet protocol. As for the network layer (Layer 3), under the US specifications, it does not have an address and thus effectively has no function, but under the European specifications, it uses position information to designate an address and is capable of multi-hop communication.

**Table 5.1.2-4 Communication specifications (Layer 3 to 4 of European and American specifications) [8], [18]-[19]**

■ **Transport layer (L4)**

| Region | US | Europe | – | |
|---|---|---|---|---|
| Protocol name | **WSMP Transport Protocols** | **Basic Transport Protocol** | UDP (Reference) | TCP (Reference) |
| Standard specifications | IEEE 1609.3 | ETSI EN 302 636-5 | IETF RFC | |
| Identification of upper layer services | Present (PSID) | Present (Port number) | | |
| 1:1 communication | Available | | | |
| 1:N communication | Available | | | Not available |
| Connection establishment | None | | | Present |
| Congestion control | None | | | Present |
| Packet division/combination | None | | | Present |
| Retransmit | None | | | Present |
| Error detection | None | | Present | |

■ **Network layer (L3)**

| Region | US | Europe | – |
|---|---|---|---|
| Protocol name | **WSMP Networking Protocols** | **Geo-Networking** | IPv6 (Reference) |
| Standard specifications | IEEE 1609.3 | ETSI EN 302 636-4 | IETF RFC |
| Identifying upper layer protocols | None | Present | |
| Specifying the destination address | Not available | Available (Location) | Available (Identification number) |
| Packet transmission | Not available | Available | |

(c) Congestion control

Congestion control communications specifications are listed in Table 5.1.2-5.

Under the European specifications, the bandwidth is controlled based on the channel usage rate as measured in Layer 1 to 2 (the upper layers change the transmission interval; DSRC adds a transmission delay and controls output; CV2X allocates resources and changes the upper limit). In the case of the US specifications, vehicle density is estimated based on signal receiving status, by which bandwidth is controlled (the upper layers change the transmission interval and CV2X allocates resources and changes the upper limit). Additionally, under both the European and the US specifications, priority control is performed based on the priority level that is set in the upper layers (a queue sorted by priority level is kept; in the case of DSRC, transmission waiting time is set according to priority level, while in CV2X, the number of resources that can be allocated is set according to priority level).

**Table 5.1.2-5 Communication specifications (congestion control in European and American specifications) [4]-[5], [29]-[30], [32]**

■ **Congestion control**

| Region | US | | Europe | |
|---|---|---|---|---|
| Protocol name | **DSRC** | **CV2X** | **DSRC** | **CV2X** |
| Standard specifications | SAE J2945/1 | SAE J3161/1 | ETSI TS 103 175, ETSI TS 102 687 | ETSI TS 103 574 |
| Information sharing with other vehicles | None | | Present (Channel utilization) (*) | None |
| Bandwidth control (upper layer) | Present (Setting of transmission interval according to vehicle density) | | Present (Setting transmission interval by channel utilization) (*) | |
| Bandwidth control (MAC) | None | Present (Setting resource limits by channel utilization) | Present (Addition of transmission delay due to channel utilization) | Present (Setting resource limits by channel utilization) |
| Priority control (MAC) | Present (According to the priority set in the upper layer) | | | |
| Output control (PHY) | Present (By channel utilization) | None | Present (By channel utilization) (*) | None |

(*) Option

(d) Multi-channel operation

Communication specifications of multi-channel operation in the case of DSRC are given in Table 5.1.2-6.

Under the US specifications, one tuner switches between two channels (CCH and SCH) while receiving signals, enabling the system to recognize services that can be used in CCH and the channel that services use (CCH or SCH), so it can switch to the desired service channel (SCH). Under European specifications, each service is anticipated to prioritize use of CCH; with a single tuner, only CCH signals would be received, while with a multi-tuner, a channel other than CCH (i.e., SCH), which low-priority-level services use when there is communication congestion, could also receive signals.

**Table 5.1.2-6 Communication specifications (multi-channel operation in European and American specifications) [9], [23]**

■ **Data link layer (L2): Multi-channel operation (DSRC only)**

| Region | US | Europe |
|---|---|---|
| Standard specifications | IEEE 1609.4 | ETSI TS 102 724 |
| Channel type | Present (Single CCH, multiple SCHs) | |
| Applications of CCH | Non-IP data (Assuming notification of channels used in non-safety-related services) | - High priority information (Assuming safety services)<br>- Low priority information (Assuming safety services. If the channel is free) |
| Uses of SCH | All data (Assuming non-safety services) | Low priority information (Assuming non-safety services) |
| Time division of CCH and SCH | Present (CH and SCH can be used even with a single tuner) | None (For single tuner, only CCH can be used) |

(3) Interlayer interface

This section begins by giving an overview of results of organizing the interlayer interfaces under the European and the US specifications (Section (a)), then provides details about the European specifications (Section (b)) and American specifications (Section (c)).

(a) Overview

An overview of the interlayer interface (request primitive parameters) under the European and the US specifications is given in Table 5.1.2-7.

Under the US specifications, the communication parameters of all the lower layers (Layer 1 to 4) are passed from the upper layers. Under the European specifications, the communication parameters of Layer 3 to 4 are mainly passed from the upper layer and the communication parameters of Layer 1 to 2 from the control entity of congestion control.

**Table 5.1.2-7 Overview of reference standards (interlayer interface) [4]-[5], [7]-[10], [18]-[19], [21], [24], [29]-[32], [37]-[38], [42]**

<table>
<tr><th rowspan="3">Layer</th><th colspan="6">Layer-to-layer interface (parameters of request primitives)</th></tr>
<tr><th colspan="3">US</th><th colspan="3">Europe</th></tr>
<tr><th colspan="2">DSRC</th><th>CV2X</th><th colspan="2">DSRC</th><th>CV2X</th></tr>
<tr><td>Upper layer<br>(Layer 5 to 7 equivalent)</td><td colspan="3">(No clear definition)</td><td colspan="3">- Information related to the event (detection time, location, etc.)<br>- Upper layer communication parameters (repeat interval, presence/absence of transfer, etc.)<br>- Layer 3 communication parameters (destination area, traffic class)<br>- Part of message (generated by application)</td></tr>
<tr><td>Transport layer<br>(Layer 4)</td><td colspan="3" rowspan="2">- Layer 4 communication parameters (information identifying upper layer services (PSID))<br>- Parameters for allocation to channels (channel identifier, time slot)<br>- Layer 2 communication parameters (destination, priority, end time)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message</td><td colspan="3">- Communication parameter of Layer 4<br>(Information that identifies the upper layer service (destination port), etc.)<br>- Communication parameter of Layer 3<br>(Transmission form, destination area, traffic class, time to live, number of hops, etc.)<br>- Message - Security layer parameters (*3)</td></tr>
<tr><td>Network layer<br>(Layer 3)</td><td colspan="3">- Communication parameter of Layer 3<br>(Transmission form, destination area, traffic class, time to live, number of hops, etc.)<br>- Message (Layer 4 PDU) - Security layer parameters (*3)</td></tr>
<tr><td rowspan="2">Data link layer<br>(Layer 2)</td><td>LLC</td><td>- Parameters for channel allocation<br>(Channel identifier, timeslot)<br>- Communication parameter of Layer 2<br>(Destination, priority, end time, channel identifier)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (Layer 3 PDU)</td><td rowspan="3">- Transmitter setting parameters<br>(Channel, etc.) (*1)<br>- Communication parameter of Layer 2<br>(Destination, priority, end time)<br>- Communication parameter of Layer 1<br>(Transmission power)<br>- Message (Layer 3 PDU)</td><td>LLC</td><td>- Parameters for channel allocation<br>(Channel number, transmitter ID) (*4)<br>- MAC communication parameters<br>(Transmission source, destination, priority (*5))<br>- Communication parameter of Layer 1<br>(Transmission power, MCS) (*4)<br>- Message (Layer 3 PDU)</td><td rowspan="3">- Communication parameter of Layer 2<br>(Priority (*4, 5))<br>- Message (Layer 3 PDU)</td></tr>
<tr><td>MAC</td><td>- Parameters for channel allocation<br>(Channel identifier, timeslot)<br>- Communication parameter of Layer 2<br>(Destination, priority, end time, channel identifier)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (LLC PDU)</td><td>MAC</td><td>- MAC communication parameters<br>(Transmission source, destination, priority (*5))<br>- Communication parameter of Layer 1<br>(Transmission power, MCS)<br>- Message (LLC PDU)</td></tr>
<tr><td>Physical layer<br>(Layer 1)</td><td colspan="2">- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (MAC PDU)</td><td colspan="2">- Communication parameter of Layer 1<br>(Transmission power, MCS)<br>- Message (MAC PDU)</td></tr>
<tr><td>Security layer</td><td colspan="6">- Security layer parameters (information identifying services (US: PSID, Europe: ITS-AID) (*2), etc.)<br>- Message (requesting layer PDU)</td></tr>
</table>

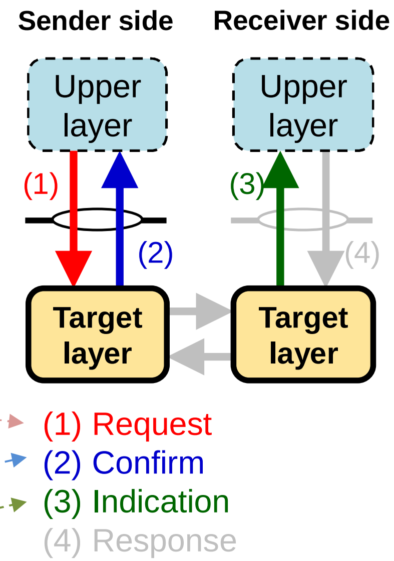
(*1) Via Layer 3-4 management entity (*2) Required to reflect service-specific permissions (*3) When signing in the network layer
(*4) Via congestion control management entity (*5) Set based on Layer 3 communication parameters (traffic class)

(b) European specifications

Table 5.1.2-8 to Table 5.1.2-14 provide interlayer interface details under the European specifications, for the upper layers, Layer 1 to 4, security layer, DSRC congestion control interface, and CV2X congestion control interface, respectively.

**Table 5.1.2-8 Interlayer interface (upper layers of European specifications) [37]-[38]**

| Target layer | Facility layer (Layer 5 to 7 equivalent) | | | |
|---|---|---|---|---|
| **Communication service (Message)** | **CA Basic Service (CAM)** | **DEN Basic Service (DENM)** | | |
| **Interface name** | **(N/A)** | **IF.DEN.1** | | |
| **Request type (Occurrence condition)** | **–** | **AppDENM_trigger (Detect new events)** | **AppDENM_update (Detect event changes)** | **AppDENM_termination (Detect end of event)** |
| **Parameter of (1)** | – | Event detection time<br>Event position<br>Event validity duration (*1)<br>Repetition duration (*1)<br>Transmission interval (*1)<br>Repetition interval (*1)<br>Information contained in the situation container (*1,2)<br>Information contained in the location container (*1,3)<br>Information contained in the a la carte container (*1,4)<br>Relevance area of the event (*1)<br>Destination area (*1)<br>Traffic class | actionID or other applicable identifier<br>Event update detection time<br>Event position<br>Event validity duration (*1)<br>Repetition duration (*1)<br>Transmission interval (*1)<br>Repetition interval (*1)<br>Information contained in the situation container (*1,2)<br>Information contained in the location container (*1,3)<br>Information contained in the a la carte container (*1,4)<br>Relevance area of the event (*1)<br>Destination area (*1)<br>Traffic class (*1) | actionID or other applicable identifier<br>Event termination detection time<br>Event position<br>Event validity duration (*1)<br>Repetition duration (*1)<br>Transmission interval (*1)<br>Repetition interval (*1)<br>Relevance area of the event (*1)<br>Destination area (*1)<br>Traffic class |
| **Parameter of (2)** | – | actionID or other applicable identifier<br>Failure notification (*1) | actionID or other applicable identifier<br>Failure notification (*1) | actionID or other applicable identifier<br>Failure notification (*1) |
| **Interface name** | **IF.CAM** | **IF.DEN.2** | | |
| **Parameter of (3)** | Received data (CAM) | Received data (DENM) (*1) | | |

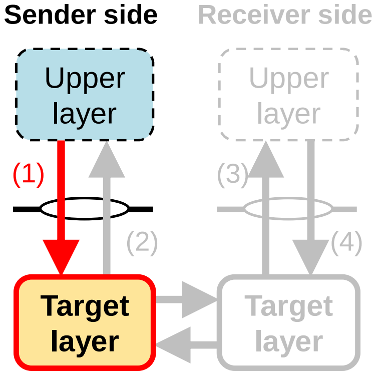



(*1) Option
(*2) Type of event, etc.
(*3) Route to event location, etc.
(*4) Use case specific information

**Table 5.1.2-9 Interlayer interface (Layer 1 to 4 of European specifications, request primitives) [10], [18]-[19], [21]**

| Target layer | Transport layer (Layer 4) | Network layer (Layer 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|---|
| **Primitive name** | **BTP-Data. request** | **GN-DATA. request** | **AL-DATA. request** | **MA-UNITDATA. request** | **PHY-TXSTART. request** |
| **Parameter** | BTP type | | | | |
| | Source port (*1) | Upper protocol entity | | | |
| | Destination port | | | | |
| | Destination port info (*1) | | | | |
| | GN Packet transport type | Packet transport type | | | |
| | | | Source MAC address | source address | |
| | GN Destination address | Destination address | Destination MAC address | destination address | |
| | | | | routing information (*3) | |
| | GN Communication profile | Communication profile | | | |
| | GN Security profile (*1) | Security profile (*1) | | | |
| | | ITS-AID (*1,2) | | | |
| | | Security permissions (*1,2) | | | |
| | | Security context information | | | |
| | | Security target ID list (*1,2) | | | |
| | GN Maximum packet lifetime (*1) | Maximum packet lifetime (*1) | | | |
| | GN Repetition interval (*1) | Repetition interval (*1) | | | |
| | GN Maximum repetition time (*1) | Maximum repetition time (*1) | | | |
| | GN Maximum hop limit (*1) | Maximum hop limit (*1) | | | |
| | GN Traffic class | Traffic class | Priority | priority | |
| | | | | drop eligible | |
| | | | | service class | |
| | | | | station vector (*4) | |
| | | | Transmit power | Transmit power (*5) | TXVECTOR |
| | | | MCS | MCS (*5) | |
| | | | Channel number | | |
| | | | Transceiver ID | | **PHY-DATA. request** |
| | Length | Length | | | |
| | Data | Data | Data | data | DATA |
| | | | | MSDU format | |
| | | | | | USER_INDEX (*4) |
| | | | | | **PHY-TXEND. request** |
| | | | | | (No parameters) |

* Layer1-2 are only for DSRC.




(1) Request
(2) Confirm
(3) Indication
(4) Response

(pink shading) : Identical to the parameters specified in the upper layer primitive (left column) (partial format change and additional data)

(*1) Option
(*2) Include length information
(*3) Always disabled for IEEE802.11
(*4) Valid only in certain cases
(*5) Not included in the original standard (IEEE 802.11)

Table 5.1.2-10 Interlayer interface (Layer 1 to 4 of European specifications, confirm primitives) [10], [18]-[19], [21]

| Target layer | Transport layer (Layer 4) | Network layer (Layer 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|---|
| Primitive Name | (N/A) | GN-DATA. confirm | (N/A) | MA-UNITDATA-STATUS.indication | PHY-TXSTART. confirm |
| Parameter | – | Result code | – | source address<br>destination address<br>transmission status<br>provided priority<br>provided service class | TXSTATUS<br>**PHY-DATA. confirm**<br>(No parameters)<br>**PHY-TXEND. Confirm**<br>SCRAMBLER_OR_CRC (*1) |

(*1) Valid only in certain cases

* Layer1-2 are only for DSRC.

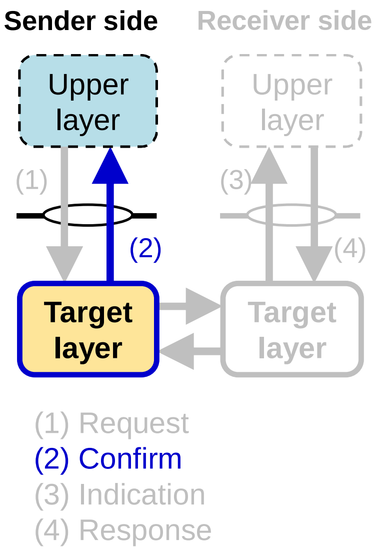
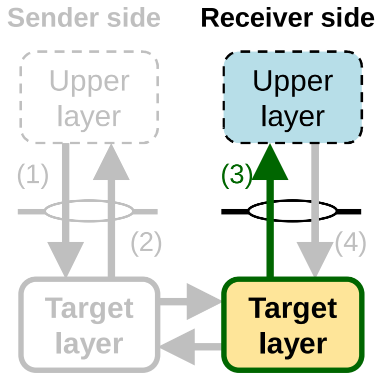


**Table 5.1.2-11 Interlayer interface (Layer 1 to 4 of European specifications, indication primitives) [10], [18]-[19], [21]**

| Target layer | Transport layer (Layer 4) | Network layer (Layer 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|---|
| Primitive name | **BTP-Data. indication** | **GN-DATA. indication** | **AL-DATA. indicate** | **MA-UNITDATA. indication** | **PHY-CCA. indication** |
| **Parameter** | Source port (*1) | | | | |
| | Destination port | Upper protocol entity | | | |
| | Destination port info (*1) | | | | |
| | GN Packet transport type | Packet transport type | | | |
| | | | Source MAC address | source address | |
| | GN Destination address | Destination | Destination MAC address | destination address | |
| | | | | routing information (*3) | |
| | GN Source position vector | Source position vector | | | |
| | GN security report (*1) | Security report (*1) | | | |
| | GN Certificate id (*1) | Certificate ID (*1) | | | |
| | | ITS-AID (*1,2) | | | |
| | GN Permissions (*2) | Security permissions (*1,2) | | | |
| | GN Traffic class | Traffic class | | | |
| | GN Remaining packet lifetime (*1) | Remaining packet life time (*1) | | | |
| | | Remaining hop limit (*1) | | | |
| | | | | reception status | STATE |
| | | | | priority | |
| | | | | drop eligible | |
| | | | | service class | |
| | | | | station vector (*4) | |
| | | | | | IPI-REPORT (*4) |
| | | | | | channel-list (*4) |
| | | | CBR | CBR (*5) | **PHY-RXSTART. indication** |
| | | | | | RXVECTOR |
| | | | Channel number | | **PHY-DATA. indication** |
| | Length | Length | Transceiver ID | | |
| | Data | Data | Data | data | DATA |
| | | | | MSDU format | **PHY-RXEND. indication** |
| | | | RSSI | RSSI (*5) | RCPI |
| | | | | | RXERROR |

* Layer1-2 are only for DSRC.




(1) Request
(2) Confirm
(3) Indication
(4) Response

(green shading) : Identical to the parameters specified in the lower layer primitive (right column) (partial format changes and additional data)

(*1) Option
(*2) Include length information
(*3) Always disabled for IEEE802.11
(*4) Valid only in certain cases
(*5) Not included in the original standard (IEEE 802.11)

**Table 5.1.2-12 Interlayer interface (security layer of European specifications) [42]**

| Target layer | Security layer (Sender side) | | Security layer (Receiver side) | |
|---|---|---|---|---|
| Generation order | 1 | 2 | 1 | 2 |
| Request/ confirm | Request ((1)) | Confirm ((2)) | Request ((1)') | Confirm ((2)') |
| Primitive name | SF-SIGN. request | SF-SIGN. confirm | SF-VERIFY. request | SF-VERIFY. confirm |
| Parameter | tbs_message_length<br>tbs_message<br>its_aid<br>permissions_length<br>Permissions<br>context_information (*1)<br>key_handle (*1) | sec_message_length<br>sec_message | sec_header_length<br>sec_header<br>message_length<br>message | report<br>certificate_id (*1)<br>its_aid_length<br>its_aid<br>permissions |

(*1) Option

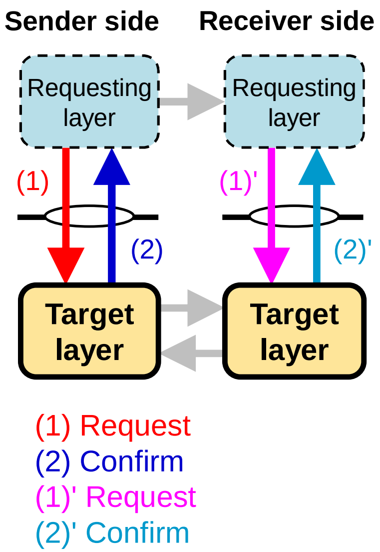


Table 5.1.2-13 Interlayer interface (European DSRC congestion control interface) [29]-[31]

| Target layer | Transport layer (Layer 4) | Transport layer, network layer (Layer 4, 3) | LLC, MAC, PHY (Layer 2, 1) |
|---|---|---|---|
| **Entity name** | **DCC_FAC** | **DCC_NET** | **DCC_ACC** |
| **DCC_CROSS** → | Available CBR ($CBR_a$) | Local CBR<br>CBR target value<br>TX power level upper limit (*1)<br>Idle time ($T_{off}$) (*2)<br>Available CBR ($CBR_a$) (*1,2) | Idle time ($T_{off}$)<br>Upper TX power level limit |
| **DCC_CROSS** ← | (No parameters) | Global CBR | Local CBR<br>Length of all transmitted messages ($T_{on}$) |

(*1) Option
(*2) Not used in current specification

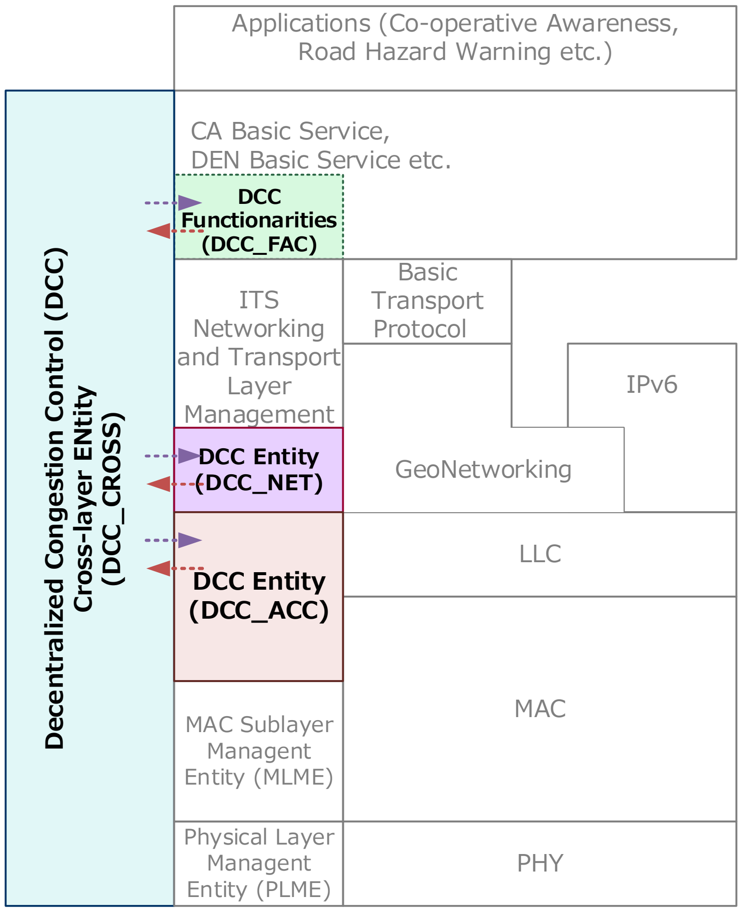
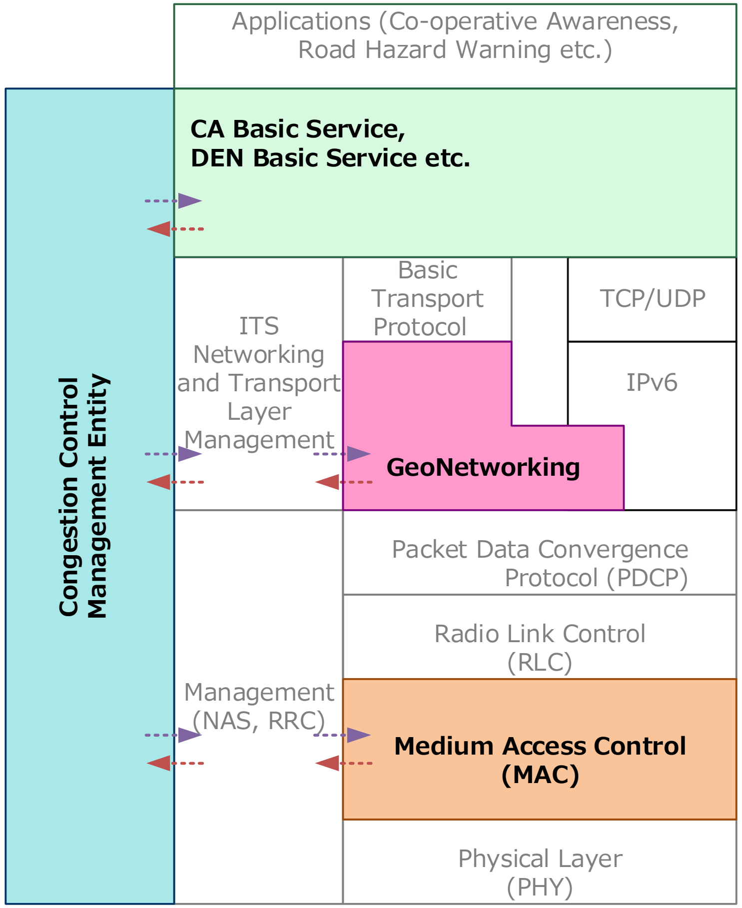


**Table 5.1.2-14 Interlayer interface (European CV2X congestion control interface) [32]**

| Target layer | Transport layer (Layer 4) | Transport layer, network layer (Layer 4, 3) | PDCP, RLC, MAC, PHY (Layer 2, 1) |
|---|---|---|---|
| Management entity | CBR<br>Suggested transmission period<br>TX packet statistics | CBR<br>Suggested transmission period | Priority (PPPP) |
| Management entity | Traffic class (*1) | (No parameters) | TX packet statistics<br>CBR<br>Maximum transmit rate |

(*1) Equivalent to priority



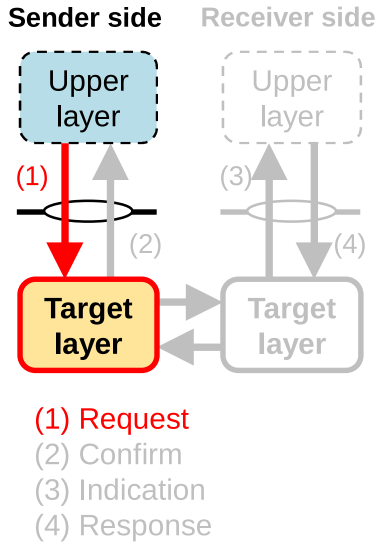
(c) US specifications

Table 5.1.2-15 to Table 5.1.2-21 provide interlayer interface details under the US specifications, for the upper layers, Layer 1 to 4, and security layer, respectively.

## Table 5.1.2-15 Interlayer interface (American DSRC Layer 1 to 4, request primitives) [8]-[10]

| Target layer | Transport layer, network layer (Layer 4, 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|
| **Primitive name** | **WSM-WaveShortMessage. request** | **DL-UNITDATAX. request** | **MA-UNITDATAX. request** | **PHY-TXSTART. request** |
| **Parameter** | Provider Service Identifier | | | |
| | | source_address | source address | |
| | Peer MAC Address | destination_address | destination address | |
| | | | routing information (*1) | |
| | User Priority | priority | priority | |
| | | | service class | |
| | Expiry Time | WsmExpiryTime | ExpiryTime | |
| | Channel Load | Channel Load | | |
| | Transmit Power Level | TxPwr_Level | TxPwr_Level | TXVECTOR |
| | Data Rate | Data Rate | Data Rate | |
| | Channel Identifier | Channel Identifier | Channel Identifier | |
| | Time Slot | Time Slot | Time Slot | |
| | Info Elements Indicator | | | **PHY-DATA. request** |
| | Length | | | |
| | Data | data | data | DATA |
| | | | | USER_INDEX (*2) |
| | | | | **PHY-TXEND. request** |
| | | | | (No parameters) |

(*1) Always disabled for IEEE802.11
(*2) Valid only in certain cases




: Identical to the parameters specified in the upper layer primitive (left column) (partial format changes and additional data)

**Table 5.1.2-16 Interlayer interface (American DSRC Layer 1 to 4, confirm primitives) [8]-[10]**

<table>
<tr><th>Target layer</th><th>Transport layer, network layer<br>(Layer 4, 3)</th><th>LLC<br>(Layer 2)</th><th>MAC<br>(Layer 2)</th><th>PHY<br>(Layer 1)</th></tr>
<tr><th>Primitive name</th><th>WSM-WaveShortMessage.<br>confirm</th><th>(N/A)</th><th>MA-UNITDATAX-<br>STATUS.indication</th><th>PHY-TXSTART.<br>confirm</th></tr>
<tr><td rowspan="5">Parameter</td><td rowspan="5">ResultCode</td><td rowspan="5">–</td><td rowspan="5">source address<br>destination address<br>transmission status<br>provided priority<br>provided service class</td><td>TXSTATUS</td></tr>
<tr><th>PHY-DATA.<br>confirm</th></tr>
<tr><td>(No parameters)</td></tr>
<tr><th>PHY-TXEND.<br>Confirm</th></tr>
<tr><td>SCRAMBLER_OR_CRC (*1)</td></tr>
</table>

(*1) Valid only in certain cases

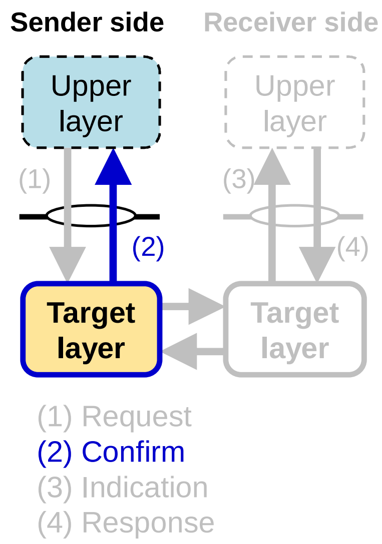
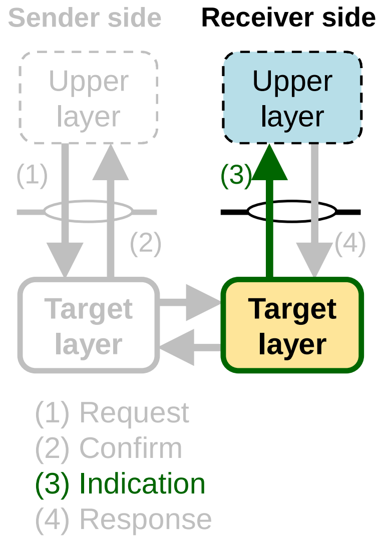


**Table 5.1.2-17 Interlayer interface (American DSRC Layer 1 to 4, indication primitives) [8]-[10]**

| Target layer | Transport layer, network layer (Layer 4, 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|
| **Primitive name** | **WSM-WaveShortMessage. indication** | **DL-UNITDATA. indication** | **MA-UNITDATA. indication** | **PHY-CCA. indication** |
| **Parameter** | Provider Service Identifier | | | |
| | Peer MAC Address | Source address | Source address | |
| | | Destination address | Destination address | |
| | | | Routing information (*1) | |
| | | | Reception status | STATE |
| | User Priority | Priority | Priority | |
| | | | Drop eligible | |
| | | | Service class | |
| | | | Station vector (*2) | |
| | | | | IPI-REPORT (*2) |
| | | | | channel-list (*2) |
| | Channel Load | | | **PHY-RXSTART.** |
| | Transmit Power Level | | | **indication** |
| | Data Rate | | | RXVECTOR |
| | Channel Number | | | **PHY-DATA.** |
| | Length | | | **indication** |
| | Data | Data | Data | DATA |
| | | | MSDU format | **PHY-RXEND.** |
| | WSMP Version | | | **indication** |
| | | | | RCPI |
| | | | | RXERROR |

(*1) Always disabled for IEEE802.11
(*2) Valid only in certain cases

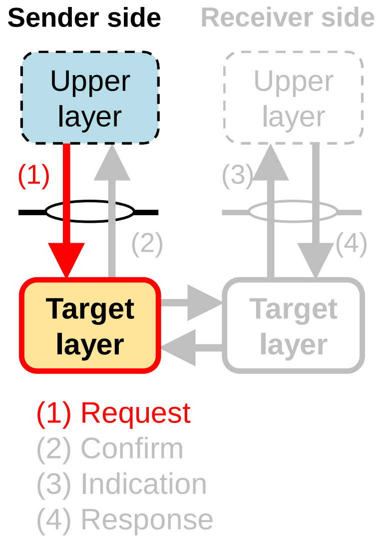



(green shading) : Identical to the parameters specified in the lower layer primitive (right column) (partial format changes and additional data)

**Table 5.1.2-18 Interlayer interface (American CV2X Layer 1 to 4, request primitives) [8]**

| Target layer | Transport layer, network layer (Layer 4, 3) | LTE-V2X (Layer 2, 1) |
|---|---|---|
| Primitive name | WSM-WaveShortMessage. request | AS-DATA. request |
| Parameter | Provider Service Identifier | |
| | Peer MAC Address | Destination Address |
| | User Priority | Priority |
| | Expiry Time | Expiry Time (PDB) |
| | Channel Load | |
| | Transmit Power Level | TxPwr Level |
| | Data Rate (*1) | |
| | Channel Identifier | |
| | Time Slot (*1) | |
| | Info Elements Indicator | |
| | Length | |
| | Data | Data |
| | | TransmitterProfile ID |
| | | Include Time Confidence |

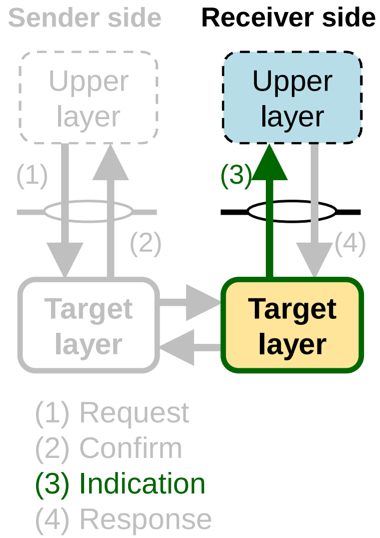
(*1) Not used for LTE-V2X




: Identical to the parameters specified in the upper layer primitive (left column) (partial format change and additional data)

**Table 5.1.2-19 Interlayer interface (American CV2X Layer 1 to 4, indication primitives) [8]**

| Target layer | Transport layer, network layer (Layer 4, 3) | LTE-V2X (Layer 2, 1) |
|---|---|---|
| Primitive name | WSM-WaveShortMessage. indication | AS-DATA. indication |
| Parameter | Provider Service Identifier | |
| | Peer MAC Address | Source Address |
| | User Priority | |
| | Channel Load | |
| | Transmit Power Level | |
| | Data Rate | |
| | Channel Number | |
| | Length | |
| | Data | Data |
| | WSMP Version | |

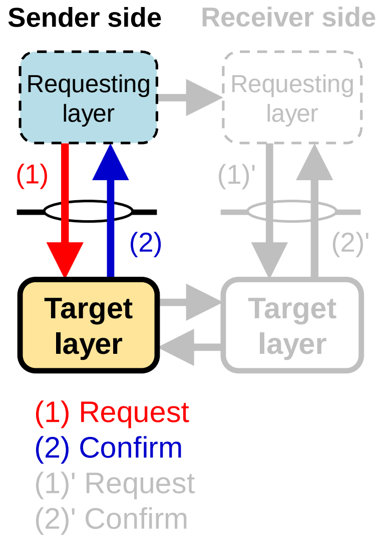



: Identical to the parameters specified in the lower layer primitive (right column) (partial format changes and additional data)

**Table 5.1.2-20 Interlayer interface (security layer of the US specifications, sender side) [7]**

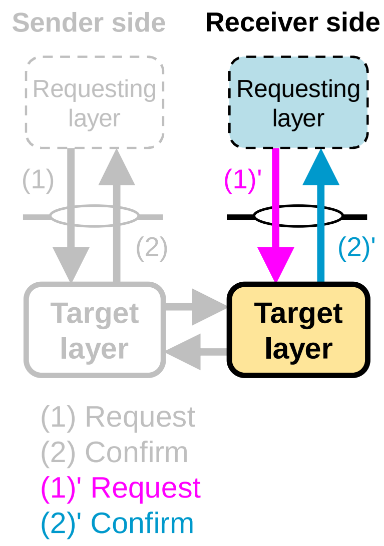
| Target layer | Security layer (Sender side) | |
|---|---|---|
| Generation order | 1 | 2 |
| Request/ confirm | Request ((1)) | Confirm ((2)) |
| Primitive name | Sec-SignedData. request | Sec-SignedData. confirm |
| Parameter | Cryptomaterial Handle<br>Data (*1)<br>Data Type (*1)<br>External Data Hash (*1,2)<br>External Data Hash Algorithm (*1,2)<br>PSID<br>Set Generation Time (*3)<br>Set Generation Location (*4)<br>Expiry Time (*1,2)<br>Signer Identifier Type<br>Signer Identifier Certificate Chain Length (*1)<br>Maximum Certificate Chain Length (*1)<br>Sign With Fast Verification<br>EC Point Format<br>Use Peer-to-peer Cert Distribution<br>SDEE ID (*1) | Signed Data<br>Result Code |

(*1) Option
(*2) Unused for BSM (SAE J2945/1, SAE J3161/1)
(*3) For BSM (SAE J2945/1, SAE J3161/1), set to enabled
(*4) For BSM (SAE J2945/1, SAE J3161/1), set to disabled



### Table 5.1.2-21 Interlayer interface (security layer of the US specifications, receiver side) [7]

| Target layer | Security layer (Receiver side) | | | |
|---|---|---|---|---|
| **Generation order** | **1** | **2** | **3** | **4** |
| **Request/ confirm** | **Request ((1)')** | **Confirm ((2)')** | **Request ((1)')** | **Confirm ((2)')** |
| **Primitive name** | **Sec-SecureData Preprocessing.request** | **Sec-SecureData Preprocessing.confirm** | **Sec-SignedData Verification.request** | **Sec-SignedData Verification.confirm** |
| **Parameter** | SDEE ID (*1) | | SDEE ID | |
| | PSID | | PSID | |
| | | | Content Type | |
| | Data | | Signed Data | |
| | | | External Data Hash (*1,2) | |
| | | | External Data Hash Algorithm (*1,2) | |
| | | | Maximum Certificate Chain Length (*1) | |
| | | | Relevance: Replay (*3) | |
| | | | Relevance: Generation Time in Past (*4) | |
| | | | Validity Period (*1) | |
| | | | Relevance: Generation Time in Future (*4) | |
| | | | Acceptable Future Data Period (*1) | |
| | | | Generation Time (*1) | |
| | | | Relevance: Expiry Time (*3) | |
| | | | Expiry Time (*1) | |
| | | | Consistency: Generation Location (*1,4) | |
| | | | Relevance: Generation Location Distance (*3) | |
| | | | Validity Distance (*1) | |
| | | | Generation Location (*1) | |
| | | | Overdue CRL Tolerance (*1) | |
| | | | Relevance: Expired Certificate (*4) | |
| | Use P2PCD | | | |
| | | Result Code | | Result Code |
| | | Content Type (*1) | | |
| | | Service Specific Permissions (*1) | | |
| | | Assurance Level (*1) | | |
| | | Earliest Next CRL Time | | |



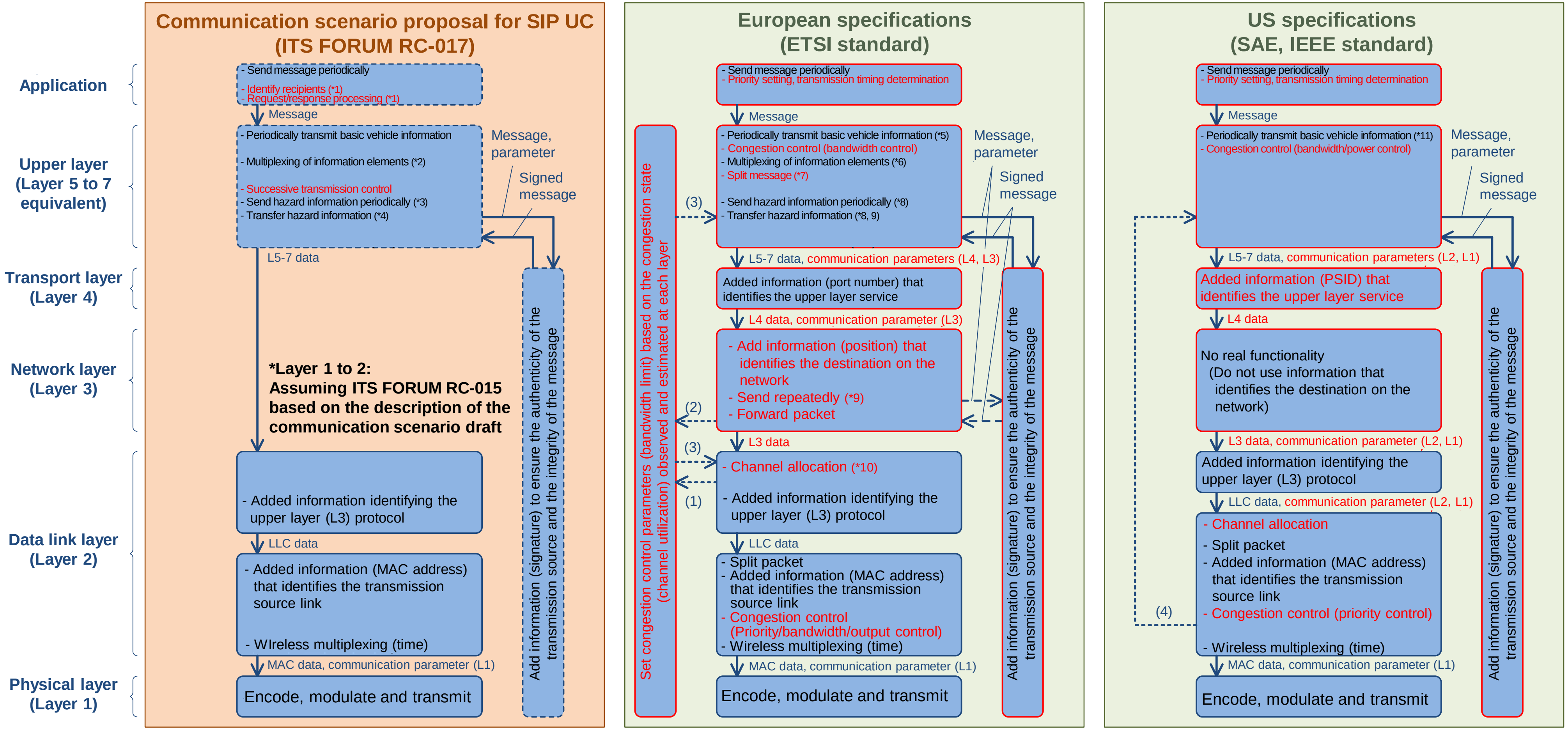

(*1) Option
(*2) Not used for BSM (SAE J2945/1, SAE J3161/1)
(*3) For BSM (SAE J2945/1, SAE J3161/1), set to disabled
(*4) For BSM (SAE J2945/1, SAE J3161/1), set to enabled

### 5.1.3 Study of communication control flows and protocol stacks

This section provides the results of a study of communication control flows and protocol stacks as a 5.9 GHz band communication protocol overview draft. From this point, the communication control flows, etc., are organized, with reference to the “Study report on communication scenarios and requirements for ‘SIP Use Cases for Cooperative Driving Automation’” [2] (below, “ITS FORUM RC-017”), a guideline issued by the ITS Forum, as communication scenarios draft of the SIP use cases for Cooperative Driving Automation (below, “SIP UC”), and these are compared to organization results for the European and American specifications (see Section 5.1.2) and analyzed (Section (1) and (2)). Next, results are reported on a study that was done on policies for creating a 5.9 GHz band communication protocol proposal by adding the unique specifications of the communication scenarios draft to the European and American specifications (Section (3)), and on a summary of the communication control flows and protocol stacks as an overview draft (Section (4)).

(1) Organization compared with European and American specifications based on communication scenarios draft

Communication control flows were organized based on the SIP UC’s communication scenarios draft as listed in ITS FORUM RC-017 and this was compared to European and American specifications for each wireless communication system (DSRC, CV2X); results are given in Fig. 5.1.3-1 and Fig. 5.1.3-2, respectively. Red text in the table indicates a difference between the communication scenarios draft and European and the US specifications. The communication scenarios draft does not mention layer categories, interlayer interfaces, or method of partitioning into transmissible message sizes, among other factors, so these must be studied when studying the communication protocols draft based on the communication scenarios draft. In addition, under the European and the US specifications, the upper layers and Layer 2 provide congestion control and a multi-channel switching function.



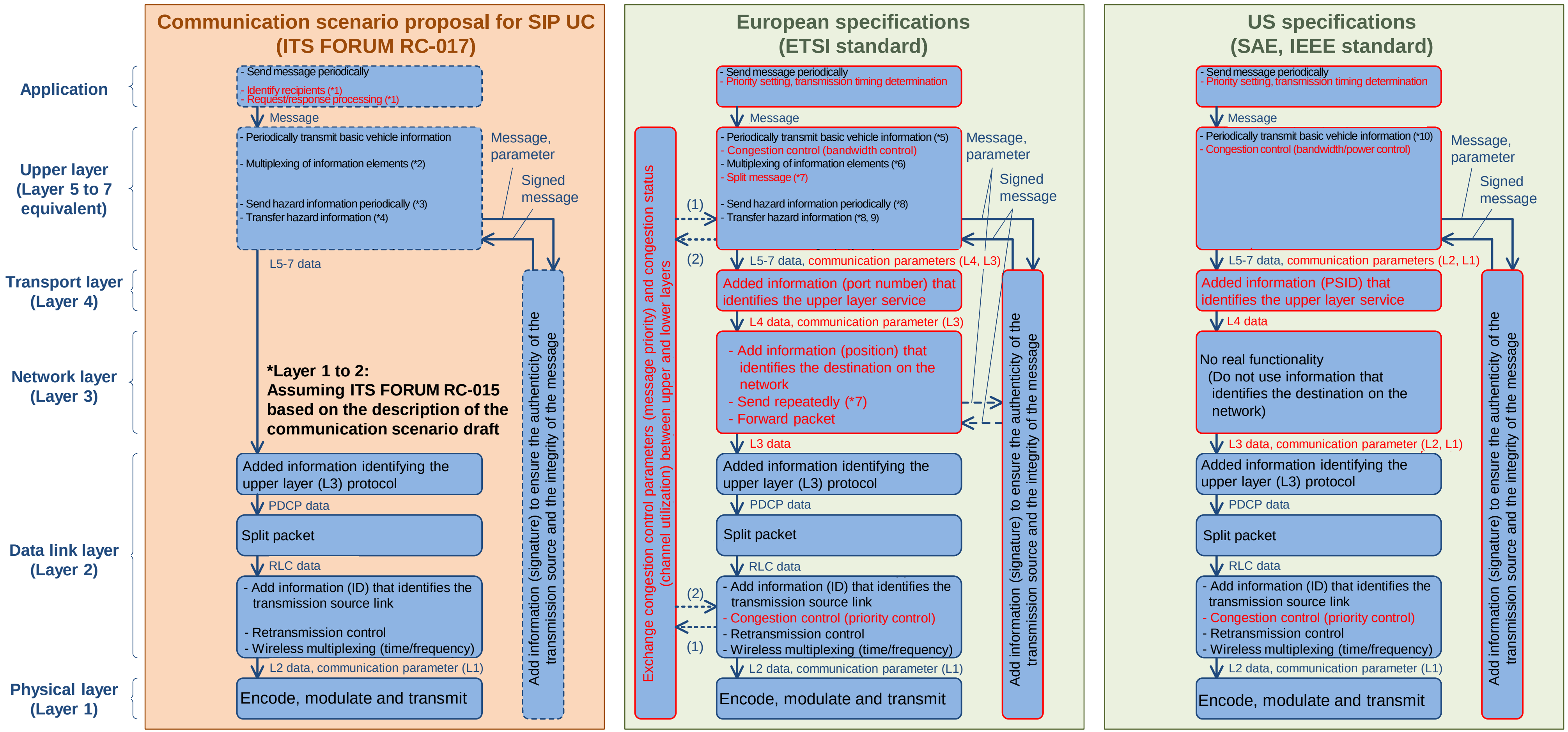

(1) Congestion state observed by own vehicle (transmission time, channel utilization)
(2) Congestion state estimated by exchanging information with other vehicles (channel utilization)
(3) Congestion control parameters (bandwidth limit) set based on (1) and (2)
(4) Congestion state observed by own vehicle (by channel utilization)

(*1) For control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3)
(*2) See discussion in Appendix 1
(*3) For use cases that distribute hazard information from roadside infrastructures (UC d-1 to 5)
(*4) For use cases that forward hazard information (UC c-1, c-3)

(*5) For CAM transmission
(*6) Consideration example according to ETSI TR 103 439
(*7) For MAPEM transmission (*8) For DENM transmission
(*9) Option (*10) Function in congestion control (DCC)
(*11) For BSM transmission

*Red text indicates a difference between the communication scenarios draft and European and American specifications

**Fig. 5.1.3-1 Comparison with communication control flow (DSRC) [2], [4], [6]-[10], [15]-[23], [26], [29]-[31], [43]**




(1) Congestion state observed by own vehicle (transmission time, channel utilization)
(2) Congestion state estimated by exchanging information with other vehicles (channel utilization)
(3) Congestion control parameters (bandwidth limit) set based on (1) and (2)

(*1) For control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3)
(*2) See discussion in Appendix 1
(*3) For use cases that distribute hazard information from roadside infrastructures (UC d-1 to 5)
(*4) For use cases that forward hazard information (UC c-1, c-3)

(*5) For CAM transmission
(*6) Consideration example according to ETSI TR 103 439
(*7) For MAPEM transmission (*8) For DENM transmission
(*9) Option (*10) For BSM transmission

*Red text indicates a difference between the communication scenarios draft and European and American specifications

**Fig. 5.1.3-2 Comparison with communication control flow (CV2X) [2], [5]-[9], [11]-[20], [24]-[28], [32], [43]**

(2) Comparative organization of communication requirements for each communication message

Results of a comparative organization of communication requirements for each communication message are given in Table 5.1.3-1 to Table 5.1.3-4

When classification is based on the content of communication messages, there is no great difference in communication requirements anticipated in upper layers as compared to the European and the US specifications, but under the European and the US specifications, congestion control causes fading of the transmission interval. Additionally, under the European specifications, a forwarding function is used in the upper layers and network layer, making it possible to select forwarding or no forwarding in some communication messages.

**Table 5.1.3-1 Comparison of communication requirements for each communication message (1 of 4) [2], [4]-[5], [25], [35], [37]-[39]**

| **Message content** | **Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.)** | | | | **Traffic signal information (Traffic light color information, signal cycle information, etc.)** | | |
|---|---|---|---|---|---|---|---|
| **Region** | **Japan** | | **Europe** | **US** | **Japan** | | **Europe** |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/ distribution by infrastructure | – | | b. Traffic signal information | c. Lookahead information: Collision avoidance | – |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Co-operative Awareness etc. | Emergency Electronic Brake Lights, etc. | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) | Intersection Collision Risk Warning etc. |
| No. | c-2-1 | f-2 | – | | b-1-1 | c-2-2 | – |
| **Communication service** | **–** | | **CA Basic Service** | **–** | **–** | | **TLM Service** |
| **Message name** | **–** | | **CAM** | **BSM** | **–** | | **SPATEM** |
| **Information element** | **Basic vehicle information** | | **–** | | **Use case specific information (Intersection information)** | | **–** |
| Communication method | V2V | V2I | V2V, V2I, I2V | | I2V | | |
| Message destination | Non-specific vehicles | | | | Non-specific vehicles | | |
| Periodic/ aperiodic | Periodic | | | | Periodic | | |
| Transmission interval | 0.1s | 1s | 0.1 to 1s | | 0.1s | | 1s |
| Transmission | None | | | | None | | None/Present |

Table 5.1.3-2 Comparison of communication requirements for each communication message (2 of 4) [2], [4]-[5], [25], [35], [37]-[39]

| **Message content** | **Detected event information<br>Occurrence time, type, position, etc.** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Region** | **Japan** | | | | | | | | **Europe** | **US** |
| Classification by function | c. Lookahead information: Collision avoidance | | e. Lookahead information: Emergency vehicle notification | d. Lookahead information: Trajectory change | | | | | – | |
| Use case | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Collision avoidance assistance by using hazard information | Driving assistance based on emergency vehicle information | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits | Driving assistance based on hazard information | Road Hazard Warning etc. | Emergency Vehicle Alert, etc. |
| No. | c-1 | c-3 | e-1 | d-1 | d-2 | d-3 | d-4 | d-5 | – | |
| **Communication service** | **–** | | | | | | | | **DEN Basic Service** | **–** |
| **Message name** | **–** | | | | | | | | **DENM** | **BSM** |
| **Information element** | **Use case specific information<br>(Hazard information)** | | | | | | | | **–** | |
| | **c-1, c-3** | | **e-1** | **d-x** | | | | | | |
| Communication method | V2V | | | V2I, I2V | | | | I2V | V2V, V2I, I2V | |
| Message destination | Non-specific vehicles | | | | | | | | | |
| Periodic/ aperiodic | Aperiodic | | | | | | | | | |
| Transmission interval | 0.1s | | | 1s | | | | | 0.1 to 1s | |
| Transmission | Present | | None | | | | | | None/Present | None |

**Table 5.1.3-3 Comparison of communication requirements for each communication message (3 of 4) [2], [4]-[5], [25], [35], [37]-[39]**

| **Message content** | **Vehicle detection information (Sensor information, detected vehicle speed/position, etc.)** | | | | | **Operation information of platoon vehicles (Acceleration, braking, etc.)** | | **Information about the formation (Followability, leading vehicle ID, etc.)** | |
|---|---|---|---|---|---|---|---|---|---|
| **Region** | **Japan** | | | | **Europe** | **Japan** | **Europe** | **Japan** | **Europe** |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | – | g. Platooning/ adaptive cruise control | – | g. Platooning/adaptive cruise control | – |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Overtaking Vehicle Warning etc. | Unmanned platooning of following vehicles by electronic towbar | Platooning | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | Platooning |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | – | g-1 | – | g-2 | – |
| **Communication service** | **–** | | | | **CP Service** | **–** | **–** | **–** | **–** |
| **Message name** | **–** | **Location information** | | | **CPM** | **–** | **PCM** | **–** | **PAM** |
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **–** | **Use case specific information (Unmanned platooning information)** | **–** | **Use case specific information (Manned platooning information)** | **–** |
| | **c-2-2** | **a-1-x** | | | | | | | |
| Communication method | I2V | | | | V2V, V2I, I2V | V2V | | V2V | |
| Message destination | Non-specific vehicles | | | | | Specific vehicles | | Non-specific vehicles | |
| Periodic/ aperiodic | Periodic | | | | | Periodic | | Periodic | |
| Transmission interval | 0.1s | | | | 0.1 to 1s | 0.02 to 0.1s | | 0.1s | 0.05 to 0.1s |
| Transmission | None | | | | None/Present | None | | None | |

Table 5.1.3-4 Comparison of communication requirements for each communication message (4 of 4) [2], [4]-[5], [25], [35], [37]-[39]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Message content** | **Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.)** | | | | | | | | | |
| **Region** | **Japan** | | | | | | | | | **Europe** |
| Classification by function | a. Merging/lane change assistance | | | | | | | | | – |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control | | | Merging assistance based on negotiations between vehicles | | Lane change assistance when the traffic is heavy | | Assistance in entering a priority road from a non-priority road during congestion | | Co-operative Lane Change etc. |
| No. | a-1-3 | | | a-1-4 | | a-2 | | a-3 | | – |
| **Communication service** | **–** | | | | | | | | | **MC Service** |
| **Message name** | **Control request** | **Negotiation request/ update request** | **Negotiation response/ update response** | **Negotiation request/ update request** | **Negotiation response/ update response** | **Negotiation request/ update request** | **Negotiation response/ update response** | **Negotiation request/ update request** | **Negotiation response/ update response** | **MCM** |
| **Information element** | **Use case specific information (Negotiation information)** | | | | | | | | | **–** |
| Communication method | V2I | I2V | V2I | V2V | | | | | | V2V, V2I, I2V |
| Message destination | Non-specific vehicle/specific vehicle | | | | | | | | | |
| Periodic/ aperiodic | Aperiodic | | | | | | | | | |
| Transmission interval | (0.1s) | | | | | | | | | 0.1 to 1s |
| Transmission | None | | | | | | | | | |

(3) Policy on studying communication protocol proposal

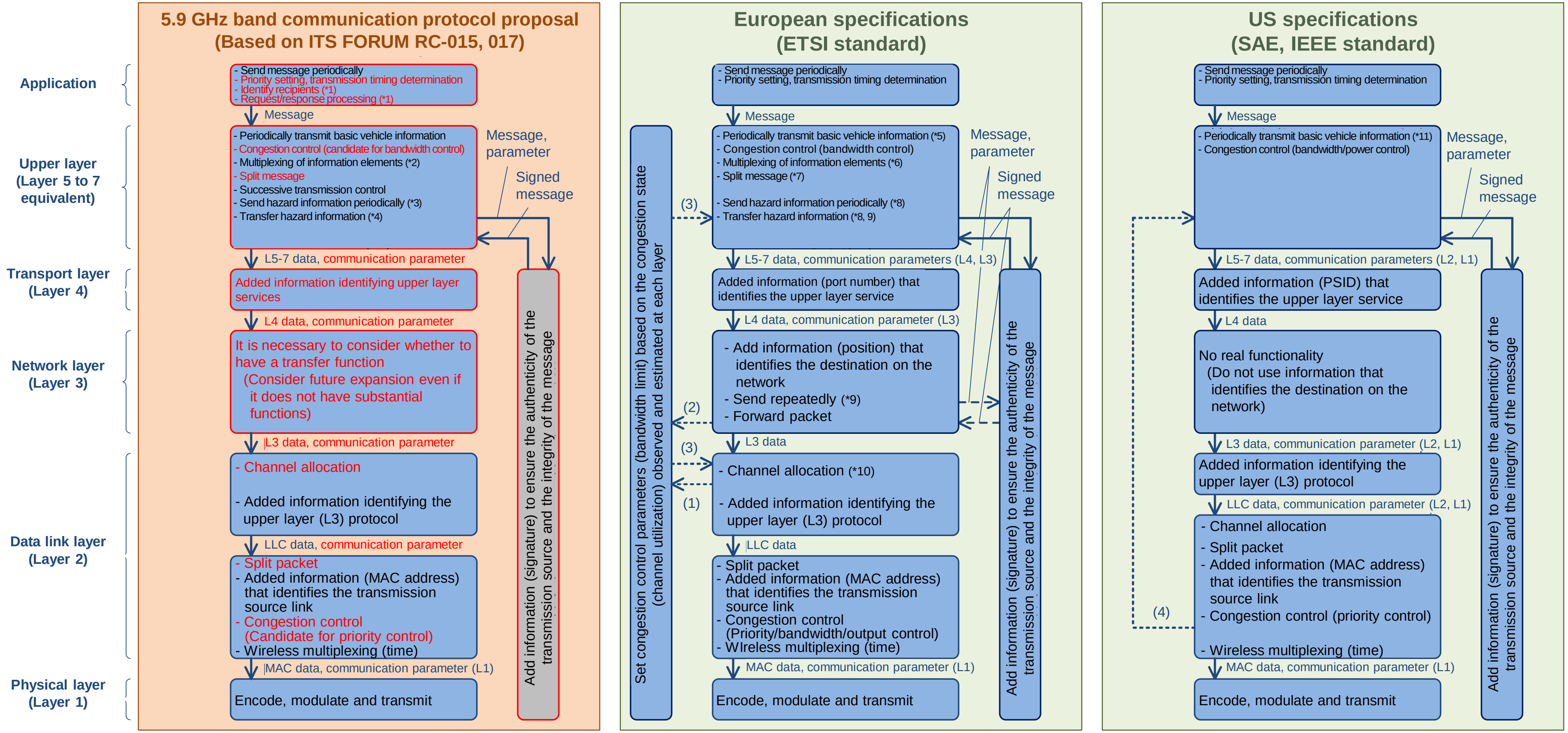
This section describes the results of a study on policies for creating a 5.9 GHz band communication protocol proposal by adding the unique specifications of the communication scenarios draft to the European and American specifications. From this point, results are reported on a study of how to proceed with creating a protocol proposal (Section (a)), followed by results of a study of the potential for using the European and American specifications in order to extract items that need to be added to the European and American specifications (unique specifications of the communication scenarios draft) (Section (b)).

(a) How to proceed with creating a protocol proposal

Based on the results of comparison of communication control flows with the European and American specifications (Section (1)), results of organizing policies on how to study communication protocol proposals for each wireless communication system (DSRC, CV2X) are given in Fig. 5.1.3-3 and Fig. 5.1.3-4, respectively.

The following must be studied when creating the communication protocol proposal from the communication scenarios draft.

- Clarification of layer categorization and interlayer interfaces in Layer 3 and above
- Organization of Layer 7 functions and operations
- Study of additional functions in Layer 2 and 7
  (Communication control system in upper layers, channel allocation, communication message partitioning, etc.)
- Study of Layer 3 to 4 functions (consider international harmonization and future expandability)

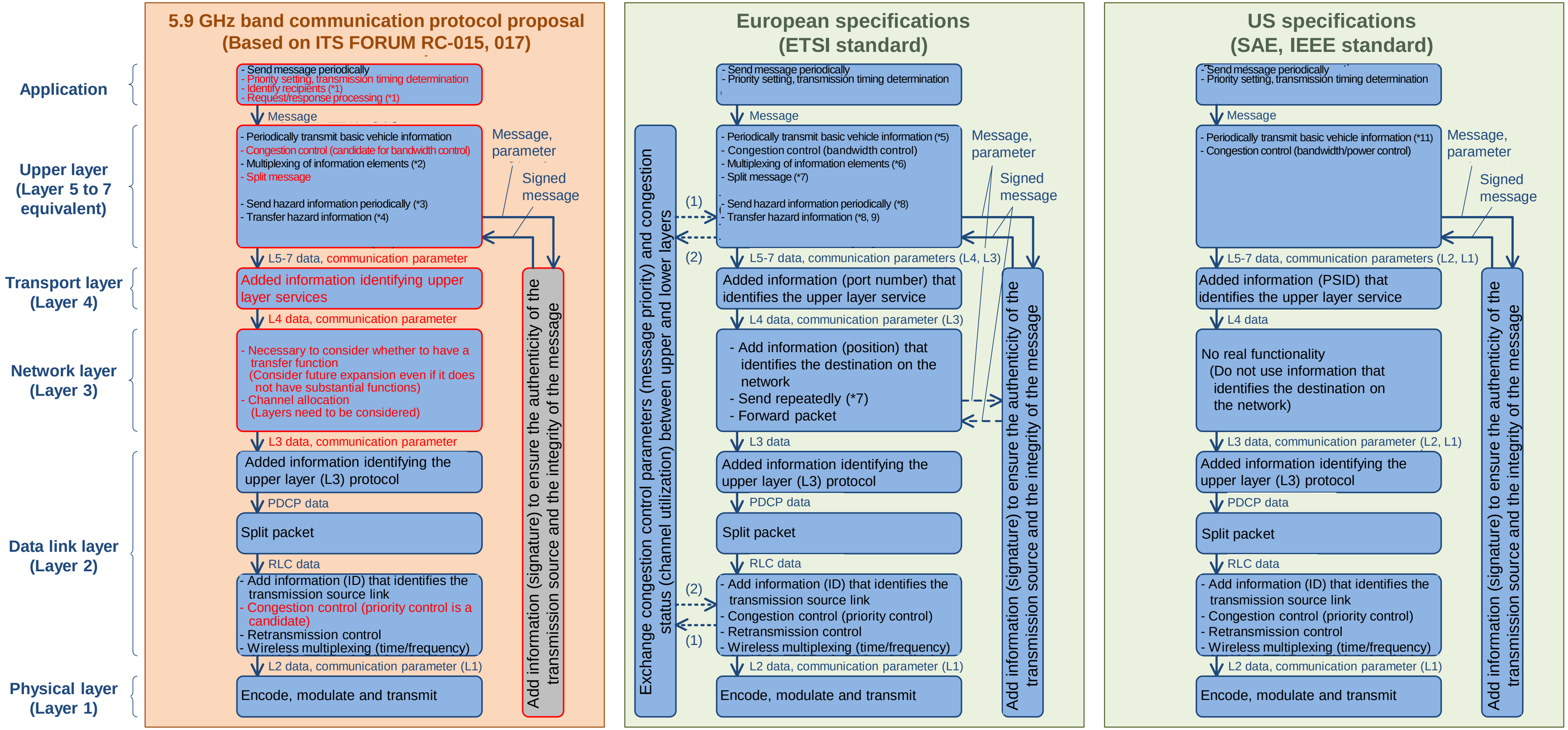



(1) Congestion state observed by own vehicle (transmission time, channel utilization)
(2) Congestion state estimated by exchanging information with other vehicles (channel utilization)
(3) Congestion control parameters (bandwidth limit) set based on (1) and (2)
(4) Congestion state observed by own vehicle (by channel utilization)

(*1) For control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3)
(*2) See discussion in Appendix 1
(*3) For use cases that distribute hazard information from roadside infrastructures (UC d-1 to 5)
(*4) For use cases that forward hazard information (UC c-1, c-3)

(*5) For CAM transmission
(*6) Consideration example according to ETSI TR 103 439
(*7) For MAPEM transmission (*8) For DENM transmission
(*9) Option (*10) Function in congestion control (DCC)
(*11) For BSM transmission

**Fig. 5.1.3-3 Policy on studying communication protocol proposal (DSRC) [2], [4], [6]-[10], [15]-[23], [26], [29]-[31], [43]**




(1) Congestion state observed by own vehicle (transmission time, channel utilization)
(2) Congestion state estimated by exchanging information with other vehicles (channel utilization)
(3) Congestion control parameters (bandwidth limit) set based on (1) and (2)

(*1) For control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3)
(*2) See discussion in Appendix 1
(*3) For use cases that distribute hazard information from roadside infrastructures (UC d-1 to 5)
(*4) For use cases that forward hazard information (UC c-1, c-3)

(*5) For CAM transmission
(*6) Consideration example according to ETSI TR 103 439
(*7) For MAPEM transmission (*8) For DENM transmission
(*9) Option (*10) For BSM transmission

**Fig. 5.1.3-4 Policy on studying communication protocol proposal (CV2X) [2], [5]-[9], [11]-[20], [24]-[28], [32], [43]**

(b) Study potential for using European and American specifications

In this section, results are reported on a study of the potential for using the European specifications (Section i) and the potential for using the US specifications (Section ii) in order to extract items that need to be added to the European and the US specifications (unique specifications of the communication scenarios draft) when creating the communication protocol proposal.

i Case of European specifications

Results of studying and organizing the potential for using the European specifications for the SIP UC's communication scenarios draft are given in Table 5.1.3-5.

Concerning use cases where information is provided (use cases where basic vehicle information, hazard information, or intersection information is transmitted), similar use cases have been standardized, and therefore the European specifications are thought to be usable. However, control/agreement use cases (use cases where negotiation information is transmitted) have not been standardized (the work to standardize similar use cases is happening now, so trends going forward will need to be confirmed), and it is thought that to realize the communication scenarios draft, it will be necessary to add new functions to identify the recipients, request/reply, etc. Other use cases (use cases of providing surrounding vehicle information, or platooning) have not been standardized (the work to standardize similar use cases is happening now, so trends going forward will need to be confirmed), but it is thought they could be realized by periodic transmission by an application.

ii Case of the US specifications

Results of studying and organizing the potential for using the US specifications for the SIP UC's communication scenarios draft are given in Table 5.1.3-6.

Concerning use cases where information is provided (use cases where basic vehicle information or hazard information is transmitted), similar use cases have been standardized, and therefore the American specifications are thought to be usable. However, control/agreement use cases (use cases where negotiation information is transmitted) have not been standardized (the work to standardize similar use cases is happening now, so trends going forward will need to be confirmed), and it is thought that to realize the communication scenarios draft, it will be necessary to add new functions to identify the recipients, request/reply, etc. Other use cases (use cases of providing intersection information or surrounding vehicle information, or platooning) have not been standardized (the work to standardize similar use cases is happening now, so trends going forward will need to be confirmed), but it is thought they could be realized by periodic transmission by an application.

## Table 5.1.3-5 Study of potential for using reference specifications (case of European specifications) [2], [18]-[19], [25], [35], [37]-[39]

| Classification by function | Use case | Communi-cation method | Information element | | European specifications: Message name | European specifications: Application, facility layer | European specifications: Transport, network layer | Main division of functions (proposal): Application: Identify recipients | Application: Transmit periodically | Application: Relay (forward) | Application: Request/ reply | Facility layer (L5-7 equivalent): Identify recipients | Facility layer: Transmit periodically | Facility layer: Relay (forward) | Network, Transport layer (L3-4): Identify recipients | Network, Transport layer: Transmit periodically | Network, Transport layer: Relay (forward) | Compatibility with European specifications (●: Acceptable, -: Need to check future trends) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| c. Lookahead information: Collision avoidance | c-2-1. Driving assistance based on intersection information (V2V) | V2V | Basic vehicle information | | CAM | ETSI EN 302 637-2 | ETSI EN 302 636-4, 5 | – | – | – | – | – | ● | – | – | – | – | ● |
| f. Information collection/distribution by infrastructure | f-2. Collection of information to optimize the traffic flow | V2I | | | | | | | | | | | | | | | | |
| c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | V2V | Use case specific information | Hazard information | DENM | ETSI EN 302 637-3 | | – | ● | – | – | – | – | ● | – | – | – | ● (Relay (transfer) can be handled at the facility layer) |
| | c-3. Collision avoidance assistance by using hazard information | | | | | | | | | | | | | | | | | |
| e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | V2V | | | | | | – | ● | – | – | – | – | – | – | – | – | ● |
| d. Lookahead information: Trajectory change | d-1. Driving assistance by notification of abnormal vehicles | V2I, I2V | | | | | | – | ● (I2V only) | – | – | – | ● (No information update) | – | – | – | – | ● Periodical transmission without information update can be handled by the facility layer |
| | d-2. Driving assistance by notification of wrong-way vehicles | | | | | | | | | | | | | | | | | |
| | d-3. Driving assistance based on traffic congestion information | | | | | | | | | | | | | | | | | |
| | d-4. Traffic congestion assistance at branches and exits | | | | | | | | | | | | | | | | | |
| | d-5. Driving assistance based on hazard information | | | | | | | | | | | | | | | | | |
| b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information | I2V | | Intersection information | SPATM | ETSI TS 103 301 | | – | ● | – | – | – | – | – | – | – | – | ● |
| c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | | | | | | | | | | | | | | | | | |
| a. Merging/lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | | | Surrounding vehicle information | CPM | ETSI TR 103 562 (Under standardization work) | | – | ● | – | – | – | – | – | – | – | – | – (Assuming periodic transmission by the application) |
| | a-1-2. Merging assistance by targeting the gap on the main lane | | | | | | | | | | | | | | | | | |
| a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | I2V | | | | | | | | | | | | | | | | |
| | | V2I, I2V | | Negotiation information | MCM | ETSI TS 103 561 *(Under standardization work)* | | ● | (●) | – | ● | – | – | – | – | – | – | – (Requires addition of destination identification and request/response functions) |
| | a-1-4. Merging assistance based on negotiations between vehicles | V2V | | | | | | | | | | | | | | | | |
| | a-2. Lane change assistance when the traffic is heavy | | | | | | | | | | | | | | | | | |
| | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | | | | | | | | | | | | | | | | | |
| g. Platooning/adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | V2V | | Unmanned platooning information | PCM | ETSI TR 103 298 *(Under standardization work)* | | (●) | ● | – | – | – | – | – | – | – | – | – (Assuming periodic transmission by the application) |
| | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | | | Manned platooning information | PAM | | | – | ● | – | – | – | – | – | – | – | – | |

**Table 5.1.3-6 Study of potential for using reference specifications (case of the US specifications) [2], [4]-[6], [8], [40]-[41]**

| Classification by function | Use case | Communication method | Information element | | US specifications: Message name | US specifications: Application, message sublayer | US specifications: Transport, network layer | Main division of functions (proposal): Application | | | | Message sublayer (L5-7 equivalent) | | | Network, transport layers (L3-4) | | | Compatibility with US specifications (●: Acceptable, -: Need to check future trends) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Identify recipients | Transmit periodically | Relay (forward) | Request/ reply | Identify recipients | Transmit periodically | Relay (forward) | Identify recipients | Transmit periodically | Relay (forward) | |
| c. Lookahead information: Collision avoidance | c-2-1. Driving assistance based on intersection information (V2V) | V2V | Basic vehicle information | | BSM | SAE J2945/1, J3161/1 | IEEE 1609.3 | – | – | – | – | – | ● | – | – | – | – | ● |
| f. Information collection/distribution by infrastructure | f-2. Collection of information to optimize the traffic flow | V2I | | | | | | | | | | | | | | | | |
| c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | V2V | Use case specific information | Hazard information | | | | – | ● | ● | – | – | – | – | – | – | – | ● (Relay (transfer) is supported by application) |
| | c-3. Collision avoidance assistance by using hazard information | | | | | | | | | | | | | | | | | |
| e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | V2V | | | | SAE J2945/2 | | – | ● | – | – | – | – | – | – | – | – | ● |
| d. Lookahead information: Trajectory change | d-1. Driving assistance by notification of abnormal vehicles | V2I, I2V | | | RWM (Similar example of I2V) | SAE J2945/3 (Similar example of I2V) | | – | ● (I2V only) | – | – | – | – | – | – | – | – | ● (Periodic transmission supported by application) |
| | d-2. Driving assistance by notification of wrong-way vehicles | | | | | | | | | | | | | | | | | |
| | d-3. Driving assistance based on traffic congestion information | | | | | | | | | | | | | | | | | |
| | d-4. Traffic congestion assistance at branches and exits | | | | | | | | | | | | | | | | | |
| | d-5. Driving assistance based on hazard information | | | | | | | | | | | | | | | | | |
| b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information | I2V | | Intersection information | SPaT | SAE J2945/B (Standardization work in progress) | | – | ● | – | – | – | – | – | – | – | – | – (Assuming periodic transmission by the application) |
| c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | | | | | | | | | | | | | | | | | |
| a. Merging/lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | | | Surrounding vehicle information | – | SAE J3224 (Standardization work in progress) | | – | ● | – | – | – | – | – | – | – | – | |
| | a-1-2. Merging assistance by targeting the gap on the main lane | | | | | | | | | | | | | | | | | |
| a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | I2V<br>V2I, I2V | | Negotiation information | – | SAE J3186 (Standardization work in progress) | | ● | (●) | – | ● | – | – | – | – | – | – | – (Requires addition of destination identification and request/response functions) |
| | a-1-4. Merging assistance based on negotiations between vehicles | V2V | | | | | | | | | | | | | | | | |
| | a-2. Lane change assistance when the traffic is heavy | | | | | | | | | | | | | | | | | |
| | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | | | | | | | | | | | | | | | | | |
| g. Platooning/adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | V2V | | Unmanned platooning information | – | SAE J2945/6 (Standardization work in progress) | | (●) | ● | – | – | – | – | – | – | – | – | – (Assuming periodic transmission by the application) |
| | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | | | Manned platooning information | – | | | – | ● | – | – | – | – | – | – | – | – | |

(4) Communication control flows and protocol stacks draft

Based on the policy on studying the communication protocol proposal (Section (3)), a communication protocol draft overview is organized in Table 5.1.3-7, and a communication control flows and protocol stacks draft for each wireless communication system (DSRC, CV2X) is given in Table 5.1.3-8 and Table 5.1.3-9, respectively.

SIP UCs mainly consist of multicasting/broadcasting-type direct communication, so the US specifications [4]-[5], [7]-[8], [40]-[41], in which Layer 3 to 4 have little function, are used as the base. However, upper layer specifications, which are already standardized in the US, consist only of BSM transmissions (small data size, no forwarding), so the European specifications and study examples in Europe [25], [38] were used as reference for message multiplexing/partitioning and forwarding functions. Moreover, to support control/agreement use cases, recipient identification and request/reply processing were added as new functions that are not included in the European and the US specifications.

**Table 5.1.3-7 Communication protocol draft overview**

| Layer | Main specification | Remarks |
|---|---|---|
| Application | - Message generation and periodic transmission<br>- Destination identification, request/reply processing (control/agreement use case)<br>- Transmission control (priority level setting, transmission timing determination) | Addition of required functions for control/agreement with European/US specifications |
| Upper layers (Layer 5 to 7) | - Broadcast communications (non-specific destination)<br>- Generation of vehicle basic information, and periodic transmission<br>- Periodic retransmission of hazard information (*)<br>- Relay (transmission) of hazard information (*) | Same as European specification (as an alternative proposal, if made the same as the US specification, (*) can be handled in the application) |
| Network and transport layers (Layer 3 to 4) | - Broadcast communications (non-specific destination)<br>- No relay/routing control | Same as US specification (as an alternative proposal, can be handled even if the same as the European specification) |
| — | Channel allocation | Static allocation assumed |
| Data link, physical layer (Layer 1 to 2) | - Conforms with ITS FORUM RC-015, the guideline for experiments on communication systems for use cases with communication for automated driving on expressways | Same as European/US specification |

### Table 5.1.3-8 Communication control flows and protocol stacks draft (DSRC)

| Layer | | Function/operation (Items in communication control flow) | 5.9 GHz band communication protocol proposal (DSRC) | European specifications (ETSI standard) | US specifications (SAE, IEEE standard) |
|---|---|---|---|---|---|
| Application | | Send message periodically | ● | ● | ● |
| | | Priority setting, transmission timing determination | ● | ● | ● |
| | | Identify recipients | ● | – | – |
| | | Request/response processing | ● | – | – |
| Upper layer (Layer 5 to 7 equivalent) | | Periodically transmit basic vehicle information | ● | ● | ● |
| | | Congestion control (bandwidth control) | ● | ● | ● |
| | | Multiplexing of information elements | ● | ● | – |
| | | Split message | ● | ● | – |
| | | Successive transmission control | ● | – | – |
| | | Send hazard information periodically | ● | ● | – |
| | | Transfer hazard information | ● | ● | – |
| Security layer | | Add information (signature) to ensure the authenticity of the transmission source and the integrity of the message | ● | ● | ● |
| Transport layer (Layer 4) | | Added information identifying upper layer services | ● | ● | ● |
| Network layer (Layer 3) | | Added information to identify the destination on the network | – | ● | – |
| | | Send repeatedly | – | ● | – |
| | | Forward packet | – | ● | – |
| Data link layer (Layer 2) | – | Channel allocation | ● | ● | ● |
| | LLC | Added information identifying the upper layer protocol | ● | ● | ● |
| | MAC | Split packet | ● | ● | ● |
| | | Added information identifying the transmission source link | ● | ● | ● |
| | | Congestion control (priority control) | ● | ● | ● |
| | | Wireless multiplexing | ● | ● | ● |
| Physical layer (Layer 1) | | Encode, modulate and transmit | ● | ● | ● |

Layer 3 and above are the same as CV2X (Excluding successive transmission control)

●: Compliant (European specifications include examples for consideration), -: Not compliant with

### Table 5.1.3-9 Communication control flows and protocol stacks draft (CV2X)

| Layer | | Function/operation (Items in communication control flow) | 5.9 GHz band communication protocol proposal (CV2X) | European specifications (ETSI standard) | US specifications (SAE, IEEE standard) |
|---|---|---|---|---|---|
| Application | | Send message periodically | ● | ● | ● |
| | | Priority setting, transmission timing determination | ● | ● | ● |
| | | Identify recipients | ● | – | – |
| | | Request/response processing | ● | – | – |
| Upper layer (Layer 5 to 7 equivalent) | | Periodically transmit basic vehicle information | ● | ● | ● |
| | | Congestion control (bandwidth control) | ● | ● | ● |
| | | Multiplexing of information elements | ● | ● | – |
| | | Split message | ● | ● | – |
| | | Retransmit hazard information periodically | ● | ● | – |
| | | Transfer hazard information | ● | ● | – |
| Security layer | | Add information (signature) to ensure the authenticity of the transmission source and the integrity of the message | ● | ● | ● |
| Transport layer (Layer 4) | | Added information identifying upper layer services | ● | ● | ● |
| Network layer (Layer 3) | | Added information to identify the destination on the network | – | ● | – |
| | | Retransmit periodically | – | ● | – |
| | | Forward packet | – | ● | – |
| Data link layer (Layer 2) | – | Channel allocation | ● | – | – |
| | PDCP | Added information identifying the upper layer protocol | ● | ● | ● |
| | RLC | Split packet | ● | ● | ● |
| | MAC | Added information identifying the transmission source link | ● | ● | ● |
| | | Congestion control (priority control) | ● | ● | ● |
| | | Retransmission control | ● | ● | ● |
| | | Wireless multiplexing | ● | ● | ● |
| Physical layer (Layer 1) | | Encode, modulate and transmit | ● | ● | ● |

Layer 3 and above are the same as DSRC (Excluding successive transmission control)

●: Compliant (European specifications include examples for consideration), -: Not compliant with

### 5.1.4 Study of each layer's functions, operations, and interfaces

Based on the 5.9 GHz band communication protocol overview draft (Section 5.1.3(4)), this section reports the results of a study of functions, operations, and interfaces as a detailed draft. From this point, results are reported of the study, which proceeded in the order of functions and operations (Section (1)) and interlayer interfaces (Section (2)).

(1) Study of functions and operations

The functions and operations of the 5.9 GHz band communication protocol were studied based on the overview draft (Section 5.1.3(4)). An overview of the functions and operations is given in Table 5.1.4-1.

Like the European and American specifications [4]-[5], [40]-[41], the application periodically transmits messages other than basic vehicle information, but to support control/agreement use cases, recipient identification and request/reply processing were added as new functions that are not included in the European and the US specifications. Moreover, transmission control functions (priority level setting and transmission timing determination) were added based on the results of the study of communication control systems in the upper layer (Section 4.2). The applications here were assumed to include the contents shown in the communication scenario proposal, up to decisions such as trajectory plan review using the received information as a means of realizing the communication function. The control system applications necessary to reflect the trajectory plan review in the vehicle behavior are out of scope, but further discussion is needed on the division of functions between the two.

Similar to the European and the US specifications [4]-[5], in the upper layers, basic vehicle information that is common to use cases is transmitted periodically. Also, referring to European specifications and study examples in Europe [25], [38] and to ITS FORUM RC-017 study results [2], to reduce security overhead, a function was added so that when there are multiple recipients or multiple use cases happening simultaneously and the size of each information element is small, information elements would be multiplexed (bundled into one message).

For the security layer, referring to the US specifications [7], it is anticipated that a signed message will be created upon request from the upper layers. For the network and transport layers, multicasting/broadcasting-type direct communication use cases are anticipated. There are no particular functions for this, but for the frame composition, etc., referring to the US specifications [8], it is thought desirable to use specifications that consider future expandability.

For Layer 1 to 2, using "Guidelines for Experiments of Communications System for Use Cases of Automated Driving on Expressways" [43] (below, "ITS FORUM RC-015"), a guideline issued by the ITS FORUM, as the base, it is anticipated that the method of realizing channel allocation in light of the study in Section 4.1 would be to provide the same number of radio units (Layer 2 and below) as there are allocation channels.

**Table 5.1.4-1 Overview of communication protocol proposal functions and operations**

| Layer | Overview of functions and operations |
|---|---|
| Application | - Periodic transmission of messages other than basic vehicle information<br>- Recipient identification, request/reply processing<br>(in control/agreement use cases)<br>- Transmission control (priority level setting, transmission timing determination) |
| Upper layer<br>(Layer 5 to 7) | - Periodic transmission of basic vehicle information common to use cases<br>- Multiplexing of information elements<br>(In situations where there are multiple recipients or multiple use cases happening simultaneously and the size of each information element is small, information elements are bundled into one message to reduce security overhead)<br>- Transmission message partitioning<br>(cases where messages exceed the size that can be received by lower layers)<br>- Periodic retransmission (cases of hazard information)<br>- Relaying (forwarding) (cases of hazard information) |
| Security layer | - Creating signed message upon request from upper layers |
| Network, transport layers<br>(Layer 3 to 4) | - No functions except identifying upper layer services<br>(because it will mainly be multicasting/broadcasting-type direct communication use cases)<br>- Consider future expandability, e.g., frame composition<br>(refer to the US specifications) |
| Physical layer, data link layer<br>(Layer 1 to 2) | - Use ITS FORUM RC-015 as the base |

| | |
|---|---|
| | (DSRC: refer to the US specifications and add necessary functions; CV2X: conform to 3GPP technical specifications)<br>- Channel allocation<br>(it is anticipated that the same number of radio units (Layer 2 and below) would be provided as there are allocation channels)<br>- Fixing the communication parameters<br>(it is anticipated this would be set in advance, since it is autonomous communication) |

Concerning details of functions and operations, results of studying and organizing preconditions, issues, and compatibility with European and American specifications for each layer and side (transmission/receiving) are given in Table 5.1.4-2 and Table 5.1.4-11.

Table 5.1.4-2 Communication protocol proposal: Transmitting-side functions and operations (application) [2], [4]-[5], [35], [38], [40]-[41]

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| Application | Send message periodically | ● | - Collect information necessary for each use case other than basic vehicle information (vehicle: hazard information, etc. Roadside infrastructure: Traffic signal information, vehicle detection information, etc.<br>- Set each information element of the message<br>- Send periodically while updating information | - Applications can access systems that have the necessary information and acquire information (vehicles: positioning systems (GNSS, etc.), in-vehicle networks (CAN, etc.), etc. Roadside infrastructure: Signal controllers, sensors, etc.)<br>- The above information is sent from each system to the application at a predetermined cycle (assuming response (distribution) type without request, not request/response type) | - Organization of requirements for information provision system (acceptable delay, etc.)<br>- The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | ● | ● |
| | Priority setting, transmission timing judgment | ● | - Determine transmission timing based on critical event determination, etc.<br>- Set priority for each message | - Since it is necessary to relax communication requirements (transmission interval, etc.), it is assumed that communication requirements will be examined and reviewed in the future | - Organization of achievable communication conditions<br>- Examination of possibility of using congestion information in lower layers | ● | ● |
| | Identify recipients | ● | - Targets control/consensus use cases, and sets the range by location, distance, etc., (in the case of negotiation request) or the ID of the vehicle/roadside infrastructure as the destination (for control requests, arbitration responses, update requests, and update responses) | - Layer 7 and below are assumed to be unspecified destinations (broadcast), and the receiving side makes decisions based on its own location and ID | - The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | – | – |
| | Request/ response processing | ● | - Targets control/agreement use cases<br>- After generating and sending a request message, wait for the reception of a response message<br>- After generating or sending a response message, wait for the next request message<br>- Perform state management ((control request) -> negotiation request -> negotiation response -> update request -> update response -> …) | - Since the request message is repeatedly sent while updating the information, the responding side must repeatedly determine whether the own vehicle can agree each time it receives it<br>- Based on the commonization of messages as arbitration information, consider as a common method in the control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3) | - Review and study based on the revision of the communication scenario draft (retransmission, response to multiple simultaneous requests/responses, etc.)<br>- Functional division within layers (common entities used by multiple services, etc.)<br>- Appropriate parameter settings (transmission interval, response wait time, etc.) | – | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

Table 5.1.4-3 Communication protocol proposal: Transmitting-side functions and operations (upper layer) [2], [4]-[5], [25], [37]-[38]

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| Upper layer (Layer 5 to 7 equivalent) | Periodically transmit basic vehicle information | ● | - Collect information necessary for basic vehicle information that is common to use cases (vehicle status (position, speed, etc.), attributes (dimensions, vehicle type, etc.), etc.)<br>- Set each information element of the message<br>- Send periodically while updating information | - The upper layers can access systems that have the necessary information and obtain information (vehicles: positioning systems (GNSS, etc.), in-vehicle networks (CAN, etc.), etc. Roadside infrastructure: Signal controllers, sensors, etc.)<br>- The above information is sent from each system to the upper layer at a predetermined cycle (assuming no-request response (delivery) type, not request/response type) | - Organization of requirements for information provision system (acceptable delay, etc.)<br>- The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | ● | ● |
| | Congestion control (Bandwidth control) | ● | - Target basic vehicle information, and decide transmission timing based on communication congestion, amount of change in own vehicle information, etc.<br>- Set the priority of basic vehicle information | - Since it is necessary to relax communication requirements (transmission interval, etc.), it is assumed that communication requirements will be examined and reviewed in the future | - Organization of achievable communication conditions<br>- Examination of possibility of using congestion information in lower layers | ● | ● |
| | Multiplexing of information elements | ● | - Combine information elements when simultaneously generating messages for multiple use cases to reduce security overhead (ITS FORUM RC-017, Appendix 1, Case 3 in Chapter 4), applicable to Method 1 | - Targets messages sent by vehicles (assuming that the size of each information element is sufficiently smaller than the size of the overhead due to security, and the size does not require message division even after combining)<br>- After multiplexing the information elements, perform security processing (add a signature to the combined message) | - Review of message format (method of identifying multiple information elements)<br>- Division of functions of multiple services related to multiplexed information elements (including consideration of the necessity of sub-layers) | ● | – |
| | Split message | ● | - Split the message into a size that can be received by the lower layer | - Assuming that the message size exceeds the size that can be supported by the lower layer (2402 bytes for US specifications)<br>- After dividing the message, perform security processing (because overhead is added to each divided message, division in the upper layer should be kept to a minimum) | - Review of message format (method of identifying divided messages)<br>- Functional division within layers (including consideration of the necessity of sub-layers) | ● | – |
| | Successive transmission control (DSRC only) | ● | - In the case of broadcast (no acknowledgment), the same message is sent multiple times (compliant with ITS FORUM RC-015) | – | Appropriate parameter setting (number of successive transmission) | – | – |
| | Retransmit hazard information periodically | ● | - Targets hazard information and sends it periodically during the validity period (no information update) | - If the hazard information is not updated, the second and subsequent transmissions can be handled by the upper layer, and no application intervention is required | – | ● | – |
| | Transfer hazard information | ● | - Targets hazard information, receives a message, and if it exists within the target area of the use case, transfers at a predetermined cycle (in order to reduce communication traffic, only the latest message received within the specified period is transferred) | - Since the information is updated and sent repeatedly, the transfer source needs to determine the latest message for each use case (service).<br>- Based on the communication scenarios of transfer use cases (UC c-1, c-3), future expansion of use cases will be taken into account, and a general method that is not limited to specific use cases will be considered | - Appropriate parameter settings (transfer cycle)<br>- Method of reducing communication traffic (introduction of transfer waiting time when transferred by others, use of position information, etc.)<br>- Necessity of cooperation with congestion control function, and cooperation method if necessary | ● | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

**Table 5.1.4-4 Communication protocol proposal: Transmitting-side functions and operations (security layer, Layer 3 to 4) [7]-[8], [18]-[20]**

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| Security layer | Add information (signature) to ensure the authenticity of the transmission source and the integrity of the message | ● | - Create signed message | - Request from upper layer (pass message after processing in security layer to Layer 4 and below) | - Examination of detailed specifications<br>- Refinement of overhead estimates (actual size may fade) | ● | ● |
| Transport layer (Layer 4) | Added information identifying upper layer services | ● | - An identification number (PSID in the US) is added to each service as information that identifies the use case (service) corresponding to the received packet message | - Broadcast type, direct communication (no transfer) is the main use case, so processing to ensure reliability and order is unnecessary<br>- Refer to IEEE 1609.3 for frame structure (considering future expandability) | - Assignment and management of identification numbers for each service | ● | ● |
| Network layer (Layer 3) | Added information to identify the destination on the network | – | (No function) | - Broadcast type, direct communication (no forwarding) use cases are the main use cases, so no routing is required<br>- Refer to IEEE 1609.3 for frame structure (considering future expandability) | - Review and study based on the possibility of expanding use cases in the future | ● | – |
| | Retransmit periodically | – | | | | ● | – |
| | Forward packet | – | | | | ● | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

**Table 5.1.4-5 Communication protocol proposal: Transmitting-side functions and operations (DSRC Layer 1 to 2) [8]-[10], [21]-[23], [43**

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (DSRC) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| – | Channel allocation | ● | - Pass the message to Layer 2 of the corresponding channel | - Assumed to have the same number of radio units as the number of allocated channels (simultaneous transmission and reception possible)<br>- Channels are fixed (preconfigured) for each use case (service) for autonomous communication<br>- Perform processing based on the channel set for each message in the upper layer | - How Layer 3 interfaces with multiple Layer 2s (add Layer 2 selection function to Layer 3, or consider sub-layers)<br>- It is permissible to have radio unit with less than the number of allocated channels, or if it is permissible, the method of channel switching | ● | ● |
| LLC (Layer 2) | Added information identifying the upper layer protocol | ● | - Compliant with IEEE 1609.3<br>(Review the interface of ITS FORUM RC-015) | – | – | ● | ● |
| MAC (Layer 2) | Split packet | ● | - Compliant with IEEE 802.11<br>(Add packet division and priority control functions to ITS FORUM RC-015, and review the interface) | – | - Method of assigning information (address) that identifies the transmission source link<br>- Appropriate communication parameter settings (transmission waiting time, etc.) | ● | ● |
| | Added information identifying the transmission source link | ● | | | | ● | ● |
| | Congestion control (Priority control) | ● | | - Perform processing based on the priority set for each message in the upper layer | | ● | ● |
| | Wireless multiplexing | ● | | - Fixing communication parameters for autonomous communication (set in advance) | | ● | ● |
| Physical layer (Layer 1) | Encode, modulate and transmit | ● | - Compliant with ITS FORUM RC-015<br>(Review the frequency band to 5.9 GHz band) | - Fixing communication parameters for autonomous communication (set in advance) | - Setting appropriate communication parameters (transmission power, data rate, etc.) | ● | ● |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

**Table 5.1.4-6 Communication protocol proposal: Transmitting-side functions and operations (CV2X Layer 1 to 2) [8], [11]-[14], [24], [43]**

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| – | Channel allocation | ● | - Pass the message to Layer 2 of the corresponding channel | - Assumed to have the same number of radio units (Layer 2 or lower) as the number of allocated channels (simultaneous transmission/reception of all channels is possible)<br>- For autonomous communication, the channel used for each use case (service) is fixed (set in advance)<br>- Perform processing based on the channel set for each message in the upper layer | - How Layer 3 interfaces with multiple Layer 2s (add Layer 2 selection function to Layer 3, or consider sub-layers)<br>- It is permissible to have radio unit with less than the number of allocated channels, or if it is permissible, the method of channel switching | ● | ● |
| PDCP (Layer 2) | Added information identifying the upper layer protocol | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.323) | – | – | ● | ● |
| RLC (Layer 2) | Split packet | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.322) | – | - Method of assigning information (address) that identifies the transmission source link<br>- Appropriate communication parameter settings (resource allocation method, number of retransmissions, etc.) | ● | ● |
| MAC (Layer 2) | Added information identifying the transmission source link | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.321) | | | ● | ● |
| | Congestion control (Priority control) | ● | | - Perform processing based on the priority set for each message in the upper layer | | ● | ● |
| | Retransmission control | ● | | - Fixing communication parameters for autonomous communication (set in advance) | | | |
| | Wireless multiplexing | ● | | | | ● | ● |
| Physical layer (Layer 1) | Encode, modulate and transmit | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.211-214) | - Fixing communication parameters for autonomous communication (set in advance) | - Setting appropriate communication parameters (transmission power, data rate, etc.) | ● | ● |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

**Table 5.1.4-7 Communication protocol proposal: Receiving-side functions and operations (application) [2], [4]-[5], [35], [38], [40]-[41]**

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| Application | Receive message | ● | - Receive the information needed for each use case and make the decisions needed by the service | - Applications can access systems that have the necessary information and acquire information (vehicles: positioning systems (GNSS, etc.), in-vehicle networks (CAN, etc.), etc. Roadside infrastructure: Signal controllers, sensors, etc.)<br>- The above information is sent from each system to the application at a predetermined cycle (assuming response (distribution) type without request, not request/response type) | - Organization of requirements for information provision system (acceptable delay, etc.)<br>- The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | ● | ● |
| | Priority setting, transmission timing judgment | ● | - Perform processing as necessary based on the priority set on the sending side (notification to upper layer, etc.) | - Since it is necessary to relax communication requirements (transmission interval, etc.), it is assumed that communication requirements will be examined and reviewed in the future | - Organization of achievable communication conditions<br>- Examination of possibility of using congestion information in lower layers | ● | ● |
| | Destination determination | ● | - Targets control/agreement use cases, determines whether the destination corresponds to a range based on location/distance, etc., (in the case of negotiation request) or a vehicle/roadside infrastructure ID (for control requests, negotiation responses, update requests, and update responses), based on the location and ID | - Layer 7 and below are assumed to be unspecified destinations (broadcast), and the receiving side makes decisions based on its own location and ID | - The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | – | – |
| | Request/ response processing | ● | - Targets control/agreement use cases<br>- After receiving a request message, generate and send a response message<br>- After receiving the response message, generate and send the next request message<br>- Perform state management ((control request) -> negotiation request -> negotiation response -> update request -> update response -> …) | - Since the request message is repeatedly sent while updating the information, the responding side must repeatedly determine whether the own vehicle can agree each time it receives it<br>- Based on the commonization of messages as arbitration information, consider as a common method in the control/agreement use cases (UC a-1-3, a-1-4, a-2, a-3) | - Review and study based on the revision of the communication scenario draft (retransmission, response to multiple simultaneous requests/responses, etc.)<br>- Functional division within layers (common entities used by multiple services, etc.)<br>- Appropriate parameter settings (transmission interval, response wait time, etc.) | – | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

Table 5.1.4-8 Communication protocol proposal: Receiving-side functions and operations (upper layers) [2], [4]-[5], [25], [37]-[38]

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| Upper layer (Layer 5 to 7 equivalent) | Receive basic vehicle information | ● | - Pass the received vehicle basic information to the upper layer | - The upper layers can access systems that have the necessary information and obtain information (vehicles: positioning systems (GNSS, etc.), in-vehicle networks (CAN, etc.), etc. Roadside infrastructure: Signal controllers, sensors, etc.)<br>- The above information is sent from each system to the upper layer at a predetermined cycle (assuming no-request response (delivery) type, not request/response type) | - Organization of requirements for information provision system (acceptable delay, etc.)<br>- The need to compensate for errors such as position due to delay, and if necessary, how to compensate<br>- Functional division within layers (common entities used by multiple services, etc.) | ● | ● |
| | Congestion control (Bandwidth control) | ● | - Perform processing as necessary based on the transmission timing and priority set by the sender (notification to upper layers, etc.) | - Since it is necessary to relax communication requirements (transmission interval, etc.), it is assumed that communication requirements will be examined and reviewed in the future | - Organization of achievable communication conditions<br>- Examination of possibility of using congestion information in lower layers | ● | ● |
| | Demultiplexing of information elements | ● | - Separate combined information elements when simultaneously generating messages for multiple use cases to reduce security overhead (ITS FORUM RC-017, Appendix 1, Case 3 in Chapter 4), applicable to Method 1 | - Targets messages sent by vehicles (assuming that the size of each information element is sufficiently smaller than the size of the overhead due to security, and the size does not require message division even after combining)<br>- After multiplexing the information elements, perform security processing (add a signature to the combined message) | - Review of message format (method of identifying multiple information elements)<br>- Division of functions of multiple services related to multiplexed information elements (including consideration of the necessity of sub-layers) | ● | – |
| | Combine messages | ● | - Combine messages that have been split to a size that can be received by the lower layer | - Assuming that the message size exceeds the size that can be supported by the lower layer (2402 bytes for US specifications)<br>- After dividing the message, perform security processing (because overhead is added to each divided message, division in the upper layer should be kept to a minimum) | - Review of message format (method of identifying divided messages)<br>- Functional division within layers (including consideration of the necessity of sub-layers) | ● | – |
| | Successive transmission control (DSRC only) | ● | - Pass all messages, including duplicates, to the upper layer (in accordance with ITS FORUM RC-015) | – | Appropriate parameter setting (number of successive transmission) | – | – |
| | Discard duplication of hazard information retransmission | ● | - Targets hazard information and discards duplicates by comparing with received information | - If the hazard information is not updated, the second and subsequent transmissions can be handled by the upper layer, and no application intervention is required | – | ● | – |
| | Transfer hazard information | ● | - Stores/updates the latest message that targets the hazard information, receives the message, and forwards it if it is within the area covered by the use case | - Since the information is updated and sent repeatedly, the transfer source needs to determine the latest message for each use case (service).<br>- Based on the communication scenarios of transfer use cases (UC c-1, c-3), future expansion of use cases will be taken into account, and a general method that is not limited to specific use cases will be considered | - Appropriate parameter settings (transfer cycle)<br>- Method of reducing communication traffic (introduction of transfer waiting time when transferred by others, use of position information, etc.)<br>- Necessity of cooperation with congestion control function, and cooperation method if necessary | ● | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

**Table 5.1.4-9 Communication protocol proposal: Receiving-side functions and operations (security layer, Layer 3 to 4) [7]-[8], [18]-[20]**

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (Common to DSRC and CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | **Response** | **Details of functions and operations** | **Preconditions** | **Issues** | | |
| Security layer | Verifies information (signatures) to ensure the authenticity of the transmission source and the integrity of the message | ● | - Verify signed message | - Request from upper layer (pass message after processing in security layer to Layer 4 and below) | - Examination of detailed specifications<br>- Refinement of overhead estimates (actual size may fade) | ● | ● |
| Transport layer (Layer 4) | Added information identifying upper layer services | ● | - An identification number (PSID in the US) is added to each service as information that identifies the use case (service) corresponding to the received packet message | - Broadcast type, direct communication (no transfer) is the main use case, so processing to ensure reliability and order is unnecessary<br>- Refer to IEEE 1609.3 for frame structure (considering future expandability) | - Assignment and management of identification numbers for each service | ● | ● |
| Network layer (Layer 3) | Identify network destinations | – | (No function) | - Broadcast type, direct communication (no forwarding) use cases are the main use cases, so no routing is required<br>- Refer to IEEE 1609.3 for frame structure (considering future expandability) | - Review and study based on the possibility of expanding use cases in the future | ● | – |
| | Discard duplication of resent data | – | | | | ● | – |
| | Forward packet | – | | | | ● | – |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

Table 5.1.4-10 Communication protocol proposal: Receiving-side functions and operations (DSRC Layer 1 to 2) [8]-[10], [21]-[23], [43]

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (DSRC) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| – | Channel allocation | ● | - Pass the message received by the corresponding channel to the upper layer | - Assumed to have the same number of radio units as the number of allocated channels (simultaneous transmission and reception possible)<br>- Channels are fixed (preconfigured) for each use case (service) for autonomous communication<br>- Perform processing based on the channel set for each message in the upper layer | - How Layer 3 interfaces with multiple Layer 2s (add Layer 2 selection function to Layer 3, or consider sub-layers)<br>- It is permissible to have radio unit with less than the number of allocated channels, or if it is permissible, the method of channel switching | ● | ● |
| LLC (Layer 2) | Identify upper layer protocols | ● | - Compliant with IEEE 1609.3<br>(Review the interface of ITS FORUM RC-015) | – | – | ● | ● |
| MAC (Layer 2) | Combine packets | ● | - Compliant with IEEE 802.11<br>(Add packet division and priority control functions to ITS FORUM RC-015, and review the interface) | – | - Method of assigning information (address) that identifies the transmission source link<br>- Appropriate communication parameter settings (receive buffer size, etc.) | ● | ● |
| | Identify transmission source link | ● | | | | ● | ● |
| | Congestion control (Priority control) | ● | | - Based on the priority set for each message on the sender side, perform processing as necessary (notification to upper layers, etc.) | | ● | ● |
| | Wireless demultiplexing | ● | | - Fixing communication parameters for autonomous communication (set in advance) | | ● | ● |
| Physical layer (Layer 1) | Demodulate and decode after receiving | ● | - Compliant with ITS FORUM RC-015<br>(Review the frequency band to 5.9 GHz band) | - Fixing communication parameters for autonomous communication (set in advance) | – | ● | ● |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

Table 5.1.4-11 Communication protocol proposal: Receiving-side functions and operations (CV2X Layer 1 to 2) [8], [11]-[14], [24], [43]

| Layer | Function/ operation | 5.9 GHz band communication protocol proposal (CV2X) | | | | European specifications | US specifications |
|---|---|---|---|---|---|---|---|
| | | Response | Details of functions and operations | Preconditions | Issues | | |
| – | Channel allocation | ● | - Pass the message received by the corresponding channel to the upper layer | - Assumed to have the same number of radio units (Layer 2 or lower) as the number of allocated channels (simultaneous transmission/reception of all channels is possible)<br>- For autonomous communication, the channel used for each use case (service) is fixed (set in advance)<br>- Perform processing based on the channel set for each message in the upper layer | - How Layer 3 interfaces with multiple Layer 2s (add Layer 2 selection function to Layer 3, or consider sub-layers)<br>- It is permissible to have radio unit with less than the number of allocated channels, or if it is permissible, the method of channel switching | ● | ● |
| PDCP (Layer 2) | Identify upper layer protocols | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.323) | – | – | ● | ● |
| RLC (Layer 2) | Split packet | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.322) | – | - Method of assigning information (address) that identifies the transmission source link<br>- Appropriate communication parameter settings (resource allocation method, number of retransmissions, etc.) | ● | ● |
| MAC (Layer 2) | Identify transmission source link | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.321) | | | ● | ● |
| | Congestion control (Priority control) | ● | | - Based on the priority set for each message on the sender side, perform processing as necessary (notification to upper layers, etc.) | | ● | ● |
| | Retransmission control | ● | | - Fixing communication parameters for autonomous communication (set in advance) | | | |
| | Wireless demultiplexing | ● | | | | ● | ● |
| Physical layer (Layer 1) | Demodulate and decode after receiving | ● | - Compliant with ITS FORUM RC-015 (Compliant with 3GPP TS 36.211-214) | - Fixing communication parameters for autonomous communication (set in advance) | – | ● | ● |

●: Compliant (European specifications include examples for consideration), -: Not compliant with

(2) Study of interlayer interfaces

This section describes the results of the study of the interlayer interfaces in the 5.9 GHz band communication protocol proposal. Below, based on the study proposal (Section (a)), is a description of the study draft that was studied (Section (b)).

(a) Study policy

The 5.9 GHz band communication protocol proposal interlayer interface study policy is given in Table 5.1.4-12.

Because the study of functions and operations (Section (1)) was based on the US specifications, the US specifications [7]-[10] (the results of survey and organization in Section 5.1.2(3)) were used as reference for interlayer interfaces also. The policy that was chosen is to allocate the parameters necessary for processing on lower layers, for example to pass the Layer 1 to 4 parameters from the upper layers and to allocate communication channels (Section 4.1) and to practice priority control based on the priority level settings of the communication control system in the upper layers (Section 4.2).

**Table 5.1.4-12 Communication protocol proposal interlayer interface study policy**

| Layer | Layer-to-layer interface (parameters of request primitives): US – DSRC | US – CV2X | Europe – DSRC | Europe – CV2X |
|---|---|---|---|---|
| Upper layer (Layer 5 to 7 equivalent) | (No clear definition) | | - Information related to the event (detection time, location, etc.)<br>- Upper layer communication parameters (repeat interval, presence/absence of transfer, etc.)<br>- Layer 3 c<br>- Part of m | |
| Transport layer (Layer 4) | - Layer 4 communication parameters (information identifying upper layer services (PSID))<br>- Parameters for allocation to channels (channel identifier, time slot)<br>- Layer 2 communication parameters (destination, priority, end time)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message | | - Commun<br>(Informati<br>- Commun<br>(Transmis<br>hops, etc.<br>- Message | .)<br>of |
| Network layer (Layer 3) | | | - Commun<br>(Transmis<br>hops, etc.)<br>- Message | of |
| Data link layer (Layer 2) | LLC: - Parameters for channel allocation (Channel identifier, timeslot)<br>- Communication parameter of Layer 2 (Destination, priority, end time, channel identifier)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (Layer 3 PDU) | - Transmitter setting parameters (Channel, etc.) (*1)<br>- Communication parameter of Layer 2 (Destination, priority, end time)<br>- Communication parameter of Layer 1 (Transmission power)<br>- Message (Layer 3 PDU) | LLC: - P<br>(C<br>- M<br>(T<br>pri<br>- C<br>1<br>(T<br>- Message (Layer 3 PDU) | ter of |
| | MAC: - Parameters for channel allocation (Channel identifier, timeslot)<br>- Communication parameter of Layer 2 (Destination, priority, end time, channel identifier)<br>- Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (LLC PDU) | | MAC: - MAC communication parameters (Transmission source, destination, priority (*5))<br>- Communication parameter of Layer 1 (Transmission power, MCS)<br>- Message (LLC PDU) | |
| Physical layer (Layer 1) | - Communication parameter of Layer 1 (transmission power, data rate)<br>- Message (MAC PDU) | | - Communication parameter of Layer 1 (Transmission power, MCS)<br>- Message (MAC PDU) | |
| Security layer | - Security layer parameters (information identifying services (US: PSID, Europe: ITS-AID) (*2), etc.<br>- Message (requesting layer PDU) | | | |

**The study policy for the inter-layer interface is as follows.**
**- Refer to US specifications (Pass Layer 1-4 parameters from higher layers)**
**- Allocate the parameters necessary for processing in the lower layer (Channel allocation, priority control)**

(*1) Via Layer 3-4 management entity (*2) Required to reflect service-specific permissions (*3) When signing in the network layer
(*4) Via congestion control management entity (*5) Set based on Layer 3 communication parameters (traffic class)

(b) Study proposal

The 5.9 GHz band communication protocol proposal interlayer interface study proposal for each wireless communication system (DSRC, CV2X) and the security layer is given in Table 5.1.4-13 to Table 5.1.4-18.

The Layer 1 to 4 interfaces when DSRC is the wireless communication system are based on ITS FORUM RC-015 [43]. For request/indication primitive, communication channels on Layer 2 are allocated referring to the US specification (IEEE 1609.3 [8]), and parameters are added that are necessary for priority control based on the communication control system in the upper layers.

The Layer 1 to 4 interfaces when CV2X is the wireless communication system were made the same as the US specification (IEEE 1609.3 [7]).

The security layer interfaces are anticipated to be the same as the US specification (IEEE 1609.2), but methods for using security-related parameters other than PSID and data will need to be studied in future along with detailed specifications.

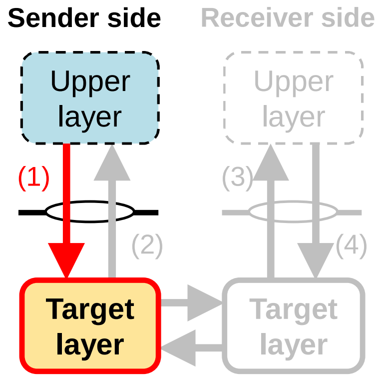
**Table 5.1.4-13 Communication protocol proposal interlayer interface (DSRC, request primitives)**

| Target layer | Transport layer, network layer (Layer 4, 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|
| **Primitive name** | **WSM-WaveShortMessage request** | **DL-UNITDATA request** | **MA-UNITDATA request** | **PHY-TXSTART request** |
| **Parameter** | Provider Service Identifier | | | |
| | | source_address | source address | |
| | Peer MAC Address | destination_address | destination address | |
| | User Priority | **priority** | **priority** | |
| | Expiry Time | **WsmExpiryTime** | **ExpriryTime** | |
| | | | | TXVECTOR |
| | Channel Identifier | **Channel Identifier** | **Channel Identifier** | |
| | | | | **PHY-DATA request** |
| | Length | | | |
| | Data | data | data | DATA |
| | | | | USER_INDEX (*1) |
| | | | | **PHY-TXEND. request** |
| | | | | (No parameters) |

(*1) Valid only in certain cases

* **Compliant with IEEE1609.3 in ITS FORUM RC-015 (In this study, only the minimum necessary parameters are shown)**

* **If you have the same number of radio units (Layer 2 or lower) as the number of allocated channels, it is not necessary because the channels set in advance will not be changed, but consider the possibility of future use**




(1) Request
(2) Confirm
(3) Indication
(4) Response

(shaded) : Identical to the parameters specified in the upper layer primitive (left column) (partial format change and additional data)

**Table 5.1.4-14 Communication protocol proposal interlayer interface (DSRC, confirm primitives)**

| Target layer | Transport layer, network layer (Layer 4, 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|
| Primitive name | WSM-WaveShortMessage confirm | (N/A) | (N/A) | PHY-TXSTART confirm |
| Parameter | ResultCode | – | – | TXSTATUS |
| | | | | **PHY-DATA. confirm** |
| | | | | (No parameters) |
| | | | | **PHY-TXEND. Confirm** |
| | | | | SCRAMBLER_OR_CRC (*1) |

(*1) Valid only in certain cases

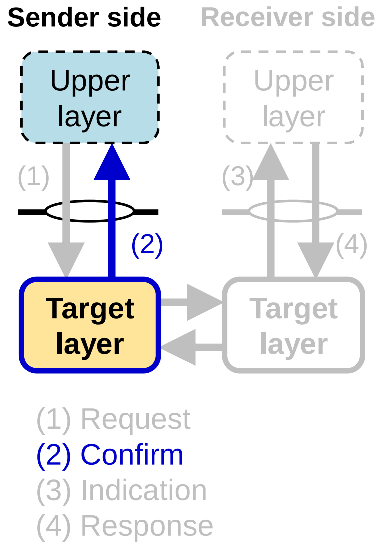
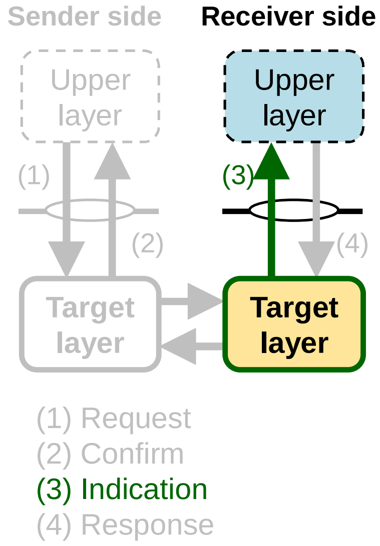


**Table 5.1.4-15 Communication protocol proposal interlayer interface (DSRC, indication primitives)**

| Target layer | Transport layer, network layer (Layer 4, 3) | LLC (Layer 2) | MAC (Layer 2) | PHY (Layer 1) |
|---|---|---|---|---|
| Primitive name | **WSM-WaveShortMessage indication** | **DL-UNITDATA indication** | **MA-UNITDATA indication** | **PHY-CCA indication** |
| **Parameter** | Provider Service Identifier | | | |
| | Peer MAC Address | Source address | Source address | |
| | | Destination address | Destination address | |
| | | | | STATE |
| | User Priority | **Priority** | **Priority** | |
| | | | | IPI-REPORT (*2) |
| | | | | channel-list (*2) |
| | | | | **PHY-RXSTART. indication** |
| | | | | RXVECTOR |
| | | | | **PHY-DATA. indication** |
| | Length | Length | | |
| | Data | Data | Data | DATA |
| | | | | **PHY-RXEND. indication** |
| | | | | RCPI |
| | | | | RXERROR |

(*1) Valid only in certain cases

*** Compliant with IEEE1609.3 in ITS FORUM RC-015 (In this study, only the minimum necessary parameters are shown)**




(green shading) : Identical to the parameters specified in the lower layer primitive (right column) (partial format changes and additional data)

Table 5.1.4-16 Communication protocol proposal interlayer interface (CV2X, request primitives)

| Target layer | Transport layer, network layer (Layer 4, 3) | LTE-V2X (Layer 2, 1) |
|---|---|---|
| Primitive name | WSM-WaveShortMessage. request | AS-DATA. request |
| Parameter | Provider Service Identifier | |
| | Peer MAC Address | Destination Address |
| | User Priority | Priority |
| | Expiry Time | Expiry Time (PDB) |
| | Channel Load | |
| | Transmit Power Level | TxPwr Level |
| | Data Rate (*1) | |
| | Channel Identifier | |
| | Time Slot (*1) | |
| | Info Elements Indicator | |
| | Length | |
| | Data | Data |
| | | TransmitterProfile ID |
| | | Include Time Confidence |

(*1) Not used for LTE-V2X

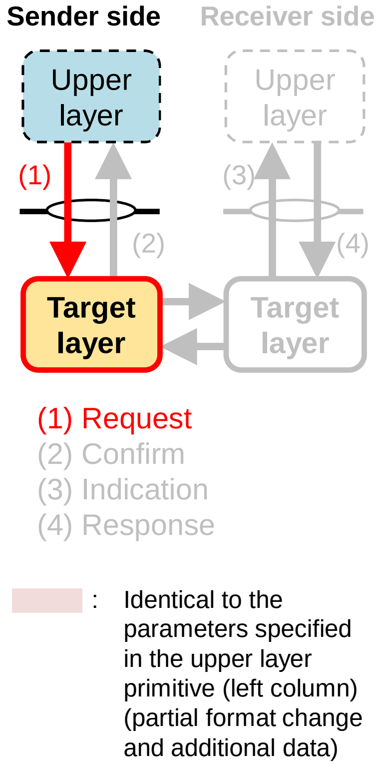
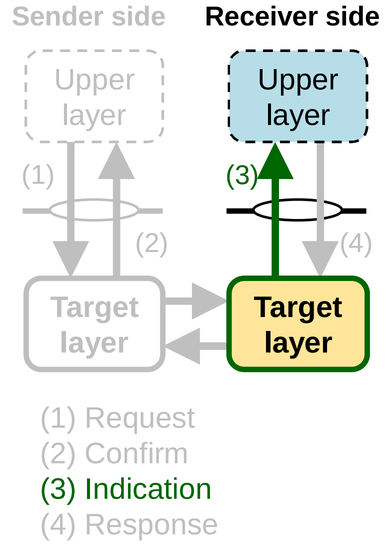


**Table 5.1.4-17 Communication protocol proposal interlayer interface (CV2X, indication primitives)**

| Target layer | Transport layer, network layer (Layer 4, 3) | LTE-V2X (Layer 2, 1) |
|---|---|---|
| Primitive name | WSM-WaveShortMessage. indication | AS-DATA. indication |
| Parameter | Provider Service Identifier | |
| | Peer MAC Address | Source Address |
| | User Priority | |
| | Channel Load | |
| | Transmit Power Level | |
| | Data Rate | |
| | Channel Number | |
| | Length | |
| | Data | Data |
| | WSMP Version | |




: Identical to the parameters specified in the lower layer primitive (right column) (partial format changes and additional data)

Table 5.1.4-18 Communication protocol proposal interlayer interface (security layer, sender side)

| Target layer | Security layer (Sender side) | |
|---|---|---|
| Generation order | 1 | 2 |
| Request/ confirm | Request ((1)) | Confirm ((2)) |
| Primitive name | Sec-SignedData. request | Sec-SignedData. confirm |
| Parameter | Cryptomaterial Handle<br>Data (*1)<br>Data Type (*1)<br>External Data Hash (*1,2)<br>External Data Hash Algorithm (*1,2)<br>PSID<br>Set Generation Time (*3)<br>Set Generation Location (*4)<br>Expiry Time (*1,2)<br>Signer Identifier Type<br>Signer Identifier Certificate Chain Length (*1)<br>Maximum Certificate Chain Length (*1)<br>Sign With Fast Verification<br>EC Point Format<br>Use Peer-to-peer Cert Distribution<br>SDEE ID (*1) | Signed Data<br>Result Code |

(*1) Option
(*2) Unused for BSM (SAE J2945/1, SAE J3161/1)
(*3) For BSM (SAE J2945/1, SAE J3161/1), set to enabled
(*4) For BSM (SAE J2945/1, SAE J3161/1), set to disabled

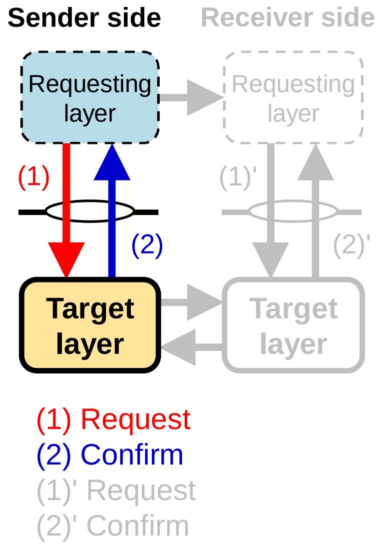
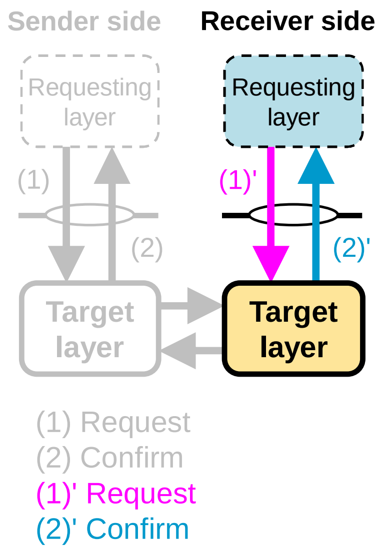


**Table 5.1.4-19 Communication protocol proposal interlayer interface (security layer, receiver side)**

| Target layer | Security layer (Receiver side) | | | |
|---|---|---|---|---|
| **Generation order** | **1** | **2** | **3** | **4** |
| **Request/ confirm** | **Request ((1)')** | **Confirm ((2)')** | **Request ((1)')** | **Confirm ((2)')** |
| **Primitive name** | **Sec-SecureData Preprocessing.request** | **Sec-SecureData Preprocessing.confirm** | **Sec-SignedData Verification.request** | **Sec-SignedData Verification.confirm** |
| **Parameter** | SDEE ID (*1) | | SDEE ID | |
| | PSID | | PSID | |
| | | | Content Type | |
| | Data | | Signed Data | |
| | | | External Data Hash (*1,2) | |
| | | | External Data Hash Algorithm (*1,2) | |
| | | | Maximum Certificate Chain Length (*1) | |
| | | | Relevance: Replay (*3) | |
| | | | Relevance: Generation Time in Past (*4) | |
| | | | Validity Period (*1) | |
| | | | Relevance: Generation Time in Future (*4) | |
| | | | Acceptable Future Data Period (*1) | |
| | | | Generation Time (*1) | |
| | | | Relevance: Expiry Time (*3) | |
| | | | Expiry Time (*1) | |
| | | | Consistency: Generation Location (*1,4) | |
| | | | Relevance: Generation Location Distance (*3) | |
| | | | Validity Distance (*1) | |
| | | | Generation Location (*1) | |
| | | | Overdue CRL Tolerance (*1) | |
| | | | Relevance: Expired Certificate (*4) | |
| | Use P2PCD | | | |
| | | Result Code | | Result Code |
| | | Content Type (*1) | | |
| | | Service Specific Permissions (*1) | | |
| | | Assurance Level (*1) | | |
| | | Earliest Next CRL Time | | |




(*1) Option
(*2) Not used for BSM (SAE J2945/1, SAE J3161/1)
(*3) For BSM (SAE J2945/1, SAE J3161/1), set to disabled
(*4) For BSM (SAE J2945/1, SAE J3161/1), set to enabled

### 5.1.5 Study of method of linking to 700 MHz Band Intelligent Transport Systems

This section, based on results of studies of the 5.9 GHz band communication protocol overview draft (Section 5.1.3) and detailed specifications draft (Section 5.1.4), describes results of the study of the method of linking to the ITS wireless communication specification (700 MHz Band Intelligent Transport Systems [3]) that already exists in Japan. Below, based on the study policy (Section (1)), is a description of the study proposal that was studied (Section (2)).

(1) Study policy

The policy on studying the method of linking to the 700 MHz Band Intelligent Transport Systems is given in Fig. 5.1.5-1. If harmonization with international trends going forward is considered, it is possible there will be differences in stack composition, security system, and the like between the 700 MHz band and 5.9 GHz band communication protocols, so the method being studied would link layers higher than Layer 7, with no link on Layer 7 and below (i.e., there would be no change to Layer 7 and below).

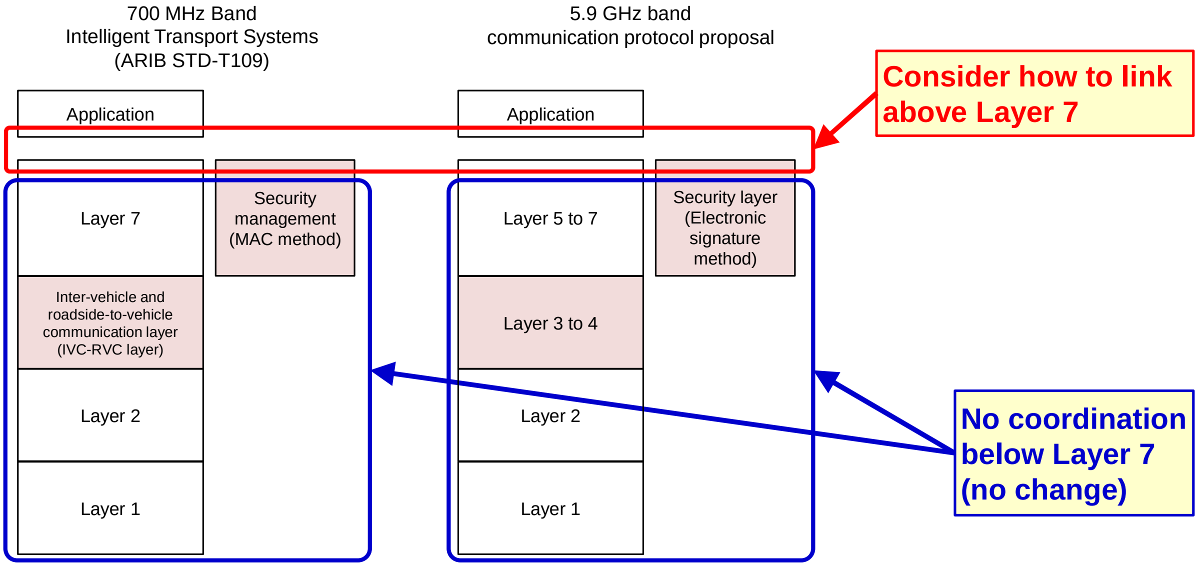


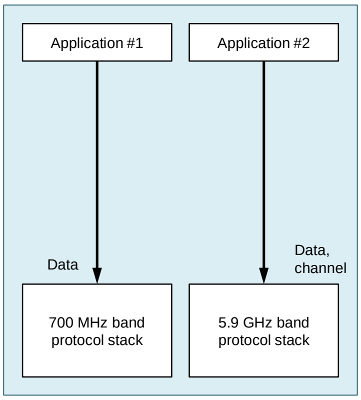
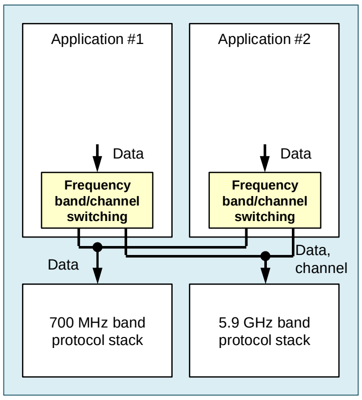
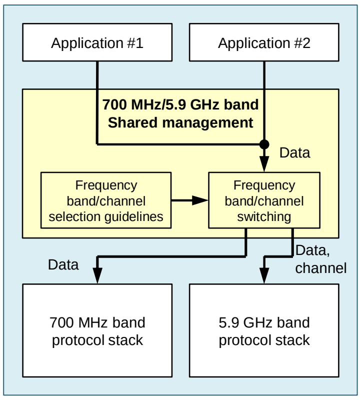

**Fig. 5.1.5-1 Policy on studying the method of linking to 700 MHz Band Intelligent Transport Systems [3]**

(2) Study proposal

The proposed methods of linking to the 700 MHz Band Intelligent Transport Systems are given in Table 5.1.5-1.

Three types, based on the degree of linkage, were studied and the advantages, issues, and composition of each were organized. Based on the development road map and relative prevalence, study will be needed in future on the method of allocating communication channels to the 700 MHz band and 5.9 GHz band in each use case. Furthermore, in order to realize new systems (cooperative driving automation) in both frequency bands, it is considered necessary to organize issues such as coexistence with existing systems and backward compatibility in the future.

**Table 5.1.5-1 Proposed methods of linking to the 700 MHz Band Intelligent Transport Systems**

| Proposal | Proposal 1 | Proposal 2 | Proposal 3 |
|---|---|---|---|
| **Cooperation method** | **Determine the frequency band in advance (no cooperation)** | **Select frequency band from application** | **Select frequency band outside the application** |
| Advantages | No need to modify existing applications | It is possible to switch the frequency used by the application according to the spread situation, etc. | It is possible to determine the frequency in consideration of the frequency utilization efficiency of the entire system |
| Issues | How to respond when the frequency used in the application is reviewed | Examination of methods for dispersing frequencies used in each application | Study of management layer for sharing 700 MHz band and 5.9 GHz band |
| Composition |  |  |  |

### 5.1.6 Communication sequence detailing based on examples of SIP UC communication scenarios and confirmation of appropriateness of study proposal

Based on the communication protocol proposal that was created (Section 5.1.3 to 5.1.4), this section describes the results of detailing the communication sequence based on examples of SIP UC communication scenarios [2] (see ITS FORUM RC-017) based on the layer categories and interlayer interfaces of the communication protocol proposal to confirm the appropriateness of the functions, operations, interfaces, etc. The following describes the implemented content (Section (1)), and in accordance with that, the results of detailing the communication sequence (Section (2)) and confirming the appropriateness of the study proposal (Section (3)).

(1) Implemented content

First, the conditions for communication messages to be generated, the procedures for transmitting and receiving them, etc., are organized based on the communication sequence (ITM FORUM RC-017) based on examples of SIP UC communication scenarios. Next, based on the communication protocol proposal that was designed, the application and each communication layer are subdivided for roadside infrastructure and vehicles and the conditions for communication messages of the application and each communication layer to be generated, the procedures for transmitting and receiving them, etc., are organized (the communication sequence is detailed). Finally, based on the results of detailing the communication sequence, the appropriateness of the communication protocol proposal's functions, operations, interfaces, etc., is confirmed.

An example of a communication sequence based on examples of SIP UC communication scenarios as described above is given in Fig. 5.1.6-1, while an image of detailing a communication sequence is given in Fig. 5.1.6-2.

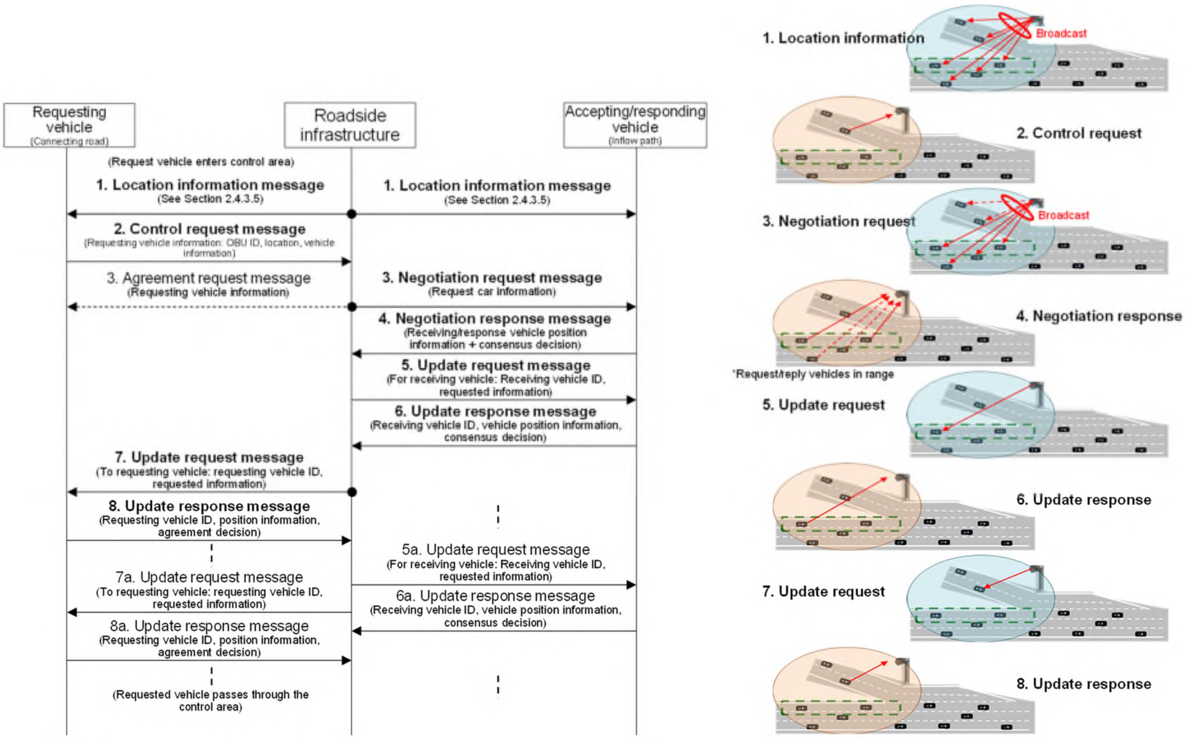



**Fig. 5.1.6-1 Example of a communication sequence based on communication scenarios [2]**

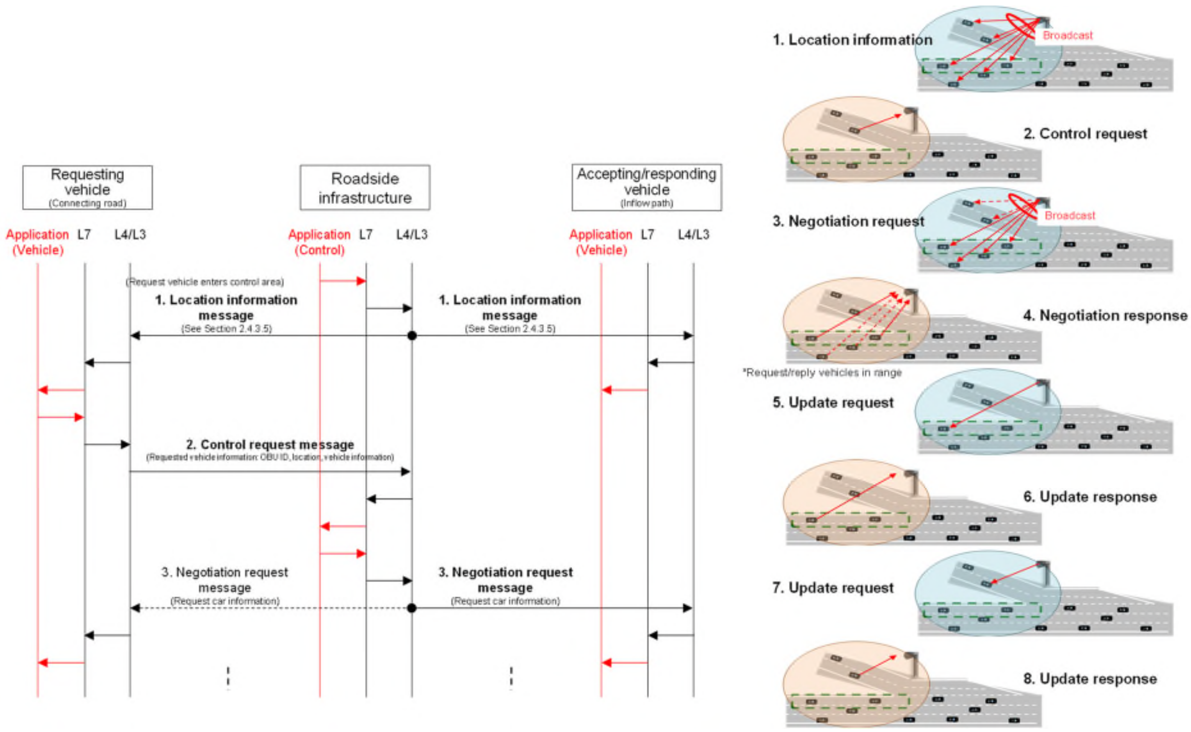



**Fig. 5.1.6-2 Image of detailing a communication sequence**

(2) Communication sequence detailing

This section describes the implemented content (Section (1)), and in accordance with that, the results of detailing the communication sequence based on examples of SIP UC communication scenarios (see ITS FORUM RC-017), as based on the layer categories and interlayer interfaces of the communication protocol proposal. The following describes these, in the order detailing of each use case (Section (a)), detailing of Layer 7 and below (Section (b)), and detailing of each communication message (Section (c)).

The above three types of detailing are explained. In "Detailing of each use case," only the application and upper layers (Layer 5 to 7) are organized. The communication sequence in communication layers other than the upper layers (i.e., the communication sequence in Layer 1 to 4 and the security layer) are common to all use cases, so these have been separately organized as “Detailing of Layer 7 and below.” Moreover, because there are use cases that use multiple messages, detailing was done that subdivided for each communication message as preparation for the detailing of each use case. Therefore, results of organizing “Detailing of each communication message” are also included for reference.

(a) Detailing of each use case

Communication sequences detailed for each use case are given in Fig. 5.1.6-3 to Fig. 5.1.6-15 (see Table 5.1.6-1 for uses case and their corresponding figure numbers). Concerning processing and function apportionment of the application and each wireless layer in use cases where traffic signal information and intersection information are transmitted (UC b-1-1, c-2-2), reference was made to “Strategic Innovation Promotion Program (SIP) Phase Two – Automated Driving (Expansion of Systems and Services), Research on the Enhancement of Technologies to Provide Traffic Signal Information toward the Realization of Automated Driving, Progress Report for Fiscal Year 2018.” [44]

In control/agreement use cases (UC a-1-3, a-1-4, a-2, and a-3, where negotiation information is transmitted and received), communication resulting from request/reply between roadside infrastructure and vehicles or between vehicles (update request/update reply are repeated after negotiation request/update reply) causes cases of waiting for a request and waiting for a reply, so status control is thought to be necessary, and detailed study will be needed in future. Also, negotiation request requires identifying a recipient range, while update request/update reply require identifying recipients; it is anticipated that the functions of request/reply and identifying recipients would be handled by the application.

In other use cases, roadside infrastructure would obtain information from external measuring systems, etc., and periodically transmit it, while vehicles would obtain information from on-board sensors, etc., and periodically transmit it (in the case of aperiodic use cases, information would be periodically transmitted after an event happens). Referring to the European and American specifications [4]-[5], [35], [37]-[38], [40]-[41], it is anticipated that the upper layers would handle the function of transmitting basic vehicle information that is common to multiple use cases, while the application would handle the function of transmitting other information.

In use cases where hazard information is transmitted, where there is relaying (forwarding) (UC c-1, c-3) and where information is periodically retransmitted (UC d-1 to d-5), referring to European specifications [38], it is anticipated that the upper layers would handle these functions.

As for the recipient’s application, in the case of roadside infrastructure, it would provide the information received to external parties, and in the case of vehicles, it would revise, etc., its trajectory based on the information received, information from the vehicle’s own on-board sensors, etc.

**Table 5.1.6-1 Results of detailing each use case and corresponding figure number**

| Classification by function | **Use case** | Communication method | Information element | | Application | | | Upper layer | | **Corresponding figure number** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Identify recipients | Transmit periodically | Request/reply | Transmit periodically | Relay (forward) | |
| a. Merging/lane change assistance | **a-1-1. Merging assistance by preliminary acceleration and deceleration** | I2V | Use case specific information | Surrounding vehicle information | — | ● | — | — | — | **Fig. 5.1.6-3** |
| | **a-1-2. Merging assistance by targeting the gap on the main lane** | | | | | | | | | — (Same as UC a-1-1) |
| | **a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control** | | | | | | | | | **Fig. 5.1.6-4** and **Fig. 5.1.6-5** |
| | | V2I, I2V | | Negotiation information | ● | — | ● | — | — | |
| | **a-1-4. Merging assistance based on negotiations between vehicles** | V2V | | | | | | | | **Fig. 5.1.6-6** |
| | **a-2. Lane change assistance when the traffic is heavy** | | | | | | | | | — (Same as UC a-1-4) |
| | **a-3. Entry assistance from non-priority roads to priority roads during traffic congestion** | | | | | | | | | — (Same as UC a-1-4) |
| b. Traffic signal information | **b-1-1. Driving assistance by using traffic signal information** | I2V | | Intersection information | — | ● | — | — | — | **Fig. 5.1.6-7** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| c. Lookahead information: Collision avoidance | **c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly** | V2V | | Hazard information | — | ● | — | — | ● | **Fig. 5.1.6-8** |
| | **c-2-1. Driving assistance based on intersection information (V2V)** | | Basic vehicle information | | — | — | — | ● | — | **Fig. 5.1.6-9** |
| | **c-2-2. Driving assistance based on intersection information (V2I)** | I2V | Use case specific information | Intersection information | — | ● | — | — | — | **Fig. 5.1.6-10** |
| | | | | Surrounding vehicle information | — | ● | — | — | — | |
| | **c-3. Collision avoidance assistance by using hazard information** | V2V | | Hazard information | — | ● | — | — | ● | — (Same as UC c-1) |
| d. Lookahead information: Trajectory change | **d-1. Driving assistance by notification of abnormal vehicles** | I2V, V2I | | Hazard information | — | ● (I2V) | — | ● (Retransmit) | — | **Fig. 5.1.6-11** |
| | **d-2. Driving assistance by notification of wrong-way vehicles** | | | | | | | | | — (Same as UC d-1) |
| | **d-3. Driving assistance based on traffic congestion information** | | | | | | | | | — (Same as UC d-1) |
| | **d-4. Traffic congestion assistance at branches and exits** | | | | | | | | | — (Same as UC d-1) |
| | **d-5. Driving assistance based on hazard information** | I2V | | | | | | | | — (Same as UC d-1) |
| e. Lookahead information: Emergency vehicle notification | **e-1. Driving assistance based on emergency vehicle information** | | | Hazard information | — | ● | — | — | — | **Fig. 5.1.6-12** |
| f. Information collection/ distribution by infrastructure | **f-2. Collection of information to optimize the traffic flow** | V2I | Basic vehicle information | | — | — | — | ● | — | **Fig. 5.1.6-13** |
| g. Platooning/ adaptive cruise control | **g-1. Unmanned platooning of following vehicles by electronic towbar** | V2V | Use case specific information | Unmanned platooning information | — | ● | — | — | — | **Fig. 5.1.6-14** |
| | **g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control** | V2V | | Manned platooning information | — | ● | — | — | — | **Fig. 5.1.6-15** |

| | |
|---|---|
| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) |
| **Information element** | **Use case specific information (Surrounding vehicle information)** |
| | **a-1-x** |
| Classification by function | a. Merging/lane change assistance |
| Use case | Merging assistance by preliminary acceleration and deceleration |
| No. | a-1-1 |
| Message name | Location information |
| Communication method | I2V |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **0.1s** |
| **Relay (forward)** | **None** |

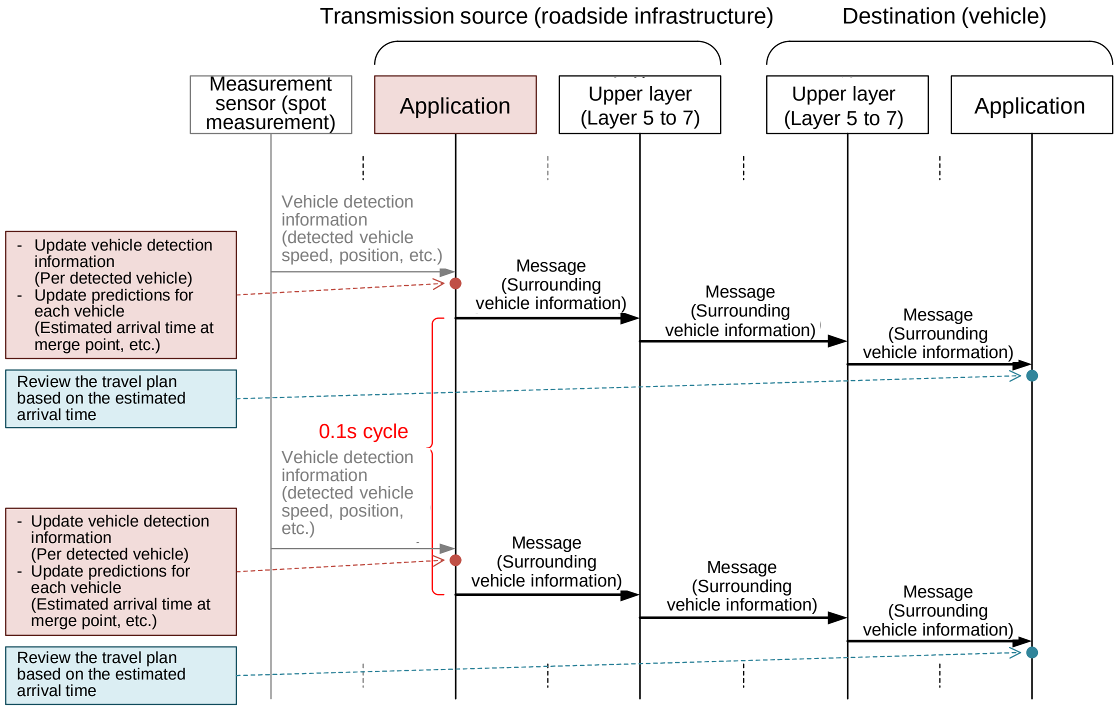



**Fig. 5.1.6-3 Detailed communication sequence (UC a-1-1)**

| | |
|---|---|
| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) |
| **Information element** | **Use case specific information (Surrounding vehicle information)** |
| Classification by function | a. Merging/lane change assistance |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control |
| No. | a-1-3 |
| Message name | Location information |
| Communication method | I2V |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **0.1s** |
| **Relay (Transmission)** | **None** |

| | | |
|---|---|---|
| Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | |
| **Use case specific information (Negotiation information)** | | |
| a. Merging/lane change assistance | | |
| Cooperative merging assistance with vehicles on the main lane by roadside control | | |
| a-1-3 | | |
| Control request | Negotiation request Update request | Negotiation response Update response |
| V2I | I2V | V2I |
| Non-specific vehicle/specific vehicle | | Roadside infrastructure |
| **Aperiodic** | | |
| – | | |
| **None** | | |

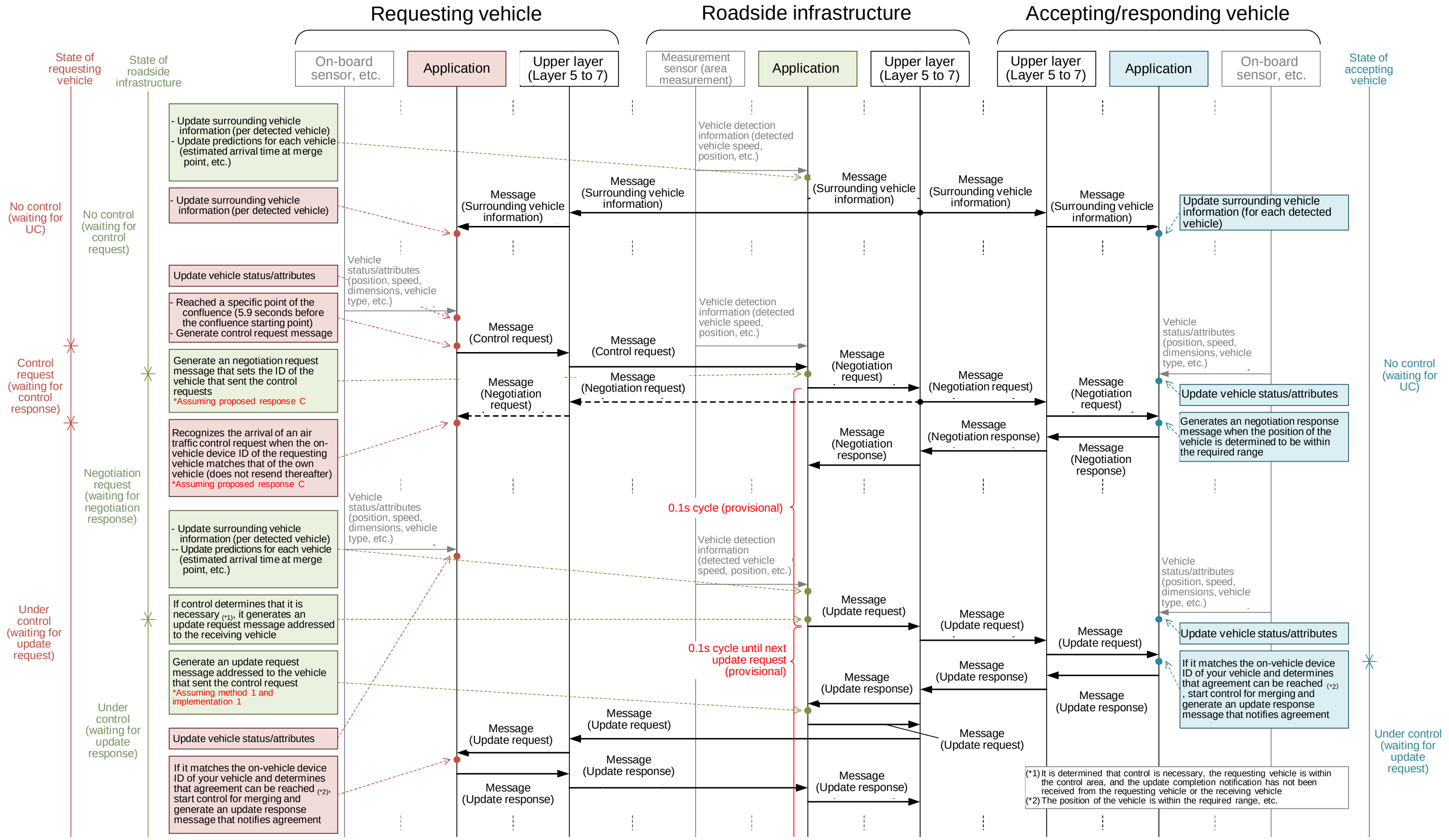



**Fig. 5.1.6-4 Detailed communication sequence (UC a-1-3, 1 of 2)**

| | |
|---|---|
| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) |
| **Information element** | **Use case specific information (Surrounding vehicle information)** |
| Classification by function | a. Merging/lane change assistance |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control |
| No. | a-1-3 |
| Message name | Location information |
| Communication method | I2V |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **0.1s** |
| **Relay (Transmission)** | **None** |

| | | |
|---|---|---|
| Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | |
| **Use case specific information (Negotiation information)** | | |
| a. Merging/lane change assistance | | |
| Cooperative merging assistance with vehicles on the main lane by roadside control | | |
| a-1-3 | | |
| Control request | Negotiation request Update request | Negotiation response Update response |
| V2I | I2V | V2I |
| Non-specific vehicle/specific vehicle | | Roadside infrastructure |
| **Aperiodic** | | |
| **–** | | |
| **None** | | |

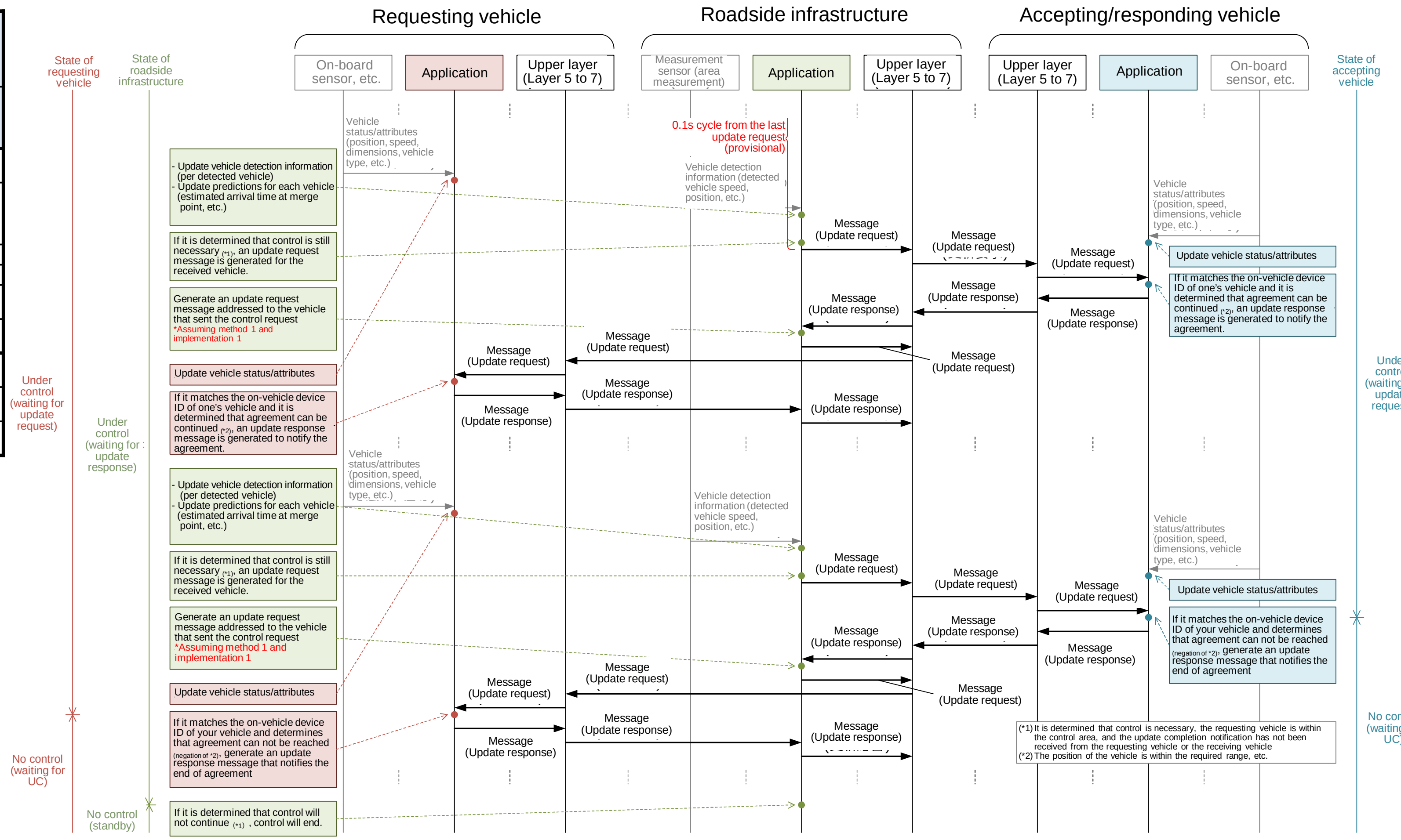



**Fig. 5.1.6-5 Detailed communication sequence (UC a-1-3, 2 of 2)**

| | | |
|---|---|---|
| Message content | Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.) | |
| **Information element** | **Use case specific information (Negotiation information)** | |
| Classification by function | a. Merging/lane change assistance | |
| Use case | Merging assistance based on negotiations between vehicles | |
| No. | a-1-4 | |
| Message name | Negotiation request Update request | Negotiation response Update response |
| Communication method | V2V | |
| Message destination | Non-specific vehicle/specific vehicle | |
| **Periodic/ aperiodic** | **Aperiodic** | |
| **Transmission interval** | **–** | |
| **Relay (forward)** | **None** | |

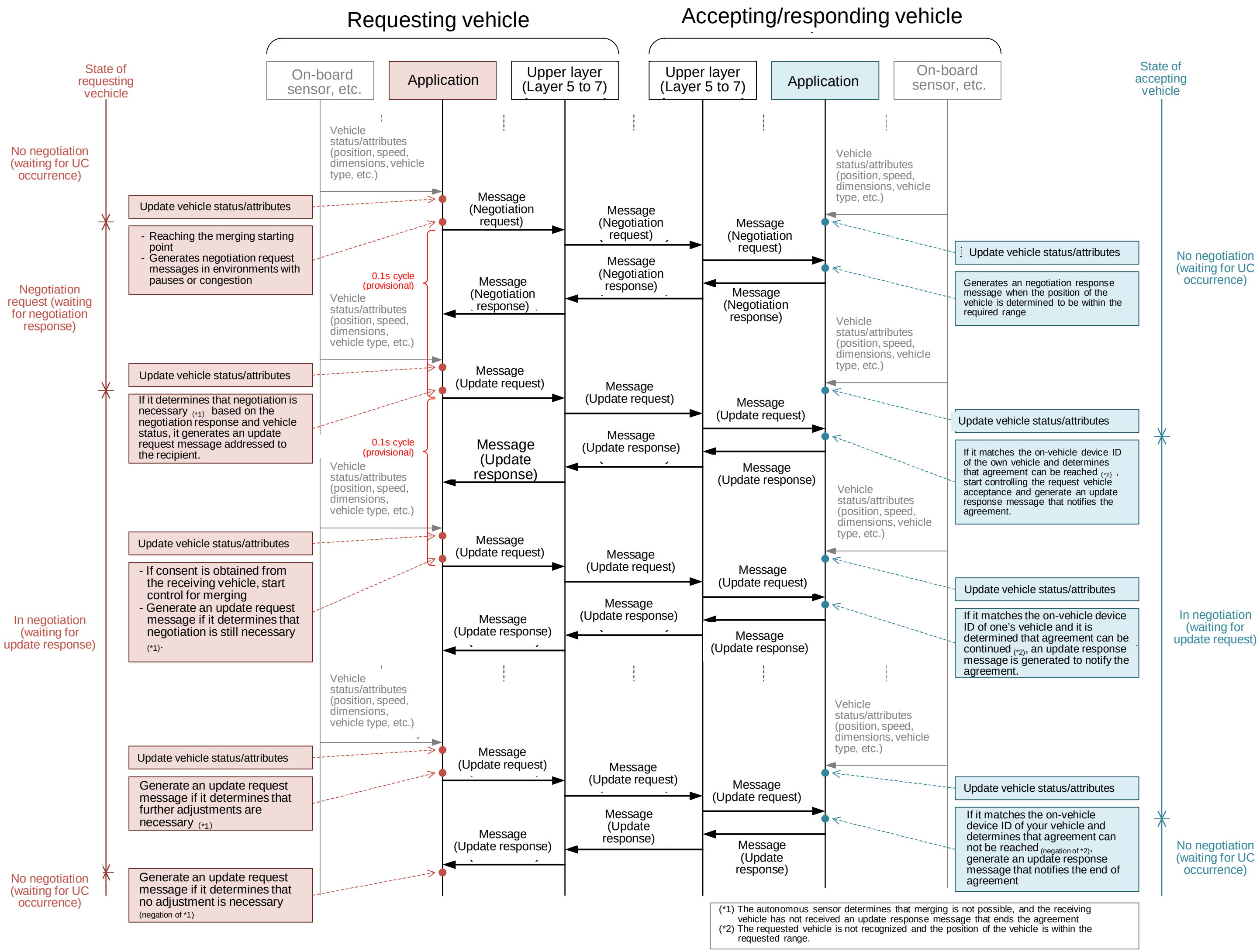
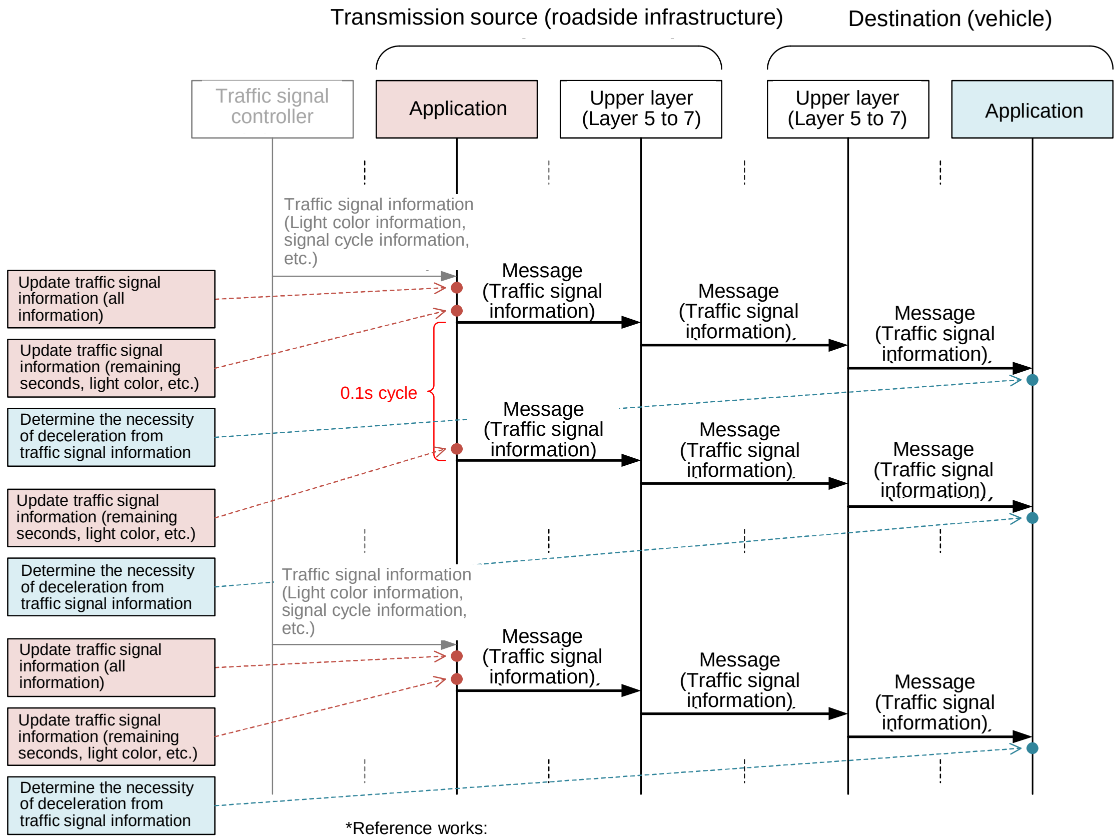



**Fig. 5.1.6-6 Detailed communication sequence (UC a-1-4)**

| | |
|---|---|
| Message content | Traffic signal information (traffic light color information, signal cycle information, etc.) |
| **Information element** | **Use case specific information (Intersection information)** |
| Classification by function | b. Traffic signal information |
| Use case | Driving assistance that uses traffic signal information |
| No. | b-1-1 |
| Message name | – |
| Communication method | I2V |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **0.1s** |
| **Relay (forward)** | **None** |




*Reference works:
Strategic Innovation Promotion Program (SIP) Phase Two – Automated Driving (Expansion of Systems and Services), Research on the Enhancement of Technologies to Provide Traffic Signal Information toward the Realization of Automated Driving, Progress Report for Fiscal Year 2018

**Fig. 5.1.6-7 Detailed communication sequence (UC b-1-1)**

| | | |
|---|---|---|
| Message content | Vehicle status/ attributes (position, speed, dimensions, vehicle type, etc.) | Detected event information (occurrence time, type, position, etc.) |
| **Information element** | **Basic vehicle information** | **Use case specific information (Hazard information)**<br>**c-1, c-3** |
| Classification by function | c. Lookahead information: Collision avoidance | |
| Use case | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | |
| No. | c-1 | |
| Message name | – | |
| Communication method | V2V | |
| Message destination | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | **Aperiodic** |
| **Transmission interval** | | **0.1s** |
| **Relay (Transmission)** | **None** | **Present** |

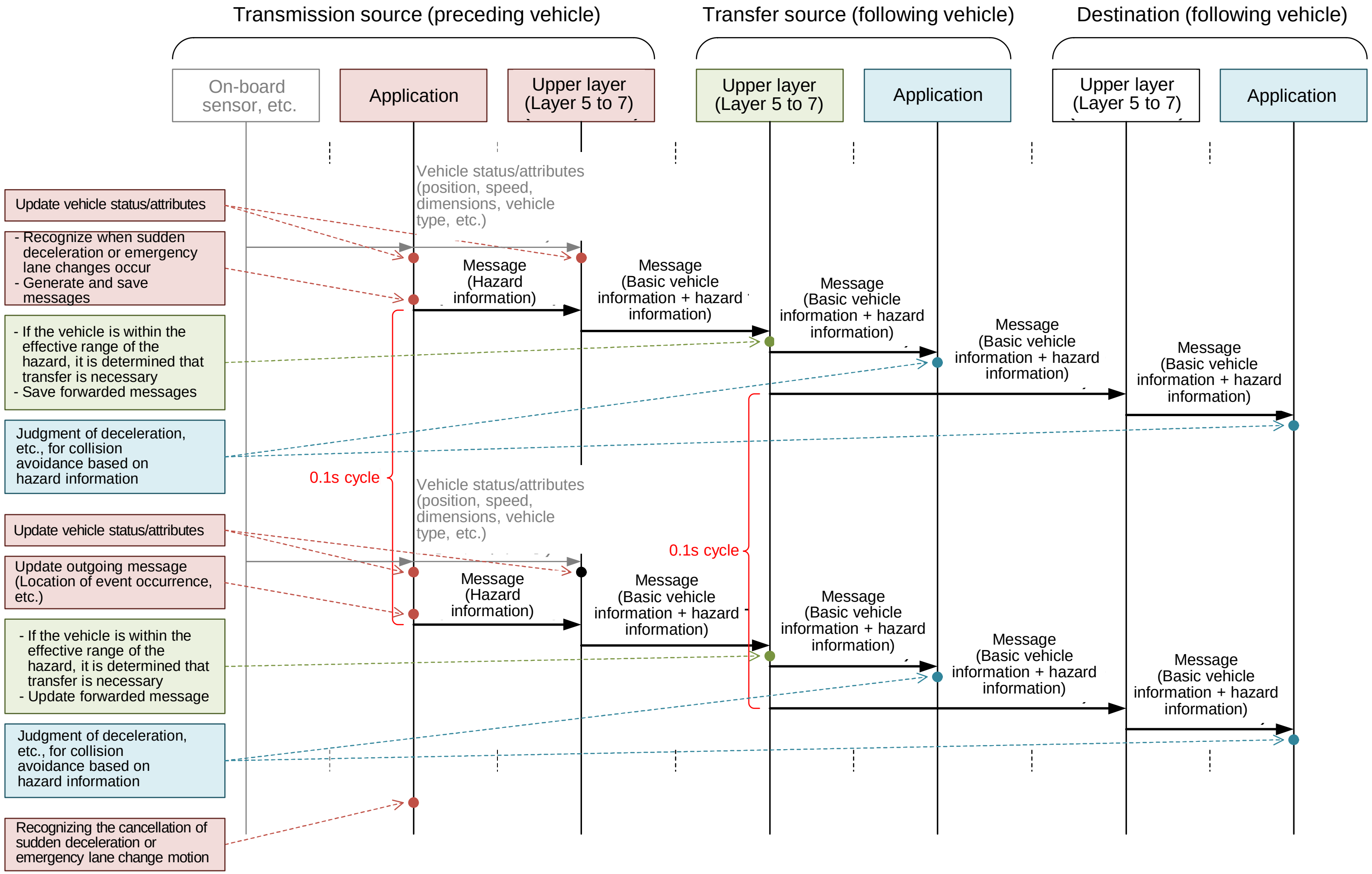



**Fig. 5.1.6-8 Detailed communication sequence (UC c-1)**

| | |
|---|---|
| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) |
| **Information element** | **Basic vehicle information** |
| Classification by function | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) |
| No. | c-2-1 |
| Message name | – |
| Communication method | V2V |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **0.1s** |
| **Relay (forward)** | **None** |

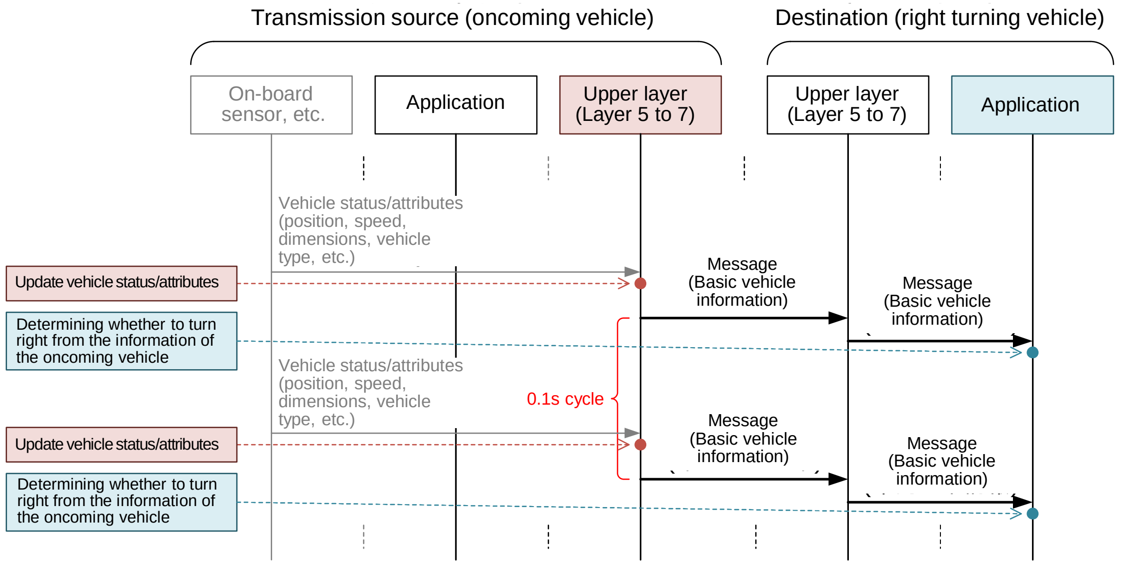



**Fig. 5.1.6-9 Detailed communication sequence (UC c-2-1)**

| Message content | Traffic signal information (traffic light color information, signal cycle information, etc.) | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) |
|---|---|---|
| **Information element** | **Use case specific information (Intersection information)** | **Use case specific information (Surrounding vehicle information)** |
| | | **c-2-2** |
| Classification by function | c. Lookahead information: Collision avoidance | |
| Use case | Driving assistance based on intersection information (V2I) | |
| No. | c-2-2 | |
| Message name | – | |
| Communication method | I2V | |
| Message destination | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | |
| **Transmission interval** | **0.1s** | |
| **Relay (forward)** | **None** | |

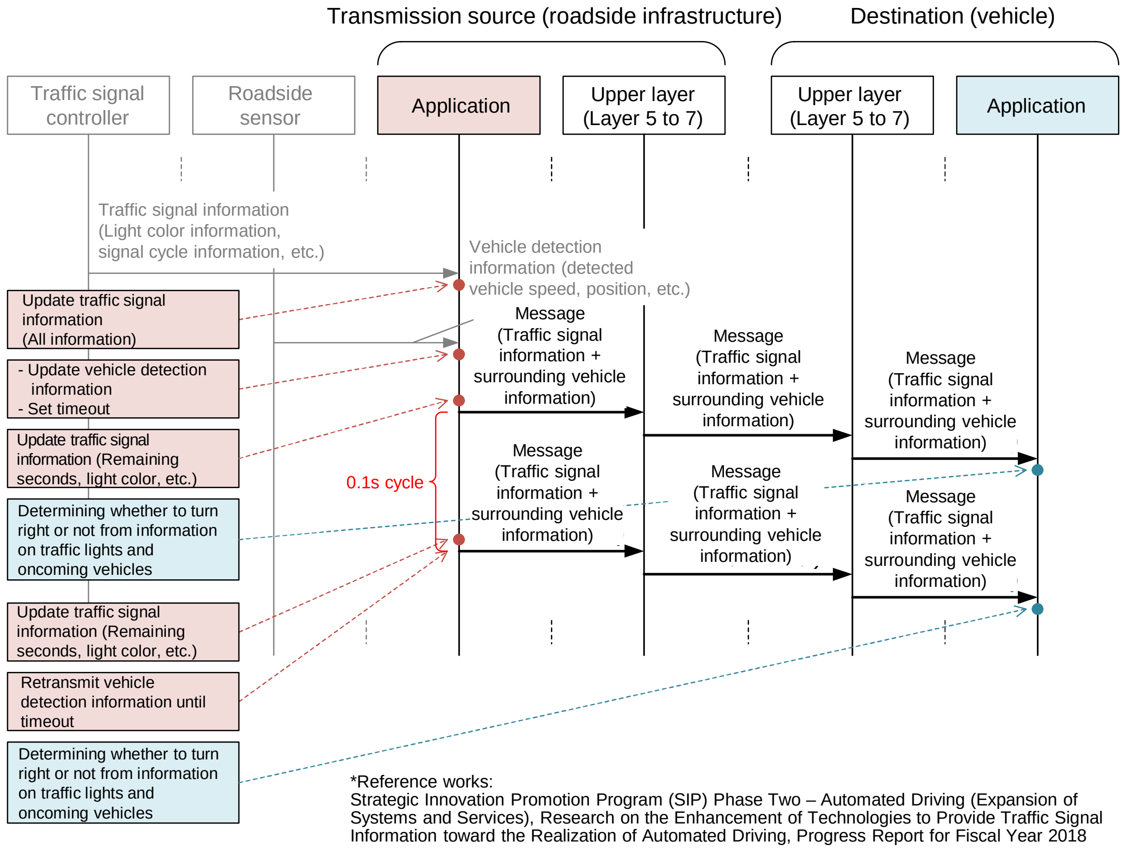



**Fig. 5.1.6-10 Detailed communication sequence (UC c-2-2)**

| | | |
|---|---|---|
| Message content | Detected event information (occurrence time, type, position, etc.) | |
| **Information element** | **Use case specific information (Hazard information)** | |
| | **d-x** | |
| Classification by function | d. Lookahead information: Trajectory change | |
| Use case | Driving assistance by notification of abnormal vehicles | |
| No. | d-1 | |
| Message name | – | |
| Communication method | V2I | I2V |
| Message destination | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Aperiodic** | |
| **Transmission interval** | **–** | **1s** |
| **Relay (Transmission)** | **None** | |

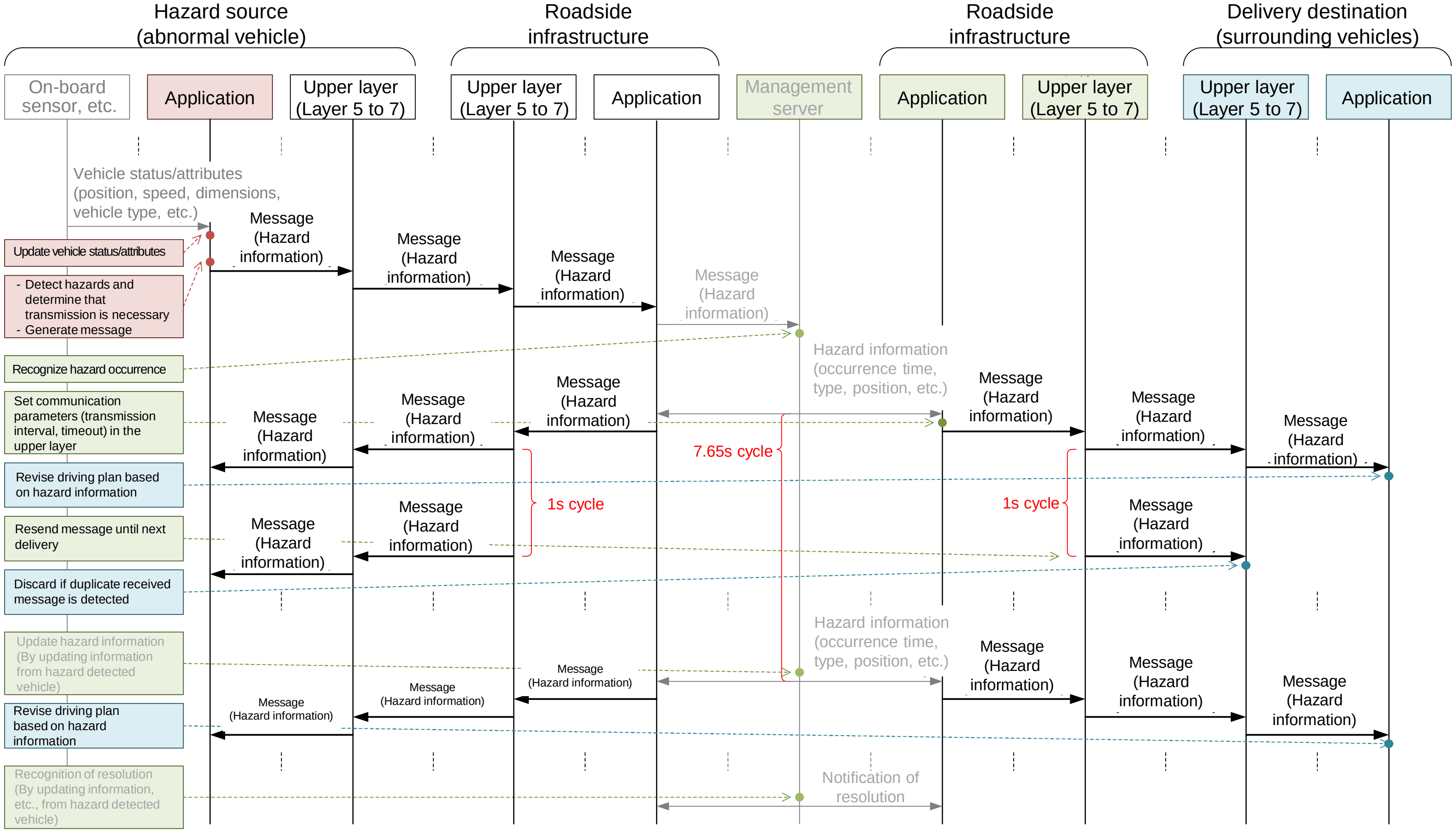



Fig. 5.1.6-11 Detailed communication sequence (UC d-1)

| | |
|---|---|
| Message content | Detected event information Occurrence time, type, position, etc. |
| **Information element** | **Use case specific information (Hazard information)** |
| | **e-1** |
| 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 |
| Message destination | Non-specific vehicles |
| **Periodic/ aperiodic** | **Aperiodic** |
| **Transmission interval** | **0.1s** |
| **Relay (forward)** | **None** |

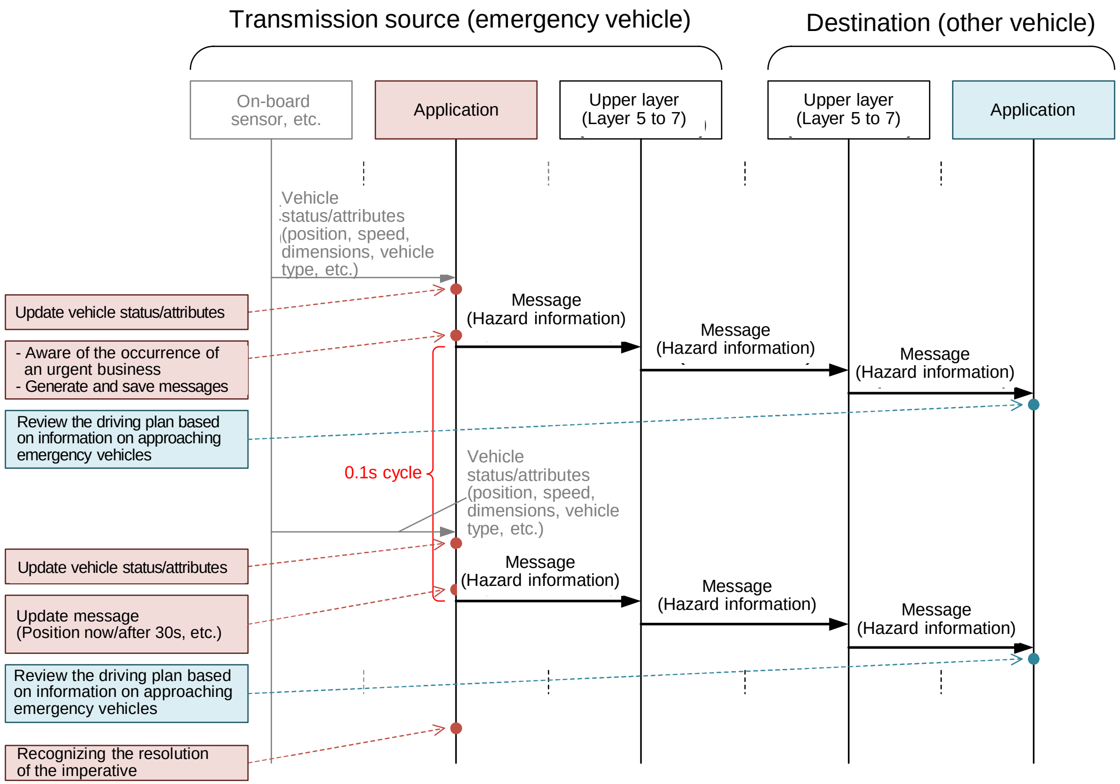
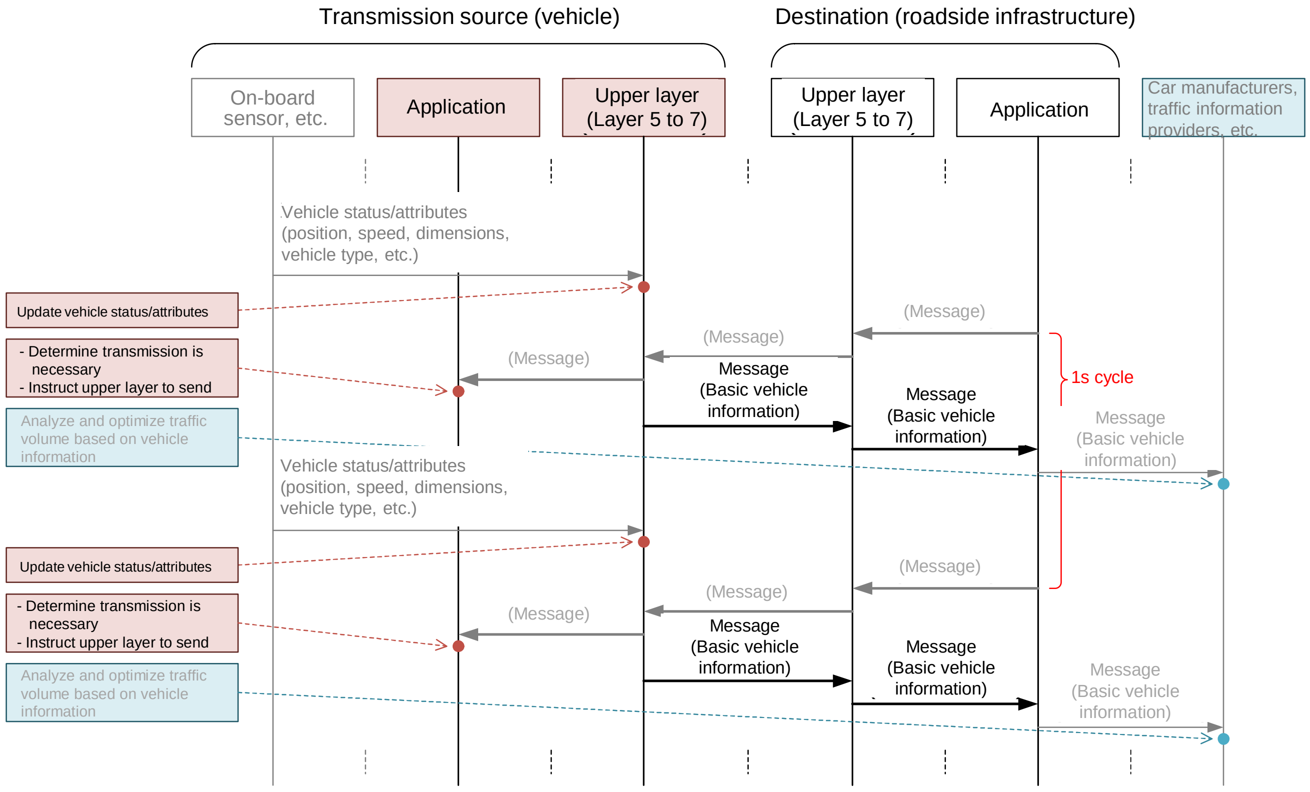



**Fig. 5.1.6-12 Detailed communication sequence (UC e-1)**

| | |
|---|---|
| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) |
| **Information element** | **Basic vehicle information** |
| Classification by function | f. Information collection/distribution by infrastructure |
| Use case | Collection of information to optimize the traffic flow |
| No. | f-2 |
| Message name | – |
| Communication method | V2I |
| Message destination | Roadside infrastructure |
| **Periodic/ aperiodic** | **Periodic** |
| **Transmission interval** | **1s** |
| **Relay (forward)** | **None** |




(*) It is assumed that the start of transmission of basic vehicle information is determined by the application.
(Future consideration is required, including information sources)

**Fig. 5.1.6-13 Detailed communication sequence (UC f-2)**

| | | |
|---|---|---|
| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | Operation information of platoon vehicles (Brake, accelerator, etc.) |
| **Information element** | **Basic vehicle information** | **Use case specific information (Unmanned platooning information)** |
| Classification by function | g. Platooning/adaptive cruise control | |
| Use case | Unmanned platooning of following vehicles by electronic towbar | |
| No. | g-1 | |
| Message name | – | |
| Communication method | V2V | |
| Message destination | Specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | |
| **Transmission interval** | **0.02 to 0.1s** | |
| **Relay (forward)** | **None** | |

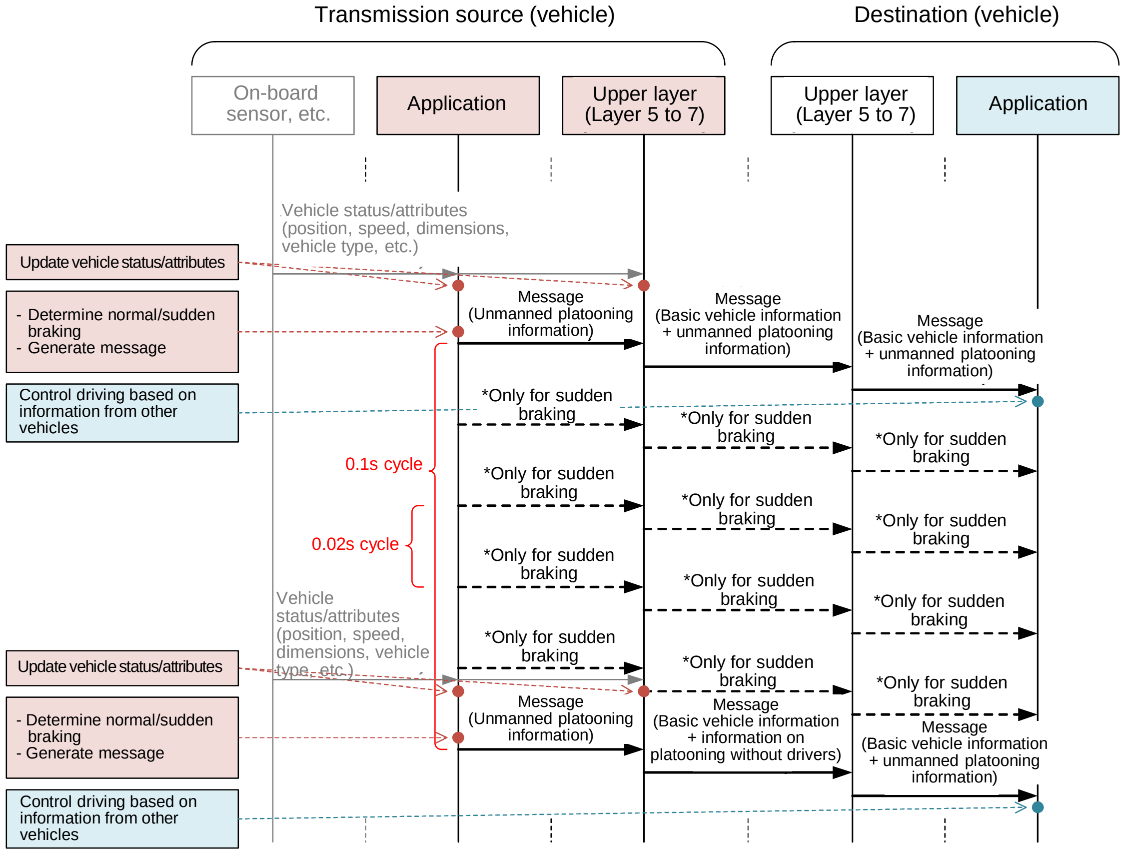



**Fig. 5.1.6-14 Detailed communication sequence (UC g-1)**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | Information about the formation (Following availability, leading vehicle ID, etc.) |
|---|---|---|
| **Information element** | **Basic vehicle information** | **Use case specific information (Manned platooning information)** |
| Classification by function | g. Platooning/adaptive cruise control | |
| Use case | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | |
| No. | g-2 | |
| Message name | – | |
| Communication method | V2V | |
| Message destination | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | |
| **Transmission interval** | **0.1s** | |
| **Relay (forward)** | **None** | |

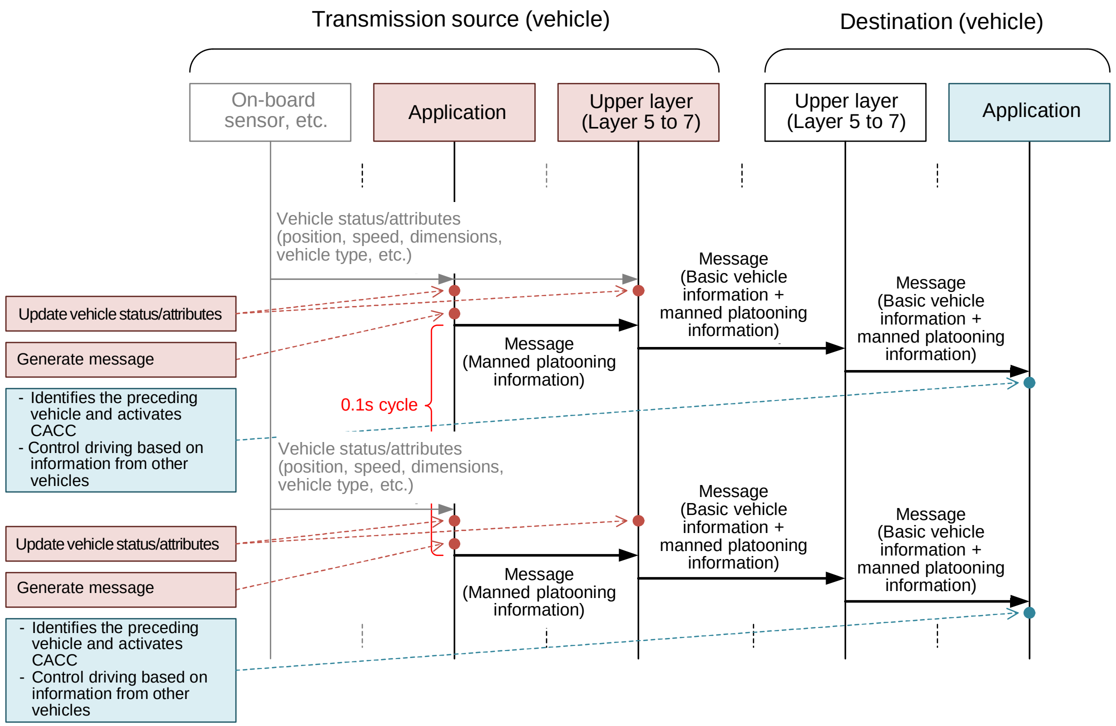



**Fig. 5.1.6-15 Detailed communication sequence (UC g-2)**

(b) Detailing of Layer 7 and below

Communication sequences where the upper layers (Layer 5 to 7) and below are detailed are given in Fig. 5.1.6-16 to Fig. 5.1.6-18.

In cases where there is no message partitioning (Fig. 5.1.6-16), the transmission source's upper layers (Layer 5 to 7) receive a communication message from the application, request an electronic signature from the security layer, receive the signed message created by the security layer, and pass it to a lower layer (Layer 4). The recipient's upper layers (Layer 5 to 7) receive the signed message from a lower layer (Layer 4), request preprocessing and electronic signature verification from the security layer, and if a reply is received from the security layer that there is no problem, pass the communication message to the application.

In situations where messages are partitioned by the upper layers (Fig. 5.1.6-17), the upper layers (Layer 5 to 7) partition the communication message because it is too large for a lower layer (Layer 4) to receive. Processing of partitioned messages is the same as in cases where messages are not partitioned. Because an electronic signature must be added to each partitioned message, the size of the security overhead increases by the number of partitions.

In situations where messages are partitioned by Layer 2 (Fig. 5.1.6-18), Layer 2 partitions the message because it is too large for a lower layer (Layer 1) to receive. Processing in a layer higher than Layer 2 (Layer 3 or higher) is the same as in cases where messages are not partitioned. In this case, because there is no partitioning in the upper layers (Layer 5 to 7), the size of the security overhead is the same as in cases where messages are not partitioned.

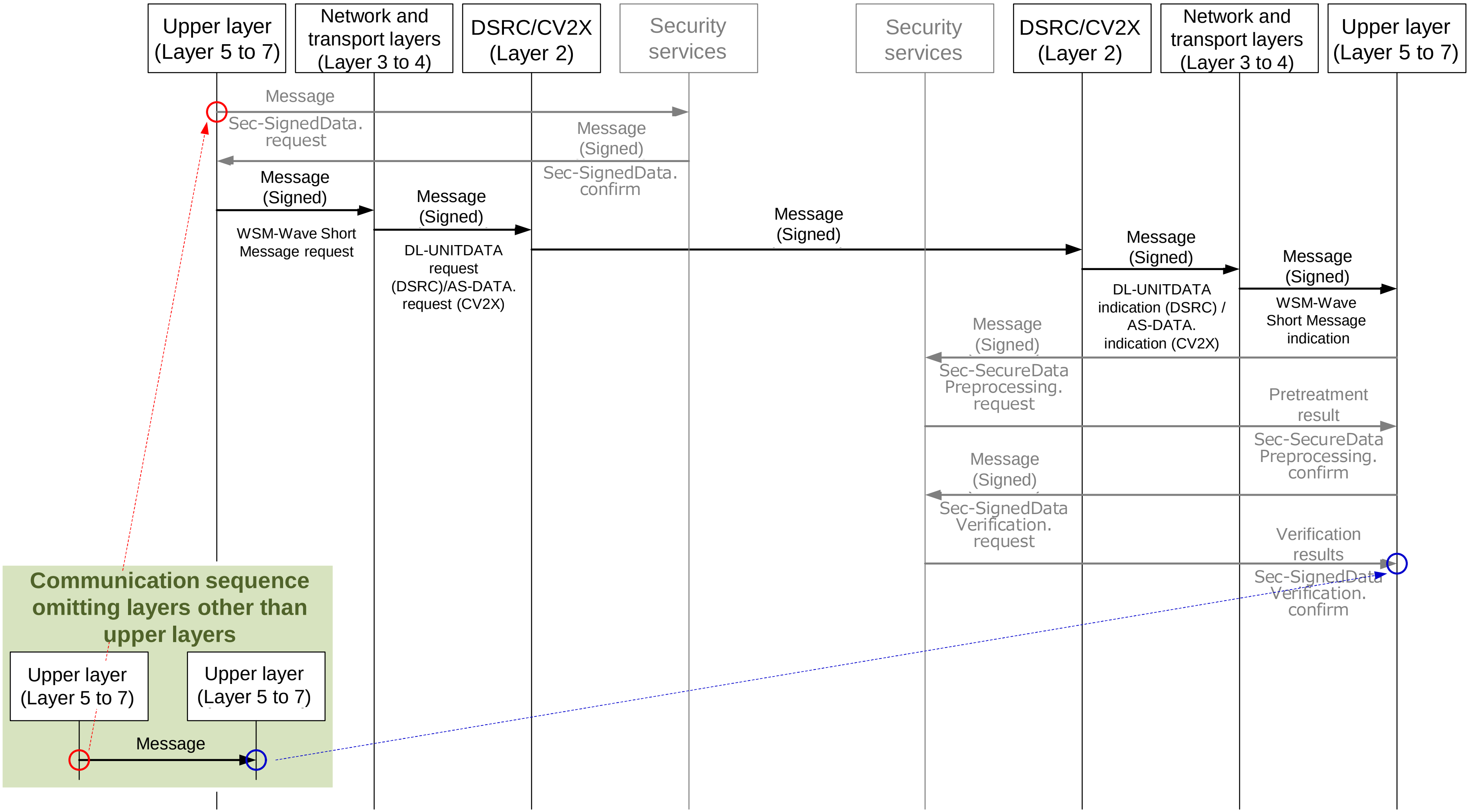



**Fig. 5.1.6-16 Communication sequence where Layer 7 and below are detailed (no message partitioning)**

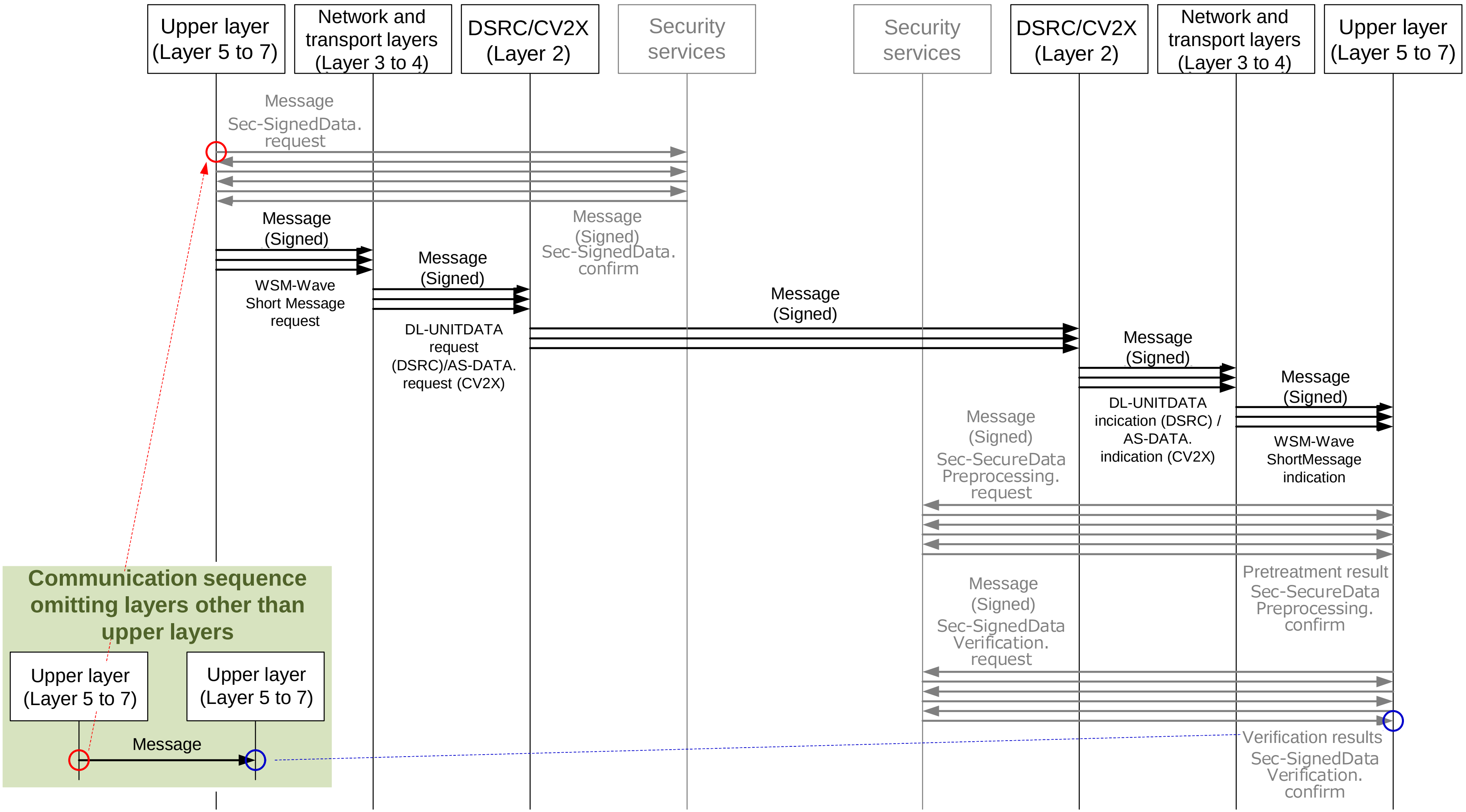



**Fig. 5.1.6-17 Communication sequence where Layer 7 and below are detailed (with message partitioning by upper layers)**

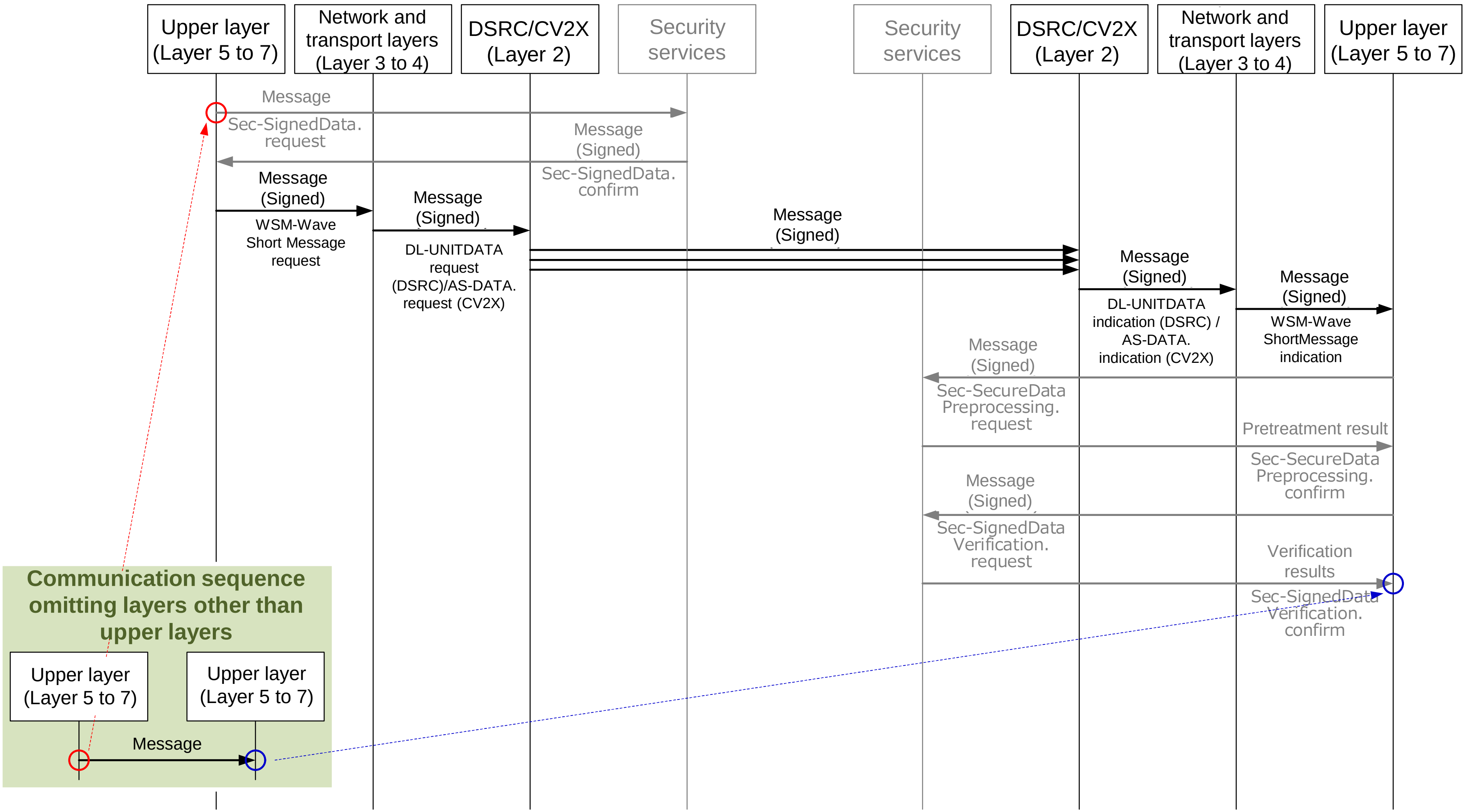



**Fig. 5.1.6-18 Communication sequence where Layer 7 and below are detailed (with message partitioning by Layer 2)**

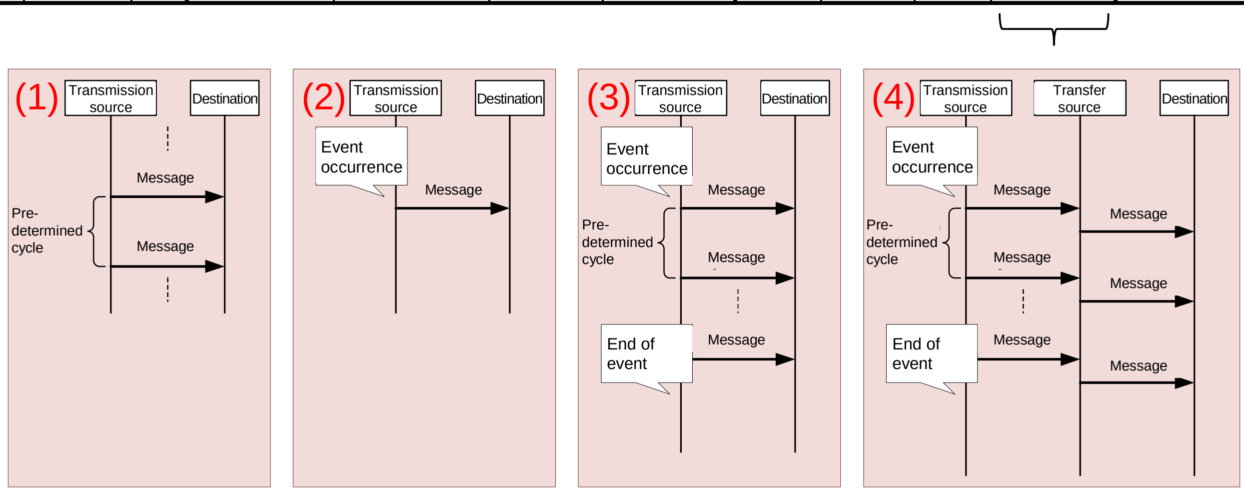
(c) Detailing of each communication message (for reference)

Detailed sequences for each communication message ("information element" listed in ITS FORUM RC-017 Appendix 1) are given in Fig. 5.1.6-19 to Fig. 5.1.6-32 as preparation for detailing of each use case. (See Table 5.1.6-2 for use cases and their corresponding figure numbers.) Here, communication sequences for each communication message are organized into four categories: (1) periodic, (2) aperiodic [aperiodic, no relaying (forwarding)], (3) aperiodic [periodic transmission, no relaying (forwarding)], and (4) aperiodic [periodic transmission, with relaying (forwarding)]. ((1) to (4) correspond to the "Communication pattern" column of Table 5.1.6-2.)

**Table 5.1.6-2 Results of detailing of each communication message (information element) and corresponding figure number**

| **Information element** | | | Classification by function | Use case | Message name | Communication method | Periodic/ aperiodic | Transmit periodically | Relay (forward) | Communication pattern | **Corresponding figure number** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Basic vehicle information** | | | c. Lookahead information: Collision avoidance | c-2-1. Driving assistance based on intersection information (V2V) | — | V2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-19 |
| **Basic vehicle information** | | | f. Information collection/ distribution by infrastructure | f-2. Collection of information to optimize the traffic flow | — | V2I | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-20 |
| **Use case specific information** | **Intersection information** | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information | — | I2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-21 |
| **Use case specific information** | **Surrounding vehicle information** | **c-2-2** | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | — | I2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-22 |
| **Use case specific information** | **Surrounding vehicle information** | **a-1-x** | a. Merging/lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | Position information | I2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-23 |
| **Use case specific information** | **Surrounding vehicle information** | **a-1-x** | a. Merging/lane change assistance | a-1-2. Merging assistance by targeting the gap on the main lane | Position information | I2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-23 |
| **Use case specific information** | **Surrounding vehicle information** | **a-1-x** | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Position information | I2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-23 |
| **Use case specific information** | **Unmanned platooning information** | | g. Platooning/ adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | — | V2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-24 |
| **Use case specific information** | **Manned platooning information** | | g. Platooning/ adaptive cruise control | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | — | V2V | Periodic | Present | None | **(1)** | **Fig**. 5.1.6-25 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Control request | V2I | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-26 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Negotiation request/ update request | I2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-27 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Negotiation response/ update response | V2I | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-26 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-1-4. Merging assistance based on negotiations between vehicles | Negotiation request/ update request | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-1-4. Merging assistance based on negotiations between vehicles | Negotiation response/ update response | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation response/ update response | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | Negotiation request/ update request | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Negotiation information** | | a. Merging/lane change assistance | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | Negotiation response/ update response | V2V | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-28 |
| **Use case specific information** | **Hazard information** | **d-x** | d. Lookahead information: Trajectory change | d-1. Driving assistance by notification of abnormal vehicles | — | V2I | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-29 |
| **Use case specific information** | **Hazard information** | **d-x** | d. Lookahead information: Trajectory change | d-2. Driving assistance by notification of | — | V2I | Aperiodic | None | None | **(2)** | **Fig**. 5.1.6-29 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | wrong-way vehicles | | | | | | | |
| | | | | d-3. Driving assistance based on traffic congestion information | | | | | | | |
| | | | | d-4. Traffic congestion assistance at branches and exits | | | | | | | |
| Use case specific information | Hazard information | **e-1** | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | Aperiodic | Present | None | (3) | **Fig**. 5.1.6-30 |
| | | **d-x** | d. Lookahead information: Trajectory change | d-1. Driving assistance by notification of abnormal vehicles | | I2V | | | | | **Fig**. 5.1.6-31 |
| | | | | d-2. Driving assistance by notification of wrong-way vehicles | | | | | | | |
| | | | | d-3. Driving assistance based on traffic congestion information | | | | | | | |
| | | | | d-4. Traffic congestion assistance at branches and exits | | | | | | | |
| | | | | d-5. Driving assistance based on hazard information | | | | | | | |
| **Use case specific information** | **Hazard information** | **c-1, c-3** | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | V2V | Aperiodic | Present | Present | (4) | **Fig**. 5.1.6-32 |
| | | | | c-3. Collision avoidance assistance by using hazard information | | | | | | | |



| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/}aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

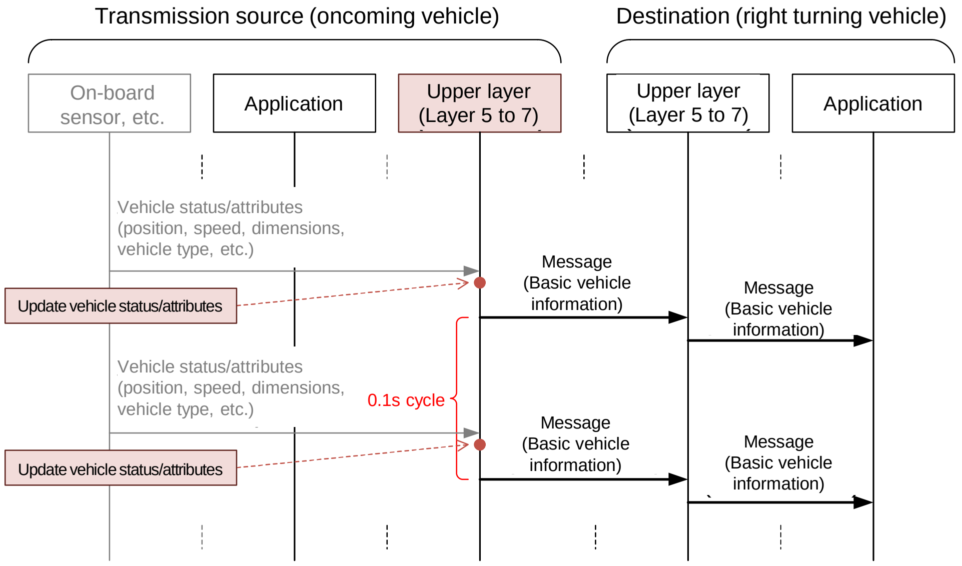
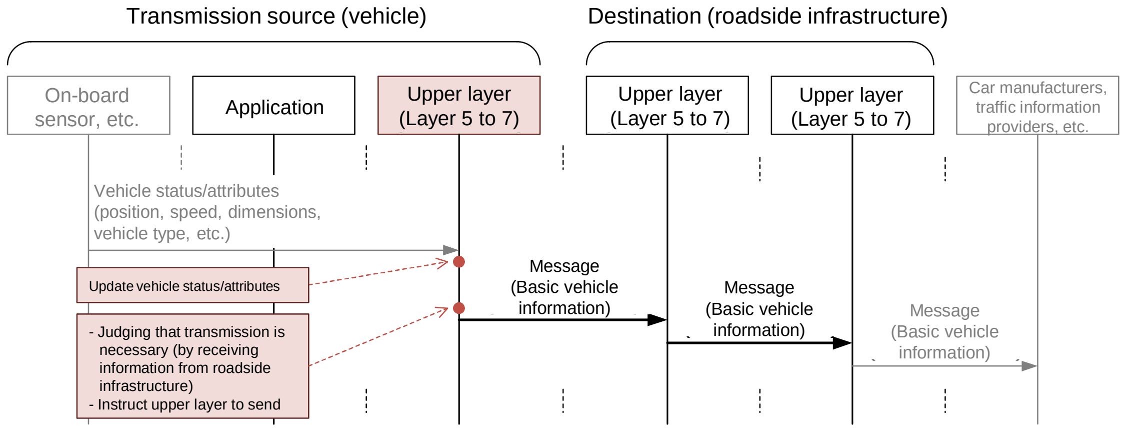



**Fig. 5.1.6-19 Detailed communication sequence (basic vehicle information, for V2V)**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

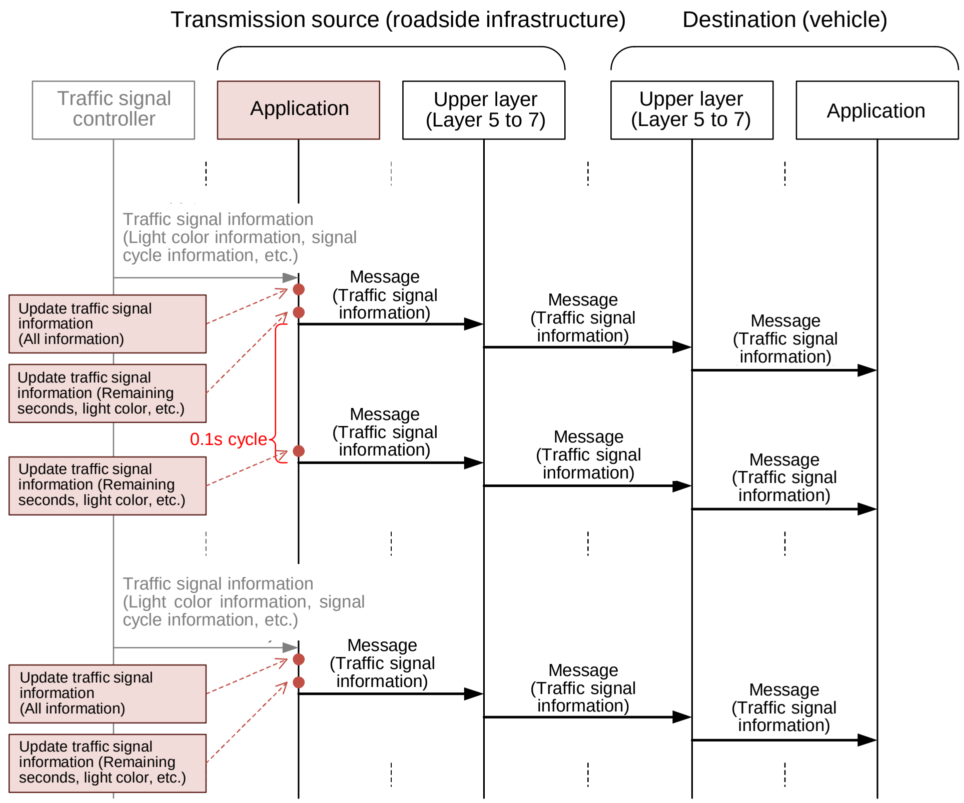



| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

**Fig. 5.1.6-20 Detailed communication sequence (basic vehicle information, for V2I)**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | Merging assistance by preliminary acceleration and deceleration | Merging assistance by targeting the gap on the main lane | Main line vehicle cooperative merging assistance by roadside control | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communicatio n method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

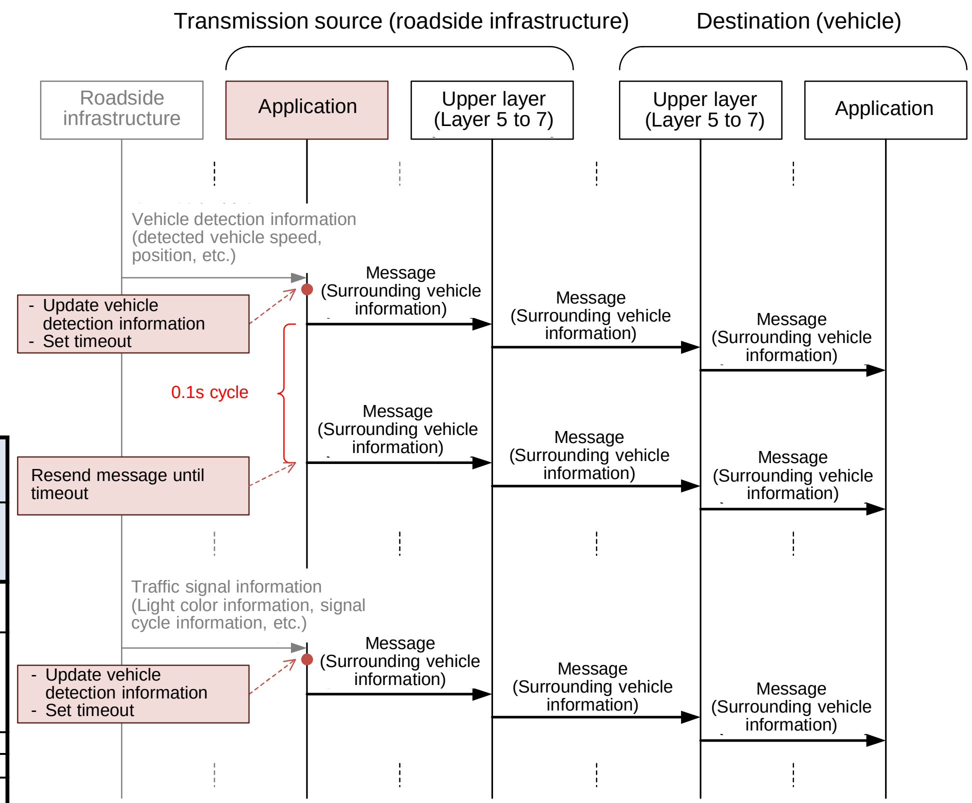



*Reference works:
FY2018 Achievement Report Cross-ministerial Strategic Innovation Promotion Program Phase 2/Automated Driving (Expansion of Systems and Services)/Investigation Related to Advancement of Traffic Signal Information Provision Technology, etc., for Realization of Automated Driving

**Fig. 5.1.6-21 Detailed communication sequence (intersection information)**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | | I2V | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | | **0.1s** | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |




*Reference works:
FY2018 Achievement Report Cross-ministerial Strategic Innovation Promotion Program Phase 2/Automated Driving (Expansion of Systems and Services)/Investigation Related to Advancement of Traffic Signal Information Provision Technology, etc., for Realization of Automated Driving

**Fig. 5.1.6-22 Detailed communication sequence (surrounding vehicle information (UC c-2-2))**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

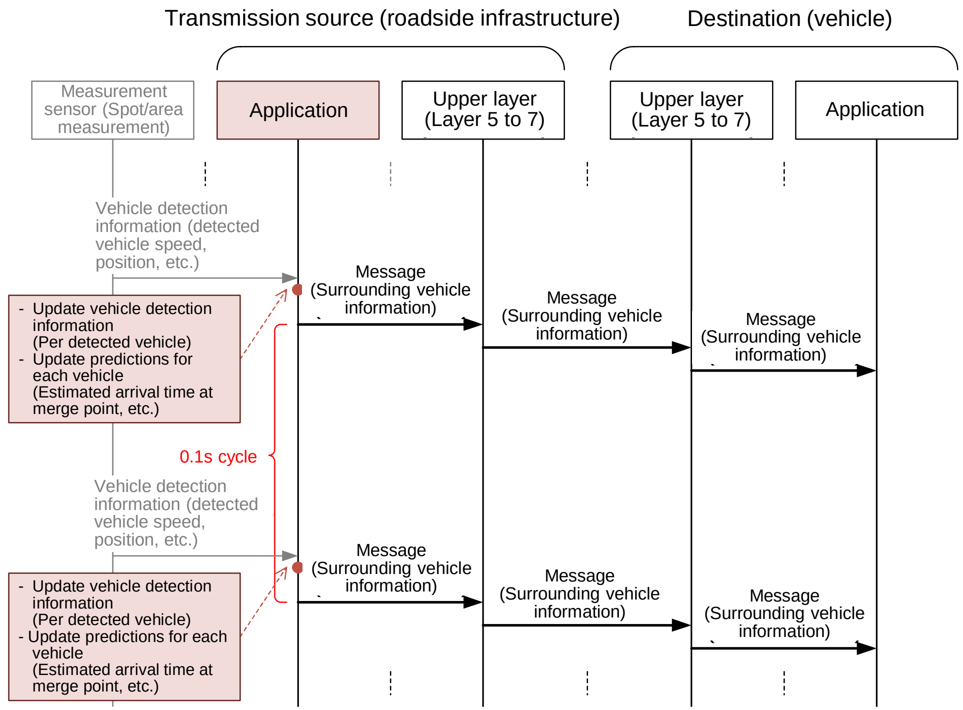



**Fig. 5.1.6-23 Detailed communication sequence (surrounding vehicle information (UC a-1-x))**

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

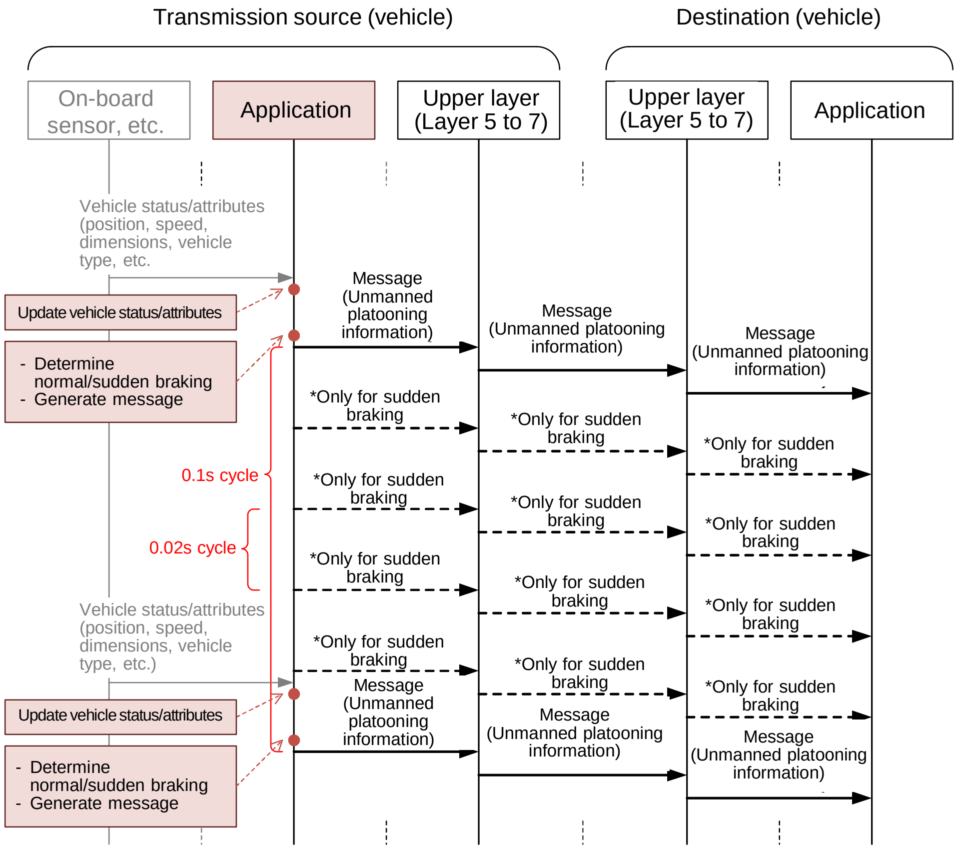



Fig. 5.1.6-24 Detailed communication sequence (unmanned platooning information)

| Message content | Vehicle condition/attribute (Position, speed, dimensions, vehicle type, etc.) | | Traffic signal information (traffic light color information, signal cycle information, etc.) | |
|---|---|---|---|---|
| **Information element** | **Basic vehicle information** | | **Use case specific information (Intersection information)** | |
| Classification by function | c. Lookahead information: Collision avoidance | f. Information collection/distribution by infrastructure | b. Traffic signal information | c. Lookahead information: Collision avoidance |
| Use case | Driving assistance based on intersection information (V2V) | Collection of information to optimize the traffic flow | Driving assistance that uses traffic signal information | Driving assistance based on intersection information (V2I) |
| No. | c-2-1 | f-2 | b-1-1 | c-2-2 |
| Message name | – | | – | |
| Communication method | V2V | V2I | I2V | |
| Message destination | Non-specific vehicles | Roadside infrastructure | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Periodic** | | | |
| **Transmission interval** | **0.1s** | **1s** | **0.1s** | |
| **Relay (forward)** | **None** | | | |

| Message content | Vehicle detection information (Sensor information, detected vehicle speed/position, etc.) | | | | Vehicle platoon operation information (brake, accelerator, etc.) | Information about the platoon (following availability, leading vehicle ID, etc.) |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Surrounding vehicle information)** | | | | **Use case specific information (Unmanned platooning information)** | **Use case specific information (Manned platooning information)** |
| | **c-2-2** | **a-1-x** | | | | |
| Classification by function | c. Lookahead information: Collision avoidance | a. Merging/lane change assistance | | | g. Platooning/adaptive cruise control | |
| Use case | Driving assistance based on intersection information (V2I) | 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 | Unmanned platooning of following vehicles by electronic towbar | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | c-2-2 | a-1-1 | a-1-2 | a-1-3 | g-1 | g-2 |
| Message name | – | Location information | | | – | – |
| Communication method | I2V | | | | V2V | |
| Message destination | Non-specific vehicles | | | | Specific vehicles | Non-specific vehicles |
| **Periodic/ aperiodic** | **Periodic** | | | | | |
| **Transmission interval** | **0.1s** | | | | **0.02 to 0.1s** | **0.1s** |
| **Relay (forward)** | **None** | | | | | |

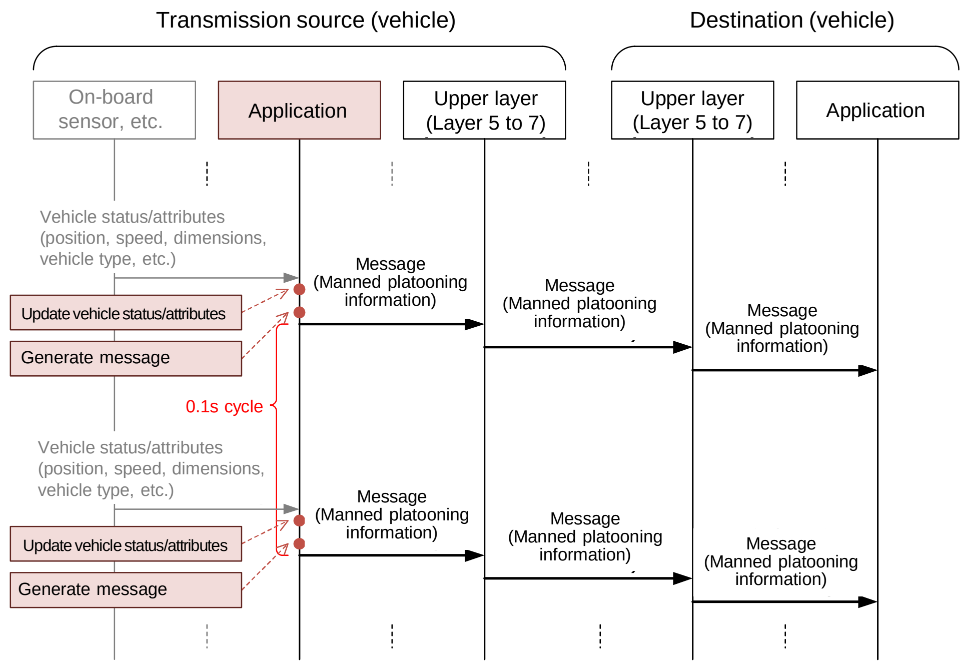
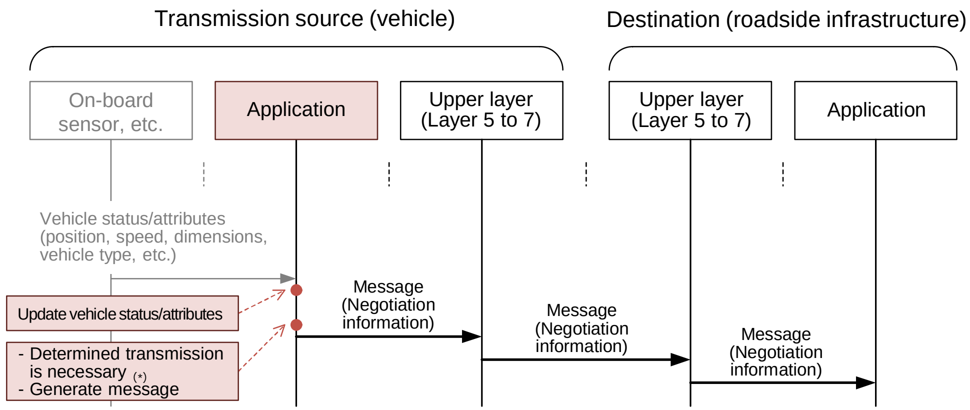



**Fig. 5.1.6-25 Detailed communication sequence (manned platooning information)**

| Message content | Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.) | | | | | |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | | | |
| 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 | | Assistance in entering a priority road from a non-priority road during congestion | |
| No. | a-1-4 | | a-2 | | a-3 | |
| Message name | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response |
| Communication method | V2V | | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **–** | | | | | |
| **Relay (forward)** | **None** | | | | | |

| Message content | Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | | Detected event information Occurrence time, type, position, etc. | | | |
|---|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | **Use case specific information (Hazard information)** **d-x** | | | |
| Classification by function | a. Merging/lane change assistance | | | d. Lookahead information: Trajectory change | | | |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control | | | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits |
| No. | a-1-3 | | | d-1 | d-2 | d-3 | d-4 |
| Message name | Control request | Negotiation request Update request | Negotiation response Update response | – | | | |
| Communication method | V2I | I2V | V2I | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | Roadside infrastructure | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | | |
| **Transmission interval** | **–** | | | | | | |
| **Relay (forward)** | **None** | | | | | | |

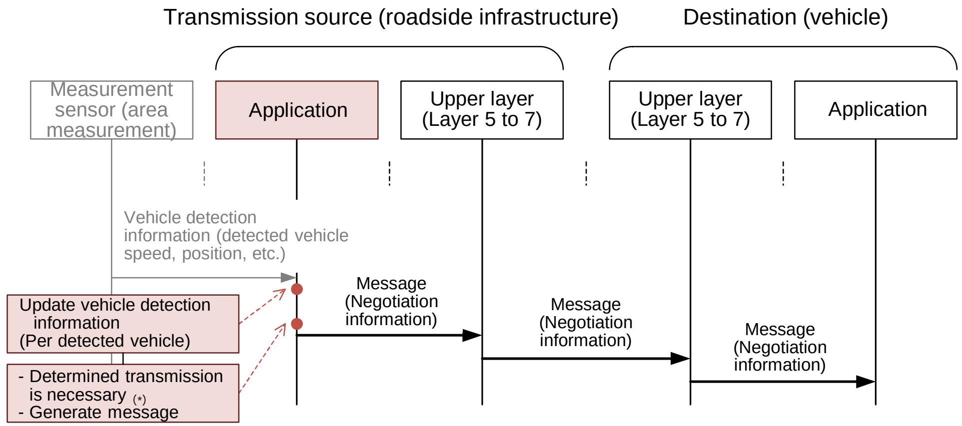



(*) Control request: When use case occurrence conditions are met (when a vehicle on the connecting road receives a position information message and determines that it is located at a specific point)
Negotiation response: When an negotiation request is received and the vehicle's position is determined to be within the request range
Update response: When an update request addressed to own vehicle is received

**Fig. 5.1.6-26 Detailed communication sequence (negotiation information, for V2I)**

| Message content | Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.) | | | | | |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | | | |
| 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 | | Assistance in entering a priority road from a non-priority road during congestion | |
| No. | a-1-4 | | a-2 | | a-3 | |
| Message name | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response |
| Communication method | V2V | | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **–** | | | | | |
| **Relay (forward)** | **None** | | | | | |

| Message content | Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | | Detected event information Occurrence time, type, position, etc. | | | |
|---|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | **Use case specific information (Hazard information)** **d-x** | | | |
| Classification by function | a. Merging/lane change assistance | | | d. Lookahead information: Trajectory change | | | |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control | | | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits |
| No. | a-1-3 | | | d-1 | d-2 | d-3 | d-4 |
| Message name | Control request | Negotiation request Update request | Negotiation response Update response | – | | | |
| Communication method | V2I | I2V | V2I | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | Roadside infrastructure | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | | |
| **Transmission interval** | **–** | | | | | | |
| **Relay (forward)** | **None** | | | | | | |

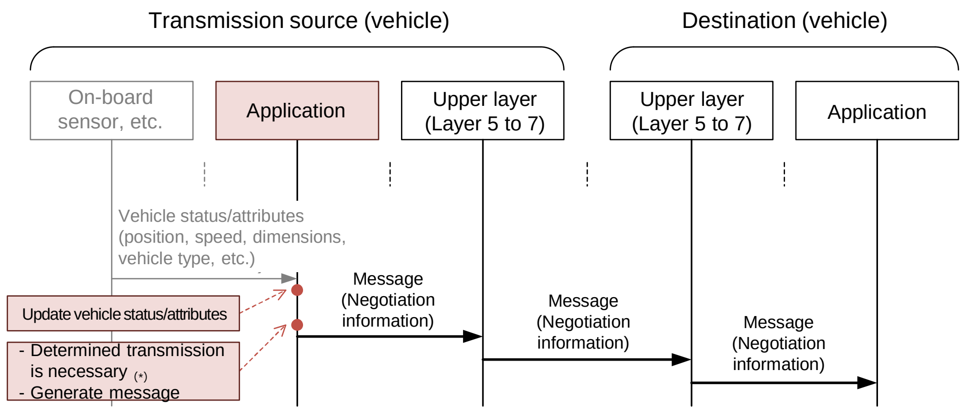



(*) Negotiation request: When a traffic control request is received / When a main lane vehicle passes a predetermined place, etc. (depends on implementation of roadside infrastructure)
Update request: When receiving an negotiation response or an update response from a nearby vehicle and determining that arbitration is necessary (implementation dependent on roadside infrastructure)

**Fig. 5.1.6-27 Detailed communication sequence (negotiation information, for I2V)**

| Message content | Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.) | | | | | |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | | | |
| 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 | | Assistance in entering a priority road from a non-priority road during congestion | |
| No. | a-1-4 | | a-2 | | a-3 | |
| Message name | Negotiation request<br>Update request | Negotiation response<br>Update response | Negotiation request<br>Update request | Negotiation response<br>Update response | Negotiation request<br>Update request | Negotiation response<br>Update response |
| Communication method | V2V | | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **–** | | | | | |
| **Relay (forward)** | **None** | | | | | |

| Message content | Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | | Detected event information Occurrence time, type, position, etc. | | | |
|---|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Negotiation information)** | | | **Use case specific information (Hazard information)**<br>**d-x** | | | |
| Classification by function | a. Merging/lane change assistance | | | d. Lookahead information: Trajectory change | | | |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control | | | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits |
| No. | a-1-3 | | | d-1 | d-2 | d-3 | d-4 |
| Message name | Control request | Negotiation request<br>Update request | Negotiation response<br>Update response | – | | | |
| Communication method | V2I | I2V | V2I | | | | |
| Message destination | Non-specific vehicle/ Specific vehicles | | Roadside infrastructure | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | | |
| **Transmission interval** | **–** | | | | | | |
| **Relay (forward)** | **None** | | | | | | |




(*) Negotiation request: When the use case generation condition is met (arrival at the confluence starting point, etc.)
Negotiation response: When an negotiation request is received and the vehicle's position is determined to be within the request range
Update request: When an negotiation response or an update response addressed to the vehicle is received, and it is received that arbitration is necessary (speed reduction due to congestion, etc.)
Update response: When an update request addressed to own vehicle is received

**Fig. 5.1.6-28 Detailed communication sequence (negotiation information, for V2V)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Message content | Information about trip targets (Target speed/lane/inter-vehicle distance, reply request range, etc.) | | | | | |
| **Information element** | **Use case specific information (Negotiation information)** | | | | | |
| 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 | | Assistance in entering a priority road from a non-priority road during congestion | |
| No. | a-1-4 | | a-2 | | a-3 | |
| Message name | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response |
| Communication method | V2V | | | | | |
| Message destination | Non-specific vehicle/specific vehicle | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **–** | | | | | |
| **Relay (forward)** | **None** | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Message content | Information about trip targets (Target speed/lane/interval distance, reply request range, etc.) | | | Detected event information Occurrence time, type, position, etc. | | | |
| **Information element** | **Use case specific information (Negotiation information)** | | | **Use case specific information (Hazard information)** **d-x** | | | |
| Classification by function | a. Merging/lane change assistance | | | d. Lookahead information: Trajectory change | | | |
| Use case | Cooperative merging assistance with vehicles on the main lane by roadside control | | | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits |
| No. | a-1-3 | | | d-1 | d-2 | d-3 | d-4 |
| Message name | Control request | Negotiation request Update request | Negotiation response Update response | – | | | |
| Communication method | V2I | I2V | | V2I | | | |
| Message destination | Non-specific vehicle/specific vehicle | | Roadside infrastructure | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | | |
| **Transmission interval** | **–** | | | | | | |
| **Relay (forward)** | **None** | | | | | | |

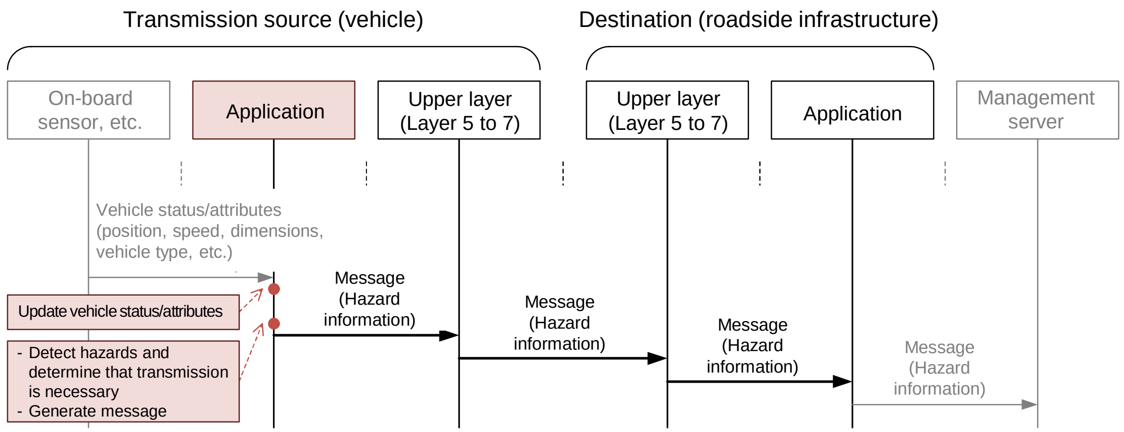



**Fig. 5.1.6-29 Detailed communication sequence (hazard information (UC d-x), for V2I)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Message content | Detected event information<br>Occurrence time, type, position, etc. | | | | | |
| **Information element** | **Use case specific information (Hazard information)** | | | | | |
| | **e-1** | **d-x** | | | | |
| Classification by function | e. Lookahead information: Emergency vehicle notification | d. Lookahead information: Trajectory change | | | | |
| Use case | Driving assistance based on emergency vehicle information | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits | Driving assistance based on hazard information |
| No. | e-1 | d-1 | d-2 | d-3 | d-4 | d-5 |
| Message name | – | | | | | |
| Communication method | V2V | I2V | | | | |
| Message destination | Non-specific vehicles | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **0.1s** | **1s** | | | | |
| **Relay (forward)** | **None** | | | | | |

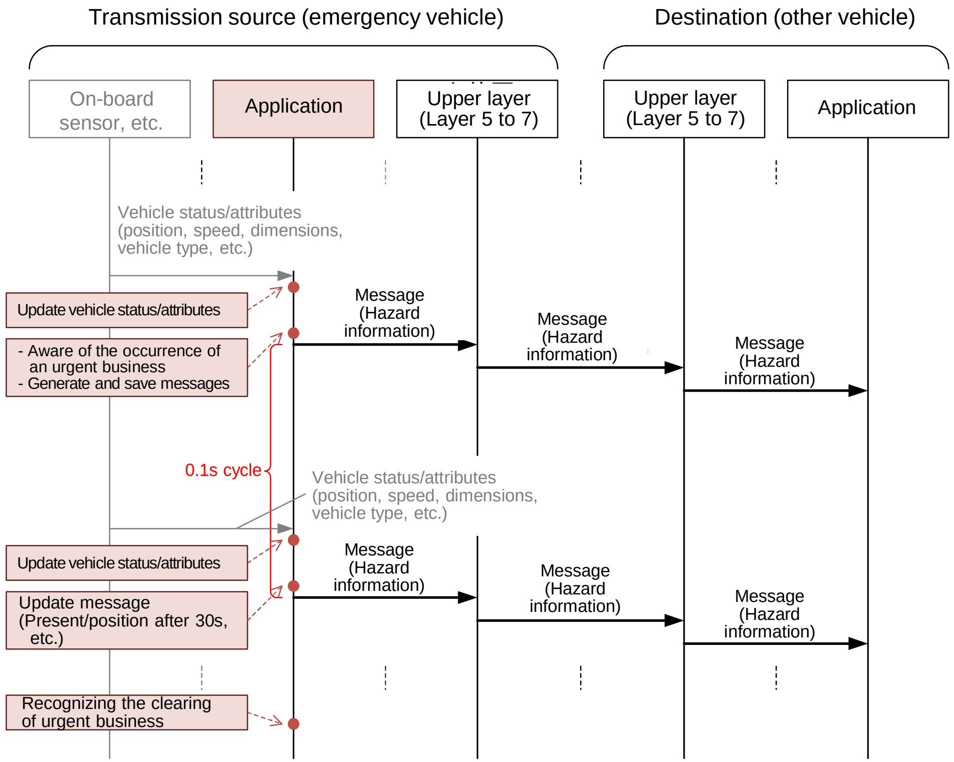



**Fig. 5.1.6-30 Detailed communication sequence (hazard information (UC e-1))**

| Message content | Detected event information Occurrence time, type, position, etc. | | | | | |
|---|---|---|---|---|---|---|
| **Information element** | **Use case specific information (Hazard information)** | | | | | |
| | **e-1** | **d-x** | | | | |
| Classification by function | e. Lookahead information: Emergency vehicle notification | d. Lookahead information: Trajectory change | | | | |
| Use case | Driving assistance based on emergency vehicle information | Driving assistance by notification of abnormal vehicles | Driving support by notification of wrong-way drivers | Collision avoidance support based on traffic congestion information | Traffic congestion assistance at branches and exits | Driving assistance based on hazard information |
| No. | e-1 | d-1 | d-2 | d-3 | d-4 | d-5 |
| Message name | – | | | | | |
| Communication method | V2V | I2V | | | | |
| Message destination | Non-specific vehicles | | | | | |
| **Periodic/ aperiodic** | **Aperiodic** | | | | | |
| **Transmission interval** | **0.1s** | **1s** | | | | |
| **Relay (forward)** | **None** | | | | | |

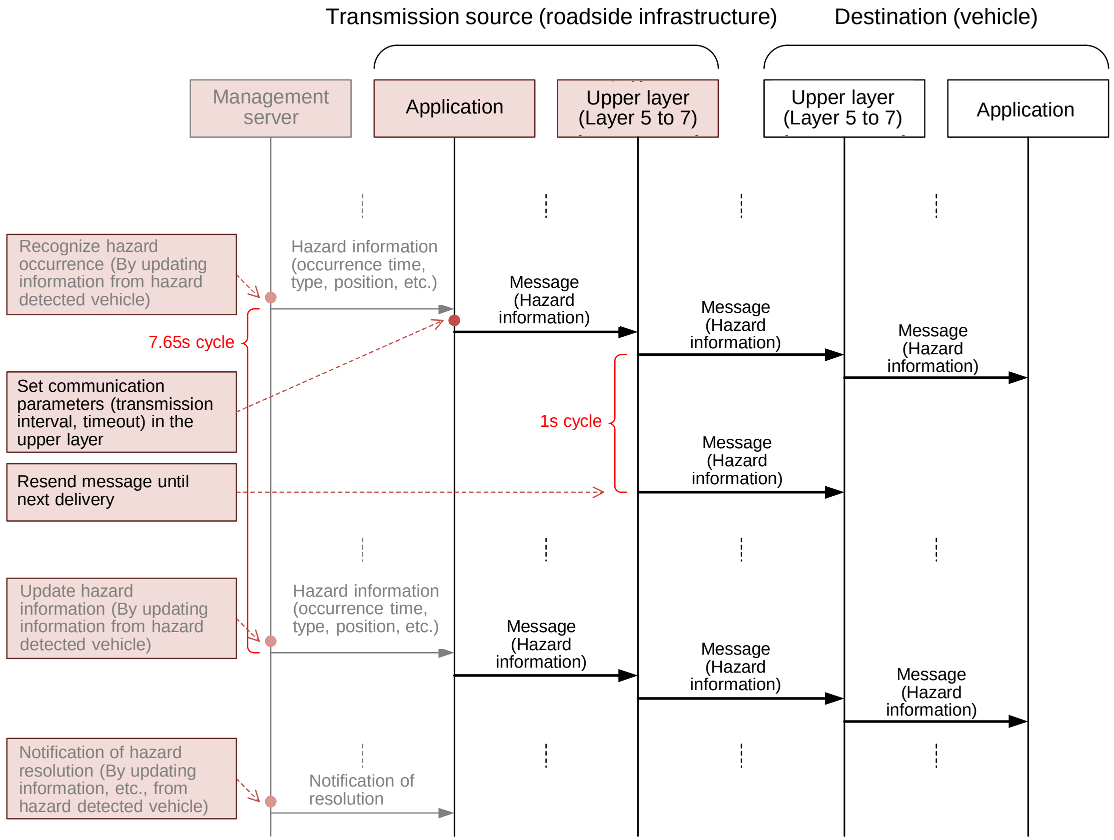



**Fig. 5.1.6-31 Detailed communication sequence (hazard information (UC d-x), for I2V)**

| | | |
|---|---|---|
| **Message content** | Detected event information Occurrence time, type, position, etc. | |
| **Information element** | **Use case specific information (Hazard information)** | |
| | **c-1, c-3** | |
| Classification by function | c. Lookahead information: Collision avoidance | |
| Use case | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Collision avoidance assistance by using hazard information |
| No. | c-1 | c-3 |
| Message name | – | |
| Communication method | V2V | |
| Message destination | Non-specific vehicles | |
| **Periodic/ aperiodic** | **Aperiodic** | |
| **Transmission interval** | **0.1s** | |
| **Relay (forward)** | **Present** | |

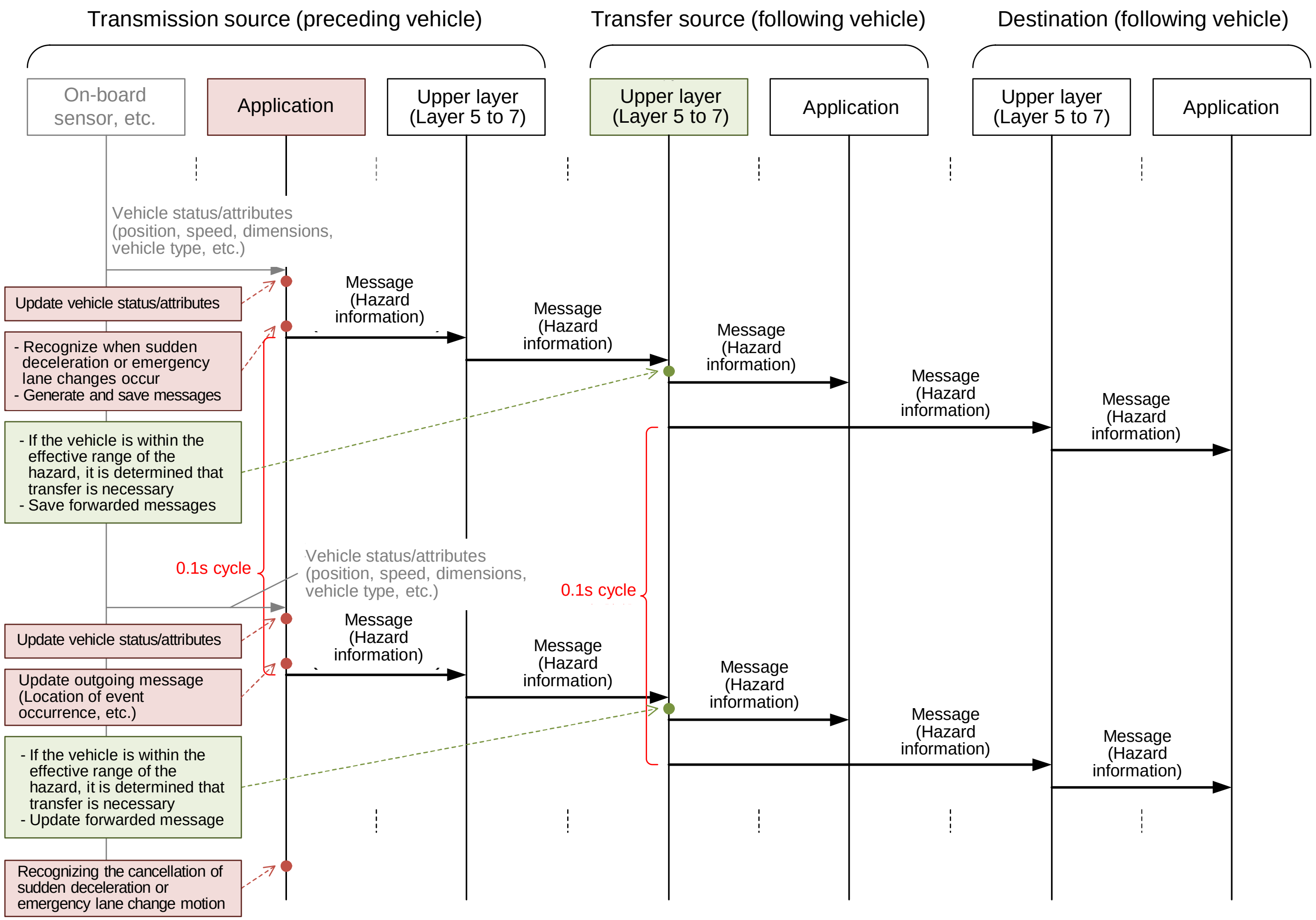



**Fig. 5.1.6-32 Detailed communication sequence (hazard information (UC c-1, c-3))**

(3) Confirmation of appropriateness of study proposal

A desktop study was done on the studied communication protocol draft and the relationships among the application, each layer, and the information provider were organized as a communication sequence, which confirmed that there is no inconsistency with the communication scenario draft. In control/agreement use cases, request/reply communication causes a state of reception waiting, so managing the state transition is thought to be necessary, and detailed study will be necessary in future.

The following may be listed as future issues.

- Verification when multiple request/reply situations happen simultaneously in control/agreement use cases
  (Roadside control with multiple vehicles in UC a-1-3, negotiation with multiple vehicles on priority roads in UC a-3, etc.)
- Verification in cases where sensor information update frequency or processing delay/transmission delay are taken into account
  (For example, cases where roadside control impacts communication, as in UC a-1-3 when location information causes a delay in vehicle recognition and when there is a gap in location information recognition between the roadside infrastructure and vehicle)
- Comparative verification of multiple drafts in communication scenario draft
  (For example, in UC a-1-3, method of replying to control request; timing of transmission of negotiation request; and deciding which to use: update request/response to requesting vehicle or location information. Or in UC a-3, for example, procedures for agreement request to multiple vehicles.)

### 5.1.7 Communication protocol proposal study issues

The following may be listed as future issues.

- **Revision and study reflecting new version of communication scenario draft and overseas trends**

It is thought that a revision study will be necessary in future, considering that a new version of the communication scenario draft is expected in light of the issues organized in ITS FORUM RC-017, such as control/agreement use cases and situations where multiple drafts have been presented in part of the specifications in the communication scenario draft, and also considering that work is currently proceeding on standardizing communication protocol for similar use cases overseas, such as control/agreement use cases and CPS, and that these trends will need to be accounted for.

- **Study of interface specifications with non-communication functions (control systems, etc.)**

Based on communication scenarios, applications and higher layer functions as a communication system were studied. However, it is considered necessary to discuss what information should be exchanged with applications that realize non-communication functions (control system applications in vehicles, etc.) and how the information should be reflected in vehicle driving, after detailing a method of updating a trajectory plan, etc. using received information in order to realize use cases for cooperative automated driving, in the future.

- **Study of detailed procedures including state transition, exception processing, etc.**

Functions, operations, and interfaces were summarized as a communication protocol proposal, but for future standardization, it is thought it will be necessary to clarify procedures (flow) including state transition, exception processing, etc., in order to detail specifications and ensure mutual connectivity.

### 5.2 Communication message set proposal study

This section describes the results of studying a communication message set proposal and organizing the issues. The following describes the process of study (Section 5.2.1), and in accordance with that, the results of studying information elements, the use cases that use them, sizes, etc. (Section 5.2.2), and in light of these, the results of organizing the issues (Section 5.2.3).

#### 5.2.1 Process of study

The process of the communication message set proposal study was as below.

The information elements, use cases that use them, sizes, etc., were organized, referring to the "Study report on communication scenarios and requirements for 'SIP Use Cases for Cooperative Driving Automation'" [2] (below, "ITS FORUM RC-017"), a guideline issued by the ITS Forum, as a communication message set proposal of the SIP use cases for Cooperative Driving Automation (below, "SIP UC"), and the consistency between the communication channel allocation proposal (Section 4.1) and communication protocol proposal (Section 5.1) was confirmed (Section 5.2.2(1)). Moreover, based on the communication protocol proposal study results, a study was done on a method enabling realization of information element multiplexing in the protocol proposal, referring to the description in ITS FORUM RC-017, and the effectiveness was verified (Section 5.2.2(2)), and finally the study issues were organized (Section 5.2.3).

An image of the organization of the communication message set as described above is given in Fig. 5.2.1-1.

## Message set proposal summary image (Information elements, use cases that use them, size)

**Organize with reference to ITS FORUM RC-017, update the study by the ITS Forum,and review based on the study results (communication channel allocation proposal) of project item b.**

| Field | Information name: Major item | Information name: Minor item | bit | Transmission of emergency hazard information from vehicles: UC 1-2-3 | Transmission of emergency hazard information from vehicles: UC1-2-4 V2I (I -> V) | Merging assistance: Merge vehicle support: UC 2-1-1 | Merging assistance: Mainline vehicle support: UC2-2 |
|---|---|---|---|---|---|---|---|
| Total message size [byte] | | | | 405 | 175/4175 | 772 | 202 |
| Common field | Management information | Message ID | 8 | ○ | ○ | ○ | ○ |
| | | Vehicle ID | 32 | | | | |
| | | Road side units ID | 32 | ○ | ○ | ○ | ○ |
| Free field | Event information | Time of occurrence | 32 | ○ | ○ | | |
| | | Occurrence event (hazard type) | 8 | ○ | ○ | | |
| | | Occurrence event (emergency avoidance action type) | 8 | | | | |
| | | Object information (speed, vehicle type) | 24 | | | | |
| | Location information | Latitude, longitude, altitude | 88 | ○ | ○ | | |
| | | Distance | 16 | ○ | ○ | | |
| | | Lane information / inbound or outbound | 4 | ○ | ○ | | |
| | | Road type, etc. | 8 | ○ | ○ | | |
| | Traffic information | Passability (is lane change necessary or not) | 2 | ○ | | | |
| | | Presence/absence of travel restrictions / designation of travel lane | 8 | | ○ | | |
| | Delivery designation information | Distributor vehicle ID | 32 | | | | |
| | | Delivery target lane / inbound/outbound | 4 | | | | |
| | | Information valid time | 32 | | | | |
| | | Redelivery distance | 16 | | | | |
| | | Latitude, longitude, altitude, distance, inbound/outbound, section | 124 | | ○ | | |
| | | Redelivery time, information valid time | 64 | | ○ | | |
| | Road side units information | Acceleration lane starting point information | 16 | | | ○ | ○ |
| | | Information update time | 32 | | | ○ | ○ |
| | Acceleration lane starting point information | Latitude, longitude, altitude | 88 | | | | |
| | | Lane information / inbound or outbound | 4 | | | | |
| | | Reply request position range (upstream, downstream) | 32 | | | | |
| | Vehicle information | Number of traveling vehicles | 8 | | | ○ | ○ |
| | | Vehicle ID | 8 | | | ○ | ○ |
| | | Vehicle location (latitude, longitude, altitude) | 88 | | | ○ | ○ |
| | | Driving lane | 8 | | | ○ | ○ |
| | | Vehicle speed | 16 | | | ○ | ○ |
| | | Vehicle length | 14 | | | ○ | ○ |
| | | Acceleration lane starting point arrival time | 16 | | | ○ | ○ |
| | | Distance from the preceding vehicle | 16 | | | | |
| | | Lane information (original lane, destination lane) | 8 | | | | |
| | Reply request range specification information | Distance | 16 | | | | |
| | Option | Simple figure information | 8000 | | ○ | | |
| | (Addition) | (Additional information when expanding) | (TBD) | | | | |

* FY2018, Ministry of Internal Affairs and Communications "Survey and study on message sets and protocols for automatic driving support communication assuming a real environment" Based on table in (https://www.sip-adus.go.jp/rd/rddata/rd01_more/503.pdf)

## Examination result image of project item b (Communication channel allocation proposal)

| | | V2I | V2V |
|---|---|---|---|
| Broadcast | Continuous | **Group A**<br>Vehicle receives broadcast from roadside unit<br>a-1-1. Merging assistance by preliminary acceleration and deceleration<br>a-1-2. Merging assistance by targeting the gap on the main lane<br>b-1-1. Driving assistance by using traffic signal information (V2I)<br>c-2-2. Driving assistance based on intersection information (V2I) | **Group C**<br>The vehicle broadcasts the position and speed of the vehicle by the moment<br>c-2-1. Driving assistance based on intersection information (V2V)<br>e-1 (1). Driving assistance based on emergency vehicle information (V2V) |
| | Emergency | | **Group D**<br>Broadcast the braking details when the vehicle is in sudden hard braking<br>c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly (V2V)<br>c-3. Collision avoidance assistance by using hazard information (V2V) |
| Mediation/ negotiation | | **Group B**<br>Automated vehicles support V2I merging arbitration<br>a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | **Group E**<br>Automated vehicles support V2V merging negotiations<br>a-1-4. Merging assistance based on negotiations between vehicles<br>a-2. Lane change assistance when the traffic is heavy<br>a-3. Entry assistance from non-priority roads to priority roads during traffic congestion |

**Fig. 5.2.1-1 Image summarizing communication message set proposal (information elements, use cases that use them, sizes)**

### 5.2.2 Study of information elements, use cases that use them, sizes, etc.

This section reports the results of the following: information elements, use cases that use them, sizes, etc., were organized, referring to the "Study report on communication scenarios and requirements for 'SIP Use Cases for Cooperative Driving Automation'" [2] (below, "ITS FORUM RC-017"), a guideline issued by the ITS Forum, as a communication message set proposal of the SIP use cases for Cooperative Driving Automation (below, "SIP UC"), and the consistency between the communication channel allocation proposal (4.1) and communication protocol proposal (Section 5.1) was confirmed (Section (1)); moreover, based on the communication protocol proposal study results, a study was done on a method enabling realization of information element multiplexing in the protocol proposal, referring to the description in ITS FORUM RC-017, and the effectiveness was verified (Section (2)).

(1) Organization of information elements, use cases that use them, sizes, etc.

Results of confirmation of study results at ITS FORUM (ITS FORUM RC-017 Appendix 1) and results of organizing information elements, use cases that use them, sizes, etc., taking account of commonizing them in different use cases, are given in overview and detail respectively in Table 5.2.2-1 to Table 5.2.2-3 and Table 5.2.2-4 to Table 5.2.2-11. Furthermore, Table 5.2.2-12 shows the results of narrowing down the use cases that are the target of the communication channel allocation (Section 4.1) and organizing the overview. The study of the organizing results, which was performed as a precondition of studying the communication protocol proposal (Section 5.1) and evaluation of communication performance by communication simulation (Section 5.3), confirmed the consistency between the communication channel allocation proposal and communication protocol proposal.

**Table 5.2.2-1 Overview of communication message set proposal (information elements, use cases that use them, sizes, etc. (1 of 3))**

| 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 | | | | 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-1-1 | a-1-2 | a-1-3 | | | | a-1-4 | | a-2 | | a-3 | |
| Message name | Location information | Location information | Location information | Control request | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response |
| Communication method | I2V | I2V | I2V | V2I | I2V | V2I | V2V | V2V | V2V | V2V | V2V | V2V |
| Required communication range | 59.3 m | 118.6 m | 270 m | 118.6 m | 270 m | 270 m | 255 m | 255 m | 255 m | 255 m | 111.1 m | 111.1 m |
| Transmission interval | 100 ms | 100 ms | 100 ms | – | – | – | – | – | – | – | – | – |
| PAR per packet | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% |
| Data size (not considering message sharing) [Byte] | 1510 | 2752 | 5236 | 287 | 285 | 287 | 291 | 287 | 291 | 287 | 291 | 287 |
| **Data size (considering message sharing) [Byte]** | **1518** | **2760** | **5244** | **329** | **298** | **329** | **329** | **329** | **329** | **329** | **329** | **329** |
| (1) Message information | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| (3) Basic vehicle information | | | | 31 | | 31 | 31 | 31 | 31 | 31 | 31 | 31 |
| (4) Use case specific information – 1 Roadside control information | 1 | 1 | 1 | | | | | | | | | |
| (4) – 2 Surrounding vehicle information – 1 Information elements sent by roadside infrastructure in a-1-x | 1249 | 2491 | 4975 | | | | | | | | | |
| (4) – 2 Surrounding vehicle information – 2 Information elements transmitted by roadside infrastructure in c-2-2 | | | | | | | | | | | | |
| (4) – 3 Negotiation information | | | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| (4) – 4 Intersection information | | | | | | | | | | | | |
| (4) – 5 Hazard information – 1 Information elements transmitted by vehicles in c-1 and c-3 | | | | | | | | | | | | |
| (4) – 5 Hazard information – 2 Information elements transmitted by roadside infrastructure or vehicles in d-1, d-2, d-3, d-4, and d-5 | | | | | | | | | | | | |
| (4) – 5 Hazard information – 3 Information element sent by the vehicle in e-1 | | | | | | | | | | | | |
| (4) – 6 Unmanned platooning information | | | | | | | | | | | | |
| (4) – 7 Manned platooning information | | | | | | | | | | | | |

Table 5.2.2-2 Overview of communication message set proposal (information elements, use cases that use them, sizes, etc. (2 of 3))

| Classification by function | b. Traffic signal information | c. Lookahead information: Collision avoidance | | | c. Lookahead information: Collision avoidance | d. Lookahead information: Trajectory change | | | |
|---|---|---|---|---|---|---|---|---|---|
| Use case | Driving assistance by using traffic signal information (V2I) | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance based on intersection information | Driving assistance based on intersection information | Collision avoidance assistance by using hazard information / collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance by notification of abnormal vehicles | | Driving assistance by notification of wrong-way vehicles | |
| No. | b-1-1 | c-1 | c-2-1 | c-2-2 | c-3 | d-1 | | d-2 | |
| Message name | – | – | – | – | – | – | – | – | – |
| Communication method | I2V | V2V | V2V | I2V | V2V | V2I | I2V | V2I | I2V |
| Required communication range | 206.3 m | 250 m | 190.8 m | 75.2 m | 250 m | 66.6 m | 66.6 m | 66.6 m | 66.6 m |
| Transmission interval | 100 ms | 100 ms | 100 ms | 100 ms | 100 ms | 1s | 1s | 1s | 1s |
| PAR per packet | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% |
| Data size (not considering message sharing) [Byte] | 690 | 312 | 282 | 1534 | 312 | 715 | 715 | 715 | 715 |
| **Data size (considering message sharing) [Byte]** | **664** | **338** | **299** | **1488** | **338** | **759** | **728** | **759** | **728** |
| (1) Message information | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| (3) Basic vehicle information | | 31 | 31 | | 31 | 31 | | 31 | |
| (4) Use case specific information: 1 Roadside control information | | | | | | | | | |
| (4) 2 Surrounding vehicle information: 1 Information elements sent by roadside infrastructure in a-1-x | | | | | | | | | |
| (4) 2 Surrounding vehicle information: 2 Information elements transmitted by roadside infrastructure in c-2-2 | | | | 824 | | | | | |
| (4) 3 Negotiation information | | | | | | | | | |
| (4) 4 Intersection information | 396 | | | 396 | | | | | |
| (4) 5 Hazard information: 1 Information elements transmitted by vehicles in c-1 and c-3 | | 39 | | | 39 | | | | |
| (4) 5 Hazard information: 2 Information elements transmitted by roadside infrastructure or vehicles in d-1, d-2, d-3, d-4, and d-5 | | | | | | 460 | 460 | 460 | 460 |
| (4) 5 Hazard information: 3 Information element sent by the vehicle in e-1 | | | | | | | | | |
| (4) 6 Unmanned platooning information | | | | | | | | | |
| (4) 7 Manned platooning information | | | | | | | | | |

## Table 5.2.2-3 Overview of communication message set proposal (information elements, use cases that use them, sizes, etc. (3 of 3))

| Classification by function | d. Lookahead information: Trajectory change | | | | | e. Lookahead information: Emergency vehicle notification | f. Information collection/distribution by infrastructure | g. Platooning/adaptive cruise control | |
|---|---|---|---|---|---|---|---|---|---|
| Use case | Driving assistance based on traffic congestion information | | Traffic congestion assistance at branches and exits | | Driving assistance based on hazard information | Driving assistance based on emergency vehicle information | Collection of information to optimize the traffic flow | Unmanned platooning of following vehicles by electronic towbar (non-rich content) | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | d-3 | | d-4 | | d-5 | e-1 | f-2 | g-1 | g-2 |
| Message name | – | – | – | – | – | – | – | – | – |
| Communication method | V2I | I2V | V2I | I2V | I2V | V2V | V2I | V2V | V2V |
| Required communication range | 66.6 m | 66.6 m | 66.6 m | 66.6 m | 66.6 m | 150 m | 171.8 m | 60 m | 141 m |
| Transmission interval | 1s | 1s | 1s | 1s | 1s | 100 ms | 1s | 100 ms (In emergencies 20 ms) | 100 ms |
| PAR per packet | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 98% (99.99% in emergencies) | 95% |
| Data size (not considering message sharing) [Byte] | 715 | 715 | 715 | 715 | 715 | 302 | 279 | 350 | 350 |
| **Data size (considering message sharing) [Byte]** | **759** | **728** | **759** | **728** | **728** | **347** | **299** | **365** | **359** |
| (1) Message information | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| (3) Basic vehicle information | 31 | | 31 | | | 31 | 31 | 31 | 31 |
| (4) Use case specific information – 1 Roadside control information | | | | | | | | | |
| (4) – 2 Surrounding vehicle information – 1 Information elements sent by roadside infrastructure in a-1-x | | | | | | | | | |
| (4) – 2 Surrounding vehicle information – 2 Information elements transmitted by roadside infrastructure in c-2-2 | | | | | | | | | |
| (4) – 3 Negotiation information | | | | | | | | | |
| (4) – 4 Intersection information | | | | | | | | | |
| (4) – 5 Hazard information – 1 Information elements transmitted by vehicles in c-1 and c-3 | | | | | | | | | |
| (4) – 5 Hazard information – 2 Information elements transmitted by roadside infrastructure or vehicles in d-1, d-2, d-3, d-4, and d-5 | 460 | 460 | 460 | 460 | 460 | | | | |
| (4) – 5 Hazard information – 3 Information element sent by the vehicle in e-1 | | | | | | 48 | | | |
| (4) – 6 Unmanned platooning information | | | | | | | | 66 | |
| (4) – 7 Manned platooning information | | | | | | | | | 60 |

# Table 5.2.2-4 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function a to c (1 of 4))

| Classification by function | | | | a. Merging/lane change assistance | | | | | | | | | | | | b. Traffic signal information | c. Lookahead information: Collision avoidance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | 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 | | Driving assistance by using traffic signal information (V2I) | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance based on intersection information | Driving assistance based on intersection information | Collision avoidance assistance by using hazard information / collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| No. | | | | a-1-1 | a-1-2 | a-1-3 | | | | a-1-4 | | a-2 | | a-3 | | b-1-1 | c-1 | c-2-1 | c-2-2 | c-3 |
| Message name | | | | Location information | Location information | Location information | Control request | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | – | – | – | – | – |
| Communication method | | | | I2V | I2V | I2V | V2I | I2V | V2I | V2V | V2V | V2V | V2V | V2V | V2V | I2V | V2V | V2V | I2V | V2V |
| Data size (total) [bit] | | | | 12144 | 22080 | 41952 | 2632 | 2384 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 5312 | 2704 | 2392 | 11904 | 2704 |
| (1) Message information | **Size (total)** | | | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** |
| | – – | – – | Data length/message size | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | | Common version | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | | | Message ID | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | | Message version | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | | | Increment ID | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | | Road side units ID | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | | In-vehicle device ID (own vehicle) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | | Transmission type identification | | | | | | | | | | | | | | | | | |
| | | | Destination | | | | | | | | | | | | | | | | | |
| | | | DE_Option Flag | | | | | | | | | | | | | | | | | |
| (2) Roadside infrastructure basic information | **Size (total)** | | | | | | | | | | | | | | | | | | | |
| | – – | – | – | | | | | | | | | | | | | | | | | |
| (3) Basic vehicle information | **Size (total)** | | | | | | **248** | | **248** | **248** | **248** | **248** | **248** | **248** | **248** | | **248** | **248** | | **248** |
| | – – | 1 Information about the time of the information | Time information | | | | 32 | | 32 | 32 | 32 | 32 | 32 | 32 | 32 | | 32 | 32 | | 32 |
| | | 2 Information about the location of the vehicle | Road number | | | | 32 | | 32 | 32 | 32 | 32 | 32 | 32 | 32 | | 32 | 32 | | 32 |
| | | | Driving lane | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | 16 | 16 | | 16 |
| | | | Vehicle location (latitude, longitude, altitude) | | | | 88 | | 88 | 88 | 88 | 88 | 88 | 88 | 88 | | 88 | 88 | | 88 |
| | | 3 Information about the state of the vehicle | Vehicle speed (target speed) | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | 16 | 16 | | 16 |
| | | | Vehicle azimuth | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | 16 | 16 | | 16 |
| | | | Vehicle acceleration/deceleration information | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | 16 | 16 | | 16 |
| | | | Vehicle speed acquisition information | | | | | | | | | | | | | | | | | |
| | | | Vehicle azimuth acquisition information | | | | | | | | | | | | | | | | | |
| | | | Vehicle acceleration/deceleration acquisition information | | | | | | | | | | | | | | | | | |
| | | | Shift position | | | | | | | | | | | | | | | | | |
| | | | Steering angle | | | | | | | | | | | | | | | | | |
| | | 4 Information about vehicle attributes | Vehicle length | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | 16 | 16 | | 16 |
| | | | Vehicle attribute information | | | | 8 | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | 8 | 8 | | 8 |
| | | | Vehicle size type | | | | | | | | | | | | | | | | | |
| | | | Vehicle width | | | | | | | | | | | | | | | | | |
| | | 5 Additional vehicle information | Vehicle information | | | | 8 | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | 8 | 8 | | 8 |
| | | | Equivalent to the common area of [1] | | | | | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. (green) : With no size increase (same size as before commonization) (yellow) : With size increase

## Table 5.2.2-5 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function a to c (2 of 4))

| Classification by function | | | | a. Merging/lane change assistance | | | | | | | | | | | | b. Traffic signal information | c. Lookahead information: Collision avoidance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | 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 | | Driving assistance by using traffic signal information (V2I) | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance based on intersection information | Driving assistance based on intersection information | Collision avoidance assistance by using hazard information / collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| No. | | | | a-1-1 | a-1-2 | a-1-3 | | | | a-1-4 | | a-2 | | a-3 | | b-1-1 | c-1 | c-2-1 | c-2-2 | c-3 |
| Message name | | | | Location information | Location information | Location information | Control request | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | – | – | – | – | – |
| Communication method | | | | I2V | I2V | I2V | V2I | I2V | V2I | V2V | V2V | V2V | V2V | V2V | V2V | I2V | V2V | V2V | I2V | V2V |
| Data size (total) [bit] | | | | 12144 | 22080 | 41952 | 2632 | 2384 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 5312 | 2704 | 2392 | 11904 | 2704 |
| (4) Use case specific information | **Size (total)** | | | **10000** | **19936** | **39808** | **240** | **240** | **240** | **240** | **240** | **240** | **240** | **240** | **240** | **3168** | **312** | | **9760** | **312** |
| | 1 Roadside control information | **Size (total)** | | **8** | **8** | **8** | | | | | | | | | | | | | | |
| | | – – | Roadside control information | 8 | 8 | 8 | | | | | | | | | | | | | | |
| | 2 Surrounding vehicle information | **Size (total)** | | **9992** | **19928** | **39800** | | | | | | | | | | | | | **6592** | |
| | | 1 Information elements sent by roadside infrastructure in a-1-x | **Size (total)** | **9992** | **19928** | **39800** | | | | | | | | | | | | | | |
| | | | **Size (mid-total)** | **56** | **56** | **56** | | | | | | | | | | | | | | |
| | | | Merge starting point information | 16 | 16 | 16 | | | | | | | | | | | | | | |
| | | | Road number | 32 | 32 | 32 | | | | | | | | | | | | | | |
| | | | Number of driving lanes | 8 | 8 | 8 | | | | | | | | | | | | | | |
| | | | **Size (mid-total)** | **9936** | **19872** | **39744** | | | | | | | | | | | | | | |
| | | | **Number of information elements (number of vehicles)** | **46** | **92** | **184** | | | | | | | | | | | | | | |
| | | | **Size (subtotal)** | **216** | **216** | **216** | | | | | | | | | | | | | | |
| | | | Vehicle ID | 16 | 16 | 16 | | | | | | | | | | | | | | |
| | | | Vehicle location (latitude, longitude, altitude) | 88 | 88 | 88 | | | | | | | | | | | | | | |
| | | | Driving lane | 8 | 8 | 8 | | | | | | | | | | | | | | |
| | | | Driving speed | 16 | 16 | 16 | | | | | | | | | | | | | | |
| | | | Vehicle length | 16 | 16 | 16 | | | | | | | | | | | | | | |
| | | | Estimated arrival time at merge point | 32 | 32 | 32 | | | | | | | | | | | | | | |
| | | | Sensor information acquisition time | 32 | 32 | 32 | | | | | | | | | | | | | | |
| | | | Information reliability | 8 | 8 | 8 | | | | | | | | | | | | | | |
| | | 2 Information elements transmitted by roadside infrastructure in c-2-2 | **Size (total)** | | | | | | | | | | | | | | | | **6592** | |
| | | | **Number of information elements (number of directions)** | | | | | | | | | | | | | | | | **4** | |
| | | | **Size (subtotal)** | | | | | | | | | | | | | | | | **1648** | |
| | | | DF_Provision point control number | | | | | | | | | | | | | | | | 24 | |
| | | | DE_Sensor ID | | | | | | | | | | | | | | | | 8 | |
| | | | DE_System State | | | | | | | | | | | | | | | | 8 | |
| | | | DE_Sensor Version | | | | | | | | | | | | | | | | 8 | |
| | | | DE_Location Type | | | | | | | | | | | | | | | | 1 | |
| | | | DE_System Design Delay Time | | | | | | | | | | | | | | | | 7 | |
| | | | DE_Resend Delay Time | | | | | | | | | | | | | | | | | |
| | | | DF_Roadway Detection Area Information | | | | | | | | | | | | | | | | 48 | |
| | | | DE_Number of Roadway Detection Area Units (I) | | | | | | | | | | | | | | | | 8 | |
| | | | DF_Road Detection Area Unit | | | | | | | | | | | | | | | | 1536 | |
| | 3 Negotiation information | **Size (total)** | | | | | **240** | **240** | **240** | **240** | **240** | **240** | **240** | **240** | **240** | | | | | |
| | | – – | Agreement response | | | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | | | | |
| | | | Vehicle speed (target speed) | | | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | | | | |
| | | | In-vehicle device ID (communication target) | | | | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | | | | | |
| | | | Information update time | | | | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | | | | | |
| | | | Reply request range | | | | 112 | 112 | 112 | 112 | 112 | 112 | 112 | 112 | 112 | | | | | |
| | | | Merge destination (target) lane | | | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | | | | |
| | | | (Target) inter-vehicle distance to the preceding vehicle | | | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | | | | |
| | | | Scheduled time of action start | | | | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. (green) : With no size increase (same size as before commonization) (yellow) : With size increase

## Table 5.2.2-6 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function a to c (3 of 4))

| Classification by function | | | | a. Merging/lane change assistance | | | | | | | | | | | | b. Traffic signal information | c. Lookahead information: Collision avoidance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | 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 | | Driving assistance by using traffic signal information (V2I) | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance based on intersection information | Driving assistance based on intersection information | Collision avoidance assistance by using hazard information / collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| No. | | | | a-1-1 | a-1-2 | a-1-3 | | | | a-1-4 | | a-2 | | a-3 | | b-1-1 | c-1 | c-2-1 | c-2-2 | c-3 |
| Message name | | | | Location information | Location information | Location information | Control request | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | – | – | – | – | – |
| Communication method | | | | I2V | I2V | I2V | V2I | I2V | V2I | V2V | V2V | V2V | V2V | V2V | V2V | I2V | V2V | V2V | I2V | V2V |
| Data size (total) [bit] | | | | 12144 | 22080 | 41952 | 2632 | 2384 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 5312 | 2704 | 2392 | 11904 | 2704 |
| (4) Use case specific information | 4 Intersection information | **Size (total)** | | | | | | | | | | | | | | **3168** | | | **3168** | |
| | | – – | DE_Operational Code | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DF_Time of Transmission | | | | | | | | | | | | | 80 | | | 80 | |
| | | | DF_Provision point control number | | | | | | | | | | | | | 24 | | | 24 | |
| | | | DE_System State | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DE_Event Counter | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DE_Number of car lights | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DE_Number of Walking Lights | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DE_Number of Connection Directions (I) | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DE_Number of Service Routes (J) | | | | | | | | | | | | | 8 | | | 8 | |
| | | | DF_Service Route Traffic Signal Information | | | | | | | | | | | | | 608 | | | 608 | |
| | | | DF_Car Lamp Information | | | | | | | | | | | | | 1664 | | | 1664 | |
| | | | DF_Walking Light Device Information | | | | | | | | | | | | | 512 | | | 512 | |
| | | | DF_Route Identification Information | | | | | | | | | | | | | 224 | | | 224 | |
| | 5 Hazard information | **Size (total)** | | | | | | | | | | | | | | | **312** | | | **312** |
| | | 1 Information elements transmitted by vehicles in c-1 and c-3 | **Size (total)** | | | | | | | | | | | | | | **312** | | | **312** |
| | | | Information update time | | | | | | | | | | | | | | 32 | | | 32 |
| | | | Time of occurrence of emergency action | | | | | | | | | | | | | | 32 | | | 32 |
| | | | Type of emergency action | | | | | | | | | | | | | | 8 | | | 8 |
| | | | Target object information | | | | | | | | | | | | | | 24 | | | 24 |
| | | | Event position information | | | | | | | | | | | | | | 88 | | | 88 |
| | | | Event distance information | | | | | | | | | | | | | | 16 | | | 16 |
| | | | Lane information | | | | | | | | | | | | | | 8 | | | 8 |
| | | | Road type information | | | | | | | | | | | | | | 8 | | | 8 |
| | | | Traffic passability information | | | | | | | | | | | | | | 8 | | | 8 |
| | | | Transmitting OBU ID | | | | | | | | | | | | | | 32 | | | 32 |
| | | | Target lane information for distribution | | | | | | | | | | | | | | 8 | | | 8 |
| | | | Information valid time | | | | | | | | | | | | | | 32 | | | 32 |
| | | | Redelivery distance | | | | | | | | | | | | | | 16 | | | 16 |
| | | 2 Information elements transmitted by roadside infrastructure or vehicles in d-1, d-2, d-3, d-4, and d-5 | **Size (total)** | | | | | | | | | | | | | | | | | |
| | | | **Number of information elements (number of hazards)** | | | | | | | | | | | | | | | | | |
| | | | **Size (subtotal)** | | | | | | | | | | | | | | | | | |
| | | | Event information | | | | | | | | | | | | | | | | | |
| | | | Location information | | | | | | | | | | | | | | | | | |
| | | | Traffic information | | | | | | | | | | | | | | | | | |
| | | 3 Information element sent by the vehicle in e-1 | **Size (total)** | | | | | | | | | | | | | | | | | |
| | | | Event information | | | | | | | | | | | | | | | | | |
| | | | Location information | | | | | | | | | | | | | | | | | |
| | | | Traffic information | | | | | | | | | | | | | | | | | |
| | | | Redelivery designation information | | | | | | | | | | | | | | | | | |
| | | | Spare | | | | | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. (green) : With no size increase (same size as before commonization) (yellow) : With size increase

## Table 5.2.2-7 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function a to c (4 of 4))

| Classification by function | | | | | | | a. Merging/lane change assistance | | | | | | | | | | | | b. Traffic signal information | c. Lookahead information: Collision avoidance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | 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 | | Driving assistance by using traffic signal information (V2I) | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | Driving assistance based on intersection information | Driving assistance based on intersection information | Collision avoidance assistance by using hazard information / collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| No. | | | | | | | a-1-1 | a-1-2 | a-1-3 | | | | a-1-4 | | a-2 | | a-3 | | b-1-1 | c-1 | c-2-1 | c-2-2 | c-3 |
| Message name | | | | | | | Location information | Location information | Location information | Control request | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | Negotiation request Update request | Negotiation response Update response | – | – | – | – | – |
| Communication method | | | | | | | I2V | I2V | I2V | V2I | I2V | V2I | V2V | V2V | V2V | V2V | V2V | V2V | I2V | V2V | V2V | I2V | V2V |
| Data size (total) [bit] | | | | | | | 12144 | 22080 | 41952 | 2632 | 2384 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 2632 | 5312 | 2704 | 2392 | 11904 | 2704 |
| (4) | Use case specific information | 6 | Unmanned platooning information | **Size (total)** | | | | | | | | | | | | | | | | | | | |
| | | | | – | – | Vehicle status information | | | | | | | | | | | | | | | | | |
| | | | | | | Vehicle attribute information | | | | | | | | | | | | | | | | | |
| | | | | | | Following vehicle information | | | | | | | | | | | | | | | | | |
| | | | | | | Inter-vehicular distance | | | | | | | | | | | | | | | | | |
| | | | | | | Acceleration, braking | | | | | | | | | | | | | | | | | |
| | | | | | | Electronic mirror image | | | | | | | | | | | | | | | | | |
| | | 7 | Manned platooning information | **Size (total)** | | | | | | | | | | | | | | | | | | | |
| | | | | – | – | Information indicating whether or not it can be followed, the manufacturer, etc. | | | | | | | | | | | | | | | | | |
| | | | | | | For the following vehicle, the ID of the target preceding vehicle, etc. | | | | | | | | | | | | | | | | | |
| | | | | | | Information on CACC compatible vehicles | | | | | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. [green] : With no size increase (same size as before commonization) [yellow] : With size increase

# Table 5.2.2-8 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function d to g (1 of 4))

| Classification by function | | | d. Lookahead information: Trajectory change | | | | | | | | | e. Lookahead information: Emergency vehicle notification | f. Information collection/distribution by infrastructure | g. Platooning/adaptive cruise control | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use case | | | Driving assistance by notification of abnormal vehicles | | Driving assistance by notification of wrong-way vehicles | | Driving assistance based on traffic congestion information | | Traffic congestion assistance at branches and exits | | Driving assistance based on hazard information | Driving assistance based on emergency vehicle information | Collection of information to optimize the traffic flow | Unmanned platooning of following vehicles by electronic towbar (non-rich content) | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | | | d-1 | | d-2 | | d-3 | | d-4 | | d-5 | e-1 | f-2 | g-1 | g-2 |
| Message name | | | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Communication method | | | V2I | I2V | V2I | I2V | V2I | I2V | V2I | I2V | I2V | V2V | V2I | V2V | V2V |
| Data size (total) [bit] | | | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 5824 | 2776 | 2392 | 2920 | 2872 |
| (1) Message information | **Size (total)** | | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** | **144** |
| (1) Message information | – – – – | Data length/message size | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | Common version | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | | Message ID | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | Message version | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | | Increment ID | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | Road side units ID | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | In-vehicle device ID (own vehicle) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | | Transmission type identification | | | | | | | | | | | | | |
| | | Destination | | | | | | | | | | | | | |
| | | DE_Option Flag | | | | | | | | | | | | | |
| (2) Roadside infrastructure basic information | **Size (total)** | | | | | | | | | | | | | | |
| | – – – | – | | | | | | | | | | | | | |
| (3) Basic vehicle information | **Size (total)** | | **248** | | **248** | | **248** | | **248** | | | **248** | **248** | **248** | **248** |
| | – – 1 Information about the time of the information | Time information | 32 | | 32 | | 32 | | 32 | | | 32 | 32 | 32 | 32 |
| | 2 Information about the location of the vehicle | Road number | 32 | | 32 | | 32 | | 32 | | | 32 | 32 | 32 | 32 |
| | | Driving lane | 16 | | 16 | | 16 | | 16 | | | 16 | 16 | 16 | 16 |
| | | Vehicle location (latitude, longitude, altitude) | 88 | | 88 | | 88 | | 88 | | | 88 | 88 | 88 | 88 |
| | 3 Information about the state of the vehicle | Vehicle speed (target speed) | 16 | | 16 | | 16 | | 16 | | | 16 | 16 | 16 | 16 |
| | | Vehicle azimuth | 16 | | 16 | | 16 | | 16 | | | 16 | 16 | 16 | 16 |
| | | Vehicle acceleration/deceleration information | 16 | | 16 | | 16 | | 16 | | | 16 | 16 | 16 | 16 |
| | | Vehicle speed acquisition information | | | | | | | | | | | | | |
| | | Vehicle azimuth acquisition information | | | | | | | | | | | | | |
| | | Vehicle acceleration/deceleration acquisition information | | | | | | | | | | | | | |
| | | Shift position | | | | | | | | | | | | | |
| | | Steering angle | | | | | | | | | | | | | |
| | 4 Information about vehicle attributes | Vehicle length | 16 | | 16 | | 16 | | 16 | | | 16 | 16 | 16 | 16 |
| | | Vehicle attribute information | 8 | | 8 | | 8 | | 8 | | | 8 | 8 | 8 | 8 |
| | | Vehicle size type | | | | | | | | | | | | | |
| | | Vehicle width | | | | | | | | | | | | | |
| | 5 Additional vehicle information | Vehicle information | 8 | | 8 | | 8 | | 8 | | | 8 | 8 | 8 | 8 |
| | | Equivalent to the common area of [1] | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. (green) : With no size increase (same size as before commonization) (yellow) : With size increase

## Table 5.2.2-9 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function d to g (2 of 4))

| Classification by function | | | d. Lookahead information: Trajectory change | | | | | | | | | e. Lookahead information: Emergency vehicle notification | f. Information collection/distribution by infrastructure | g. Platooning/adaptive cruise control | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use case | | | Driving assistance by notification of abnormal vehicles | | Driving assistance by notification of wrong-way vehicles | | Driving assistance based on traffic congestion information | | Traffic congestion assistance at branches and exits | | Driving assistance based on hazard information | Driving assistance based on emergency vehicle information | Collection of information to optimize the traffic flow | Unmanned platooning of following vehicles by electronic towbar (non-rich content) | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | | | d-1 | | d-2 | | d-3 | | d-4 | | d-5 | e-1 | f-2 | g-1 | g-2 |
| Message name | | | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Communication method | | | V2I | I2V | V2I | I2V | V2I | I2V | V2I | I2V | I2V | V2V | V2I | V2V | V2V |
| Data size (total) [bit] | | | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 5824 | 2776 | 2392 | 2920 | 2872 |
| (4) Use case specific information | | **Size (total)** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **384** | | **528** | **480** |
| 1 Roadside control information | | **Size (total)** | | | | | | | | | | | | | |
| 1 Roadside control information | – – | Roadside control information | | | | | | | | | | | | | |
| 2 Surrounding vehicle information | | **Size (total)** | | | | | | | | | | | | | |
| 2 Surrounding vehicle information | 1 Information elements sent by roadside infrastructure in a-1-x | **Size (total)** | | | | | | | | | | | | | |
| | | **Size (mid-total)** | | | | | | | | | | | | | |
| | | Merge starting point information | | | | | | | | | | | | | |
| | | Road number | | | | | | | | | | | | | |
| | | Number of driving lanes | | | | | | | | | | | | | |
| | | **Size (mid-total)** | | | | | | | | | | | | | |
| | | **Number of information elements (number of vehicles)** | | | | | | | | | | | | | |
| | | **Size (subtotal)** | | | | | | | | | | | | | |
| | | Vehicle ID | | | | | | | | | | | | | |
| | | Vehicle location (latitude, longitude, altitude) | | | | | | | | | | | | | |
| | | Driving lane | | | | | | | | | | | | | |
| | | Driving speed | | | | | | | | | | | | | |
| | | Vehicle length | | | | | | | | | | | | | |
| | | Estimated arrival time at merge point | | | | | | | | | | | | | |
| | | Sensor information acquisition time | | | | | | | | | | | | | |
| | | Information reliability | | | | | | | | | | | | | |
| 2 Surrounding vehicle information | 2 Information elements transmitted by roadside infrastructure in c-2-2 | **Size (total)** | | | | | | | | | | | | | |
| | | **Number of information elements (number of directions)** | | | | | | | | | | | | | |
| | | **Size (subtotal)** | | | | | | | | | | | | | |
| | | DF_Provision point control number | | | | | | | | | | | | | |
| | | DE_Sensor ID | | | | | | | | | | | | | |
| | | DE_System State | | | | | | | | | | | | | |
| | | DE_Sensor Version | | | | | | | | | | | | | |
| | | DE_Location Type | | | | | | | | | | | | | |
| | | DE_System Design Delay Time | | | | | | | | | | | | | |
| | | DE_Resend Delay Time | | | | | | | | | | | | | |
| | | DF_Roadway Detection Area Information | | | | | | | | | | | | | |
| | | DE_Number of Roadway Detection Area Units (I) | | | | | | | | | | | | | |
| | | DF_Road Detection Area Unit | | | | | | | | | | | | | |
| 3 Negotiation information | | **Size (total)** | | | | | | | | | | | | | |
| 3 Negotiation information | – – | Agreement response | | | | | | | | | | | | | |
| | | Vehicle speed (target speed) | | | | | | | | | | | | | |
| | | In-vehicle device ID (communication target) | | | | | | | | | | | | | |
| | | Information update time | | | | | | | | | | | | | |
| | | Reply request range | | | | | | | | | | | | | |
| | | Merge destination (target) lane | | | | | | | | | | | | | |
| | | (Target) inter-vehicle distance to the preceding vehicle | | | | | | | | | | | | | |
| | | Scheduled time of action start | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. [green] : With no size increase (same size as before commonization) [yellow] : With size increase

## Table 5.2.2-10 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function d to g (3 of 4))

| Classification by function | | | | d. Lookahead information: Trajectory change | | | | | | | | | e. Lookahead information: Emergency vehicle notification | f. Information collection/distribution by infrastructure | g. Platooning/adaptive cruise control | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use case | | | | Driving assistance by notification of abnormal vehicles | | Driving assistance by notification of wrong-way vehicles | | Driving assistance based on traffic congestion information | | Traffic congestion assistance at branches and exits | | Driving assistance based on hazard information | Driving assistance based on emergency vehicle information | Collection of information to optimize the traffic flow | Unmanned platooning of following vehicles by electronic towbar (non-rich content) | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | | | | d-1 | | d-2 | | d-3 | | d-4 | | d-5 | e-1 | f-2 | g-1 | g-2 |
| Message name | | | | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Communication method | | | | V2I | I2V | V2I | I2V | V2I | I2V | V2I | I2V | I2V | V2V | V2I | V2V | V2V |
| Data size (total) [bit] | | | | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 5824 | 2776 | 2392 | 2920 | 2872 |
| (4) Use case specific information | 4 Intersection information | **Size (total)** | | | | | | | | | | | | | | |
| | | – – | DE_Operational Code | | | | | | | | | | | | | |
| | | | DF_Time of Transmission | | | | | | | | | | | | | |
| | | | DF_Provision point control number | | | | | | | | | | | | | |
| | | | DE_System State | | | | | | | | | | | | | |
| | | | DE_Event Counter | | | | | | | | | | | | | |
| | | | DE_Number of car lights | | | | | | | | | | | | | |
| | | | DE_Number of Walking Lights | | | | | | | | | | | | | |
| | | | DE_Number of Connection Directions (I) | | | | | | | | | | | | | |
| | | | DE_Number of Service Routes (J) | | | | | | | | | | | | | |
| | | | DF_Service Route Traffic Signal Information | | | | | | | | | | | | | |
| | | | DF_Car Lamp Information | | | | | | | | | | | | | |
| | | | DF_Walking Light Device Information | | | | | | | | | | | | | |
| | | | DF_Route Identification Information | | | | | | | | | | | | | |
| | 5 Hazard information | **Size (total)** | | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **384** | | | |
| | | 1 Information elements transmitted by vehicles in c-1 and c-3 | **Size (total)** | | | | | | | | | | | | | |
| | | | Information update time | | | | | | | | | | | | | |
| | | | Time of occurrence of emergency action | | | | | | | | | | | | | |
| | | | Type of emergency action | | | | | | | | | | | | | |
| | | | Target object information | | | | | | | | | | | | | |
| | | | Event position information | | | | | | | | | | | | | |
| | | | Event distance information | | | | | | | | | | | | | |
| | | | Lane information | | | | | | | | | | | | | |
| | | | Road type information | | | | | | | | | | | | | |
| | | | Traffic passability information | | | | | | | | | | | | | |
| | | | Transmitting OBU ID | | | | | | | | | | | | | |
| | | | Target lane information for distribution | | | | | | | | | | | | | |
| | | | Information valid time | | | | | | | | | | | | | |
| | | | Redelivery distance | | | | | | | | | | | | | |
| | | 2 Information elements transmitted by roadside infrastructure or vehicles in d-1, d-2, d-3, d-4, and d-5 | **Size (total)** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | **3680** | | | | |
| | | | **Number of information elements (number of hazards)** | **20** | **20** | **20** | **20** | **20** | **20** | **20** | **20** | **20** | | | | |
| | | | **Size (subtotal)** | **184** | **184** | **184** | **184** | **184** | **184** | **184** | **184** | **184** | | | | |
| | | | Event information | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | | | | |
| | | | Location information | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | | | | |
| | | | Traffic information | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | | | |
| | | 3 Information element sent by the vehicle in e-1 | **Size (total)** | | | | | | | | | | **384** | | | |
| | | | Event information | | | | | | | | | | 64 | | | |
| | | | Location information | | | | | | | | | | 216 | | | |
| | | | Traffic information | | | | | | | | | | 8 | | | |
| | | | Redelivery designation information | | | | | | | | | | 88 | | | |
| | | | Spare | | | | | | | | | | 8 | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. (green) : With no size increase (same size as before commonization) (yellow) : With size increase

## Table 5.2.2-11 Details of communication message set proposal (information elements, use cases that use them, sizes, etc., for classification by function d to g (4 of 4))

| Classification by function | | | d. Lookahead information: Trajectory change | | | | | | | | | e. Lookahead information: Emergency vehicle notification | f. Information collection/distribution by infrastructure | g. Platooning/adaptive cruise control | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use case | | | Driving assistance by notification of abnormal vehicles | | Driving assistance by notification of wrong-way vehicles | | Driving assistance based on traffic congestion information | | Traffic congestion assistance at branches and exits | | Driving assistance based on hazard information | Driving assistance based on emergency vehicle information | Collection of information to optimize the traffic flow | Unmanned platooning of following vehicles by electronic towbar (non-rich content) | Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control |
| No. | | | d-1 | | d-2 | | d-3 | | d-4 | | d-5 | e-1 | f-2 | g-1 | g-2 |
| Message name | | | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Communication method | | | V2I | I2V | V2I | I2V | V2I | I2V | V2I | I2V | I2V | V2V | V2I | V2V | V2V |
| Data size (total) [bit] | | | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 6072 | 5824 | 5824 | 2776 | 2392 | 2920 | 2872 |
| (4) Use case specific information | 6 Unmanned platooning information | **Size (total)** | | | | | | | | | | | | **528** | |
| | | – – Vehicle status information | | | | | | | | | | | | 16 | |
| | | Vehicle attribute information | | | | | | | | | | | | 32 | |
| | | Following vehicle information | | | | | | | | | | | | 480 | |
| | | Inter-vehicular distance | | | | | | | | | | | | | |
| | | Acceleration, braking | | | | | | | | | | | | | |
| | | Electronic mirror image | | | | | | | | | | | | | |
| | 7 Manned platooning information | **Size (total)** | | | | | | | | | | | | | **480** |
| | | – – Information indicating whether or not it can be followed, the manufacturer, etc. | | | | | | | | | | | | | 480 |
| | | For the following vehicle, the ID of the target preceding vehicle, etc. | | | | | | | | | | | | | |
| | | Information on CACC compatible vehicles | | | | | | | | | | | | | |

* The numbers in the table are in bits, and the coloring in the table indicates whether or not the size of the message is increased by the message commonization. [green] : With no size increase (same size as before commonization) [yellow] : With size increase

**Table 5.2.2-12 Summary of communication message set proposal (target use cases for communication channel allocation)**

| Classification by function | Use case | No. | Message name | Communication method | Data size [bytes] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Total** | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | | | |
| | | | | | | | | | Roadside control information | Surrounding vehicle information | | Negotiation information | Intersection information | Hazard information | |
| | | | | | | | | | | a-1-x | c-2-2 | | | c-1, c-3 | e-1 |
| a. Merging/lane change assistance | Merging assistance by preliminary acceleration and deceleration | a-1-1 | Location information | I2V | **1518** | 250 | 18 | | 1 | 1249 | | | | | |
| | Merging assistance by targeting the gap on the main lane | a-1-2 | Location information | I2V | **2760** | 250 | 18 | | 1 | 2491 | | | | | |
| | Cooperative merging assistance with vehicles on the main lane by roadside control | a-1-3 | Location information | I2V | **5244** | 250 | 18 | | 1 | 4975 | | | | | |
| | | | Control request | V2I | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | | | Negotiation request<br>Update request | I2V | **298** | 250 | 18 | | | | | 30 | | | |
| | | | Negotiation response<br>Update response | V2I | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | Merging assistance based on negotiations between vehicles | a-1-4 | Negotiation request<br>Update request | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | | | Negotiation response<br>Update response | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | Lane change assistance when the traffic is heavy | a-2 | Negotiation request<br>Update request | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | | | Negotiation response<br>Update response | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | Entry assistance from non-priority roads to priority roads during traffic congestion | a-3 | Negotiation request<br>Update request | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| | | | Negotiation response<br>Update response | V2V | **329** | 250 | 18 | 31 | | | | 30 | | | |
| b. Traffic signal information | Driving assistance that uses traffic signal information (V2I) | b-1-1 | – | I2V | **664** | 250 | 18 | | | | | | 396 | | |
| c. Lookahead information: Collision avoidance | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | c-1 | – | V2V | **338** | 250 | 18 | 31 | | | | | | 39 | |
| | Driving assistance based on intersection information (V2V) | c-2-1 | – | V2V | **299** | 250 | 18 | 31 | | | | | | | |
| | Driving assistance based on intersection information (V2I) | c-2-2 | – | I2V | **1488** | 250 | 18 | | | | 824 | | 396 | | |
| | Driving assistance based on hazard information | c-3 | – | V2V | **338** | 250 | 18 | 31 | | | | | | 39 | |
| e. Lookahead information: Emergency vehicle notification | Driving assistance based on emergency vehicle information | e-1 | – | V2V | **347** | 250 | 18 | 31 | | | | | | | 48 |

(2) Study of information element multiplexing method

This section describes the results of the study, based on the communication protocol proposal study results, on a method enabling realization of information element multiplexing in the protocol proposal, referring to the description in ITS FORUM RC-017, and also describes the results of verification of effectiveness. Below, based on the study policy (Section (a)), is a description of the study proposal that was studied (Section (b)).

(a) Study policy

One issue that can be noted with the communication protocol proposal concerns reducing communication capacity, since security causes overhead size (250 bytes) to be greater than message size (30 bytes in the case of negotiation information), which increases communication capacity. Specifically, in environments where there are multiple recipients for the same use case or environments where there are multiple use cases together, when packets are transmitted with security information added to each recipient or use case, security overhead will be added in the same number as there are recipients or use cases, which increases communication capacity, so that reducing communication capacity is an issue.

Referring to study results by ITS FORUM (ITS FORUM RC-017 Appendix 1, “4 Information element multiplexing”), the countermeasure to the above that was studied was to multiplex information elements (bundle them into one packet) in the following two cases so that there is only one security overhead and thereby reduce communication volume.

- Study Proposal 1: When roadside infrastructure transmits a negotiation/update request to multiple vehicles
  (Corresponds to Case 2 in ITS FORUM RC-017)
- Study draft 2: When vehicle transmits information from multiple use cases
  (Corresponds to Case 3 in ITS FORUM RC-017)

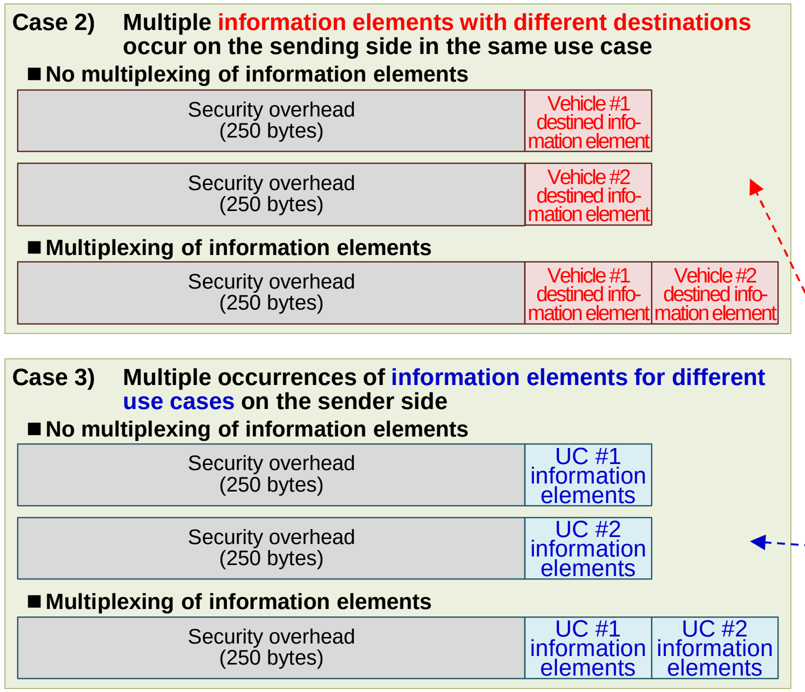
An image of information element multiplexing as described above is given in Fig. 5.2.2-1.

(b) Study proposal

This section describes results of the specifications study and effectiveness verification for two study proposals studied in the information element multiplexing method study policy (Section (a)).

In the case of Study Proposal 1 (in which the roadside infrastructure transmits a negotiation/update request to multiple vehicles), the multiplexing of information elements (negotiation information) with different recipient vehicles that the roadside infrastructure transmits is studied for the negotiation/update request in UC a-1-3 (Cooperative merging assistance with vehicles on the main lane by roadside control). The number of recipient vehicles for which information elements can be multiplexed is determined by the maximum size that can be transmitted without packet partitioning, but to give an example, information for up to 15 vehicles (718 bytes/ms) can be bundled into one packet in the case of CV2X (LTE V2X (PC5)) with a 10 MHz channel, QPSK, and an encoding rate of 0.5. An example of effectiveness verification in this study is given in Fig. 5.2.2-2. It is expected that information element multiplexing will reduce communication volume to about one-seventh of the original volume for the number of transmitting vehicles (48 vehicles) shown in the communication requirements of ITS FORUM RC-017.

In the case of Study Proposal 2 (in which a vehicle transmits information from multiple use cases), the multiplexing of information elements (use case specific information) from each use case that is being transmitted on the same channel is studied. An example of effectiveness verification in this study is given in Fig. 5.2.2-3. Details of the multiplexing method as based on the communication channel allocation proposal were studied in the evaluation of communication performance by communication simulation (Section 5.3).

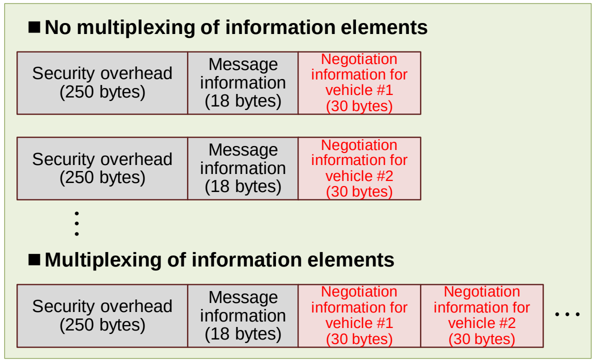



- Case 1) When multiple information elements/messages of different types occur on the sender side in the same use case
  - As an example, in the merging support use case a-1-3, a situation may arise where information that is sent periodically in the roadside infrastructure, such as location information messages, and information that is sent at specific events/sequences, such as control/agreement communication sequences, is occurring.
- Case 2) When multiple information elements/messages of different recipients occur on the sender side in the same use case
  - As an example, in the merging support use case a-1-3, a situation may arise where the roadside infrastructure implements control procedures for multiple vehicles in parallel, resulting in multiple control information.
- Case 3) When multiple information elements/messages for different use cases occur on the sender side
  - As an example, a situation may arise where a location information message for merging support use case a-1-3 and a message required for traffic congestion assistance at branches and exits use case d-4 are occurring simultaneously in the roadside infrastructure.

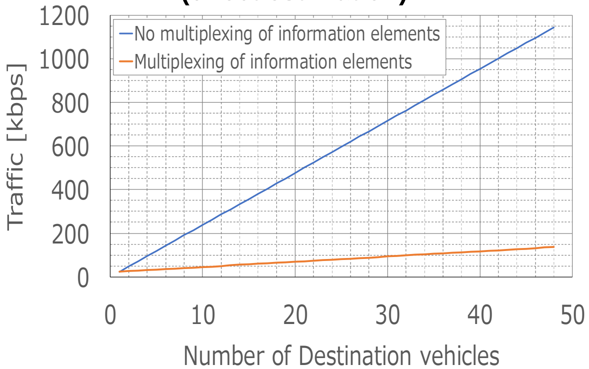
*Quote source: ITS FORUM RC-017, Appendix 1 “4 Information element multiplexing”

**Fig. 5.2.2-1 Image of information element multiplexing**

## Multiplexing method of Proposal 1




## Comparison of data traffic (effect estimation)

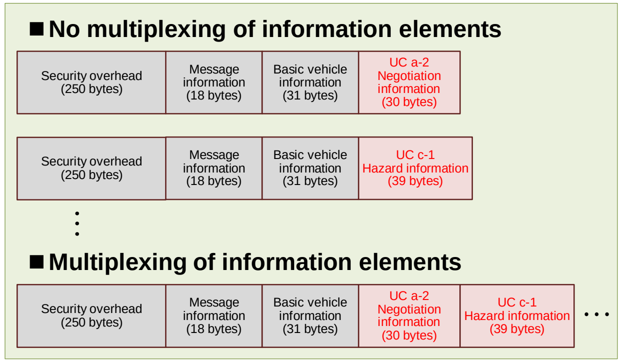



## Subject use case of Study Proposal 1

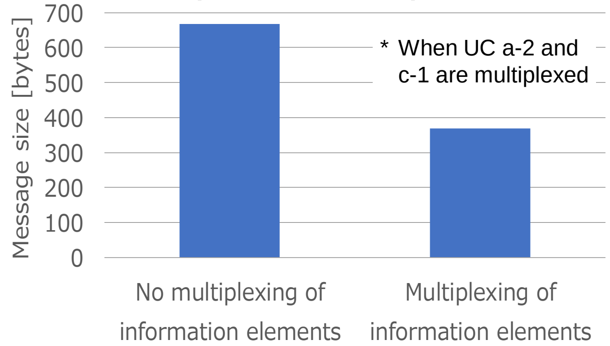
| Classification by function | Use case | No. | Message name | Communication Method | Transmission period | Number of transmitting vehicles pre area | Data size [bytes]: Total | Security overhead | (1) Message information | (3) Vehicle basic information | (4) Use case specific information: Roadside control information | Surrounding vehicle information: a-1-x | Surrounding vehicle information: c-2-2 | Negotiation information | Intersection information | Hazard information: c-1, c-3 | Hazard information: e-1 | Target of Study Proposal 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. Merging/lane change assistance | Merging assistance by preliminary acceleration and deceleration | a-1-1 | Location information | I2V | 100ms | 1 | **1518** | 250 | 18 | | 1 | 1249 | | | | | | – |
| | Merging assistance by targeting the gap on the main lane | a-1-2 | Location information | I2V | 100ms | 1 | **2760** | 250 | 18 | | 1 | 2491 | | | | | | – |
| | Cooperative merging assistance with vehicles on the main lane by roadside control | a-1-3 | Location information | I2V | 100ms | 1 | **5244** | 250 | 18 | | 1 | 4975 | | | | | | – |
| | | | Control request | V2I | – | 1 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | | | Negotiation request Update request | I2V | 100ms (*1) | (*2) | **298** | 250 | 18 | | | | | 30 | | | | ● |
| | | | Negotiation response Update response | V2I | 100ms (*1) | 48 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | Merging assistance based on negotiations between vehicles | a-1-4 | Negotiation request Update request | V2V | 100ms (*1) | 1 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 36 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | Lane change assistance when the traffic is heavy | a-2 | Negotiation request Update request | V2V | 100ms (*1) | 73 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 48 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | Entry assistance from non-priority roads to priority roads during traffic congestion | a-3 | Negotiation request Update request | V2V | 100ms (*1) | 2 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 68 | **329** | 250 | 18 | 31 | | | | 30 | | | | – |
| b. Traffic signal information | Driving assistance by using traffic signal information (V2I) | b-1-1 | - | I2V | 100ms | 1 | **664** | 250 | 18 | | | | | | 396 | | | – |
| c. Lookahead information: collision avoidance | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | c-1 | - | V2V | 100ms | 139 | **338** | 250 | 18 | 31 | | | | | | 39 | | – |
| | Driving assistance based on intersection information (V2V) | c-2-1 | - | V2V | 100ms | 125 | **299** | 250 | 18 | 31 | | | | | | | | – |
| | Driving assistance based on intersection information (V2I) | c-2-2 | - | I2V | 100ms | 1 | **1488** | 250 | 18 | | | | 824 | | 396 | | | – |
| | Collision avoidance assistance by using hazard information | c-3 | - | V2V | 100ms | 139 | **338** | 250 | 18 | 31 | | | | | | 39 | | – |
| e. Lookahead information: emergency vehicle notification | Driving assistance based on emergency vehicle information | e-1 | - | V2V | 100ms | 1 | **347** | 250 | 18 | 31 | | | | | | | 48 | – |

**Fig. 5.2.2-2 Example of effectiveness verification for information element multiplexing Study Proposal 1**

## Multiplexing method of Study Proposal 2




## Comparative example of data traffic (effect estimation)




## Subject use case of Study Proposal 2

| Classification by function | Use case | No. | Message name | Communication Method | Transmission period | Number of transmitting vehicles pre area | Data size [bytes]: Total | Security overhead | (1) Message information | (3) Vehicle basic information | (4) Use case specific information: Roadside control information | Surrounding vehicle information: a-1-x | Surrounding vehicle information: c-2-2 | Negotiation information | Intersection information | Hazard information: c-1, c-3 | Hazard information: e-1 | Target of Study Proposal 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. Merging/lane change assistance | Merging assistance by preliminary acceleration and deceleration | a-1-1 | Location information | I2V | 100ms | 1 | **1518** | 250 | 18 | | 1 | 1249 | | | | | | – |
| | Merging assistance by targeting the gap on the main lane | a-1-2 | Location information | I2V | 100ms | 1 | **2760** | 250 | 18 | | 1 | 2491 | | | | | | – |
| | Cooperative merging assistance with vehicles on the main lane by roadside control | a-1-3 | Location information | I2V | 100ms | 1 | **5244** | 250 | 18 | | 1 | 4975 | | | | | | – |
| | | | Control request | V2I | – | 1 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | | | Negotiation request Update request | I2V | 100ms (*1) | (*2) | **298** | 250 | 18 | | | | | 30 | | | | – |
| | | | Negotiation response Update response | V2I | 100ms (*1) | 48 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | Merging assistance based on negotiations between vehicles | a-1-4 | Negotiation request Update request | V2V | 100ms (*1) | 1 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 36 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | Lane change assistance when the traffic is heavy | a-2 | Negotiation request Update request | V2V | 100ms (*1) | 73 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 48 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | Entry assistance from non-priority roads to priority roads during traffic congestion | a-3 | Negotiation request Update request | V2V | 100ms (*1) | 2 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| | | | Negotiation response Update response | V2V | 100ms (*1) | 68 | **329** | 250 | 18 | 31 | | | | 30 | | | | ● |
| b. Traffic signal information | Driving assistance by using traffic signal information (V2I) | b-1-1 | - | I2V | 100ms | 1 | **664** | 250 | 18 | | | | | | 396 | | | – |
| c. Lookahead information: collision avoidance | Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | c-1 | - | V2V | 100ms | 139 | **338** | 250 | 18 | 31 | | | | | | 39 | | ● |
| | Driving assistance based on intersection information (V2V) | c-2-1 | - | V2V | 100ms | 125 | **299** | 250 | 18 | 31 | | | | | | | | ● |
| | Driving assistance based on intersection information (V2I) | c-2-2 | - | I2V | 100ms | 1 | **1488** | 250 | 18 | | | | 824 | | 396 | | | – |
| | Collision avoidance assistance by using hazard information | c-3 | - | V2V | 100ms | 139 | **338** | 250 | 18 | 31 | | | | | | 39 | | ● |
| e. Lookahead information: emergency vehicle notification | Driving assistance based on emergency vehicle information | e-1 | - | V2V | 100ms | 1 | **347** | 250 | 18 | 31 | | | | | | | 48 | ● |

**Fig. 5.2.2-3 Example of effectiveness verification for information element multiplexing, Study Proposal 2**

### 5.2.3 Challenges of Communication message set proposal study

The following may be listed as future issues.

- **Study reflecting future message set revisions**

Concerning message commonizing, there is currently a continuing study of further commonizing in multiple use cases where commonizing has not yet been achieved. For this and other reasons, based on the issues organized in ITS FORUM RC-017, the communication message set proposal is expected to be revised, and it is thought that it will be necessary to study revisions in future.

- **Study and evaluation of detailed procedures for information element multiplexing**

If after discussion of the necessity of information element multiplexing for future standardization, if it is found necessary, it is thought it will necessary to establish specifications by setting clear detailed procedures, such as the communication layer where multiplexing will occur in multiple use cases, and the timing.

## 5.3 Evaluation of communication performance by communication simulation

This section describes the results of the evaluation of communication performance by communication simulation, discussion of the evaluation, and organization of the issues. The following describes the process of evaluation (Section 5.3.1), and in accordance with that, the results of evaluation in road sections of uninterrupted flow, merging sections, and intersections, discussion, and organization of the issues (Section 5.3.2 to 5.3.3).

### 5.3.1 Process of evaluation

Based on the communication protocol proposal and communication message set proposal study results (Section 5.1 and Section 5.2), an evaluation was conducted to verify the effectiveness of communication channel allocation (Section 4.1), communication congestion control system in the upper layers (Section 4.2), and information element multiplexing (Section 5.2.2(2)). The SIP use cases for Cooperative Driving Automation [1] (below, “SIP UC”) that were the subject of evaluation were those uses cases with direct communication (V2V and V2I). While considering combinations of use cases that could occur simultaneously at each location, evaluation was done in the order of evaluation in road sections of uninterrupted flow (Section 5.3.2) followed by evaluation in merging sections and intersections (Section 5.3.3). Only cases that used CV2X (LTE V2X (PC5)) as the wireless communication system were evaluated.

The flow of the process of evaluation as described above is given in Fig. 5.3.1-1.

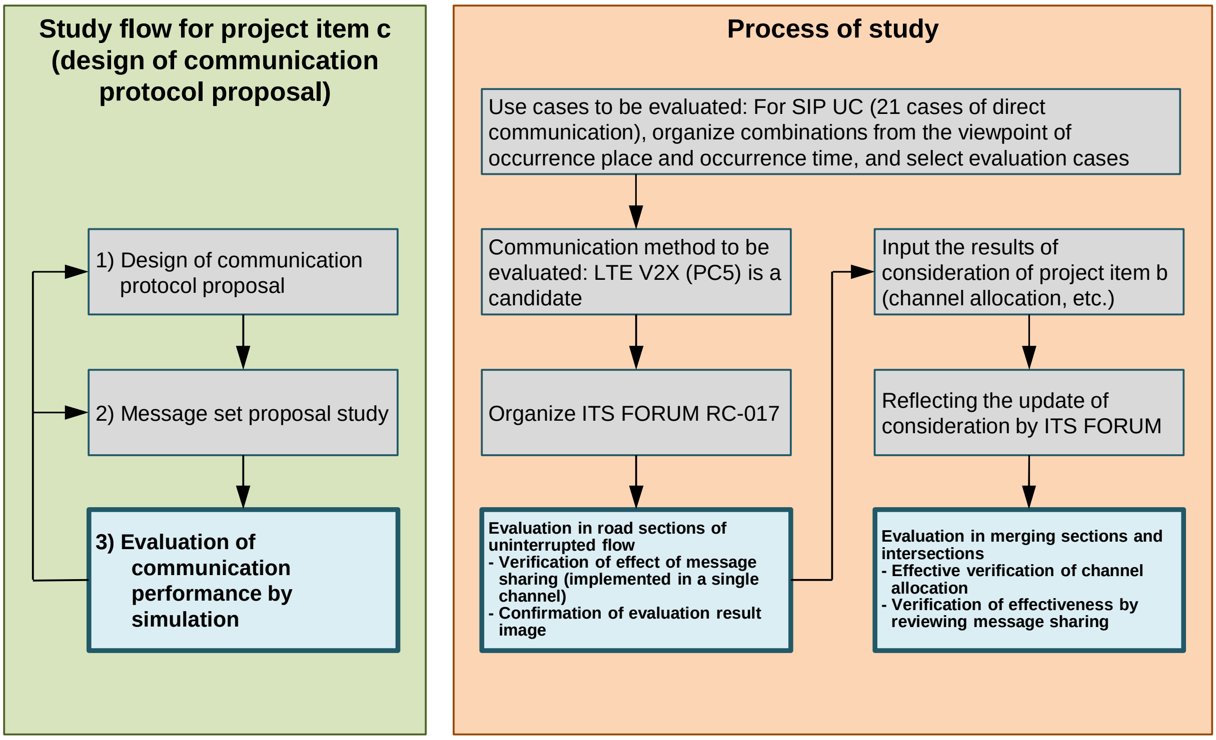



**Fig. 5.3.1-1 Process of evaluation of communication performance by communication simulation**

### 5.3.2 Evaluation in road sections of uninterrupted flow

This section describes the results of evaluation of the SIP use cases for Cooperative Driving Automation [1] (below, "SIP UC") that were use cases with direct communication (V2V); for use cases where location does not matter, results are given for evaluation of single use cases and evaluation of multiple use cases in combination (Section 5.3.2). The following describes the results in the order of evaluation conditions (Section (1)), link budget results (Section (2)), communication simulation results (Section (3)), and evaluation results discussion and issues (Section (4)).

(1) Evaluation conditions

This section describes the evaluation conditions in road sections of uninterrupted flow.

- Overview of evaluation conditions

First, results of organizing the evaluation conditions in communication simulation are given in Table 5.3.2-1. Evaluation conditions were set that reflected the studies of communication channel allocation (Section 4.1) and communication message commonizing (the information element multiplexing method in Section 5.2.2(2)); along with that, evaluation conditions from FY2021 studies (*) were compared and more detailed communication parameters and evaluation indicators were selected. Next, an overview is given of the evaluation conditions in road sections of uninterrupted flow. The evaluation conditions in road sections of uninterrupted flow are bounded by the red box. There is a single communication channel. When evaluating single use cases, cases evaluated were limited to those use cases where location does not matter (UC a-2, c-1, e-1). Combinations of UC a-2, c-1, and e-1 were also used to evaluate multiple use cases. When evaluating multiple use cases, based on message commonizing (information element multiplexing method) study results (Section 5.2.2(2)), the effectiveness is verified as a condition for information element multiplexing.

(*) FY2021 research and development for expansion of radio wave resources of Ministry of Internal Affairs and Communications "Technical Study on 5.9 GHz Band V2X Communication System" (written as "FY2021 Ministry of Internal Affairs and Communications (5.9 GHz CV2X)" in Table 5.3.2-1); FY 2021 "Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase 2 - Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation" (written as "FY2021 SIP 5.9 GHz CV2X" in Table 5.3.2-1); and "2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of

Cooperative Driving Automation: Evaluation of 700 MHz band ITS" (written as "FY2021 SIP 700 MHz ITS" in Table 5.3.2-1)

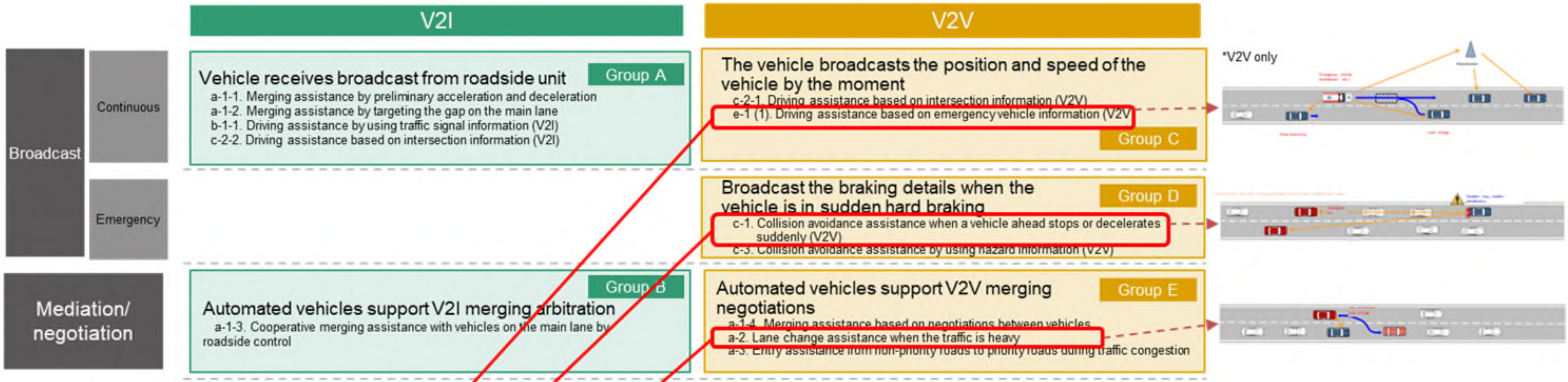
## Table 5.3.2-1 Organization of evaluation conditions

| Items | | Main business: Evaluation in merging sections and intersections | Main business: Evaluation in road sections of uninterrupted flow | FY2021 Ministry of Internal Affairs and Communications (5.9 GHz CV2X) | FY2021 SIP: 5.9 GHz CV2X | FY2021 SIP: 700 MHz ITS (reference) |
|---|---|---|---|---|---|---|
| Operation modes | Security overhead | 250 bytes<br>(Assumptions of ITS FORUMRC-017) | | | None | Road side unit: 273 + 28n bytes, on-board unit:<br>27 bytes (assuming the method of the existing service) |
| | Communication channel | Multiple (reflecting consideration of item b) | Single | | | |
| L1/L2 related | Communication specifications | LTE V2X (PC5) | | | | ARIB STD-T109 |
| | Number of transmissions | Twice (Blind HARQ) | | | Once | |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) | | | None | |
| Radio wave propagation | Path loss | ITU-R P.1411 | | | | Road-to-vehicle: 700 MHz ITS road-to-vehicle and road-to-road model<br>Vehicle-to-vehicle distance: Ito/Taga model |
| | Instantaneous fading | Present (3GPP EVA) | | | Present (Rayleigh/Nakagami) | Present (normal distribution) |
| | Shadowing | Present (logarithmic normal distribution (standard deviation: 3.68 dB)) | | | None | |
| | Shadowing loss | Present (consider shielding by large vehicles (10 dB)) | | | None | Present (0.5 dB/vehicle (maximum 8 dB)) |
| Communication conditions | Evaluation case (SIP UC) | - Multiple UCs (two ways around merging sections and around intersections, and select a combination that is expected to cause communication congestion) | - Single UC (UC a-2, c-1, e-1 are candidates)<br>- Multiple UCs (a combination of the above)<br>*Targets V2V UC in any location, including UC (c-1) subject to effect verification in section b | - Single UC (all)<br>- Multiple UCs (limited to model cases) | - Single UC (UC a-1-4 around merging sections)<br>- Multiple UCs (UC b-1-1, c-1, c-2-2 around intersections)<br>*Select cases where communication congestion is assumed | - Single UC (expressway / prefectural and municipal roads and vehicle-to-road/vehicle-to-vehicle represented by 4 cases)<br>- Multiple UCs (all UCs) |
| | Common message | Present (refer to the results of ITS FORUM RC-017) | | None (separate message for each UC) | | Present (refer to ITS Connect TD-001) |
| | Source of interference | Present (on-board unit always transmits at 100 ms cycle) | | None (not considered for outside the communication area of the target UC) | | Present (existing services on the same channel) |
| Evaluation index | Item evaluated | PAR, delay (99% value), delay (time until PAR required value is reached) | | | PAR, delay (average) | PAR, delay (time until PAR required value is reached) |
| | Definition of communication quality | Per packet | | | | |

- Subject use cases, channel allocation

The relationships between the subject use cases and channel allocation are given in Fig. 5.3.2-1. The use cases subject to evaluation are those where location of V2V communication does not matter: UC a-2 (Lane change assistance when the traffic is heavy), c-1 (Collision avoidance support for sudden stop or sudden deceleration in front), and e-1 (Driving assistance based on emergency vehicle information). Concerning channel allocation, based on the state of the study of communication channel allocation (Section 4.1) (Proposals 1 to 4), the evaluation focuses on one channel and includes situations where use cases exist together on the same channel. In UC e-1, c-1, and a-2, Groups C, D, and E respectively apply in the study of communication channel allocation (Section 4.1). In evaluation case 1, the situation where one use case (UC e-1 of Group C in Proposal 4) is allocated to Channel 1 ((2)) is evaluated. In evaluation case 2, the situation where one use case (UC c-1 of Group D in Proposal 4) is allocated to one channel ((3)) is evaluated. In evaluation case 3 the situation where one use case (UC a-2 of Group E in Proposal 4) is allocated to one channel ((4)) is evaluated. In evaluation case 4, the situation where two use cases (UC e-1 of Group C and UC c-1 of Group D in Proposal 2) are allocated to one channel ((2)) is evaluated. In evaluation case 5, the situation where two use cases (UC e-1 of Group C and UC a-2 of Group E in Proposal 1) are allocated to one channel ((2)) is evaluated.

Based on the above, there are a total of five ways that use cases are evaluated: three in which one use case is allocated to one channel (UC e-1 only, c-1 only, and a-2 only) and two in which two use cases are allocated to one channel (a situation where UC e-1 and c-1 exist together and a situation where UC e-1 and a-2 exist together).




| Communication method | Group | Basic | Proposal 1 | Proposal 2 | Proposal 3 | Proposal 4 |
|---|---|---|---|---|---|---|
| V2I | Group A Broadcast from road side units | (1) | (1) | (1) | (1) | (1) |
| | Group B Negotiation from road side units | (2) | (1) | (1) | (2) | (1) |
| V2V | Group C Broadcast from vehicle (continuous) | (3) | (2) | (2) | (1) | (2) |
| | Group D Broadcast from vehicle (emergency) | (4) | (3) | (2) | (3) | (3) |
| | Group E Negotiation between vehicles | (5) | (2) | (3) | (4) | (4) |

| Evaluation case | Mixed UC in the same channel | Classification by function | Use case |
|---|---|---|---|
| 1 | None | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information |
| 2 | None | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| 3 | None | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy |
| 4 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly |
| 5 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy |

**Fig. 5.3.2-1 Evaluation conditions in road sections of uninterrupted flow (subject use cases, channel allocation)**

*SIP Use Cases for Cooperative Driving Automation - Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2019 - Based on figure in (https://www.sip-adus.go.jp/rd/rddata/usecase.pdf)

- Message composition and size

Message composition and size are given in Table 5.3.2-2. Based on the results of the study on message commonizing (information element multiplexing method) (Section 5.2.2(2)), messages are commonized in situations where multiple use cases exist together on the same channel. Specifically, along with common message information and basic vehicle information on the OBU, information specific to the use cases existing together on the same channel is all added, so that messages are commonized.

**Table 5.3.2-2 Evaluation conditions in road sections of uninterrupted flow (message composition and size)**

| Evaluation case | Mixed UC in the same channel | Classification by function | Use case | Data size [bytes] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | | | | | | |
| | | | | | | | Roadside control information | Surrounding vehicle information | | Negotiation information | Intersection information | Hazard information | | | Information on platooning without drivers | Information on platooning with drivers |
| | | | | | | | | a-1-x | c-2-2 | | | c-1, c-3 | e-1 (*1) | d-x | | |
| 1 | None | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 334 | 18 | 31 | | | | | | | 35 | | | |
| 2 | None | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 338 | 18 | 31 | | | | | | 39 | | | | |
| 3 | None | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 329 | 18 | 31 | | | | 30 | | | | | | |
| 4 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 338 | 18 | 31 | | | | | | 39 (*2) | | | | |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | | | | | | | | | | | | | |
| 5 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 364 | 18 | 31 | | | | 30 | | | 35 | | | |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | | | | | | | | | | | | | |

* For message size and message commonizing, the following two points are anticipated, referring to a study (method of adding SIP information in TD-001 message set) in FY2021's SIP project ("Evaluation Concerning 700 MHz Band ITS in Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation").

(*1) The information elements in UC e-1 were reduced from 48 to 35 bytes by excluding those information elements with the comment "Not expected to be used" in the table in ITS FORUM RC-017 [2] 6.2.1.10(1).

(*2) Use case specific information for UC e-1 and UC c-1 was formed as emergency information sharing the same region and was set to 39 bytes, which holds both e-1 (35 bytes) and c-1 (39 bytes).

- Details of evaluation conditions

Details of evaluation conditions in road sections of uninterrupted flow are given in Table 5.3.2-3. Concerning antenna diversity, security overhead, number of transmissions, instantaneous fading, shadowing, and shadowing loss, evaluation conditions from FY2021 studies (*) were compared and more detailed communication parameters and evaluation indicators were selected.

(*) Ministry of Internal Affairs and Communications FY2021 frequency strain countermeasures technical experimentation office “Technical Study on 5.9 GHz Band V2X Communication System”; “Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation” in SIP 2nd phase automated driving (system and service expansion) FY2021 research and development; and “Evaluation Concerning 700 MHz Band ITS in Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation”

**Table 5.3.2-3 Details of evaluation conditions in road sections of uninterrupted flow**

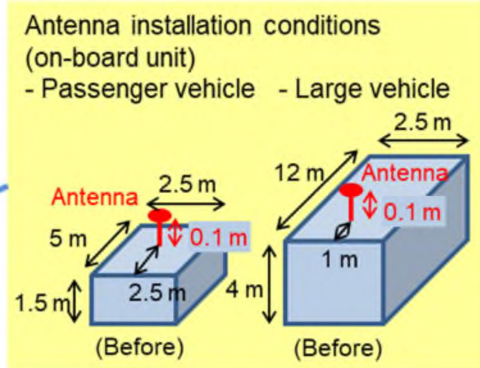
| Items | | Value |
|---|---|---|
| L1/L2 related | Center frequency | 5890 MHz |
| | Antenna power | 23 dBm |
| | System bandwidth | 10 MHz |
| | Modulation method | QPSK, 16QAM/SC-FDM |
| | Error correction (encoding rate) | Data signal: turbo code (0.5)<br>Control signal: TBCC (0.1) |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) |
| | Noise power density | -173.9 dBm/Hz |
| | Noise figure | 10 dB |
| | Fixed deterioration | 5 dB |
| | Antenna gain | Road side unit: 6 dBi, on-board unit: 4 dBi |
| | Antenna directivity | None |
| | Cable/connector loss | Road side unit: 0 dBi, on-board unit: 4 dBi |
| | Security overhead | 250 bytes<br>(Assumptions of ITS FORUM RC-017) |
| | Sensing window | 1000 ms |
| | Resource selection window | 50 ms |
| | Syncronization | GNSS |
| | Number of transmissions | Twice (blind HARQ) |
| Radio wave propagation | Path loss | ITU-R P.1411 |
| | Instantaneous fading | Consideration model by 3GPP (*1) |
| | Shadowing | Logarithmic normal distribution (standard deviation: 3.68 dB) (*2) |
| | Shadowing loss | When there is a large vehicle between the sending and receiving: 10 dB (*3) |
| | Antenna height | Road side unit: 6.0 m,<br>on-board unit: 1.6 m (passenger vehicle), 4.1 m (large vehicle) |

*1 Extended Vehicular A model 3GPP TS 36.101 and 3GPP TS 36.104

*2 Fading model considering spatial correlation, referring to 3GPP TR 36.885 (A.1.4 channel model)

*3 Based on 3GPP TR 38.901 Blockage model B (knife edge diffraction model), attenuation caused by one adjacent large vehicle was calculated based on vehicle speed of 40 km/h with one-second vehicle interval

Compare the evaluation conditions of FY2021 examination (SIP, Ministry of Internal Affairs and Communications' research and development) and select more precise communication parameters and evaluation indicators



- Subjects of link budget and simulation

The subjects of link budget and simulation are shown in Table 5.3.2-4. The symbol ● means that link budget or simulation is performed, while — means it is not performed. As the table shows, all evaluation cases are subject to link budget. All evaluation cases, except a case where there is one transmitting vehicle per communication area, are subject to simulation. In evaluation cases that include UC c-1 or a-2 (evaluation cases 2 to 5), considering situations where the UCs on the same channel simultaneously occur in multiple locations, a source of interference that would transmit the same message was placed out of communication area.

**Table 5.3.2-4 Organization of subjects of link budget and simulation in evaluation in road sections of uninterrupted flow**

| Evaluation case | Mixed UC in the same channel | Classification by function | Use case | Number of transmission units per communication area | Source of interference | Link budget | Simulation |
|---|---|---|---|---|---|---|---|
| 1 | None | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 1 vehicle | None | ● | – |
| 2 | None | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 277 vehicles | Present | ● | ● |
| 3 | None | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 121 vehicles | Present | ● | ● |
| 4 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 1 vehicle | Present | ● | ● |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 277 vehicles | | | |
| 5 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 1 vehicle | Present | ● | ● |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 121 vehicles | | | |

(●: Implemented, -: Not implemented)

(2) Link budget results

The link budget results are shown in Table 5.3.2-5. If the symbol below "Supported?" is ○, it means that the system margin at the communication range necessary for the required PAR is at least 0 dB. If the symbol is ×, the system margin is less than 0 dB. If there is no shadowing by a large vehicle, all use cases are supported (i.e., the link margin at the maximum communication range is at least 0 dB), but if there is shadowing by a large vehicle, e-1 (Driving assistance based on emergency vehicle information), which has a short maximum communication range (within 150 meters), is supported, but c-1 (Collision avoidance support for sudden stop or sudden deceleration in front) and a-2 (Lane change assistance when the traffic is heavy), in which the maximum communication range is great (250 meters or more) and exceeds the maximum communication range of the link budget, are not supported.

Table 5.3.2-5 Results of link budget in evaluation in road sections of uninterrupted flow

| Evaluation case | Mixed UC in the same channel | Classification by function | Use case | Communication requirements (Data/distance/PAR) | Link margin (With/without large vehicle shielding) | Maximum communication range (With/without large vehicle shielding) | Availability (With/without large vehicle shielding) |
|---|---|---|---|---|---|---|---|
| 1 | None | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 334 bytes/150 m/99% | +4.6 dB/+14.6 dB | 225.1 m/400.3 m | O/O |
| 2 | None | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 338 bytes/250 m/99% | -1.8 dB/+8.2 dB | 225.1 m/400.3 m | ×/O |
| 3 | None | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 329 bytes/255 m/99% | -2.2 dB/+7.8 dB | 225.1 m/400.3 m | ×/O |
| 4 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 338 bytes/150 m/99% | +4.6 dB/+14.6 dB | 225.1 m/400.3 m | O/O |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 338 bytes/250 m/99% | -1.8 dB/+8.2 dB | 225.1 m/400.3 m | ×/O |
| 5 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 364 bytes/150 m/99% | +4.6 dB/+14.6 dB | 225.1 m/400.3 m | O/O |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 364 bytes/250 m/99% | -1.8 dB/+8.2 dB | 225.1 m/400.3 m | ×/O |

Regarding the availability of correspondence;
Available (O): The link margin at the required communication range is 0 dB or more
Not available (×): Link margin at required communication range is less than 0 dB

(3) Communication simulation results

Here, the following three items are given for communication simulation results.

– PAR per message

*Governed by ITS FORUM RC-017, Section 1.4.

– Delay (99% value)

*The 99% value of delay as defined in ITS FORUM RC-017, Section 1.3.

– Delay (time until PAR required value is reached)

*Referring to FY2021's study ("Evaluation Concerning 700 MHz Band ITS in Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation" in FY2021 research and development), the probability that at least one packet can be received was calculated by the following formula as the time until the required value of (1) is achieved (which is found by multiplying the number of transmissions until the required value of (1) is achieved by 100 ms, which is the transmission interval).

$$\text{Delay (time to reach the required PAR value)} = \text{ceil}\left[\frac{\log(1-P_D)}{\log(1-P_x)}\right] \times 100 \ \ [ms]$$

$P_D$: PAR required value per message (99%), $P_x$: PAR per message

- Evaluation case 4 (UC e-1: Driving assistance based on emergency vehicle information)

A summary of evaluation results for UC e-1 (Driving assistance based on emergency vehicle information) in evaluation case 4 (a situation where UC e-1 and c-1 exist together on one channel), PAR per message, delay (99% value), and delay (time until PAR required value is reached) are given in Table 5.3.2-6, Fig. 5.3.2-2, Fig. 5.3.2-3, and Fig. 5.3.2-4, respectively. The communication requirements were not met either during normal times (vehicle speed 120 km/h with two-second vehicle interval) or during congestion (vehicle speed 60 km/h with one-second vehicle interval) in the communication scenario.

**Table 5.3.2-6 Summary of results of evaluation case 4 (UC e-1: Driving assistance based on emergency vehicle information)**

| Use case | Inter-vehicular distance | Required communication range | PAR per message | Delay (99% value) | Delay (time until PAR required value is reached) |
|---|---|---|---|---|---|
| e-1. Driving assistance based on emergency vehicle information | 120 km/h, 2s | 150 m | 95.6% | – | 200 ms |
| | 60 km/h, 1s | | 57.1% | – | 600 ms |

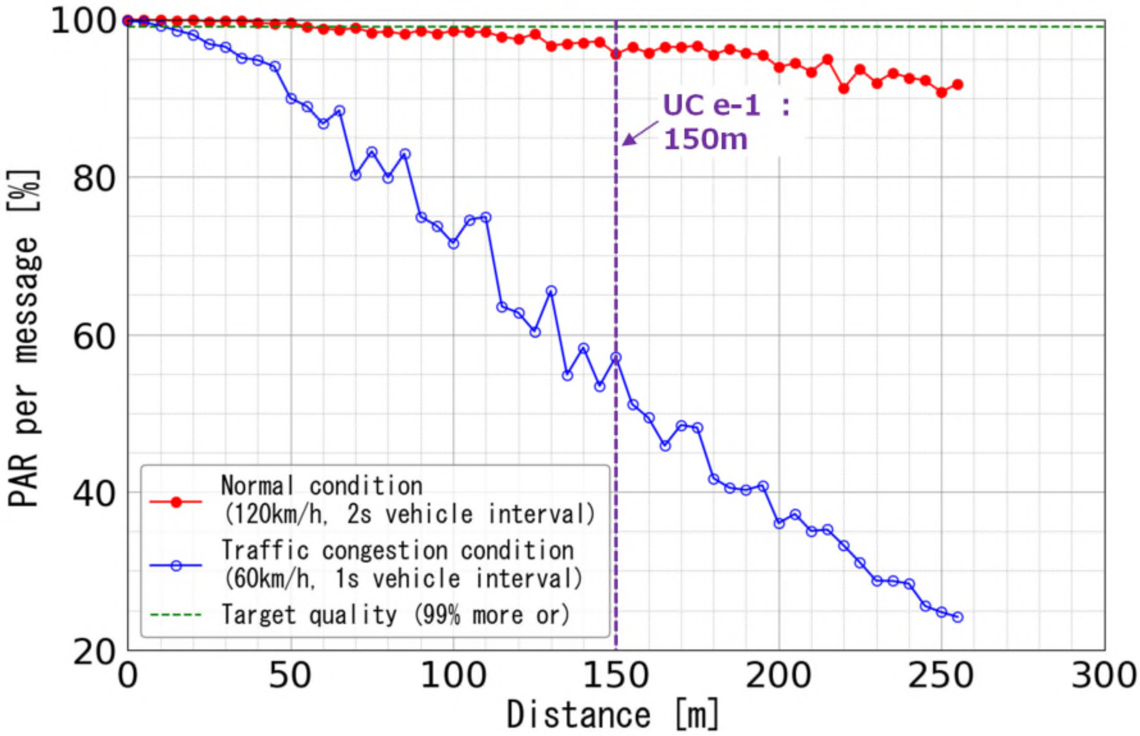



**Fig. 5.3.2-2 Results of evaluation case 4 (UC e-1: Driving assistance based on emergency vehicle information)**
**PAR per message**

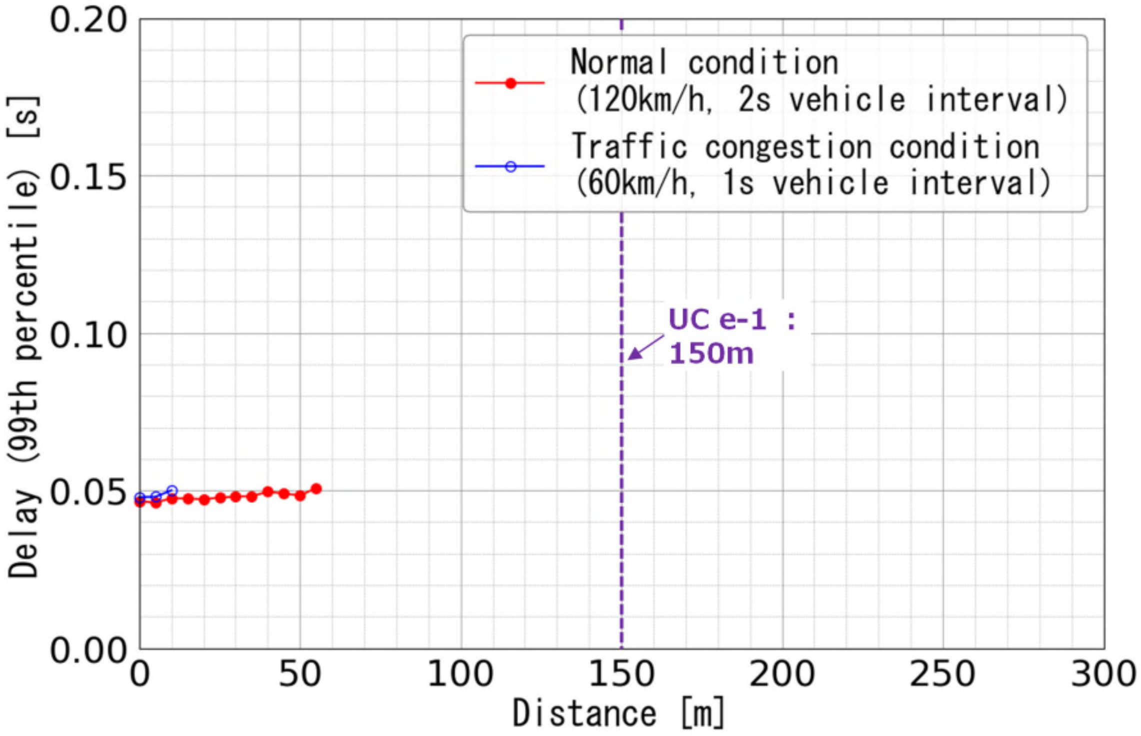



**Fig. 5.3.2-3 Results of evaluation case 4 (UC e-1: Driving assistance based on emergency vehicle information)**
**Delay (99% value)**

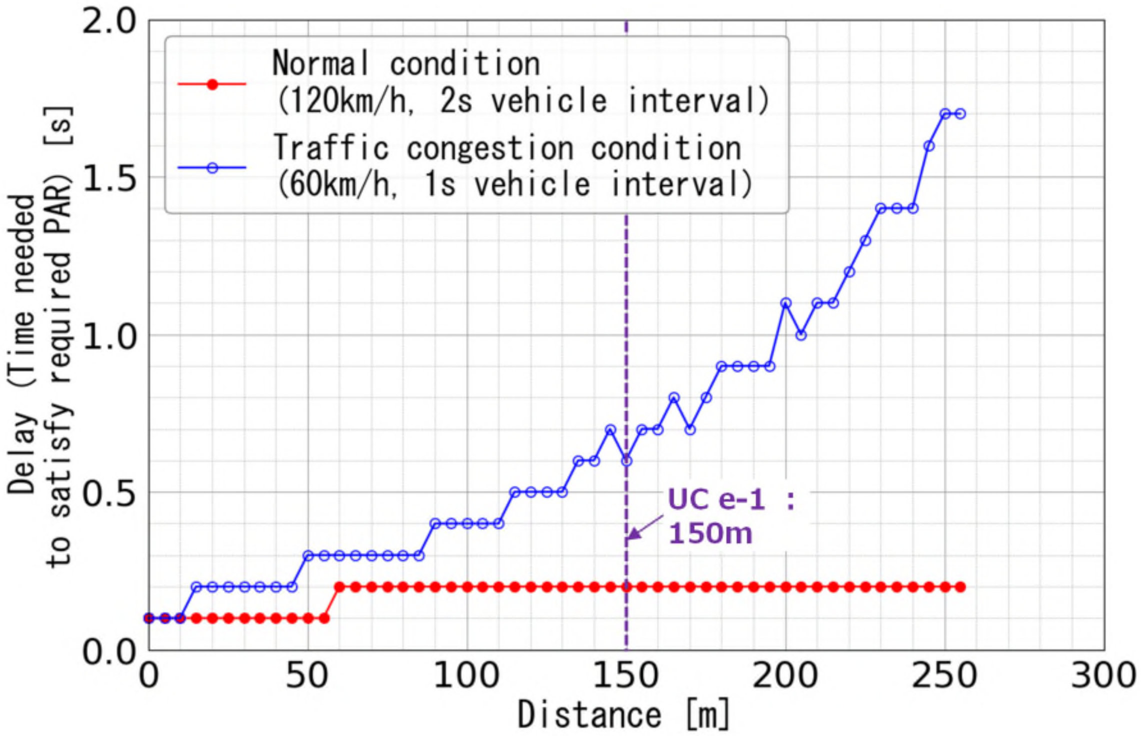



**Fig. 5.3.2-4 Results of evaluation case 4 (UC e-1: Driving assistance based on emergency vehicle information)**
**Delay (time until PAR required value is reached)**

- Evaluation case 4 (UC c-1: Collision avoidance support for sudden stop or sudden deceleration in front)

A summary of evaluation results for UC c-1 (Collision avoidance support for sudden stop or sudden deceleration in front) in evaluation case 4 (a situation where UC e-1 and c-1 exist together on one channel), PAR per message, delay (99% value), and delay (time until PAR required value is reached) are given in Table 5.3.2-7, Fig. 5.3.2-5, Fig. 5.3.2-6, and Fig. 5.3.2-7, respectively. The communication requirements are met both during normal times (vehicle speed 120 km/h with two-second vehicle interval) and during congestion (vehicle speed 60 km/h with one-second vehicle interval) in the communication scenario.

**Table 5.3.2-7 Summary of results of evaluation case 4 (UC c-1: Collision avoidance support for sudden stop or sudden deceleration in front)**

| Use case | Inter-vehicular distance | Required communication range | PAR per message | Delay (99% value) | Delay (time until PAR required value is reached) |
|---|---|---|---|---|---|
| c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 120 km/h, 2s | 250 m (Direct communication) | 100.0% | 85.8 ms | 100 ms |
| | | 1000 m (Relay communication) | 100.0% | 134.5 ms | 200 ms |
| | 60 km/h, 1s | 250 m (Direct communication) | 99.3% | 88.4 ms | 100 ms |
| | | 1000 m (Relay communication) | 100.0% | 179.8 ms | 200 ms |

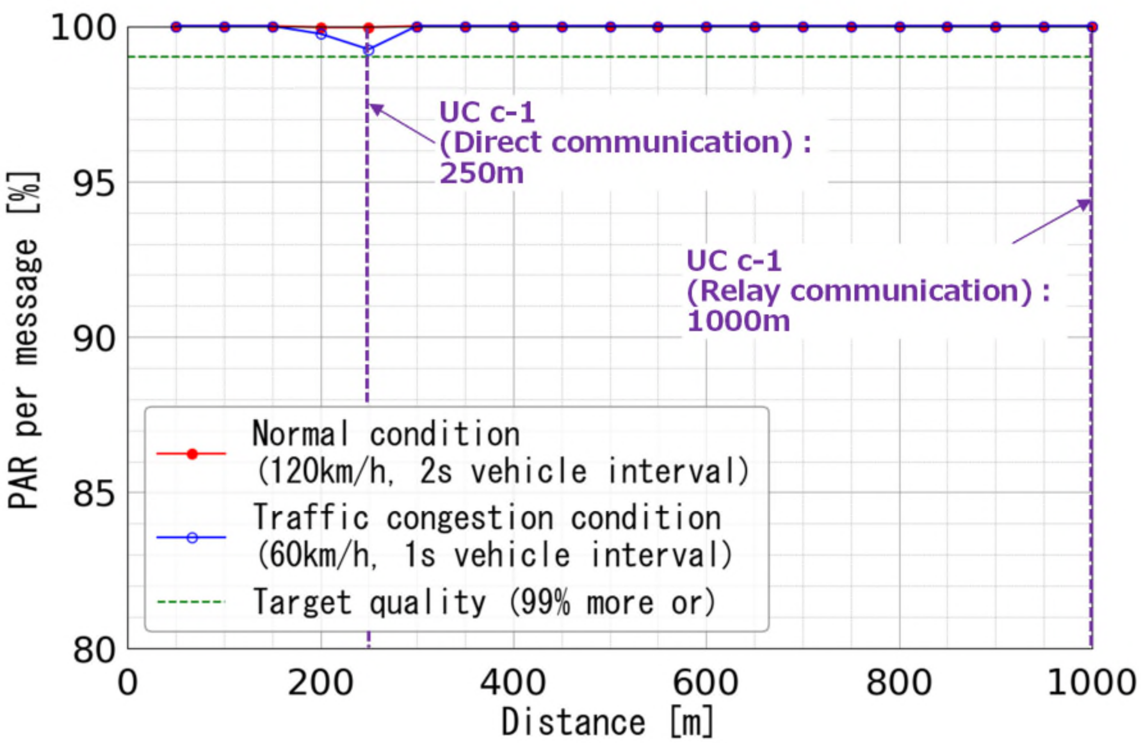



**Fig. 5.3.2-5 Results of evaluation case 4 (UC c-1: Collision avoidance support for sudden stop or sudden deceleration in front): PAR per message**

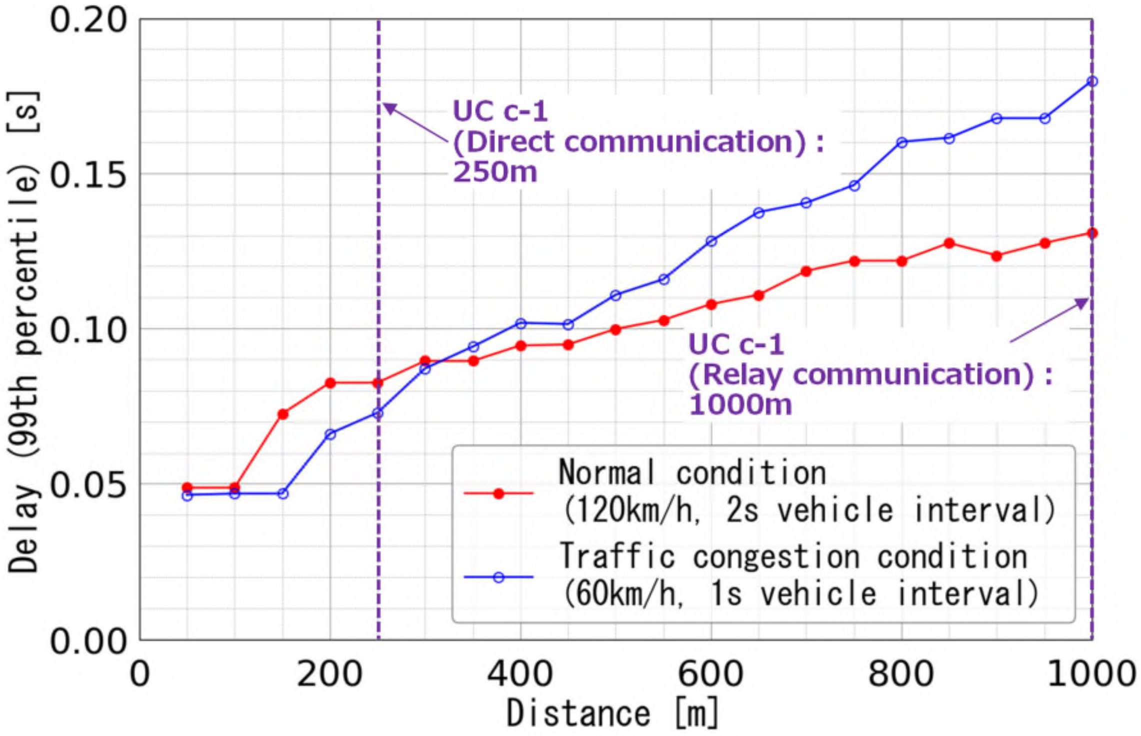



**Fig. 5.3.2-6 Results of evaluation case 4 (UC c-1: Collision avoidance support for sudden stop or sudden deceleration in front):**
**Delay (99% value)**

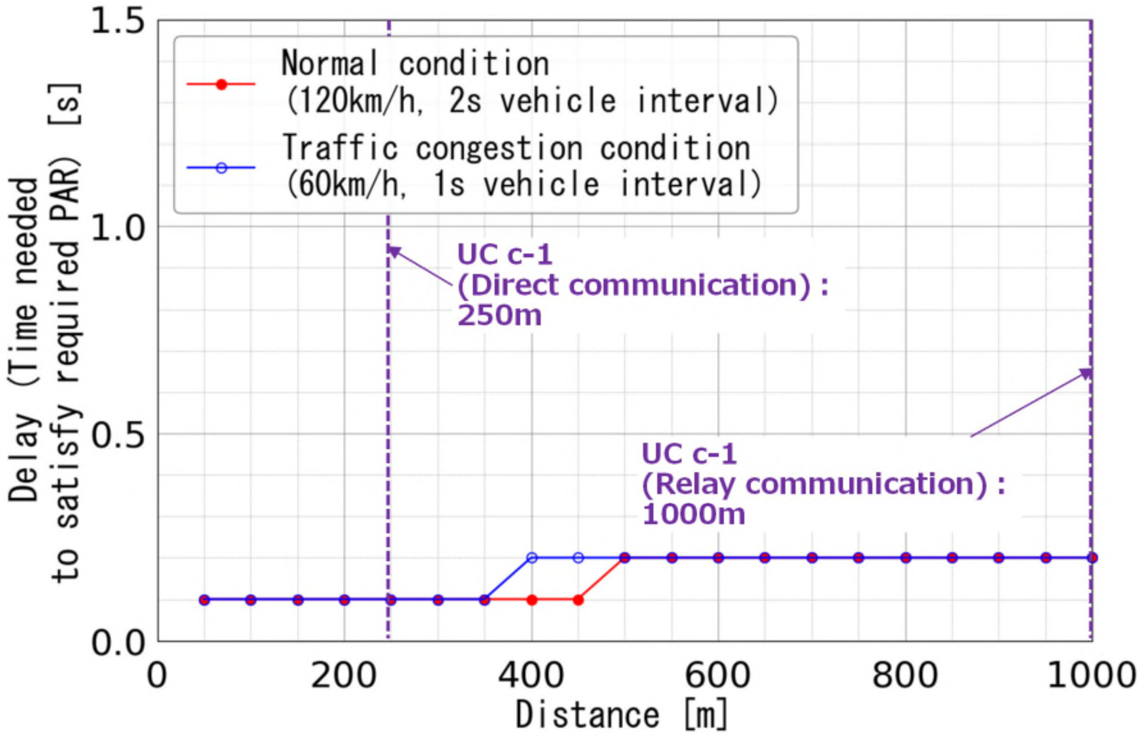



**Fig. 5.3.2-7 Results of evaluation case 4 (UC c-1: Collision avoidance support for sudden stop or sudden deceleration in front):**
**Delay (time until PAR required value is reached)**

- Evaluation case 5 (UC e-1: Driving assistance based on emergency vehicle information, UC a-2: Lane change assistance when the traffic is heavy)

A summary of evaluation results for each use case in evaluation case 5 (a situation where UC e-1 and a-2 exist together on one channel), PAR per message, delay (99% value), and delay (time until PAR required value is reached) are given in Table 5.3.2-8, Fig. 5.3.2-8, Fig. 5.3.2-9, and Fig. 5.3.2-10, respectively. The communication requirements were not met either during normal times (vehicle speed 120 km/h with two-second vehicle interval) or during congestion (vehicle speed 60 km/h with one-second vehicle interval) in the communication scenario.

**Table 5.3.2-8 Summary of results of evaluation case 5 (UC e-1: Driving assistance by providing information on emergency vehicles, UC a-2: Lane change assistance when the traffic is heavy)**

| Use case | Inter-vehicular distance | Required communication range | PAR per message | Delay (99% value) | Delay (time until PAR required value is reached) |
|---|---|---|---|---|---|
| e-1. Driving assistance based on emergency vehicle information | 120 km/h, 2s | 150 m | 95.6% | – | 200 ms |
| | 60 km/h, 1s | | 57.1% | – | 600 ms |
| a-2. Lane change assistance when the traffic is heavy | 120 km/h, 2s | 255 m | 91.8% | – | 200 ms |
| | 60 km/h, 1s | | 24.2% | – | 1700 ms |

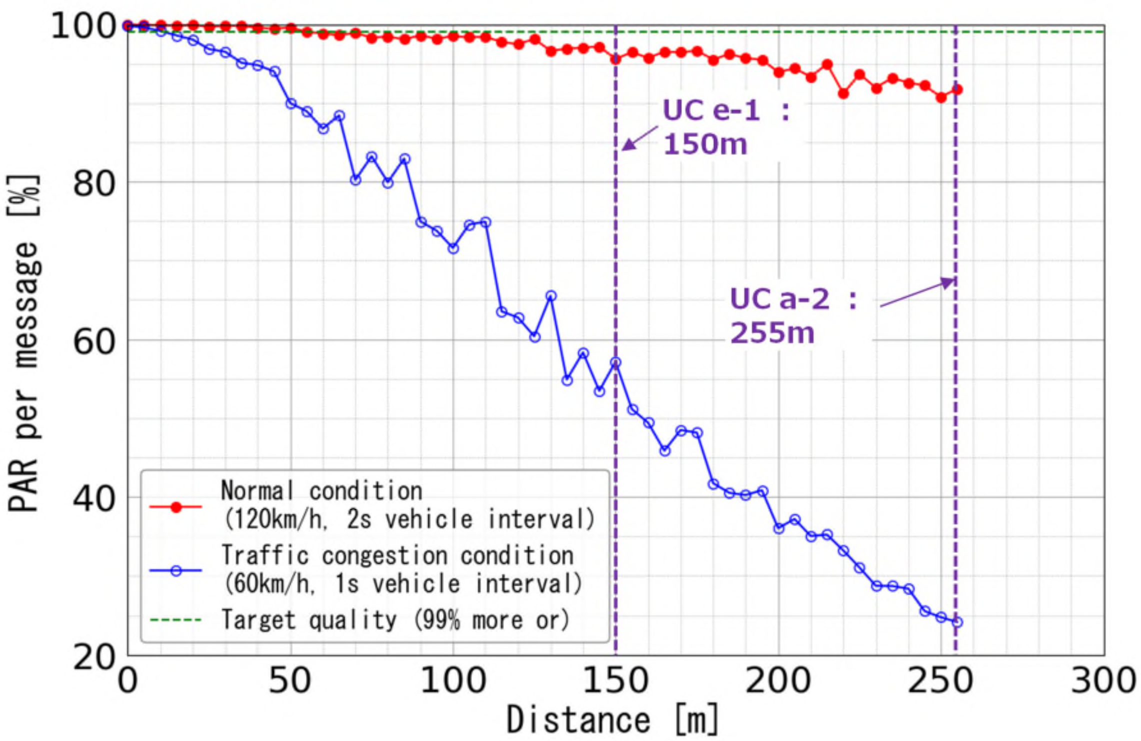



**Fig. 5.3.2-8 Results of evaluation case 5 (UC e-1: Driving assistance by providing information on emergency vehicles, UC a-2: Lane change assistance when the traffic is heavy): PAR per message**

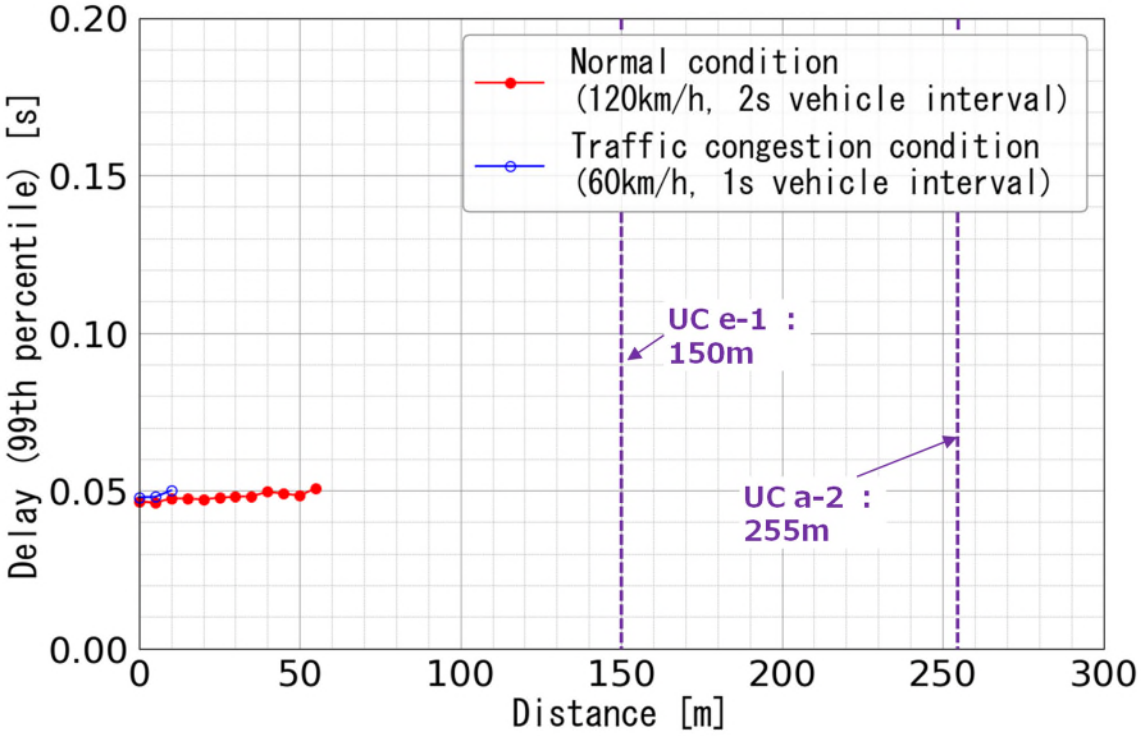



**Fig. 5.3.2-9 Results of evaluation case 5 (UC e-1: Driving assistance by providing information on emergency vehicles, UC a-2: Lane change assistance when the traffic is heavy): Delay (99% value)**

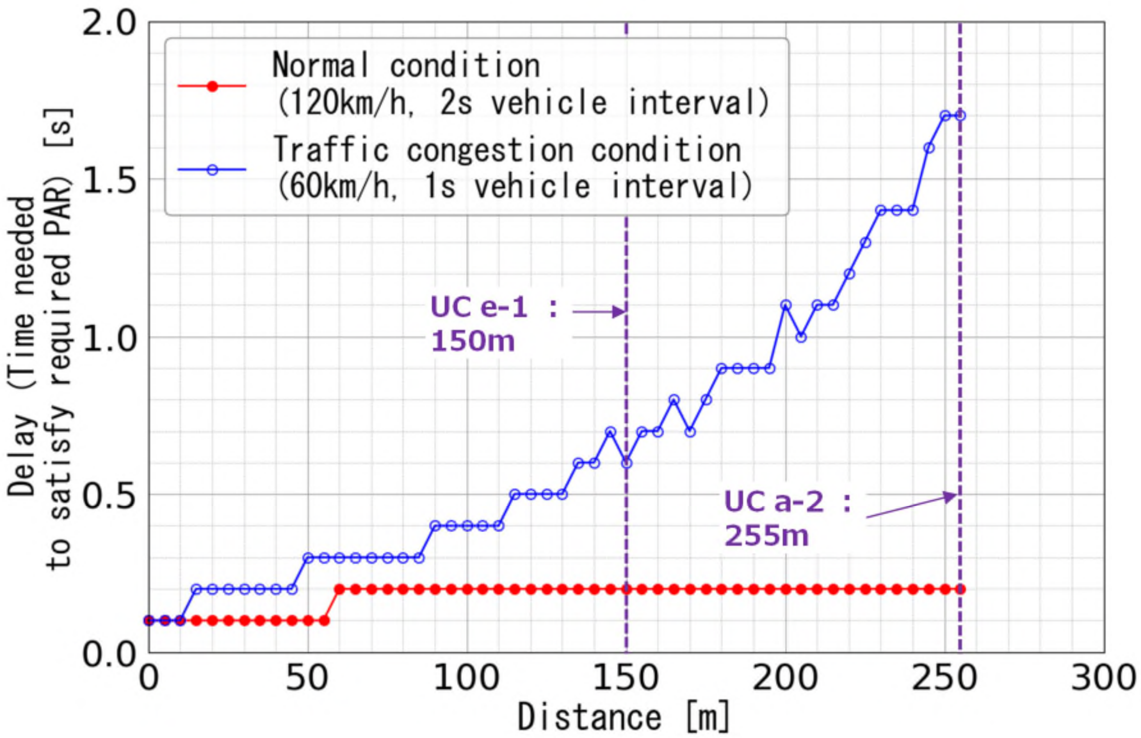



**Fig. 5.3.2-10 Results of evaluation case 5 (UC e-1: Driving assistance by providing information on emergency vehicles, UC a-2: Lane change assistance when the traffic is heavy): Delay (time until PAR required value is reached)**

(4) Discussion and issues regarding evaluation results

A summary of evaluation results in road sections of uninterrupted flow is given in Table 5.3.2-9. Evaluation cases in which use cases exist together (4 and 5) showed the same level of communication quality as evaluation cases in which use cases do not exist together (2 and 3). This is an effect of reducing size by message commonizing (information element multiplexing method).

In UC c-1 (Collision avoidance support for sudden stop or sudden deceleration in front), the communication requirements were met, regardless of whether there was a source of interference or the use case existed together with UC e-1. Because this use case relays messages, although the communication volume is large, multiple terminals are relaying messages, so packets can reach their destination. In UC e-1 (Driving assistance based on emergency vehicle information) and UC a-2 (Lane change assistance when the traffic is heavy), communication requirements were not met. This is because the necessary communication range is large and reception power is relatively small, so packet collision with other vehicles, including the source of interference, causes significant impact from interference.

Concerning vehicle interval distance, communication quality was better at a vehicle interval distance of two seconds at 120 km/h than one second at 60 km/h. It is thought that the greater vehicle interval distance means fewer vehicles transmitting and therefore less impact from interference. Therefore, it is possible that when the vehicle transmission interval is lengthened as a way of communications control technology, it could be an effective way to improve communication quality, since it decreases the number of vehicles transmitting per unit time, which lowers the impact from interference.

Performing an evaluation with a longer transmission interval as a way of communications control technology is an issue for the future.

**Table 5.3.2-9 Summary of evaluation in road sections of uninterrupted flow**

| Evaluation case | Mixed UC in the same channel | Classification by function | Use case | Communication requirements (Data/distance/PAR/delay) | Number of lanes/inter-vehicle distance: 3 lanes/120 km/h, 2s — Communication performance (PAR/delay) | Availability | Delay (Time until PAR required value is reached) | 3 lanes/60 km/h, 1s — Communication performance (PAR/delay) | Availability | Delay (Time until PAR required value is reached) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | None | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 338 bytes/250 m/99%/100 ms | 100%/85.8 ms | O | 100 ms | 99.3%/88.4 ms | O | 100 ms |
| 3 | None | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 329 bytes/255 m/99%/100 ms | 91.8%/ – | × | 200 ms | 24.2%/ – | × | 1700 ms |
| 4 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 338 bytes/150 m/99%/100 ms | 95.6%/ – | × | 200 ms | 57.1%/ – | × | 600 ms |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 338 bytes/250 m/99%/100 ms | 100%/85.8 ms | O | 100 ms | 99.3%/88.4 ms | O | 100 ms |
| 5 | Present | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 364 bytes/150 m/99%/100 ms | 95.6%/ – | × | 200 ms | 57.1%/ – | × | 600 ms |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | 364 bytes/255 m/99%/100 ms | 91.8%/ – | × | 200 ms | 24.2%/ – | × | 1700 ms |

Regarding the availability of correspondence;
Acceptable (O): Satisfies communication requirements (PAR, delay) within the communication area
Not acceptable (×): Communication requirements (PAR, delay) not achieved within communication area

### 5.3.3 Evaluation in merging sections and intersections

This section describes the results of the evaluation at merging sections and intersections, with the subject of evaluation being those SIP use cases for Cooperative Driving Automation [1] (below, “SIP UC”) that use direct communication (V2V and V2I), while considering combinations of use cases that could occur simultaneously at each location. The following describes the results in the order of evaluation conditions (Section (1)), link budget results (Section (2)), communication simulation results (Section (3)), and evaluation results discussion and issues (Section (4)).

(1) Evaluation conditions

This section describes the evaluation conditions in merging sections and intersections.

First, results of organizing the evaluation conditions in communication simulation are given in Table 5.3.3.1. Evaluation conditions were set that reflected the studies of communication channel allocation (Section 4.1) and communication message commonizing (the information element multiplexing method in Section 5.2.2(2)); along with that, evaluation conditions from FY2021 studies (*) were compared and more detailed communication parameters and evaluation indicators were selected. Next, details of evaluation conditions in merging sections and intersections are given in Table 5.3.3-2. As the content in the red box indicates, two of the communication channel allocation proposals (Section 4.1.3) (Proposal 1, with 10 MHz × three channels, and Proposal 6, with a 10 MHz channel and 20 MHz channel) were selected and V2V/V2I communication use cases that could occur simultaneously at merging sections and intersections are combined. It was anticipated that a source of interference would also exist, resulting from multiple occurrences of the same use case around the area subject to the use case. Also, based on the results of the study of message commonizing (information element multiplexing method) (Section 5.2.2(2)), information element multiplexing was set as a condition when there are information elements for multiple recipients in the same use case and when there are multiple use cases in the same channel. Furthermore, to verify the effectiveness of the communication control system in the upper layers (Section 4.2), a situation where the transmission interval is longer than the communication requirements was also evaluated.

(*) FY2021 research and development for expansion of radio wave resources of Ministry of Internal Affairs and Communications “Technical Study on 5.9 GHz Band V2X Communication System” (written as “FY2021 Ministry of Internal Affairs and Communications (5.9 GHz CV2X)” in Table 5.3.3 1); FY 2021 “Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase 2 - Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation” (written as “FY2021 SIP 5.9 GHz CV2X” in Table 5.3.3 1); and “2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS” (written as “FY2021 SIP 700 MHz ITS” in Table 5.3.3 1)

**Table 5.3.3-1 Evaluation of communication performance by communication simulation: organization of evaluation conditions**

| Items | | Main business | | FY2021 Ministry of Internal Affairs and Communications (5.9 GHz CV2X) | FY2021 SIP | |
|---|---|---|---|---|---|---|
| | | Evaluation | Prior evaluation | | 5.9 GHz CV2X | 700 MHz ITS (reference) |
| Operation modes | Security overhead | 250 bytes<br>(Assumptions of ITS FORUMRC-017) | | | None | Road side unit: 273 + 28n bytes, on-board unit:<br>27 bytes (assuming the method of the existing service) |
| | Communication channel | Multiple (reflecting consideration of project item b) | Single | | | |
| L1/L2 related | Communication specifications | LTE V2X (PC5) | | | | ARIB STD-T109 |
| | Number of transmissions | Twice (Blind HARQ) | | | Once | |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) | | | None | |
| Radio wave propagation | Path loss | ITU-R P.1411 | | | | Road-to-vehicle: 700 MHz ITS road-to-vehicle and road-to-road model<br>Vehicle-to-vehicle distance: Ito/Taga model |
| | Instantaneous fading | Present (3GPP EVA) | | | Present (Rayleigh/Nakagami) | Present (normal distribution) |
| | Shadowing | Present (logarithmic normal distribution (standard deviation: 3.68 dB)) | | | None | |
| | Shadowing loss | Present (consider shielding by large vehicles (10 dB)) | | | None | Present (0.5 dB/vehicle (maximum 8 dB)) |
| Communication conditions | Evaluation case<br>(SIP UC) | - Multiple UCs (two ways around merging sections and around intersections, and select a combination that is expected to cause communication congestion) | - Single UC (UC a-2, c-1, e-1 are candidates)<br>- Multiple UCs (a combination of the above)<br>*Targets V2V UC in any location, including UC (c-1) subject to effect verification in section b | - Single UC (all)<br>- Multiple UCs (limited to model cases) | - Single UC (UC a-1-4 around merging sections)<br>- Multiple UCs (UC b-1-1, c-1, c-2-2 around intersections)<br>*Select cases where communication congestion is assumed | - Single UC (expressway / prefectural and municipal roads and vehicle-to-road/vehicle-to-vehicle represented by 4 cases)<br>- Multiple UCs (all UCs) |
| | Common message | Present (refer to the results of ITS FORUM RC-017) | | None (separate message for each UC) | | Present (refer to ITS Connect TD-001) |
| | Source of interference | Present (on-board unit always transmits at 100 ms cycle) | | None (not considered for outside the communication area of the target UC) | | Present (existing services on the same channel) |
| Evaluation index | Item evaluated | PAR, delay (99% value), delay (time until PAR required value is reached) | | | PAR, delay (average) | PAR, delay (time until PAR required value is reached) |
| | Definition of communication quality | Per packet | | | | |

**Table 5.3.3-2 Details of evaluation conditions in merging sections and intersections**

| Items | | Main business | | FY2021 Ministry of Internal Affairs and Communications (5.9 GHz CV2X) | FY2021 SIP | |
|---|---|---|---|---|---|---|
| | | Evaluation | Prior evaluation | | 5.9 GHz CV2X | 700 MHz ITS (reference) |
| Operation modes | Security overhead | 250 bytes (Assumptions of ITS FORUMRC-017) | | | | …3 + 28n bytes, on-board unit: …g the method of the existing service) |
| | Communication channel | Multiple (reflecting consideration of project item b) | Single | | | |
| L1/L2 related | Communication specifications | LTE V2X (PC5) | | | | |
| | Number of transmissions | Twice (Blind HARQ) | | | | |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) | | | | |
| Radio wave propagation | Path loss | ITU-R P.1411 | | | | …00 MHz ITS road-to-vehicle and road- … distance: Ito/Taga model |
| | Instantaneous fading | Present (3GPP EVA) | | | | …stribution) |
| | Shadowing | Present (logarithmic normal distribution (standard deviation: 3.68 dB)) | | | | |
| | Shadowing loss | Present (consider shielding by large vehicles (10 dB)) | | | | …hicle (maximum 8 dB)) |
| Communication conditions | Evaluation case (SIP UC) | - Multiple UCs (two ways around merging sections and around intersections, and select a combination that is expected to cause communication congestion) | - Single UC (UC a-2, c-1, e-1 are candidates)<br>- Multiple UCs (a combination of the above)<br>*Targets V2V UC in any location, including UC (c-1) subject to effect verification in section b | | | …ssway / prefectural and municipal …e-to-road/vehicle-to-vehicle … cases) …UCs) |
| | Common message | Present (refer to the results of ITS FORUM RC-017) | | | | …TS Connect TD-001) |
| | Source of interference | Present (on-board unit always transmits at 100 ms cycle) | | | | …services on the same channel) |
| Evaluation index | Item evaluated | PAR, delay (99% value), delay (time until PAR required value is reached) | | | | …until PAR required value is reached) |
| | Definition of communication quality | Per packet | | | | |

- **Channel allocation: 2 ways**
  - **10 MHz × 3** (proposal 1 for consideration of project item b) and **10 MHz+20 MHz** (Proposal 6)
  - Consider the influence of adjacent channels (interference power)
- **Communication congestion control: Transmission interval review**
  - As an alternative, verify the possibility of improving communication quality when the transmission interval is set larger than the communication requirements (not considering time change)
- **Target locations: 2 ways**
  - Candidates for **merging sections and intersections**
- **Subject use cases: Multiple**
  - Combine V2I and V2V use cases that can occur simultaneously in the above two places
  - Multiplex messages for multiple use cases (Refer to the study of ITS FORUM RC-017)
- **Source of interference: With interference**
  - Interference sources exist outside the coverage area of the target use case (considering that the use case occurs in multiple places at the same time)

The subject use cases and road environments at merging sections and intersections are given in Table 5.3.3-3, while images of the overlapping of use cases at each location are given in Fig. 5.3.3-1 and Fig. 5.3.3-2, respectively.

**Table 5.3.3-3 Subject use cases and road environments at merging sections and intersections**

| | Merging section on expressway | Intersection on general roads |
|---|---|---|
| Subject use cases | V2I use case (UC a-1-3), V2V use case (UC a-2, c-1, e-1) existing together<br>*A use case that could happen simultaneously is combined with a use case of merging assistance with roadside control (UC a-1-3) | V2I use case (UC b-1-1, c-2-2), V2V use case (UC a-2, c-1, e-1) existing together<br>*A use case that could happen simultaneously is combined with a use case of driving assistance with traffic signal information or intersection information |
| Road conditions | Mainline: 3 lanes; connecting road: 1 lane | 3 lanes in each direction |
| Traffic flow (vehicle density) | - During normal times (vehicle speed of 100 km/h, 2 s vehicle interval)<br>- During congestion (vehicle speed of 50 km/h, 1 s vehicle interval)<br>*See study conditions in UC a-1-3 communication scenario draft | Lateral driving lanes (outer side and central):<br>- During normal times (vehicle speed of 70 km/h, 2 s vehicle interval)<br>- During congestion (vehicle speed of 30 km/h, 1 s vehicle interval)<br>Lateral right-turn lane (inner side), longitudinal lanes:<br>- Static (2 m vehicle interval)<br>*See study conditions in UC c-2-2 communication scenario draft |
| Source of interference | Exists outside communication area of subject use case (surrounding vehicle transmits all information from the same use case)<br>*Exists within a range of about 500 m both upstream and downstream, with the position of the receiving vehicle that is the subject of evaluation as the center | Exists outside communication area of subject use case (surrounding vehicle transmits all information from the same use case)<br>*Exists within a range of about 500 m both upstream and downstream, with the position of the receiving vehicle that is the subject of evaluation as the center. Vehicles in the longitudinal direction exist within a range of about 100 m from the center of the intersection (not within line of sight from the position of receiving vehicle in the lateral direction) |

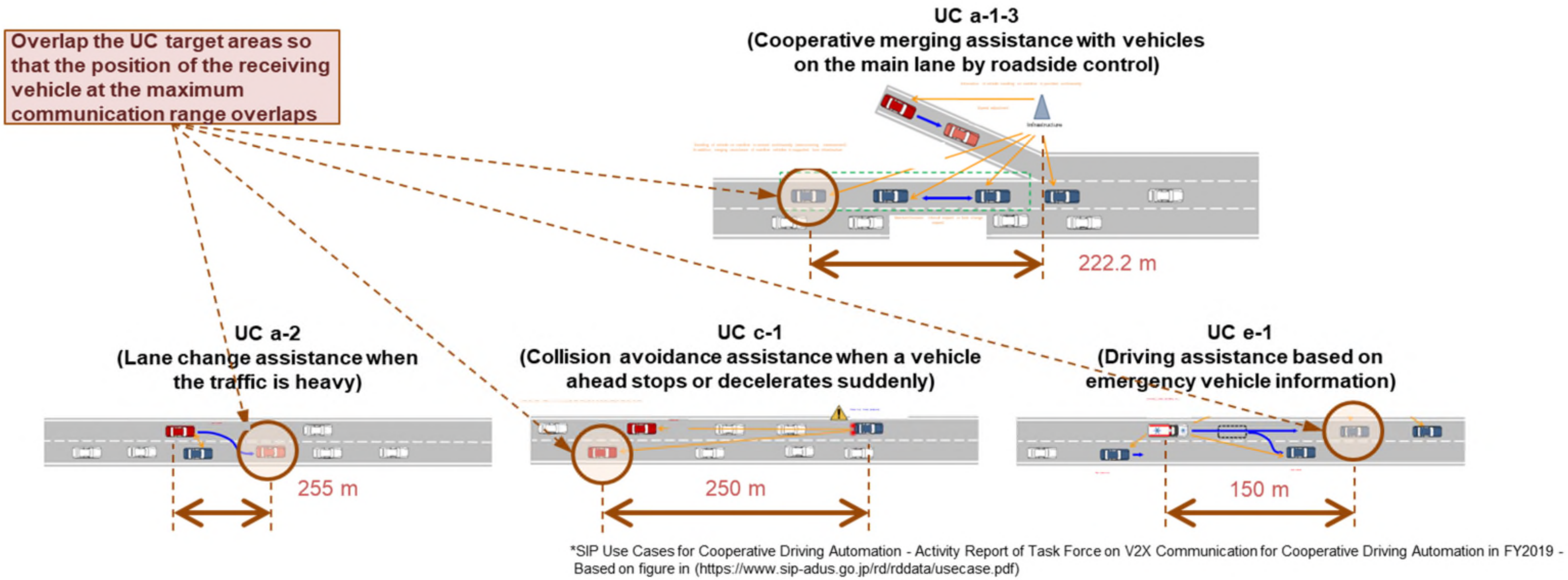



**Fig. 5.3.3-1 Image of overlapping of use cases (merging section on expressway)**

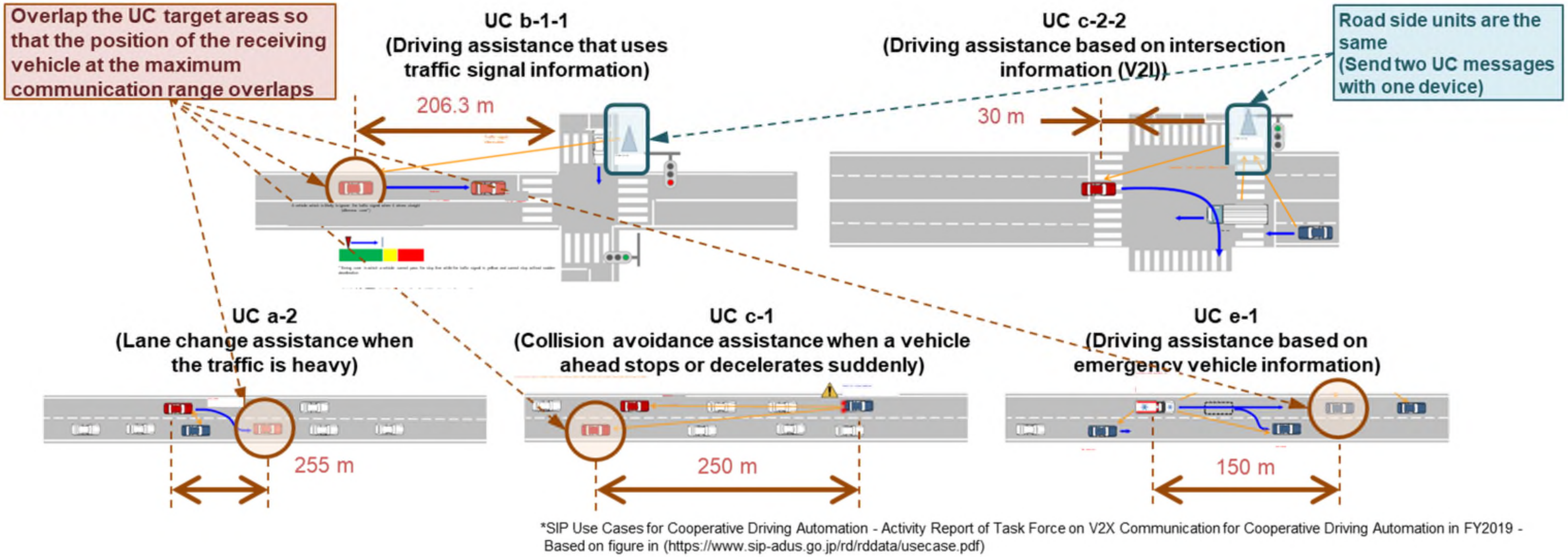



**Fig. 5.3.3-2 Image of overlapping of use cases (intersection on general roads)**

Correspondences between use cases and channels at each location are given in Table 5.3.3-4 and Table 5.3.3-5 respectively. Situations with a single channel were also evaluated for comparison to the channel allocation proposal (where there are multiple channels) selected as an evaluation condition, and the conditions are listed side by side.

**Table 5.3.3-4 Correspondences between use cases and channels (merging section on expressway)**

<table>
<tr><th rowspan="2">Classification by function</th><th rowspan="2">Use case</th><th rowspan="2">Communication method</th><th colspan="2">Multiple channels (Communication channel allocation proposal)</th><th colspan="2">Single channel (Conditions performed for comparison)</th></tr>
<tr><th>Proposal 1 (10 MHz × 3Ch)</th><th>Proposal 6 (10 MHz + 20 MHz)</th><th>10 MHz</th><th>20 MHz</th></tr>
<tr><td>a. Merging/lane change assistance</td><td>a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control</td><td>V2I</td><td>Ch1 (10 MHz)</td><td>Ch1 (10 MHz)</td><td rowspan="4">Ch1 (10 MHz)</td><td rowspan="4">Ch1 (20 MHz)</td></tr>
<tr><td>e. Lookahead information: Emergency vehicle notification</td><td>e-1. Driving assistance based on emergency vehicle information</td><td rowspan="3">V2V</td><td rowspan="2">Ch2 (10 MHz)</td><td rowspan="3">Ch2 (20 MHz)</td></tr>
<tr><td>a. Merging/ lane change assistance</td><td>a-2. Lane change assistance when the traffic is heavy</td></tr>
<tr><td>c. Lookahead information: Collision avoidance</td><td>c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly</td><td>Ch3 (10 MHz)</td></tr>
</table>

**Table 5.3.3-5 Correspondences between use cases and channels (intersection on general roads)**

<table>
<tr><th rowspan="2">Classification by function</th><th rowspan="2">Use case</th><th rowspan="2">Communication method</th><th colspan="2">Multiple channels (Communication channel allocation proposal)</th><th colspan="2">Single channel (Conditions performed for comparison)</th></tr>
<tr><th>Proposal 1 (10 MHz × 3Ch)</th><th>Proposal 6 (10 MHz + 20 MHz)</th><th>10 MHz</th><th>20 MHz</th></tr>
<tr><td>b. Traffic signal information</td><td>b-1-1. Driving assistance by using traffic signal information (V2I)</td><td rowspan="2">V2I</td><td rowspan="2">Ch1 (10 MHz)</td><td rowspan="2">Ch1 (10 MHz)</td><td rowspan="5">Ch1 (10 MHz)</td><td rowspan="5">Ch1 (20 MHz)</td></tr>
<tr><td>c. Lookahead information: Collision avoidance</td><td>c-2-2. Driving assistance based on intersection information (V2I)</td></tr>
<tr><td>e. Lookahead information: Emergency vehicle notification</td><td>e-1. Driving assistance based on emergency vehicle information</td><td rowspan="3">V2V</td><td rowspan="2">Ch2 (10 MHz)</td><td rowspan="3">Ch2 (20 MHz)</td></tr>
<tr><td>a. Merging/ lane change assistance</td><td>a-2. Lane change assistance when the traffic is heavy</td></tr>
<tr><td>c. Lookahead information: Collision avoidance</td><td>c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly</td><td>Ch3 (10 MHz)</td></tr>
</table>

Correspondences between use cases and data sizes at each location are given in Table 5.3.3-6 and Table 5.3.3-7 respectively. As indicated earlier, in this evaluation, information element multiplexing was set as a condition when there are information elements for multiple recipients in the same use case and when there are multiple use cases in the same channel. Therefore, concerning negotiation/update requests in UC a-1-3 (Cooperative merging assistance with vehicles on the main lane by roadside control), information elements (negotiation information) with different recipient vehicles are multiplexed, and further, when the vehicle transmits information from multiple use cases, information elements (use case specific information) from each use case that is being transmitted on the same channel are multiplexed. The information element multiplexing method at each location is given in Table 5.3.3-8 to Table 5.3.3-11 and Table 5.3.3-12 to Table 5.3.3-15, respectively.

Details of communication conditions are given in Table 5.3.3-16. As explained in Section 5.3.1, only cases that used CV2X (LTE V2X (PC5)) as the wireless communication system were evaluated.

### Table 5.3.3-6 Correspondences between use cases and data sizes (merging section on expressway)

| Soucre | Classification by function | Use case | Message name | Communication method | Multiplexing of information elements (Conditions set in this evaluation) | | | | | | | | No multiplexing of information elements (reference) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Multiple channels (Communication channel allocation plan) | | | | Single channel (Conditions performed for comparison) | | | | |
| | | | | | Proposal 1 (10 MHz × 3Ch) | | Proposal 6 (10 + 20 MHz) | | 10 MHz | | 20 MHz | | |
| | | | | | Channel | **Data size [byte]** | Channel | **Data size [byte]** | Channel | **Data size [byte]** | Channel | **Data size [byte]** | **Data size [byte]** |
| Roadside infrastructure | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information (*1) | I2V | Ch1 | **1572** | Ch1 | **1572** | Ch1 | **1572** | Ch1 | **1572** | **1572** |
| | | | Negotiation request<br>Update request<br>(*2) | | | **718 (×4)** | | **718 (×4)** | | **718 (×4)** | | **718 (×4)** | **298 (×48)** |
| Vehicle | | | Control request | V2I | | **329** | | **329** | | **398** | | **398** | **329** |
| | | | Negotiation response<br>Update response | | | | | | | | | | |
| | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | Ch2 | **364** | Ch2 | **368** | | | | | **334** |
| | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request | | | | | | | | | | **329** |
| | | | Negotiation response<br>Update response | | | | | | | | | | |
| | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | Ch3 | **338** | | | | | | | **338** |

(*1) The data size is for vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 708 bytes)

(*2) The data size is for vehicle speed of 50 km/h and 1s between vehicles (for 100 km/h and 2s between vehicles, with multiplexed information elements: 718 (× 2) bytes, without multiplexed: 298 (× 16) bytes) and "718 (× 4)" indicates that 718 bytes are transmitted four times).

**Table 5.3.3-7 Correspondences between use cases and data sizes (intersection on general roads)**

| Source | Classification by function | Use case | Message name | Communication method | Multiplexing of information elements (Conditions set in this evaluation) | | | | | | | | No multiplexing of information elements (reference) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Multiple channels (Communication channel allocation plan) | | | | Single channel (Conditions performed for comparison) | | | | |
| | | | | | Proposal 1 (10 MHz × 3Ch) | | Proposal 6 (10 + 20 MHz) | | 10 MHz | | 20 MHz | | |
| | | | | | Channel | **Data size [bytes]** | Channel | **Data size [bytes]** | Channel | **Data size [byte]** | Channel | **Data size [bytes]** | **Data size [bytes]** |
| Roadside infrastructure (*1) | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | I2V | Ch1 | **1488** | Ch1 | **1488** | Ch1 | **1488** | Ch1 | **1488** | **1488** |
| | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | | | | | | | | | | |
| Vehicle | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | Ch2 | **364** | Ch2 | **368** | | **368** | | **368** | **334** |
| | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request | | | | | | | | | | **329** |
| | | | Negotiation response<br>Update response | | | | | | | | | | |
| | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | Ch3 | **338** | | | | | | | **338** |

(*1) Since the UC b-1-1 message is included in the UC c-2-2 message, it is assumed that only one message (UC c-2-2 message) will be sent from the roadside infrastructure

## Table 5.3.3-8 Information element multiplexing method (merging section on expressway) – Communication channel Proposal 1 –

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | | | | | |
| | | | | | | | | | | | Roadside control information | Surrounding vehicle information | Negotiation information (UC a-1-3) | | | | Negotiation information (UC a-2) | Hazard information | |
| | | | | | | | | | | | | a-1-x | Vehicle #1 | Vehicle #2 | ··· | Vehicle #15 (*2) | | c-1,c-3 | e-1 (*5) |
| Roadside infrastructure | Non-specific vehicles | Ch1 | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | I2V | 1572 (*3) | 250 | 18 | | 1 | 1303 (*4) | | | | | | | |
| | Vehicle #1 to Vehicle #15 | | | | Negotiation request Update request | | 718 (*6) | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | Vehicle #16 to Vehicle #30 | | | | Negotiation request Update request | | 718 | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | Vehicle #31 to Vehicle #45 | | | | Negotiation request Update request | | 718 | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | Vehicle #45 to Vehicle #48 (*1) | | | | Negotiation request Update request | | 718 | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| Vehicle | Roadside infrastructure | Ch1 | | | Control request Negotiation response Update response | V2I | 329 | 250 | 18 | 31 | | | 30 | | | | | | |
| | Non-specific vehicles | Ch2 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | 364 | 250 | 18 | 31 | | | | | | | 30 | | 35 |
| | | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request Update request | | | | | | | | | | | | | | |
| | | | | | Negotiation response Update response | | | | | | | | | | | | | | |
| | | Ch3 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | 338 | 250 | 18 | 31 | | | | | | | | 39 | |

(*1) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, maximum is 16) (*2) For 10 MHz bandwidth (vehicle #39 is the largest for 20 MHz bandwidth)
(*3) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 708 bytes) (*4) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 439 bytes)
(*5) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."
(*6) For 10 MHz bandwidth (1438 bytes for 20 MHz bandwidth)

**Table 5.3.3-9 Information element multiplexing method (merging section on expressway) – Communication channel Proposal 6 –**

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | | | | | |
| | | | | | | | | | | | Roadside control information | Surrounding vehicle information | Negotiation information (UC a-1-3) | | | | Negotiation information (UC a-2) | Hazard information | |
| | | | | | | | | | | | | a-1-x | Vehicle #1 | Vehicle #2 | ··· | Vehicle #15 (*2) | | c-1,c-3 | e-1 (*5) |
| Roadside infrastructure | **Non-specific vehicles** | **Ch1** | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | I2V | **1572 (*3)** | 250 | 18 | | 1 | 1303 (*4) | | | | | | | |
| | **Vehicle #1 to Vehicle #15** | | | | Negotiation request<br>Update request | | **718 (*6)** | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | **Vehicle #16 to Vehicle #30** | | | | Negotiation request<br>Update request | | **718** | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | **Vehicle #31 to Vehicle #45** | | | | Negotiation request<br>Update request | | **718** | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| | **Vehicle #45 to Vehicle #48 (*1)** | | | | Negotiation request<br>Update request | | **718** | 250 | 18 | | | | 30 | 30 | ··· | 30 | | | |
| Vehicle | **Roadside infrastructure** | **Ch1** | | | Control request<br>Negotiation response<br>Update response | V2I | **329** | 250 | 18 | 31 | | | 30 | | | | | | |
| | **Non-specific vehicles** | **Ch2** | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | **368** | 250 | 18 | 31 | | | | | | | 30 | 39 (*7) | |
| | | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request<br>Negotiation response<br>Update response | | | | | | | | | | | | | | |
| | | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | | | | | | | | | | | | | |

(*1) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, maximum is 16) (*2) For 10 MHz bandwidth (vehicle #39 is the largest for 20 MHz bandwidth)

(*3) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 708 bytes) (*4) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 439 bytes)

(*5) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

(*6) For 10 MHz bandwidth (1438 bytes for 20 MHz bandwidth)

(*7) Use case-specific information for UC e-1 and c-1 with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") assumes 39 bytes that share the same area as emergency information and can accommodate both UC e-1 (35 bytes) and c-1 (39 bytes).

## Table 5.3.3-10 Information element multiplexing method (merging section on expressway) – Single channel –

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes] Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information: Roadside control information | Surrounding vehicle information | Negotiation information (UC a-1-3) | | | | Negotiation information (UC a-2) | Hazard information | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | a-1-x | Vehicle #1 | Vehicle #2 | ・・・ | Vehicle #15 (*2) | | c-1,c-3 | e-1 (*5) |
| Roadside infrastructure | **Non-specific vehicles** | **Ch1** | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | I2V | **1572 (*3)** | 250 | 18 | | 1 | 1303 (*4) | | | | | | | |
| | **Vehicle #1 to Vehicle #15** | | | | Negotiation request Update request | | **718 (*6)** | 250 | 18 | | | | 30 | 30 | ・・・ | 30 | | | |
| | **Vehicle #16 to Vehicle #30** | | | | Negotiation request Update request | | **718** | 250 | 18 | | | | 30 | 30 | ・・・ | 30 | | | |
| | **Vehicle #31 to Vehicle #45** | | | | Negotiation request Update request | | **718** | 250 | 18 | | | | 30 | 30 | ・・・ | 30 | | | |
| | **Vehicle #45 to Vehicle #48 (*1)** | | | | Negotiation request Update request | | **718** | 250 | 18 | | | | 30 | 30 | ・・・ | 30 | | | |
| Vehicle | **Roadside infrastructure** | | | | Control request | V2I | | | | | | | | | | | | | |
| | | | | | Negotiation response Update response | | | | | | | | | | | | | | |
| | **Non-specific vehicles** | | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | | | | | | | | | | | | | |
| | | **Ch1** | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request Update request | | **398** | 250 | 18 | 31 | | | 30 | | | | 30 | 39 (*7) | |
| | | | | | Negotiation response Update response | | | | | | | | | | | | | | |
| | | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | | | | | | | | | | | | | |

(*1) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, maximum is 16) (*2) For 10 MHz bandwidth (vehicle #39 is the largest for 20 MHz bandwidth)
(*3) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 708 bytes) (*4) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 439 bytes)
(*5) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."
(*6) For 10 MHz bandwidth (1438 bytes for 20 MHz bandwidth)
(*7) Use case-specific information for UC e-1 and c-1 with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") assumes 39 bytes that share the same area as emergency information and can accommodate both UC e-1 (35 bytes) and c-1 (39 bytes).

## Table 5.3.3-11 Information element multiplexing method (merging section on expressway) – No multiplexing of information elements (for reference) –

| Source | Destination | Classification by function | Use case | Message name | Communication method | Data size [bytes] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | | | | | |
| | | | | | | | | | | Roadside control information | Surrounding vehicle information | Negotiation information (UC a-1-3) | | | | Negotiation information (UC a-2) | Hazard information | |
| | | | | | | | | | | | a-1-x | Vehicle #1 | Vehicle #2 | ・・・ | Vehicle #15 (*2) | | c-1,c-3 | e-1 (*5) |
| Roadside infrastructure | **Non-specific vehicles** | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | I2V | **1572 (*3)** | 250 | 18 | | 1 | 1303 (*4) | | | | | | | |
| | **Vehicle #1** | | | Negotiation request<br>Update request | | **298** | 250 | 18 | | | | 30 | | | | | | |
| | **Vehicle #2** | | | Negotiation request<br>Update request | | **298** | 250 | 18 | | | | 30 | | | | | | |
| | ・・・ | | | ・・・ | | | | | | | | | | | | | | |
| | **Vehicle #48 (*1)** | | | Negotiation request<br>Update request | | **298** | 250 | 18 | | | | 30 | | | | | | |
| Vehicle | **Roadside infrastructure** | | | Control request<br>Negotiation response<br>Update response | V2I | **329** | 250 | 18 | 31 | | | 30 | | | | | | |
| | **Non-specific vehicles** | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | **334** | 250 | 18 | 31 | | | | | | | | | 35 |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request<br>Negotiation response<br>Update response | | **329** | 250 | 18 | 31 | | | | | | | 30 | | |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | **338** | 250 | 18 | 31 | | | | | | | | 39 | |

(*1) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, maximum is 16) (*2) For 10 MHz bandwidth (vehicle #39 is the largest for 20 MHz bandwidth)

(*3) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 708 bytes) (*4) For vehicle speed of 50 km/h and 1s between vehicles (for vehicle speed of 100 km/h and 2s between vehicles, 439 bytes)

(*5) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

### Table 5.3.3-12 Information element multiplexing method (intersection on general roads) – Communication channel allocation Proposal 1 –

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes]: Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information: Surrounding vehicle information | Intersection information | Negotiation information | Hazard information | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | c-2-2 | | | c-1,c-3 | e-1 (*2) |
| Roadside infrastructure | Non-specific vehicles | Ch1 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | I2V | 1488 (*1) | 250 | 18 | | 824 | 396 | | | |
| | | | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | | | | | | | | | | |
| Vehicle | Non-specific vehicles | Ch2 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | 364 | 250 | 18 | 31 | | | 30 | | 35 |
| | | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request | | | | | | | | | | |
| | | | | | Negotiation response<br>Update response | | | | | | | | | | |
| | | Ch3 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | 338 | 250 | 18 | 31 | | | | 39 | |

(*1) Since the UC b-1-1 message is included in the UC c-2-2 message, it is assumed that only one message (UC c-2-2 message) will be sent from the roadside infrastructure
(*2) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

## Table 5.3.3-13 Information element multiplexing method (intersection on general roads) – Communication channel allocation Proposal 6 –

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes] Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information: Surrounding vehicle information c-2-2 | Intersection information | Negotiation information | Hazard information c-1,c-3 | Hazard information e-1 (*2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Roadside infrastructure** | **Non-specific vehicles** | **Ch1** | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | I2V | **1488 (*1)** | 250 | 18 | | 824 | 396 | | | |
| | | | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | | | | | | | | | | |
| **Vehicle** | **Non-specific vehicles** | **Ch2** | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | **368** | 250 | 18 | 31 | | | 30 | 39 (*3) | |
| | | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request | | | | | | | | | | |
| | | | | | Negotiation response<br>Update response | | | | | | | | | | |
| | | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | | | | | | | | | |

(*1) Since the UC b-1-1 message is included in the UC c-2-2 message, it is assumed that only one message (UC c-2-2 message) will be sent from the roadside infrastructure

(*2) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

(*3) Use case-specific information for UC e-1 and c-1 with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") assumes 39 bytes that share the same area as emergency information and can accommodate both UC e-1 (35 bytes) and c-1 (39 bytes).

## Table 5.3.3-14 Information element multiplexing method (intersection on general roads) – Single channel –

| Source | Destination | Channel | Classification by function | Use case | Message name | Communication method | Data size [bytes] Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information: Surrounding vehicle information c-2-2 | Intersection information | Negotiation information | Hazard information c-1,c-3 | Hazard information e-1 (*2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roadside infrastructure | Non-specific vehicles | Ch1 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | I2V | 1488 (*1) | 250 | 18 | | 824 | 396 | | | |
| | | | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | | | | | | | | | | |
| Vehicle | Non-specific vehicles | Ch1 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | 368 | 250 | 18 | 31 | | | 30 | 39 (*3) | |
| | | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request | | | | | | | | | | |
| | | | | | Negotiation response<br>Update response | | | | | | | | | | |
| | | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | | | | | | | | | |

(*1) Since the UC b-1-1 message is included in the UC c-2-2 message, it is assumed that only one message (UC c-2-2 message) will be sent from the roadside infrastructure

(*2) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

(*3) Use case-specific information for UC e-1 and c-1 with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") assumes 39 bytes that share the same area as emergency information and can accommodate both UC e-1 (35 bytes) and c-1 (39 bytes).

## Table 5.3.3-15 Information element multiplexing method (intersection on general roads) – No multiplexing of information elements (for reference) –

| Source | Destination | Classification by function | Use case | Message name | Communication method | Data size [bytes] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Overhead | (1) Message information | (3) Basic vehicle information | (4) Use case specific information | | | | |
| | | | | | | | | | | Surrounding vehicle information | Intersection information | Negotiation information | Hazard information | |
| | | | | | | | | | | c-2-2 | | | c-1,c-3 | e-1 (*2) |
| Roadside infrastructure | **Non-specific vehicles** | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | I2V | **1488 (*1)** | 250 | 18 | – | 824 | 396 | | | |
| | | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | | | | | | | | | | |
| Vehicle | **Non-specific vehicles** | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | V2V | **334** | 250 | 18 | 31 | | | | | 35 |
| | | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request<br>Update request<br>Negotiation response<br>Update response | | **329** | 250 | 18 | 31 | | | 30 | | |
| | | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | | **338** | 250 | 18 | 31 | | | | 39 | |

(*1) Since the UC b-1-1 message is included in the UC c-2-2 message, it is assumed that only one message (UC c-2-2 message) will be sent from the roadside infrastructure
(*2) ITS FORUM RC-017 6.2.1.10 (1) table with reference to last year's study ("2021 Cross-Ministerial Strategic Innovation Promotion Program (SIP) Phase 2 – Automated Driving (Expansion of Systems and Services) A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS") 35 bytes are assumed, excluding the information elements described as"assumed not to be used."

**Table 5.3.3-16 Evaluation in merging sections and intersections, details of communication conditions**

| Items | | Value |
|---|---|---|
| L1/L2 related | Center frequency | 5890 MHz |
| | Antenna power | 23 dBm |
| | System bandwidth | 10 MHz |
| | Modulation method | QPSK, 16QAM/SC-FDM |
| | Error correction (encoding rate) | Data signal: turbo code (0.5)<br>Control signal: TBCC (0.1) |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) |
| | Noise power density | -173.9 dBm/Hz |
| | Noise figure | 10 dB |
| | Fixed deterioration | 5 dB |
| | Antenna gain | Road side unit: 6 dBi, on-board unit: 4 dBi |
| | Antenna directivity | None |
| | Cable/connector loss | Road side unit: 0 dBi, on-board unit: 4 dBi |
| | Security overhead | 250 bytes<br>(Assumptions of ITS FORUM RC-017) |
| | Sensing window | 1000 ms |
| | Resource selection window | 50 ms |
| | Syncronization | GNSS |
| | Number of transmissions | Twice (blind HARQ) |
| Radio wave propagation | Path loss | ITU-R P.1411 |
| | Instantaneous fading | Consideration model by 3GPP (*1) |
| | Shadowing | Logarithmic normal distribution (standard deviation: 3.68 dB) (*2) |
| | Shadowing loss | When there is a large vehicle between the sending and receiving: 10 dB (*3) |
| | Antenna height | Road side unit: 6.0 m,<br>on-board unit: 1.6 m (passenger vehicle), 4.1 m (large vehicle) |

*1 Extended Vehicular A model 3GPP TS 36.101 and 3GPP TS 36.104

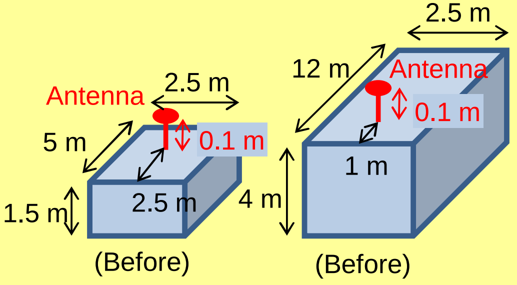
*2 Fading model considering spatial correlation, referring to 3GPP TR 36.885 (A.1.4 channel model)

*3 Based on 3GPP TR 38.901 Blockage model B (knife edge diffraction model), attenuation caused by one adjacent large vehicle was calculated based on vehicle speed of 40 km/h with one-second vehicle interval

Compare the evaluation conditions of FY2021 examination (SIP, Ministry of Internal Affairs and Communications' research and development) and select more precise communication parameters and evaluation indicators

Antenna installation conditions (on-board unit)

- Passenger vehicle - Large vehicle



(2) Link budget results

This section describes the results of doing link budget as an evaluation at the link level (1:1 communication). Results of link budget where the communication channel allocation proposals are Proposal 1 (10 MHz × 3 channels) and Proposal 6 (10 MHz + 20 MHz), as indicated in the evaluation conditions (Section (1)), are given in Table 5.3.3-17 and Table 5.3.3-18 respectively.

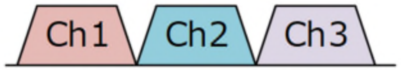
If there is no shadowing by a large vehicle, all use cases are supported (i.e., the link margin at the maximum communication range is at least 0 dB), but if there is shadowing by a large vehicle, UC a-1-3 (Cooperative merging assistance with vehicles on the main lane by roadside control) and e-1 (Driving assistance based on emergency vehicle information), which have a short maximum communication range (within 150 meters), are supported, but UC c-1 (Collision avoidance support for sudden stop or sudden deceleration in front) and a-2 (Lane change assistance when the traffic is heavy), in which the maximum communication range is great (255 meters) and exceeds the maximum communication range of the link budget, are not supported.

For the sake of comparison with situations where multiple channels are used (communication channel allocation Proposals 1 and 6), results of link budget with a single channel (10 MHz and 20 MHz) are given in Table 5.3.3-19 and Table 5.3.3-20 respectively.

Because use cases exist together on one channel more often when there is a single channel than when there are multiple channels, the packet sizes grow larger, but the size of each use case’s information elements (a few dozen bytes) is smaller than the security overhead size (250 bytes), so even if information element multiplexing causes information elements from multiple use cases to be bundled together into one packet, there is not a big difference in packet size, so the results with a single channel are similar to those with multiple channels.

**Table 5.3.3-17 Link budget results (communication channel allocation Proposal 1, 10 MHz × 3 channels)**

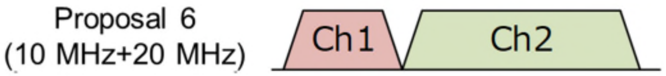
Proposal 1
(10 MHz × 3Ch)




| No. | Classification by function | Use case | Message name | Group | Channel | Communication requirements (Data/distance/PAR) | Link margin (With/without large vehicle shielding) | Maximum communication range (With/without large vehicle shielding) | Availability (With/without large vehicle shielding) |
|---|---|---|---|---|---|---|---|---|---|
| **Merging section on expressway** | | | | | | | | | |
| 1 | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | B | 1 | 1572 bytes/222.2 m/99% | +2.8 dB/+12.8 dB | 308.3 m/852.6 m | O/O |
| 2 | | | Negotiation request/ update request | B | 1 | 718 bytes/222.2 m/99% | +5.1 dB/+15.1 dB | 398.3 m/969.0 m | O/O |
| 3 | | | Negotiation response/ update response | B | 1 | 329 bytes/222.2 m/99% | +6.8 dB/+16.8 dB | 488.2 m/1072.9 m | O/O |
| 4 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 2 | 368 bytes/150.0 m/99% | +4.3 dB/+14.3 dB | 220.6 m/392.2 m | O/O |
| 5 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 2 | 368 bytes/255.0 m/99% | -2.5 dB/+7.5 dB | 220.6 m/392.2 m | ×/O |
| 6 | | | Negotiation response/ update response | E | 2 | 368 bytes/255.0 m/99% | -2.5 dB/+7.5 dB | 220.6 m/392.2 m | ×/O |
| 7 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 3 | 338 bytes/250.0 m/99% | -2.2 dB/+7.8 dB | 220.6 m/392.2 m | ×/O |
| **Intersection on general roads** | | | | | | | | | |
| 8 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | A | 1 | 1488 bytes/206.3 m/99% | +4.2 dB/+14.2 dB | 334.4 m/887.9 m | O/O |
| 9 | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | A | 1 | 1488 bytes/75.2 m/99% | +12.9 dB/+22.9 dB | 334.4 m/887.9 m | O/O |
| 10 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 2 | 368 bytes/150.0 m/99% | +3.7 dB/+13.7 dB | 214.0 m/380.5 m | O/O |
| 11 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 2 | 368 bytes/255.0 m/99% | -3.0 dB/+7.0 dB | 214.0 m/380.5 m | ×/O |
| 12 | | | Negotiation response/ update response | E | 2 | 368 bytes/255.0 m/99% | -3.0 dB/+7.0 dB | 214.0 m/380.5 m | ×/O |
| 13 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 3 | 338 bytes/250.0 m/99% | -2.7 dB/+7.3 dB | 214.0 m/380.5 m | ×/O |

Available (O): Link margin at the required communication range is 0 dB or more
Not available (×): Link margin at required communication range is less than 0 dB

**Table 5.3.3-18 Link budget results (communication channel allocation Proposal 6, 10 MHz + 20 MHz)**




| No. | Classification by function | Use case | Message name | Group | Channel | Communication requirements (Data/distance/PAR) | Link margin (With/without large vehicle shielding) | Maximum communication range (With/without large vehicle shielding) | Availability (With/without large vehicle shielding) |
|---|---|---|---|---|---|---|---|---|---|
| **Merging section on expressway** | | | | | | | | | |
| 1 | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | B | 1 | 1572 bytes/222.2 m/99% | +2.8 dB/+12.8 dB | 308.3 m/852.6 m | O/O |
| 2 | | | Negotiation request/ update request | B | 1 | 718 bytes/222.2 m/99% | +5.1 dB/+15.1 dB | 398.3 m/969.0 m | O/O |
| 3 | | | Negotiation response/ update response | B | 1 | 329 bytes/222.2 m/99% | +6.8 dB/+16.8 dB | 488.2 m/1072.9 m | O/O |
| 4 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 2 | 368 bytes/150.0 m/99% | +4.4 dB/+14.4 dB | 222.1 m/394.9 m | O/O |
| 5 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 2 | 368 bytes/255.0 m/99% | -2.4 dB/+7.6 dB | 222.1 m/394.9 m | ×/O |
| 6 | | | Negotiation response/ update response | E | 2 | 368 bytes/255.0 m/99% | -2.4 dB/+7.6 dB | 222.1 m/394.9 m | ×/O |
| 7 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 2 | 368 bytes/250.0 m/99% | -2.1 dB/+7.9 dB | 222.1 m/394.9 m | ×/O |
| **Intersection on general roads** | | | | | | | | | |
| 8 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | A | 1 | 1488 bytes/206.3 m/99% | +4.2 dB/+14.2 dB | 334.4 m/887.9 m | O/O |
| 9 | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | A | 1 | 1488 bytes/75.2 m/99% | +12.9 dB/+22.9 dB | 334.4 m/887.9 m | O/O |
| 10 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 2 | 368 bytes/150.0 m/99% | +3.8 dB/+13.8 dB | 215.5 m/383.1 m | O/O |
| 11 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 2 | 368 bytes/255.0 m/99% | -2.9 dB/+7.1 dB | 215.5 m/383.1 m | ×/O |
| 12 | | | Negotiation response/ update response | E | 2 | 368 bytes/255.0 m/99% | -2.9 dB/+7.1 dB | 215.5 m/383.1 m | ×/O |
| 13 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 2 | 368 bytes/250.0 m/99% | -2.6 dB/+7.4 dB | 215.5 m/383.1 m | ×/O |

Available (O): Link margin at the required communication range is 0 dB or more
Not available (×): Link margin at required communication range is less than 0 dB

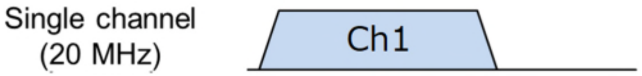
**Table 5.3.3-19 Link budget results (single channel, 10 MHz)**

Single channel
(10 MHz)


| No. | Classification by function | Use case | Message name | Group | Channel | Communication requirements (Data/distance/PAR) | Link margin (With/without large vehicle shielding) | Maximum communication range (With/without large vehicle shielding) | Availability (With/without large vehicle shielding) |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Merging section on expressway** | | | | | | |
| 1 | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | B | 1 | 1572 bytes/222.2 m/99% | +2.8 dB/+12.8 dB | 308.3 m/852.6 m | O/O |
| 2 | | | Negotiation request/ update request | B | 1 | 718 bytes/222.2 m/99% | +5.1 dB/+15.1 dB | 398.3 m/969.0 m | O/O |
| 3 | | | Negotiation response/ update response | B | 1 | 368 bytes/222.2 m/99% | +6.8 dB/+16.8 dB | 488.2 m/1072.9 m | O/O |
| 4 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 1 | 368 bytes/150.0 m/99% | +4.3 dB/+14.3 dB | 220.6 m/392.2 m | O/O |
| 5 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 1 | 368 bytes/255.0 m/99% | -2.5 dB/+7.5 dB | 220.6 m/392.2 m | ×/O |
| 6 | | | Negotiation response/ update response | E | 1 | 368 bytes/255.0 m/99% | -2.5 dB/+7.5 dB | 220.6 m/392.2 m | ×/O |
| 7 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 1 | 368 bytes/250.0 m/99% | -2.2 dB/+7.8 dB | 220.6 m/392.2 m | ×/O |
| | | | **Intersection on general roads** | | | | | | |
| 8 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | A | 1 | 1488 bytes/206.3 m/99% | +4.2 dB/+14.2 dB | 334.4 m/887.9 m | O/O |
| 9 | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | A | 1 | 1488 bytes/75.2 m/99% | +12.9 dB/+22.9 dB | 334.4 m/887.9 m | O/O |
| 10 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 1 | 368 bytes/150.0 m/99% | +3.7 dB/+13.7 dB | 214.0 m/380.5 m | O/O |
| 11 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 1 | 368 bytes/255.0 m/99% | -3.0 dB/+7.0 dB | 214.0 m/380.5 m | ×/O |
| 12 | | | Negotiation response/ update response | E | 1 | 368 bytes/255.0 m/99% | -3.0 dB/+7.0 dB | 214.0 m/380.5 m | ×/O |
| 13 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 1 | 368 bytes/250.0 m/99% | -2.7 dB/+7.3 dB | 214.0 m/380.5 m | ×/O |

Available (O): Link margin at the required communication range is 0 dB or more
Not available (×): Link margin at required communication range is less than 0 dB

Table 5.3.3-20 Link budget results (single channel, 20 MHz)




| No. | Classification by function | Use case | Message name | Group | Channel | Communication requirements (Data/distance/PAR) | Link margin (With/without large vehicle shielding) | Maximum communication range (With/without large vehicle shielding) | Availability (With/without large vehicle shielding) |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Merging section on expressway** | | | | | | |
| 1 | a. Merging/lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | B | 1 | 1572 bytes/222.2 m/99% | +0.1 dB/+10.1 dB | 225.2 m/712.4 m | O/O |
| 2 | | | Negotiation request/ update request | B | 1 | 1438 bytes/222.2 m/99% | +2.3 dB/+12.3 dB | 288.9 m/825.3 m | O/O |
| 3 | | | Negotiation response/ update response | B | 1 | 368 bytes/222.2 m/99% | +7.0 dB/+17.0 dB | 494.9 m/1080.2 m | O/O |
| 4 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 1 | 368 bytes/150.0 m/99% | +4.4 dB/+14.4 dB | 222.1 m/394.9 m | O/O |
| 5 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 1 | 368 bytes/255.0 m/99% | -2.4 dB/+7.6 dB | 222.1 m/394.9 m | ×/O |
| 6 | | | Negotiation response/ update response | E | 1 | 368 bytes/255.0 m/99% | -2.4 dB/+7.6 dB | 222.1 m/394.9 m | ×/O |
| 7 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 1 | 368 bytes/250.0 m/99% | -2.1 dB/+7.9 dB | 222.1 m/394.9 m | ×/O |
| | | | **Intersection on general roads** | | | | | | |
| 8 | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | – | A | 1 | 1488 bytes/206.3 m/99% | +1.3 dB/+11.3 dB | 240.9 m/753.7 m | O/O |
| 9 | c. Lookahead information: Collision avoidance | c-2-2. Driving assistance based on intersection information (V2I) | – | A | 1 | 1488 bytes/75.2 m/99% | +10.1 dB/+20.1 dB | 240.9 m/753.7 m | O/O |
| 10 | e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | – | C | 1 | 368 bytes/150.0 m/99% | +3.8 dB/+13.8 dB | 215.5 m/383.1 m | O/O |
| 11 | a. Merging/lane change assistance | a-2. Lane change assistance when the traffic is heavy | Negotiation request/ update request | E | 1 | 368 bytes/255.0 m/99% | -2.9 dB/+7.1 dB | 215.5 m/383.1 m | ×/O |
| 12 | | | Negotiation response/ update response | E | 1 | 368 bytes/255.0 m/99% | -2.9 dB/+7.1 dB | 215.5 m/383.1 m | ×/O |
| 13 | c. Lookahead information: Collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | D | 1 | 368 bytes/250.0 m/99% | -2.6 dB/+7.4 dB | 215.5 m/383.1 m | ×/O |

Available (O): Link margin at the required communication range is 0 dB or more
Not available (×): Link margin at required communication range is less than 0 dB

(3) Communication simulation results

This section describes the results of communication simulation evaluation as an evaluation at the system level (N:N communication). Results of simulating communication at merging sections on expressways and intersections on general roads are given in Table 5.3.3-21 and Table 5.3.3-22 respectively. To verify the effectiveness at each location of the communication control system in the upper layers in situations where the communication channel allocation proposals are Proposal 1 (10 MHz × 3 channels) and Proposal 6 (10 MHz + 20 MHz), as indicated in the evaluation conditions (Section (1)) and where, for comparison, there is a single channel (10 MHz and 20 MHz), simulation was also conducted with a longer transmission interval than in the communication requirements and the results are listed along with the others. Additionally, concerning vehicle density (speed and vehicle time gap), results are shown for normal times (vehicle speed of 100 km/h, two-second vehicle interval at merging sections on expressways and vehicle speed of 70 km/h, two-second vehicle interval at intersections on general roads) and during congestion (vehicle speed of 50 km/h, one-second vehicle interval at merging sections on expressways and vehicle speed of 30 km/h, one-second vehicle interval at intersections on general roads) on the top and bottom of each table, respectively.

Four categories of results are shown for each use case message: “PAR per packet” ((1)), “Delay (99% value)” ((2)), “Supported?” ((3)), and “Delay (time until PAR required value is reached)” ((4)). (1) is governed by ITS FORUM RC-017, Section 1.4. (2) is the 99% value of delay as defined in ITS FORUM RC-017, Section 1.3. Under (3), “○” is written when the required value of (1) (99%) is achieved, and "×" is written when it is not achieved. Concerning (4), referring to last year’s study (“Evaluation Concerning 700 MHz Band ITS in Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation” in FY2021 research and development), the probability that at least one packet can be received was calculated by the following formula as the time until the required value of (1) is achieved (which is found by multiplying the number of transmissions until the required value of (1) is achieved by 100 ms, which is the transmission interval).

$$\text{Delay (time to reach the required PAR value)} = \text{ceil}\left[\frac{\log(1-P_D)}{\log(1-P_x)}\right] \times 100 \ \ [ms]$$

$P_D$: PAR required value per packet (99%), $P_x$: PAR per packet

Of the above communication simulation results, use case PAR per packet and metric property at each location are given as a detailed example for communication channel allocation Proposal 6 (10 MHz + 20 MHz) in Fig. 5.3.3-3 and Fig. 5.3.3-4 respectively.

For this evaluation, the condition was set that information elements would be multiplexed and there would be retransmission [two transmissions by blind HARQ in the case of LTE V2X (PC5)] as a wireless communication parameter. To verify the effectiveness of information element multiplexing and retransmission, situations with no information element multiplexing and no retransmission were evaluated and the results were compared for communication channel allocation Proposal 6 (10 MHz + 20 MHz). Comparative results for each location are given in Table 5.3.3-23 and Table 5.3.3-24.

## Table 5.3.3-21 Communication simulation results (merging section on expressway)

### ■ For vehicle speed of 100 km/h, 2s between vehicles

Road side unit: 100 ms (no change), on-board equipment: 200 ms (changed from 100 ms)

| Communication method, etc. | Use case | Message name | Required communication range | Single channel | | | | | | | | Multiple channels (Communication channel allocation proposal) | | | | | | | | Verification of effectiveness of congestion control (When the cycle is widened) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10 MHz | | | | 20 MHz | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V (Main lane) | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | 222.2 m | 100.0% | 49.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 98.0% | – | × | 200 ms | 97.6% | – | × | 200 ms | 99.0% | – | × | 200 ms | 99.7% | 50.0 ms | ○ | 100 ms |
| | | Negotiation request Update request | 222.2 m | 99.0% | 50.0 ms | ○ | 100 ms | 100.0% | 45.0 ms | ○ | 100 ms | 96.4% | – | × | 200 ms | 98.7% | – | × | 200 ms | 98.9% | – | × | 200 ms | 99.0% | – | × | 200 ms |
| V2I (Main lane) | | Negotiation response Update response | 222.2 m | 42.0% | – | × | 900 ms | 86.8% | – | × | 300 ms | 54.4% | – | × | 600 ms | 43.1% | – | × | 900 ms | 78.9% | – | × | 400 ms | 76.9% | – | × | 400 ms |
| I2V (Merging lane) | | Location information | 66.7 m | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms |
| | | Negotiation request Update request | 66.7 m | 99.7% | 46.0 ms | ○ | 100 ms | 100.0% | 44.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 100.0% | 46.0 ms | ○ | 100 ms | 99.8% | 46.0 ms | ○ | 100 ms | 99.8% | 46.0 ms | ○ | 100 ms |
| V2I (Marging lane) | | Negotiation response Update response | 66.7 m | 95.6% | – | × | 200 ms | 100.0% | 46.4 ms | ○ | 100 ms | 96.4% | – | × | 200 ms | 96.1% | – | × | 200 ms | 98.2% | – | × | 200 ms | 97.6% | – | × | 200 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 50.5% | – | × | 700 ms | 86.5% | – | × | 300 ms | 60.3% | – | × | 500 ms | 81.1% | – | × | 300 ms | 84.2% | – | × | 400 ms | 91.5% | – | × | 200 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 84.0% | – | × | 300 ms | 98.8% | – | × | 200 ms | 89.8% | – | × | 300 ms | 95.5% | – | × | 200 ms | 95.6% | – | × | 200 ms | 97.9% | – | × | 200 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 98.7% | 103.6 ms | × | 200 ms | 100.0% | 58.2 ms | ○ | 100 ms | 100.0% | 65.1 ms | ○ | 100 ms | 100.0% | 70.8 ms | ○ | 100 ms | 100.0% | 88.5 ms | ○ | 200 ms | 99.9% | 82.8 ms | ○ | 200 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 152.7 ms | ○ | 200 ms | 100.0% | 128.7 ms | ○ | 200 ms | 100.0% | 152.8 ms | ○ | 200 ms | 100.0% | 133.1 ms | ○ | 200 ms | 100.0% | 173.3 ms | ○ | 200 ms | 100.0% | 136.7 ms | ○ | 200 ms |

### ■ For vehicle speed of 50 km/h, 1s between vehicles

Road side unit: 100 ms (no change), on-board equipment: 300 ms (changed from 100 ms)

| Communication method, etc. | Use case | Message name | Required communication range | Single channel | | | | | | | | Multiple channels (Communication channel allocation proposal) | | | | | | | | Verification of effectiveness of congestion control (When the cycle is widened) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10 MHz | | | | 20 MHz | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V (Main lane) | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | 222.2 m | 6.5% | – | × | 6900 ms | 30.0% | – | × | 1300 ms | 0.0% | – | × | – | 0.0% | – | × | – | 57.7% | – | × | 600 ms | 64.4% | – | × | 500 ms |
| | | Negotiation request Update request | 222.2 m | 30.4% | – | × | 1300 ms | 57.3% | – | × | 600 ms | 22.6% | – | × | 1900 ms | 23.7% | – | × | 1800 ms | 77.6% | – | × | 400 ms | 83.3% | – | × | 300 ms |
| V2I (Main lane) | | Negotiation response Update response | 222.2 m | 1.8% | – | × | 25200 ms | 14.1% | – | × | 3100 ms | 0.0% | – | × | – | 0.0% | – | × | – | 34.4% | – | × | 1200 ms | 33.3% | – | × | 1200 ms |
| I2V (Merging lane) | | Location information | 66.7 m | 76.8% | – | × | 400 ms | 94.3% | – | × | 200 ms | 64.4% | – | × | 500 ms | 74.7% | – | × | 400 ms | 93.2% | – | × | 200 ms | 97.8% | – | × | 200 ms |
| | | Negotiation request Update request | 66.7 m | 86.6% | – | × | 300 ms | 94.7% | – | × | 200 ms | 84.9% | – | × | 300 ms | 91.8% | – | × | 200 ms | 99.6% | 45.0 ms | ○ | 100 ms | 98.9% | – | × | 200 ms |
| V2I (Marging lane) | | Negotiation response Update response | 66.7 m | 39.3% | – | × | 1000 ms | 81.3% | – | × | 300 ms | 47.0% | – | × | 800 ms | 37.1% | – | × | 1000 ms | 80.6% | – | × | 300 ms | 80.3% | – | × | 300 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 1.1% | – | × | 40100 ms | 20.5% | – | × | 2100 ms | 5.8% | – | × | 7700 ms | 19.9% | – | × | 2100 ms | 48.3% | – | × | 900 ms | 64.2% | – | × | 600 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 20.5% | – | × | 2100 ms | 53.7% | – | × | 600 ms | 17.5% | – | × | 2400 ms | 53.4% | – | × | 700 ms | 75.7% | – | × | 600 ms | 87.0% | – | × | 300 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 70.0% | 172.8 ms | × | 400 ms | 99.2% | 98.8 ms | ○ | 100 ms | 92.2% | 124.3 ms | × | 200 ms | 100.0% | 68.7 ms | ○ | 100 ms | 100.0% | 67.4 ms | ○ | 300 ms | 100.0% | 83.9 ms | ○ | 300 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 316.9 ms | ○ | 400 ms | 100.0% | 161.5 ms | ○ | 200 ms | 100.0% | 283.3 ms | ○ | 300 ms | 100.0% | 166.1 ms | ○ | 200 ms | 100.0% | 149.9 ms | ○ | 300 ms | 100.0% | 145.9 ms | ○ | 300 ms |

* The color of the table is based on the value of the delay (time until PAR required value is reached). : 100 ms : 200 ms to 300 ms : 400 ms to 600 ms : 700 ms to 1200 ms : From 1300 ms

## Table 5.3.3-22 Communication simulation results (intersection on general roads)

### ■ For vehicle speed of 70 km/h, 2s between vehicles

Road side unit: 100 ms (no change), on-board unit: 200 ms for running/waiting right turn vehicle,1000 ms for stationary vehicle (changed from 100 ms)

| Communication method, etc. | Use case | Message name | Required communication range | Single channel | | | | | | | | Multiple channels (Communication channel allocation proposal) | | | | | | | | Verification of effectiveness of congestion control (When the cycle is widened) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10 MHz | | | | 20 MHz | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V | b-1-1. Driving assistance by using traffic signal information (V2I) | – | 138.5 m (Passenger vehicles) | 11.3% | – | × | 3900 ms | 35.5% | – | × | 1100 ms | 84.0% | – | × | 300 ms | 93.5% | – | × | 200 ms | 90.9% | – | × | 200 ms | 93.7% | – | × | 200 ms |
| | | – | 206.3 m (Large vehicles) | 0.0% | – | × | – | 9.7% | – | × | 4600 ms | 86.8% | – | × | 300 ms | 95.9% | – | × | 200 ms | 98.5% | – | × | 200 ms | 98.9% | – | × | 200 ms |
| | c-2-2. Driving assistance based on intersection information (V2I) | – | 30 m | 88.1% | – | × | 300 ms | 83.2% | – | × | 300 ms | 100.0% | 48.4 ms | ○ | 100 ms | 100.0% | 41.2 ms | ○ | 100 ms | 100.0% | 47.4 ms | ○ | 100 ms | 100.0% | 46.4 ms | ○ | 100 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 3.1% | – | × | 14700 ms | 19.1% | – | × | 2200 ms | 3.3% | – | × | 13800 ms | 10.9% | – | × | 4000 ms | 19.4% | – | × | 2200 ms | 50.0% | – | × | 800 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 21.4% | – | × | 2000 ms | 61.4% | – | × | 500 ms | 22.3% | – | × | 1900 ms | 63.5% | – | × | 500 ms | 52.6% | – | × | 800 ms | 85.6% | – | × | 400 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 94.7% | 110.9 ms | × | 200 ms | 99.7% | 80.9 ms | ○ | 100 ms | 84.3% | 153.2 ms | × | 300 ms | 100.0% | 85.9 ms | ○ | 100 ms | 96.7% | 109.7 ms | × | 200 ms | 100.0% | 64.8 ms | ○ | 200 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 276.9 ms | ○ | 300 ms | 100.0% | 150.9 ms | ○ | 200 ms | 100.0% | 333.9 ms | ○ | 400 ms | 100.0% | 147.9 ms | ○ | 200 ms | 100.0% | 196.7 ms | ○ | 200 ms | 100.0% | 124.8 ms | ○ | 200 ms |

### ■ For vehicle speed of 30 km/h, 2s between vehicles

Road side unit: 100 ms (no change), on-board unit: 200 ms for running/waiting right turn vehicle,1000 ms for stationary vehicle (changed from 100 ms)

| Communication method, etc. | Use case | Message name | Required communication range | Single channel | | | | | | | | Multiple channels (Communication channel allocation proposal) | | | | | | | | Verification of effectiveness of congestion control (When the cycle is widened) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10 MHz | | | | 20 MHz | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | | Proposal 1 (10 MHz × 3 Ch) | | | | Proposal 6 (10 MHz + 20 MHz) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V | b-1-1. Driving assistance by using traffic signal information (V2I) | – | 138.5 m (Passenger vehicles) | 0.0% | – | × | – | 16.3% | – | × | 2600 ms | 67.0% | – | × | 500 ms | 82.8% | – | × | 300 ms | 89.4% | – | × | 300 ms | 97.3% | – | × | 200 ms |
| | | – | 206.3 m (Large vehicles) | 0.0% | – | × | – | 0.0% | – | × | – | 92.5% | – | × | 200 ms | 94.1% | – | × | 200 ms | 97.4% | – | × | 200 ms | 98.7% | – | × | 200 ms |
| | c-2-2. Driving assistance based on intersection information (V2I) | – | 30 m | 66.9% | – | × | 500 ms | 76.7% | – | × | 400 ms | 100.0% | 50.4 ms | ○ | 100 ms | 96.5% | – | × | 200 ms | 100.0% | 45.4 ms | ○ | 100 ms | 98.2% | – | × | 200 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 0.0% | – | × | – | 1.7% | – | × | 26700 ms | 0.0% | – | × | – | 13.7% | – | × | 3200 ms | 26.9% | – | × | 1500 ms | 73.7% | – | × | 600 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 4.4% | – | × | 10300 ms | 34.4% | – | × | 1100 ms | 5.7% | – | × | 8000 ms | 34.9% | – | × | 1100 ms | 45.9% | – | × | 900 ms | 84.4% | – | × | 300 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 56.3% | 189.9 ms | × | 600 ms | 100.0% | 83.3 ms | ○ | 100 ms | 51.0% | 172.1 ms | × | 700 ms | 99.8% | 98.9 ms | ○ | 100 ms | 100.0% | 80.7 ms | ○ | 300 ms | 100.0% | 59.6 ms | ○ | 300 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 414.9 ms | ○ | 500 ms | 100.0% | 182.9 ms | ○ | 200 ms | 100.0% | 429.9 ms | ○ | 500 ms | 100.0% | 179.8 ms | ○ | 200 ms | 100.0% | 178.7 ms | ○ | 300 ms | 100.0% | 96.3 ms | ○ | 300 ms |

* The color of the table is based on the value of the delay (time until PAR required value is reached). : 100 ms : 200 ms to 300 ms : 400 ms to 600 ms : 700 ms to 1200 ms : From 1300 ms

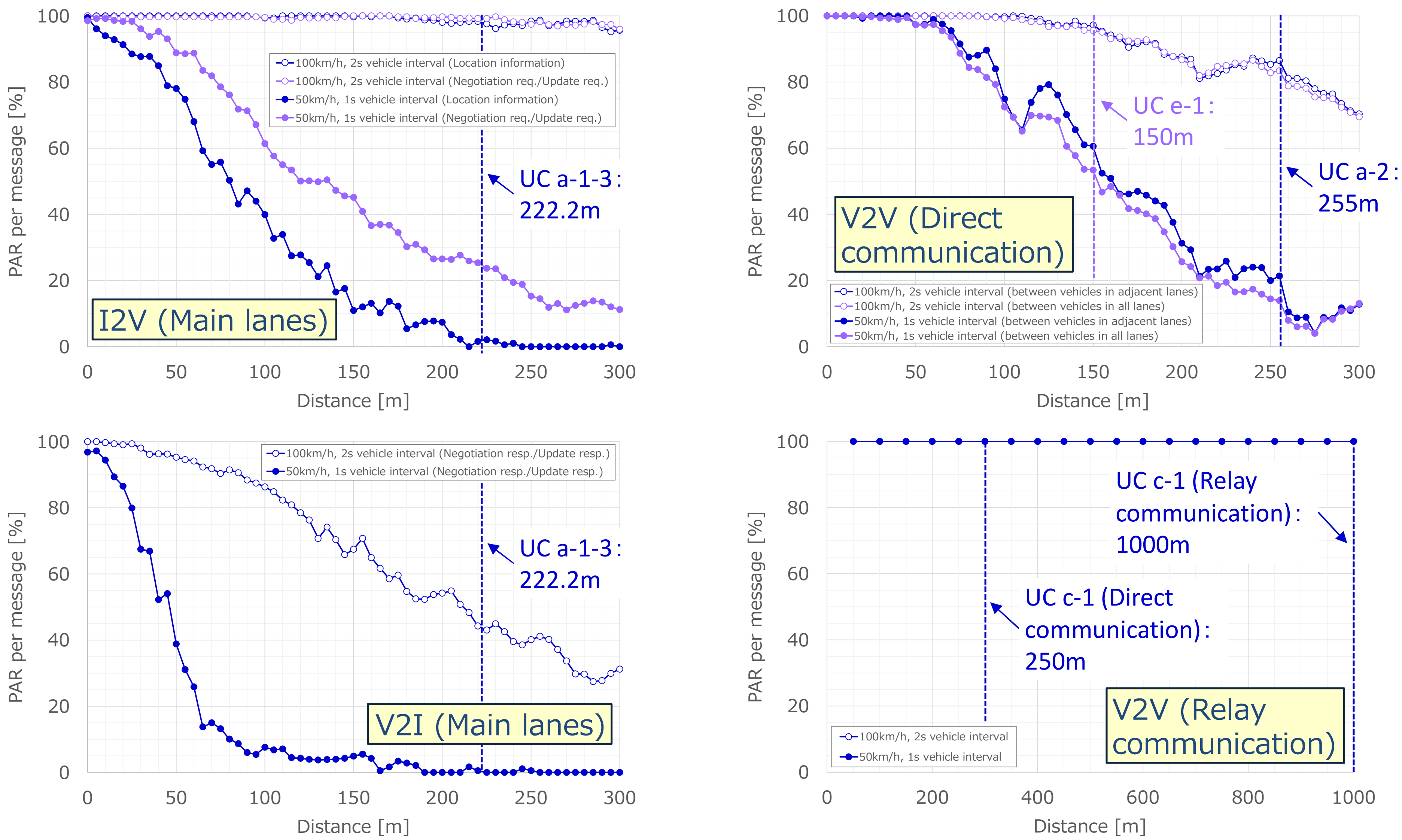



**Fig. 5.3.3-3 Detailed example of communication simulation results (merging section on expressway)**

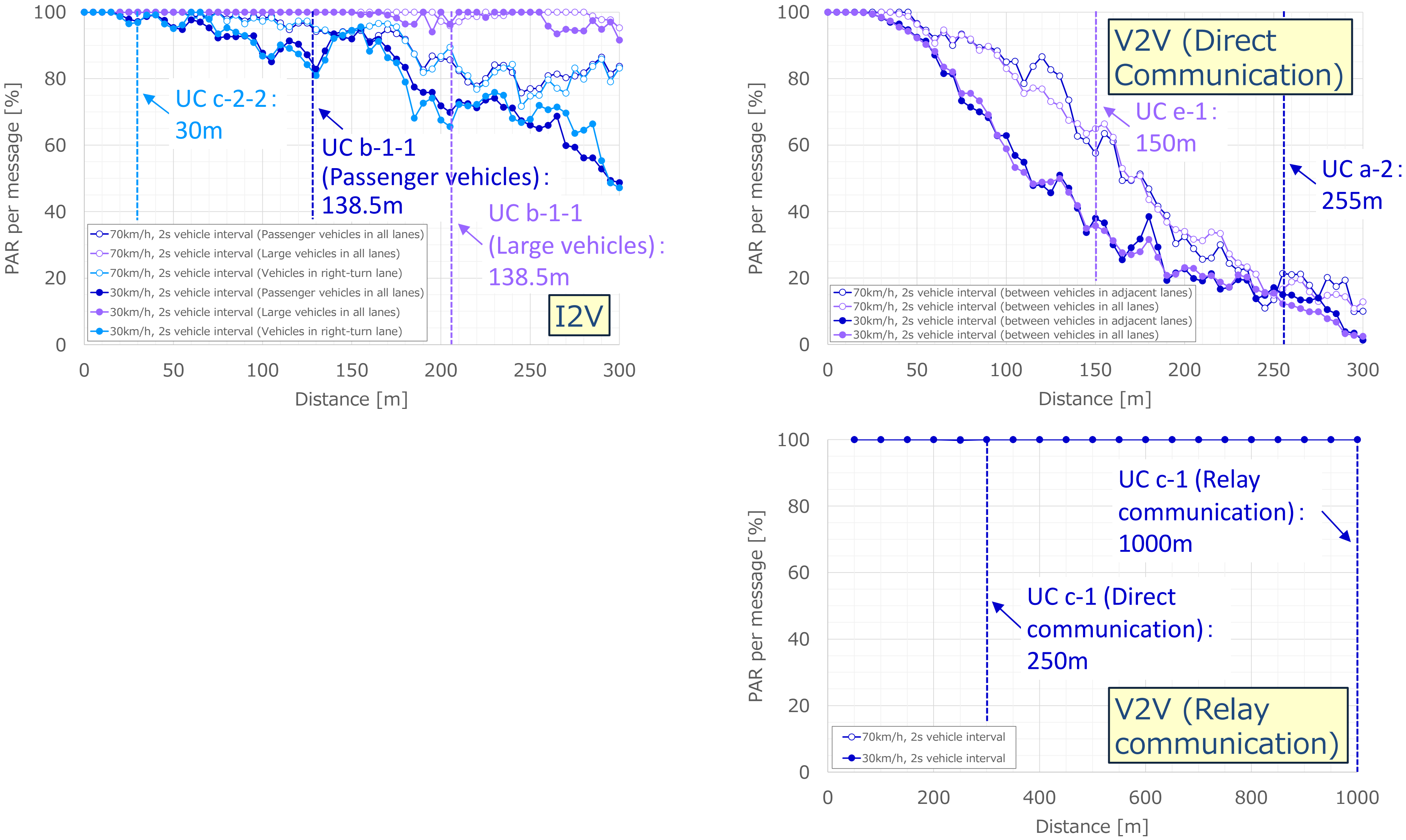



**Fig. 5.3.3-4 Detailed example of communication simulation results (intersection on general roads)**

**Table 5.3.3-23 Comparison with situations with no information element multiplexing/no retransmission (merging section on expressway)**

## ■For vehicle speed of 100 km/h, 2s between vehicles

| Communication method, etc. | Use case | Message name | Required communication range | Multiplexing of information elements | | | | | | | | Retransmission | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Present | | | | None (Reference) | | | | Present | | | | None (Reference) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V (Main lane) | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | 222.2 m | 97.6% | – | × | 200 ms | 25.1% | – | × | 1600 ms | 97.6% | – | × | 200 ms | 94.9% | – | × | 200 ms |
| | | Negotiation request Update request | 222.2 m | 98.7% | – | × | 200 ms | 42.5% | – | × | 900 ms | 98.7% | – | × | 200 ms | 88.7% | – | × | 300 ms |
| V2I (Main lane) | | Negotiation response Update response | 222.2 m | 43.1% | – | × | 900 ms | 5.9% | – | × | 7600 ms | 43.1% | – | × | 900 ms | 74.8% | – | × | 400 ms |
| I2V (Merging lane) | | Location information | 66.7 m | 100.0% | 46.0 ms | ○ | 100 ms | 66.5% | – | × | 500 ms | 100.0% | 46.0 ms | ○ | 100 ms | 95.5% | – | × | 200 ms |
| | | Negotiation request Update request | 66.7 m | 100.0% | 46.0 ms | ○ | 100 ms | 81.9% | – | × | 300 ms | 100.0% | 46.0 ms | ○ | 100 ms | 97.3% | – | × | 200 ms |
| V2I (Marging lane) | | Negotiation response Update response | 66.7 m | 96.1% | – | × | 200 ms | 39.0% | – | × | 1000 ms | 96.1% | – | × | 200 ms | 98.5% | – | × | 200 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 81.1% | – | × | 300 ms | 42.9% | – | × | 900 ms | 81.1% | – | × | 300 ms | 79.4% | – | × | 300 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 95.5% | – | × | 200 ms | 77.7% | – | × | 400 ms | 95.5% | – | × | 200 ms | 93.7% | – | × | 200 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 100.0% | 70.8 ms | ○ | 100 ms | 98.5% | 106.3 ms | × | 200 ms | 100.0% | 70.8 ms | ○ | 100 ms | 100.0% | 68.6 ms | ○ | 100 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 133.1 ms | ○ | 200 ms | 100.0% | 159.3 ms | ○ | 200 ms | 100.0% | 133.1 ms | ○ | 200 ms | 100.0% | 154.5 ms | ○ | 200 ms |

## ■For vehicle speed of 50 km/h, 1s between vehicles

| Communication method, etc. | Use case | Message name | Required communication range | Multiplexing of information elements | | | | | | | | Retransmission | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Present | | | | None (Reference) | | | | Present | | | | None (Reference) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V (Main lane) | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Location information | 222.2 m | 0.0% | – | × | – | 0.0% | – | × | – | 0.0% | – | × | – | 42.9% | – | × | 900 ms |
| | | Negotiation request Update request | 222.2 m | 23.7% | – | × | 1800 ms | 0.2% | – | × | 283200 ms | 23.7% | – | × | 1800 ms | 67.4% | – | × | 500 ms |
| V2I (Main lane) | | Negotiation response Update response | 222.2 m | 0.0% | – | × | – | 0.0% | – | × | – | 0.0% | – | × | – | 2.8% | – | × | 16300 ms |
| I2V (Merging lane) | | Location information | 66.7 m | 74.7% | – | × | 400 ms | 0.0% | – | × | – | 74.7% | – | × | 400 ms | 53.9% | – | × | 600 ms |
| | | Negotiation request Update request | 66.7 m | 91.8% | – | × | 200 ms | 12.0% | – | × | 3700 ms | 91.8% | – | × | 200 ms | 98.9% | – | × | 200 ms |
| V2I (Marging lane) | | Negotiation response Update response | 66.7 m | 37.1% | – | × | 1000 ms | 0.7% | – | × | 61200 ms | 37.1% | – | × | 1000 ms | 61.3% | – | × | 500 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 19.9% | – | × | 2100 ms | 1.6% | – | × | 28400 ms | 19.9% | – | × | 2100 ms | 32.1% | – | × | 1200 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 53.4% | – | × | 700 ms | 18.9% | – | × | 2200 ms | 53.4% | – | × | 700 ms | 55.1% | – | × | 600 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 100.0% | 68.7 ms | ○ | 100 ms | 79.2% | 152.8 ms | × | 300 ms | 100.0% | 68.7 ms | ○ | 100 ms | 100.0% | 67.4 ms | ○ | 100 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 166.1 ms | ○ | 200 ms | 100.0% | 312.4 ms | ○ | 400 ms | 100.0% | 166.1 ms | ○ | 200 ms | 100.0% | 147.2 ms | ○ | 200 ms |

* The color of the table is based on the value of the delay (time until PAR required value is reached). : 100 ms : 200 ms to 300 ms : 400 ms to 600 ms : 700 ms to 1200 ms : From 1300 ms

## Table 5.3.3-24 Comparison with situations with no information element multiplexing/no retransmission (intersection on general roads)

### ■ For vehicle speed of 70 km/h, 2s between vehicles

| Communication method, etc. | Use case | Message name | Required communication range | Multiplexing of information elements | | | | | | | | Retransmission | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Present | | | | None (Reference) | | | | Present | | | | None (Reference) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V | b-1-1. Driving assistance by using traffic signal information (V2I) | – | 138.5 m (Passenger vehicles) | 93.5% | – | × | 200 ms | 72.8% | – | × | 400 ms | 93.5% | – | × | 200 ms | 81.3% | – | × | 300 ms |
| | | – | 206.3 m (Large vehicles) | 95.9% | – | × | 200 ms | 94.1% | – | × | 200 ms | 95.9% | – | × | 200 ms | 88.2% | – | × | 300 ms |
| | c-2-2. Driving assistance based on intersection information (V2I) | – | 30 m | 100.0% | 41.2 ms | ○ | 100 ms | 97.4% | – | × | 200 ms | 100.0% | 41.2 ms | ○ | 100 ms | 97.4% | – | × | 200 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 10.9% | – | × | 4000 ms | 0.0% | – | × | – | 10.9% | – | × | 4000 ms | 39.7% | – | × | 1000 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 63.5% | – | × | 500 ms | 19.9% | – | × | 2100 ms | 63.5% | – | × | 500 ms | 74.5% | – | × | 400 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 100.0% | 85.9 ms | ○ | 100 ms | 89.4% | 131.5 ms | × | 300 ms | 100.0% | 85.9 ms | ○ | 100 ms | 100.0% | 66.9 ms | ○ | 100 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 147.9 ms | ○ | 200 ms | 100.0% | 239.5 ms | ○ | 300 ms | 100.0% | 147.9 ms | ○ | 200 ms | 100.0% | 124.9 ms | ○ | 200 ms |

### ■ For vehicle speed of 30 km/h, 2s between vehicles

| Communication method, etc. | Use case | Message name | Required communication range | Multiplexing of information elements | | | | | | | | Retransmission | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Present | | | | None (Reference) | | | | Present | | | | None (Reference) | | | |
| | | | | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) | PAR per packet | Delay (99% value) | Availability | Delay (time until PAR required value is reached) |
| I2V | b-1-1. Driving assistance by using traffic signal information (V2I) | – | 138.5 m (Passenger vehicles) | 82.8% | – | × | 300 ms | 51.6% | – | × | 700 ms | 82.8% | – | × | 300 ms | 70.0% | – | × | 400 ms |
| | | – | 206.3 m (Large vehicles) | 94.1% | – | × | 200 ms | 75.3% | – | × | 400 ms | 94.1% | – | × | 200 ms | 77.9% | – | × | 400 ms |
| | c-2-2. Driving assistance based on intersection information (V2I) | – | 30 m | 96.5% | – | × | 200 ms | 96.7% | – | × | 200 ms | 96.5% | – | × | 200 ms | 91.5% | – | × | 200 ms |
| V2V (no relay) | a-2. Lane change assistance when the traffic is heavy | – | 255 m | 13.7% | – | × | 3200 ms | 0.0% | – | × | – | 13.7% | – | × | 3200 ms | 17.8% | – | × | 2400 ms |
| | e-1. Driving assistance based on emergency vehicle information | – | 150 m | 34.9% | – | × | 1100 ms | 3.6% | – | × | 12800 ms | 34.9% | – | × | 1100 ms | 62.1% | – | × | 500 ms |
| V2V (with relay) | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | – | 250 m (Direct communication) | 99.8% | 98.9 ms | ○ | 100 ms | 83.9% | 138.0 ms | × | 300 ms | 99.8% | 98.9 ms | ○ | 100 ms | 99.9% | 66.8 ms | ○ | 100 ms |
| | | – | 1000 m (Relay communication) | 100.0% | 179.8 ms | ○ | 200 ms | 100.0% | 329.0 ms | ○ | 400 ms | 100.0% | 179.8 ms | ○ | 200 ms | 100.0% | 130.1 ms | ○ | 200 ms |

* The color of the table is based on the value of the delay (time until PAR required value is reached). : 100 ms : 200 ms to 300 ms : 400 ms to 600 ms : 700 ms to 1200 ms : From 1300 ms

(4) Discussion and issues regarding evaluation results

This section discusses the communication simulation results (Section (3)) and describes the results of organizing them.

A comparison of multiple channel allocation proposals showed that communication quality was generally better when V2V use cases were assigned to one channel than when they were assigned to two channels within a 20 MHz bandwidth. When information elements on the same channel is multiplexed and combined into a single packet, a smaller number of channels means fewer packets per bandwidth, which can reduce transmission frequency and security overhead (communications traffic) and is considered effective in reducing intra- and inter-channel interference.

Compared to single channel cases (up to 20 MHz bandwidth), the result did not necessarily show an improvement in the communication quality. In cases where vehicles transmissions are distributed across the multiple channels due to the multiple channel allocation, this is considered to be due to inability to multiplex information elements across the different channels, which increases the number of packets per bandwidth and thus increases intra- and inter-channel interference.

To verify the effectiveness of the communication control technology, the communication performance with a longer vehicle transmission interval was evaluated. Under conditions where communication is congested and PAR required value cannot be achieved, it was confirmed that improved communication quality can be expected (the delay in which the PAR required value can be achieved becomes smaller) by making the transmission interval longer than in the communication requirements.

To verify the effectiveness of information element multiplexing, a situation without information element multiplexing was evaluated and the results were compared. The results showed that situations with information element multiplexing offered better communication than situations with no information element multiplexing. Bundling multiple information elements by information element multiplexing and transmitting them as one packet can reduce communication volume (security overhead) and the frequency of transmission, thus confirming that information element multiplexing is effective.

To verify the effectiveness of retransmission [two transmissions by blind HARQ in the case of LTE V2X (PC5)], a situation without retransmission was evaluated and the results compared. The results showed that in situations where the PAR per packet was close to the required value (99%), having retransmission provided better communication quality than not having retransmission. It is thought that in an environment with no communication congestion, ensuring that retransmission packets arrive twice makes SNR improvement likely. On the other hand, the results showed that in situations where the PAR per packet was significantly worse, not having retransmission provided better communication quality than having retransmission. It is thought that in an environment with communication congestion, not doing retransmission, but decreasing the communication volume and transmission frequency makes it easier for communication packets to arrive, even if only transmitted once. Based on the above results, varying the number of retransmissions according to communication congestion status is thought to be one countermeasure to communication congestion in situations where linking Layer 2 and below to the communication control technology in the upper layers.

Based on the evaluation results, to improve communication quality in situations where multiple use cases occur simultaneously and communications traffic is high, it is considered effective to transmit information elements together in a single packet on a small number of channels (with less communications traffic and lower transmission frequency by decreasing the number of packets per bandwidth) and to control transmission periods and the number of retransmission according to congestion conditions (and reduce transmission frequency during congestion).

The following may be listed as future issues.

- **Comparison of performance with single/multiple channels in the same bandwidth**

(Example: In the case of NR V2X, is it better to have one channel in a 30 MHz bandwidth or to split it into two or more channels?)

- **Verification of effectiveness by channel allocation method other than by use case units**

(Example: When multiplexing information elements, it is possible that dividing the channel not by use case units but by transmission source units could offer better channel use efficiency. divide into roadside infrastructure transmission (I -> V direction in V2I communication) and vehicle transmission (V -> I direction in V2I communication + V2V communication))

- **Detailed evaluation of communication control technology that considers transmission interval time changes, priority level, etc.**

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# 6. Drafting of radio unit specifications

This part describes the results of a study of 5.9 GHz band V2X system radio unit (OBU and road side unit (below, “RSU”) ) specifications and organizing it into a radio unit specifications draft (Section 6.1). It also describes the results of FOTS (Field Operational Tests) with actual equipment on a test course, etc. (Section 6.2). It furthermore describes the results of organizing the implementation issues and a study of strategies for resolving them (Section 6.3).

## 6.1 Study of radio unit specifications

This section describes the results of a study of 5.9 GHz band V2X system radio unit (OBU and RSU) specifications and organizing it into a radio unit specifications draft. The following describes the process of study (Section 6.1.1), and in accordance with that and in reference to the existing systems’ equipment specifications, the listing of items for the organized radio unit specifications draft by extracting and subdividing radio unit specification items (Section 6.1.2), and based on the survey results of Parts 3, 4, and 5, the results of drafting radio unit specifications by organizing the specifications and parameters to apply to the list of radio unit specification items (Section 6.1.3) and organizing the issues (Section 6.1.4).

### 6.1.1 Process of study

Referring to items and content studied as radio unit specifications and functions in existing systems’ (ETC/ETC2.0, etc.) equipment specification documents and specification documents relating to system requirements, a list of items for the radio unit specifications draft was made by extracting and subdividing items to be organized as radio unit specifications. Based on the survey results of Parts 3, 4, and 5, specifications and parameters to apply to that list of items were studied and organized with a view to linking to existing wireless systems, and radio unit specifications were drafted thereby.

The flow of the process of study as described above is given in Fig. 6.1.1-1.

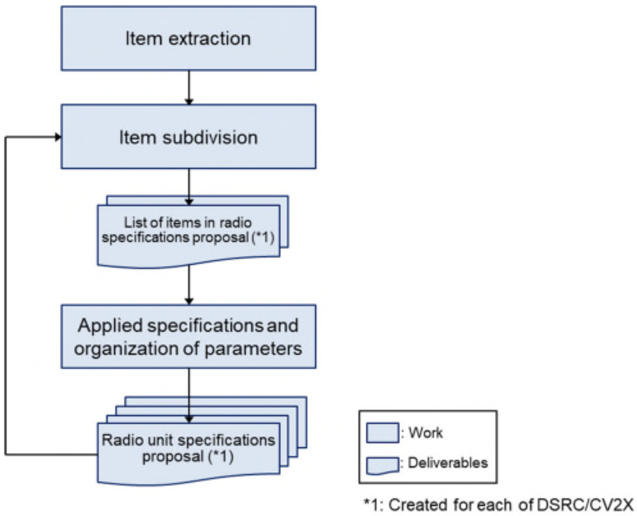



**Fig. 6.1.1-1 Study of radio unit specifications: study flow**

### 6.1.2 Study of list of items of radio unit specifications

(1) Organization of reference standards

Standards for existing systems in Japan and abroad, which were used as reference for the study of items of radio unit specifications, are given in Table 6.1.2-1. ETC/ETC2.0 equipment standard documents were the subject of the survey as equipment standard documents of existing ITS systems in Japan. ITS Connect is another example of an existing ITS system, but it is not included in the scope of this survey since the information is restricted to members. Concerning ITS systems outside Japan, based on the survey results of Part 3, SAE J2945, SAE J3161, ETSI TS302 665, and ETSI TS103 723, which govern the overall image of DSRC and CV2X communication specifications in the US and Europe, were in the scope of the survey. Concerning SAE J2945 and SAE J3161, those standards already issued that use V2I and V2V as the communication method were in the scope of the survey. J2945/5 was not in the scope of the survey because it is a document relating to design of specific parameters.

**Table 6.1.2-1 Standards from Japan and abroad in scope of survey [1]-[11]**

**US: SAE**

| No. | Title | Communication method | Issue status (*1) | Survey target |
|---|---|---|---|---|
| J2945 | Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts | — | Published | ○ |
| J2945/1 | On-Board System Requirements for V2V Safety Communications | V2V | Published | ○ |
| J2945/2 | Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness | V2V | Published | ○ |
| J2945/3 | Requirements for Road Weather Applications | V2I | Published | ○ |
| J2945/4 | Road Safety Applications | V2I | Unpublished | — |
| J2945/5 | Service Specific Permissions and Security Guidelines for Connected Vehicle Applications | — | Published | — |
| J2945/6 | Performance Requirements for Cooperative Adaptive Cruise Control and Platooning | V2V, V2I | Unpublished | — |
| J2945/7 | Positioning Enhancements for V2X Systems | — | Unpublished | — |
| J2945/8 | Cooperative Perception System | V2X, P2I | Unpublished | — |
| J2945/9 | Vulnerable Road User Safety Message Minimum Performance Requirements | P2V | Published | — |
| J2945/A | Road user-to-Road User Courteous Communication | V2I | Unpublished | — |
| J2945/B | Recommended Practices for Signalized Intersection Applications | V2I | Unpublished | — |
| J2945/C | Requirements for Probe Data Collection Applications | V2I | Published | ○ |
| J2945/D | Road user-to-Road User Courteous Communication | V2X | Unpublished | — |
| J3161 | LTE Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters for Single Radio Channel Multi-Service Coexistence | — | Published | ○ |
| J3161/1 | On-Board System Requirements for LTE-V2X V2V Safety Communications | V2V | Published | ○ |
| J3161/2 | LTE Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters for 10 MHz Channel | — | Unpublished | — |

**Europe: ETSI**

| No. | Title | Communication method |
|---|---|---|
| TS302 665 | Intelligent Transport Systems (ITS); Communication architecture | V2V, V2I |
| TS103 723 | Intelligent Transport Systems (ITS); Profile for LTE-V2X Direct Communication | V2V, V2I |

**In Japan: 6 expressway (*2)**

| Title | Communication method |
|---|---|
| 5.8GHz band DSRC roadside unit standards | V2I |
| 5.8 GHz band DSRC vehicle standard | V2V |

*1 From Works of the following SAE Committees as of July 2022
C-V2X Technical Committee, V2X Security Technical Committee, V2X Core Technical Committee, Infrastructure Applications Technical Committee, V2X Vehicular Applications Technical Committee
Source: https://www.sae.org/servlets/works/

*2 Nippon Expressway Co., Ltd., Central Nippon Expressway Co., Ltd., West Nippon Expressway Co., Ltd., Metropolitan Expressway Co., Ltd., Hanshin Expressway Co., Ltd., Honshu-Shikoku Bridge Expressway Co., Ltd.

(2) Extraction of items of radio unit specifications

Based on the results of organizing reference specifications ((1)), items and content governed by each specification were organized.

Table 6.1.2-2 to Table 6.1.2-4 provide the table of contents and content overview of standards in the scope of the survey. The figures cover SAE J2945/1 (and SAE J3161/1), ETSI EN302 665, and the 5.8 GHz band DSRC roadside wireless equipment standard as examples of SAE, ETSI, and Japanese standards, respectively. Because there is such a wide range of items governed by radio unit specifications, during item extraction and subsequent study, items necessary for creating communication specifications were the subject of priority study. For that reason, items that were considered of low priority level and for which no detailed specifications study was performed are shown as “Not subject to study” in Table 6.1.2-2 to Table 6.1.2-4. Specific examples are non-communication functions (e.g., functions and characteristics of breakdown detection part and functions and characteristics of power supply part in 5.8 GHz band DSRC roadside wireless equipment standard) and interface hardware (HW) specifications. Concerning security, similarly to Part 5, the preconditions necessary to study the communication protocol proposal (interfaces, processing procedures, etc.) were considered, but a study of detailed specifications was outside the scope of this effort. Although the chapter arrangement of the content governed by SAE J2945/2,3,C is different, these standards already issued are not very different in terms of the items governed by Parts 4 to 6 of SAE J2945/1 because they cover multicasting/broadcasting applications that do not require a response. For that reason, SAE J2945/1 is studied as a representative example of DSRC and SAE J3161/1 as a representative example of CV2X below.

**Table 6.1.2-2 Table of contents and content overview of SAE J2945/1 and SAE J3161/1 [2],[7]**

| SAE 2945/1 "On-Board System Requirements for V2V Safety Communications",<br>SAE 3161/1 "On-Board System Requirements for LTE-V2X V2V Safety Communications" | |
|---|---|
| Contents | Description |
| **1. SCOPE** | |
| 1.1 Purpose | Purpose of the standard |
| **2. REFERENCES** | |
| 2.1 Applicable Documents | Citation |
| 2.2 Related Publications | Reference works |
| **3. TERMS AND DEFINITIONS** | |
| 3.1 Definitions | Definition of terms |
| 3.2 Abbreviations and Acronyms | Definition of abbreviations |
| 3.3 Requirement Numbering Convention | Requirement number definition |
| **4. V2V SAFETY SYSTEMS CONCEPT OF OPERATIONS AND SYSTEM DESCRIPTION** | |
| 4.1 V2V System Overview | V2V system outline, system configuration diagram |
| 4.2 V2V Safety Features | Scenarios and application features to realize them |
| **5. INTERFACE DESCRIPTION** | |
| 5.1 V2V Over-the-Air Data Description | Information exchanged over the radio section interface (Includes options that apply to BSM) |
| 5.2 System Interfaces | Overview of interfaces between layers, security certificate management system, and positioning system |
| **6. MINIMUM REQUIREMENTS** | |
| 6.1 Standards Profiles | Protocol stack and specific citations |
| 6.2 Positioning and Timing Requirements | GNSS, availability of correction, coordinate system, time requirements |
| 6.3 BSM Transmission Requirements on Channel vChannelNumber | BSM transmission requirements (Transmission conditions, channel spacing, device startup conditions, etc.) |
| 6.4 RF Performance Requirements | Definition and accuracy of transmission power measurement method, reception sensitivity |
| 6.5 Security and Privacy Requirements | Details of security signing and verification procedures |
| 6.6 Security Management | Functions of the security management system (operations during registration, etc.) |
| **7. PARAMETER SETTINGS** | Concrete values and grounds for the variables mentioned in Chapter 6 |
| **8. NOTES** | |
| 8.1 Revision Indicator | Explanation of how to describe revisions |

☐: Subject of consideration
☐: Not subject of consideration

**Table 6.1.2-3 Table of contents and content overview of ETSI EN 302 665 [8]**

| ETSI EN 302 665 "Intelligent Transport Systems (ITS);Communication architecture" | |
|---|---|
| Contents | Description |
| **1. SCOPE** | |
| **2. REFERENCES** | |
| 2.1 Normative references | Citation |
| 2.2 Informative references | Reference works |
| **3 Definitions and abbreviations** | |
| 3.1 Definitions | Definition of terms |
| 3.2 Abbreviations | Abbreviations |
| **4 Basics** | |
| 4.1 Document overview | Document overview |
| 4.2 Severability clause | Severability clause |
| 4.3 ITSC design principles | Design principles of ITSC |
| 4.4 ITS station reference architecture | ITS station reference architecture |
| 4.5 Functional elements of ITSC | Functional elements of ITSC |
| 4.6 ITSC networking | ITSC Networking |
| 4.7 ITSC implementation architecture | ITSC implementation architecture |
| **5 ITS applications** | |
| 5.1 Context | Context |
| 5.2 Classes of applications | Class of application |
| 5.3 Prioritization and channel assignment | Prioritization and channel assignment |
| 5.4 Secure maintenance | Secure maintenance |
| 5.5 Registration authority | Registration authority |
| **6 ITSC OSI protocol stack** | |
| 6.1 Access layer | Access layer requirements |
| 6.2 Networking & transport layer | Network and transport layer requirements |
| 6.3 Facilities layer | Facility tier requirements |
| **7 ITSC management entity** | |
| 7.1 Context | Context |
| 7.2 Functionality | Functions of management entities |
| **8 ITSC Security** | |
| 8.1 Context | Context |
| 8.2 General functionality | Common features |

☐: Subject of consideration
☐: Not subject of consideration

**Table 6.1.2-4 Table of contents and content overview of 5.8 GHz band DSRC roadside unit equipment standards [10]**

| 5.8GHz band DSRC roadside unit standards | |
|---|---|
| Contents | Description |
| **Chapter 1 General items** | |
| 1-1 Scope of application of this standard | Schematic configuration of the system, schematic configuration of the device, and scope of application of the standard |
| 1-2 Applicable standard | Applicable standards for matters not specified in the standard document |
| 1-3 Explanation of terms | Explanation of terms and abbreviations used in the standard |
| 1-4 Outline of roadside radio equipment | Device overview, device configuration, communication area |
| 1-5 Prerequisites for roadside radio equipment | Requirements, functions, considerations, etc. |
| **Chapter 2 Requirements** | |
| 2-1 Internal configuration | Internal configuration of the device |
| 2-2 Structure | Requirements for housing, etc. |
| 2-3 Functions and characteristics of the antenna part | Antenna type, gain, directivity, polarization |
| 2-4 Functions and characteristics of transmitter and receiver | Applied parameters for transmitter and receiver |
| 2-5 Functions and characteristics of the congestion control part | Applied parameters and functions for L1 to L7 are described |
| 2-6 Functions and characteristics of the fault detector | Function to notify the supervisory CU when an abnormality occurs |
| 2-7 Functions and characteristics of the supervisory control part | Information transfer to remote control device, active/backup switching function |
| 2-8 Functions and characteristics of the power supply | Outline of power supply requirements, details are 2-12 |
| 2-9 Optional features | Examples of optional functions |
| 2-10 Interface | Physical/logical interface between layers and application processing part (AP processing part) |
| 2-11 Environmental condition | See IEC standard |
| 2-12 Power supply | Input conditions, power consumption, insulation resistance, withstand voltage |
| 2-13 Reliability | Serviceability, mean time between failures (MTBF) |
| 2-14 Quality management | Quality control certification required for manufacturers |
| 2-15 Accessories, maintenance supplies | Accessories (e.g. mounting bolts), maintenance items (spare units) |
| 2-16 Submission of documents | Submission of specifications to prove that performance and specifications are satisfied |
| **Chapter 3 Performance test** | |
| 3-1 Purpose | Method the manufacturer verifies the function and characteristics of the device |
| 3-2 Type | |
| 3-3 Implementation method | |

☐: Subject of consideration
☐: Not subject of consideration

Table 6.1.2-5 provides a list of items from the 5.9 GHz band V2X system's radio unit specifications. Corresponding content from the reference standards is given in the same table. The V2X system radio unit specification items were listed by summarizing the objectives, preconditions, and the like under "1. Scope"; system configuration and equipment composition of the system under "2. Overview of V2X system"; and the specifications and interfaces of each layer in "3. V2X communication functions/performance/interfaces."

**Table 6.1.2-5 Comparison of list of radio unit specification items with existing specifications, and organization**

| 5.9 GHz band V2X system Item list of radio unit specifications | 5.8 GHz band DSRC roadside unit equipment standards | SAE J2945/1 "On-Board System Requirements for V2V Safety Communications" | ETSI EN 302 665 "Intelligent Transport Systems (ITS); Communication architecture" |
|---|---|---|---|
| **1. Scope**<br>- Objectives<br>- Scope of application, preconditions (Target UC, requirements, etc.) | 1-1 Scope of application of this standard<br>1-5 Prerequisites for roadside radio equipment | 1. SCOPE<br>4.2 V2V Safety Features<br>5.1 V2V Over-the-Air Data Description | 1. SCOPE<br>4.3 ITSC design principles<br>5 ITS applications |
| **2. Overview of V2X system**<br>- System composition<br>- Equipment configuration | 1-4 Outline of roadside radio equipment<br>2-1 Internal configuration | 4.1 V2V System Overview | 4.5 Functional elements of ITSC<br>4.6 ITSC networking |
| **3. Functions/characteristics/interfaces of V2X communication**<br>- General requirements and wireless equipment technical requirements<br>- Congestion control part functions, characteristics, interfaces | 2-3 Functions and characteristics of the antenna part<br>2-4 Functions and characteristics of transmitter and receiver<br>2-5 Functions and characteristics of the congestion control part<br>2-10 Interface | 5.2 System Interfaces: Overview<br>6.1 Standards profiles: Details<br>6.3 BSM Transmission Requirements on Channel vChannelNumber: Details (congestion control) | 6 ITSC OSI protocol stack<br>7 ITSC management entity |

(3) Detail item extraction

"3. V2X communication functions/characteristics/interfaces" on the list of radio unit specification items is subdivided. During subdividing, the existing standards were referred to just as they were in (2).

First, detail items from general requirements and wireless equipment technical requirements were extracted following the procedure below (Fig. 6.1.2-1).

(i) Extract detail items from existing standards
(ii) Take the OR of items and organize them as V2X communication detail items

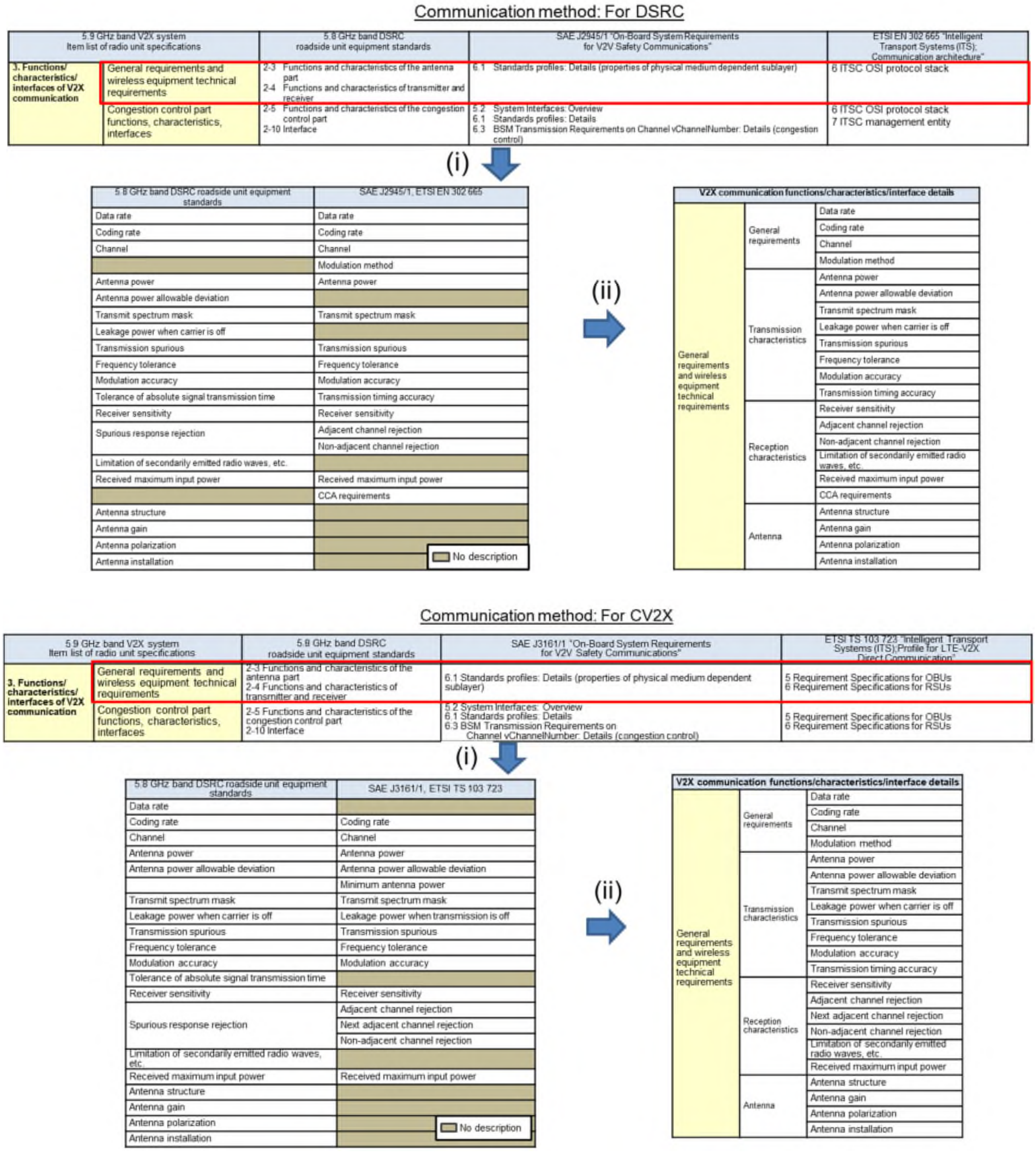



**Fig. 6.1.2-1 General requirements and wireless equipment technical requirements: how detail items were extracted**

Next, detail items of the functions, characteristics, and interfaces of the communication control part were extracted by the following procedure (Fig. 6.1.2-2).

(i) Extract detail items from existing standards
(ii) Give items the same name used in one of the specifications if they have similar content
(iii) Exclude functions that are application-specific in existing specification documents from items
(iv) Organize for each UC
(v) Take the OR of items and organize them as V2X communication detail items

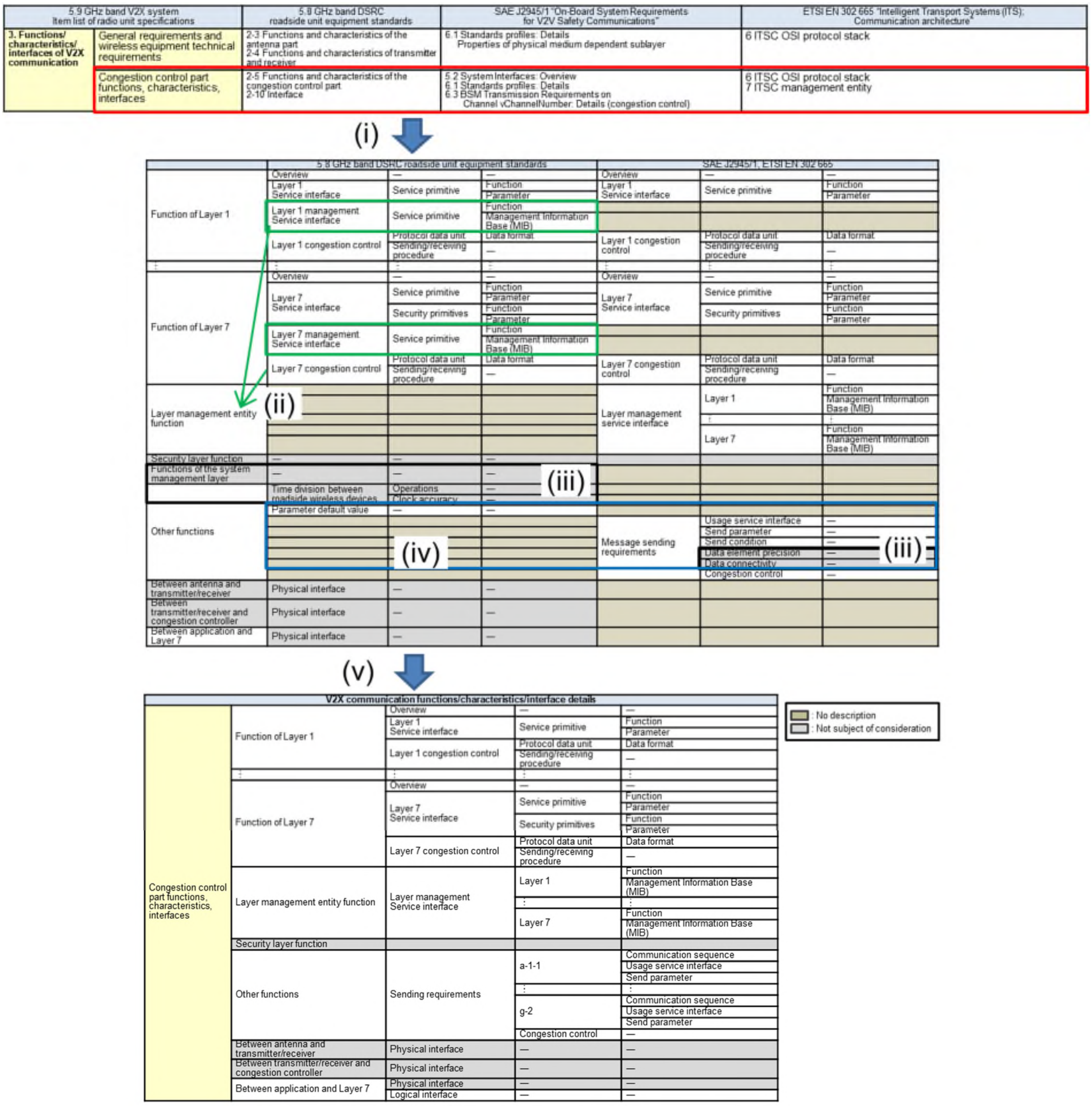



Fig. 6.1.2-2 Functions, characteristics, and interfaces of the communication control part: method of extracting detail items

Lists of radio unit specification items reflecting detail item extraction results are given in Table 6.1.2-6 and Table 6.1.2-7.

**Table 6.1.2-6 List of radio unit specification items (DSRC)**
**After detail item extraction**

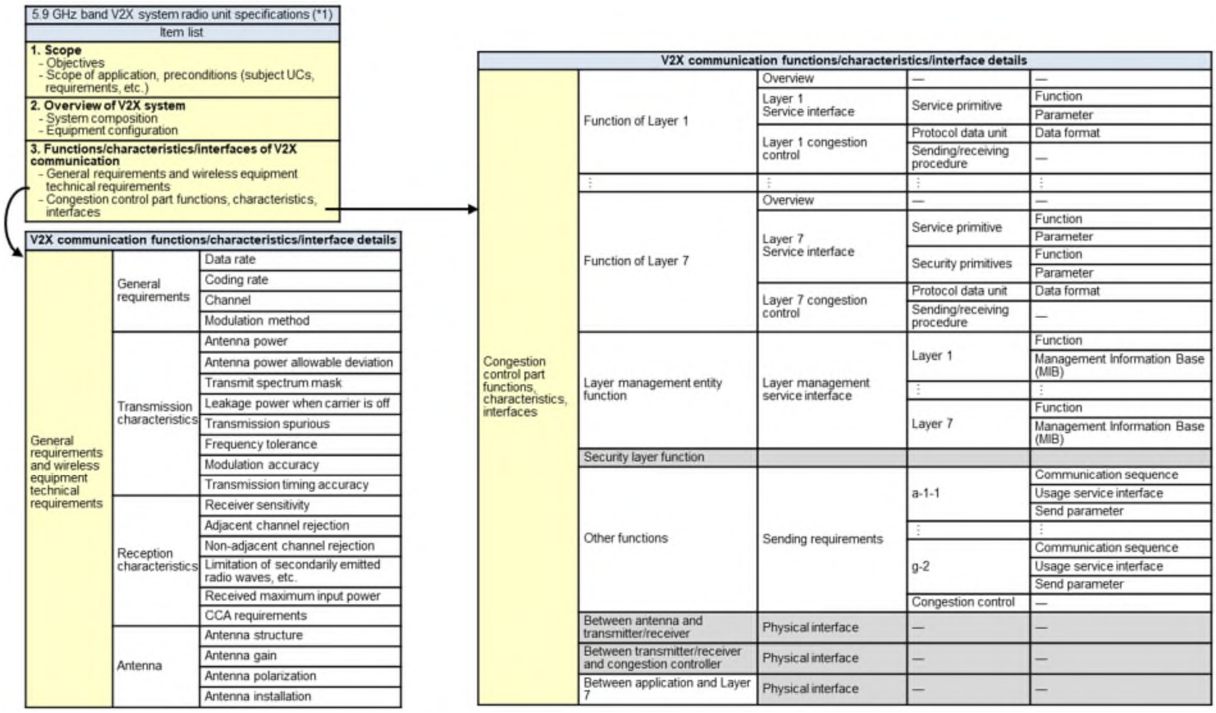
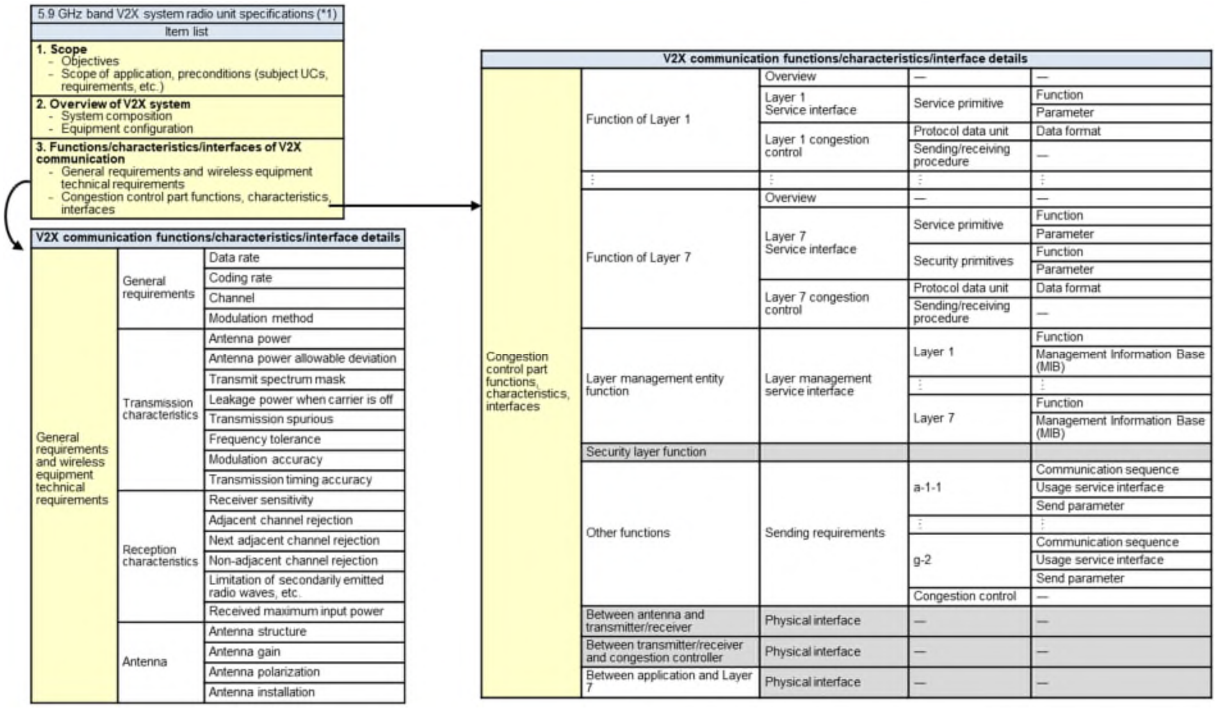



**Table 6.1.2-7 List of radio unit specification items (CV2X)**
**After detail item extraction**




### 6.1.3 Study of specifications, parameters to apply to list of radio unit specification items

This section describes how a radio unit specifications draft was created by organizing specifications and parameters to apply to the list of radio unit specification items that resulted from the study of the previous section.

(1) Scope

Following are the results of organizing the objectives, scope of application, and preconditions (subject UCs, requirements, etc.) as "1. Scope" in the list of radio unit specification items. The content of this section is organized based on the objectives of this project and the scope of study of Parts 3 to 6.

(a) Objectives

To accelerate issue resolution and study relating to the implementation of a V2X system using 5.9 GHz band radio waves to help realize cooperative driving automation, a radio unit specifications draft was compiled that includes communication protocols necessary for such implementation.

(b) Scope of application, preconditions (subject UCs, requirements, etc.)

<u>Scope of application</u>

Applies to communication layers as well as application and interfaces between communication layers and application as a radio unit specifications draft. Unless specifically noted, "application" in this section refers to an application for communication control; the application achieves the functions to exchange messages in each use case and information necessary to those messages.

<u>Preconditions</u>

- The access layer is based on ITS FORUM RC-015, the guideline for experiments on communication systems for use cases with communication for automated driving on expressways [12]
- Of the 25 types of use cases studied by SIP, those addressed when creating this specifications draft are those with V2I communication and V2V communication [13]
- Of the requirements (data volumes, communication areas, allowable delay time, communication speed, packet arrival rate, etc.; below, "ITS FORUM communication requirements") and message sets for communication as automated vehicles become more prevalent that are being studied by the ITS Info-communications Forum (below, "ITS FORUM"), those that concern DSRC (dedicated short range communication) (V2I communication and V2V communication) [14]

(2) Overview of V2X system

Results of organizing the system composition and equipment composition are described as "2. Overview of V2X system" in the list of radio unit specification items. Although the upper layers (Layer 5 to 7) and application are not necessarily separated as equipment, in this section, they are written separately to clarify the logic block that needs information.

(a) System composition

Systems connecting to the radio unit (and application) in the anticipated scenarios in each use case in ITS FORUM RC-017 and the communication sequence study results (Section 5.1.6) were organized and the system composition of both V2I communication and V2V communication in a V2X system was studied.

The results of organizing connecting systems in each use case are given in Table 6.1.3-1. Based on the study results of Part 5, because basic vehicle information is transmitted by the upper layers and messages other than basic vehicle information are transmitted by the application, OBUs require vehicle sensor information for both the upper layers and application. For that reason, even though there is only one type of connecting external system on the vehicle side, they are organized separately as a connecting method too. Concerning road side units, messages are transmitted from the application, so the interface with external systems is likewise the application. On the other hand, the external systems needing connection differ in each use case. There are five types: "roadside sensor group," "traffic signal controller," "roadside sensor group, traffic signal controller," "control server," and "automobile manufacturer, traffic information provider, etc."

Results of organizing V2I communication and V2V communication system compositions based on the list of connecting systems are given in Fig. 6.1.3-1. Here, it is assumed that information from onboard sensors, etc., will be indirectly delivered through vehicle-side control equipment, etc., so block diagrams are shown as the vehicle side. Additionally, situations where the application is built into the equipment and situations where it is not are both conceivable, but in this system composition diagram, it is expected the application will not be built into the equipment and an application processing device is provided separately. The application processing device has a function allowing multiple applications to operate.

As noted previously, the OBU’s method of connecting to the vehicle side would vary by use case, but because it is anticipated that OBUs would be used in common regardless of the use case, just one type of composition was used that would support both connecting methods. A single RSU would not necessarily support all use cases; rather, because it is possible that use cases supported will vary according to the operating form and operator, RSUs were organized into the minimum number of interfaces necessary to realize each use case. However, connections such as “control server” and “automobile manufacturer, traffic information provider, etc.” would connect through a network, so RSUs were organized into one composition that would likewise form a network as a direct interface on the radio unit side.

When organizing this, it was assumed that the method of getting own-vehicle information in the interface with vehicles would be indirect delivery through vehicle-side control equipment, etc., but details about the interface will have to be determined in consultation with groups concerned with building vehicle-side systems.

**Table 6.1.3-1 List of connecting systems in each use case**

List of connecting systems in each use case

| Classification by function | Use case | Communication Form | Connection system: Between external system and application | | Connection system: Between external system and upper layer | |
|---|---|---|---|---|---|---|
| | | | Road side units | OBU | Road side units | OBU |
| a. Merging/lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | I2V | Roadside sensor group | Vehicle side (In-vehicle sensor, etc.) | – | – |
| | a-1-2. Merging assistance by targeting the gap on the main lane | | | | | |
| | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | I2V / V2I | | | | |
| | a-1-4. Merging assistance based on negotiations between vehicles | V2V | – | | | |
| | a-2. Lane change assistance when the traffic is heavy | | | | | |
| | a-3. Entry assistance from non-priority roads to priority roads during congestion | | | | | |
| b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information | I2V | Traffic signal controller | | | |
| 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 | | – | | Vehicle side (In-vehicle sensor, etc.) |
| | c-2-2. Driving assistance based on intersection information (V2I) | I2V | Roadside sensor group, traffic signal Control machine | Vehicle side (In-vehicle sensor, etc.) | | – |
| | c-3. Collision avoidance assistance by using hazard information | V2V | – | | | |
| d. Lookahead information: Trajectory change | d-1. Driving assistance by notification of abnormal vehicles | I2V | Management server (Network) | | | |
| | d-2. Driving assistance by notification of wrong-way vehicles | | | | | |
| | d-3. Driving assistance based on traffic congestion information | | | | | |
| | d-4. Traffic congestion assistance at branches and exits | | | | | |
| | d-5. Driving assistance based on hazard information | | | | | |
| e. Lookahead information: Emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | V2V | – | | | |
| f. Information collection/ distribution by infrastructure | f-2. Collection of information to optimize the traffic flow | V2I | Car maker, traffic information provision Business operators, etc. (Network) | – | | Vehicle side (In-vehicle sensor, etc.) |
| g. Platooning/ adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | V2V | – | Vehicle side (In-vehicle sensor, etc.) | | – |
| | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | | | | | |

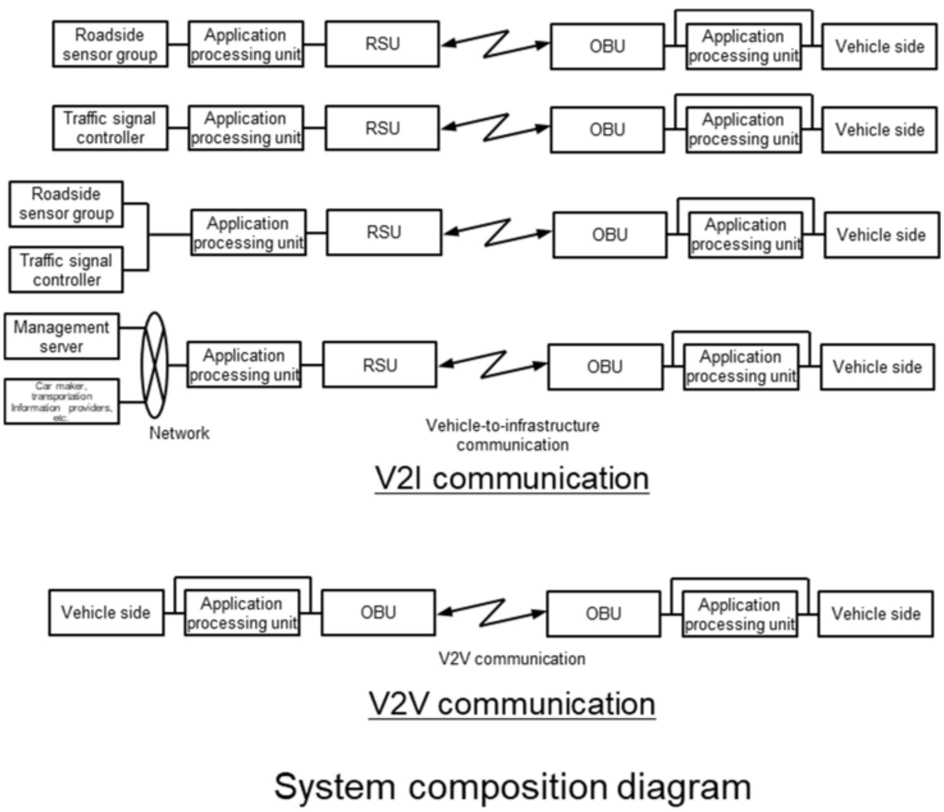



**Fig. 6.1.3-1 System composition diagram**

(b) Equipment composition

Based on the system composition diagram on the previous page and the results of the communication protocol proposal study (Section 5.1), a proposal for the anticipated composition inside the radio unit was organized. Additionally, based on the communication system roadmap [15], the composition when linked to the existing ITS (700 MHz) was organized.

Equipment composition: 5.9 GHz band radio unit only

The equipment composition of the 5.9 GHz band radio unit is given in Fig. 6.1.3-2. Considering that the functions and operations relating to channel allocation in the communication protocol proposal [anticipating that the same number of wireless parts (Layer 2 and below) would be provided as there are channels to allocate], to support multi-channel, it would be necessary to provide wireless parts or wireless parts + communication control parts (L3 to L7) in the same number as channels to allocate, so both equipment composition proposals were organized. The content in the red box in each composition diagram is the composition corresponding to the channel allocation count, since the number of units implemented changes depending on the channel allocation count. In the composition diagrams below that consider linkage to existing ITS, a situation with the same number of wireless parts as there are channels to allocate is shown as an example.

The characteristics of the composition of wireless parts in a method that supports multi-channel are given in Table 6.1.3-2. The symbol △ in this table indicates an item where there is concern this composition could be inferior to other composition proposals. Because the table provides only a qualitative comparison, it will be necessary in future to do quantitative evaluations of performance requirements, cost, implementation conditions, etc., with each composition and to clarify whether each composition meets the system requirements in order to decide whether it should be implementation-dependent or specified as a radio unit specification.

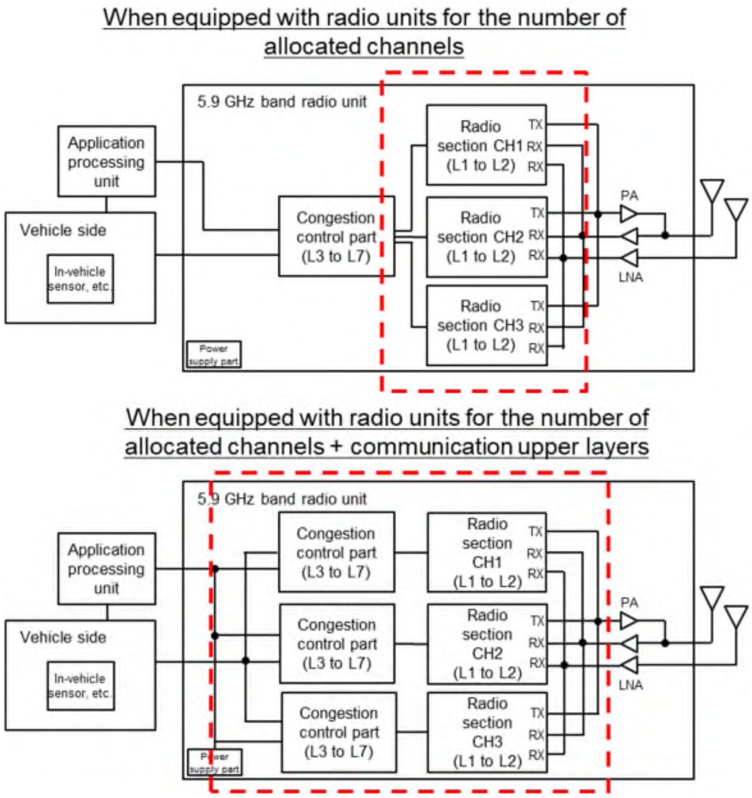



**Fig. 6.1.3-2 Equipment composition　5.9 GHz band radio unit only**

**Table 6.1.3-2 Characteristics of composition of wireless parts in a method that supports multi-channel**

| Composition | Manufacturing cost | Equipment size | Throughput (/ entire 30 MHz) | Remarks | Additions Considerations |
|---|---|---|---|---|---|
| Single radio section: Single channel | ○ | ○ | △ (20 MHz is the maximum in the referenced access layer specification) | - By applying NR-V2X in the case of C-V2X, it is possible to support 30 MHz width and improve throughput | - Detailed study of congestion control technology in upper layer |
| Single radio section: Multiple channels | ○ | ○ | △ (Delay due to channel switching and control method is a concern) | ― | - Detailed study of congestion control technology in upper layer<br>- Channel switching method in communication protocol |
| Multiple radio section Multiple channels | △ | △ | ○ | - When transmission and reception timings overlap on multiple channels, communication quality may deteriorate due to intra-terminal interference<br>- Better communication quality when applying transmission control between channels | - Detailed study of congestion control technology in upper layer<br>- Examination of required values for transmission control method and synchronization performance |

Next, composition when linked to existing ITS (700 MHz) was organized based on the communication method roadmap that was studied and organized in SIP Roadmap of V2X Communication Methods for Cooperative Driving Automation - Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2021 - . When studying the composition, reference was made to Proposals 1 to 3 of methods of linking to 700 MHz Intelligent Transport System (Section 5.1.5).

The SIP Roadmap of V2X Communication Methods for Cooperative Driving Automation is given in Fig. 6.1.3-3. Following are expected usage methods and timelines in the communication methods roadmap.

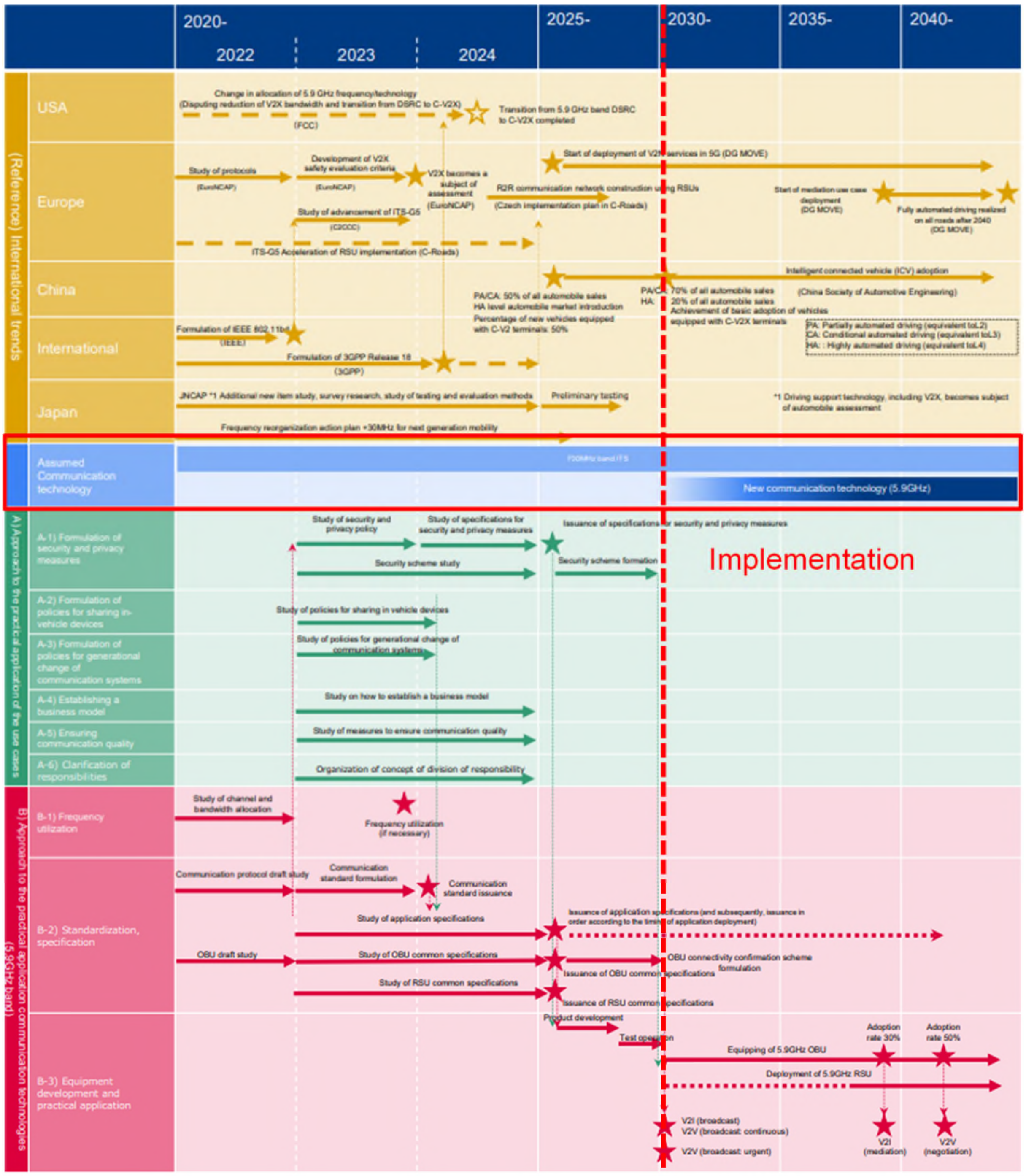
- A new communication method (5.9 GHz) is expected to be implemented in 2030
- Existing ITS wireless (700 MHz band), etc., will be used until new communication media can be provided

Based on the above expectations, the equipment composition of 5.9 GHz band radio unit was organized anticipating that there would be two time periods: implementation and after implementation. Proposals 1 to 3 are given below as the results of this effort.

- Implementation: Use of 5.9 GHz band radio unit while continuing to use existing ITS radio unit previously implemented
- After implementation: Anticipates that there will be a need for more compact communication equipment,

simpler wiring with peripheral equipment, etc.; will integrate with existing ITS radio unit

It should be noted that it is necessary to be able to continue to provide the services targeted by the old wireless device even after the introduction of the new wireless device until the replacement is completed. For this purpose, it is necessary to study the timing and method of switching frequencies used in applications in the future. A future task is to update the equipment configuration plan based on the timing and method.




Source: SIP Roadmap of V2X Communication Methods for Cooperative Driving Automation
- Activity Report of Task Force on V2X Communication for Cooperative Driving Automation in FY2021 -
https://www.sip-adus.go.jp/rd/rddata/roadmap.pdf

**Fig. 6.1.3-3 SIP Roadmap of V2X Communication Methods for Cooperative Driving Automation**

Equipment composition considering method of linkage to existing ITS: Proposal 1, Implementation of 5.9 GHz band radio unit (no linkage)

Equipment composition Proposal 1 is given in Fig. 6.1.3-4. This is one of the proposals that anticipate the period of implementation of a new communication method (5.9 GHz) in the above-mentioned roadmap; it expects existing ITS radio unit to be used as is (corresponds to linkage method Proposal 1). Since the existing ITS radio unit and their applications do not need modification, the hurdles to implementation are low, but it would be difficult to respond to revisions in the services provided by each radio unit (the frequency used by each application).

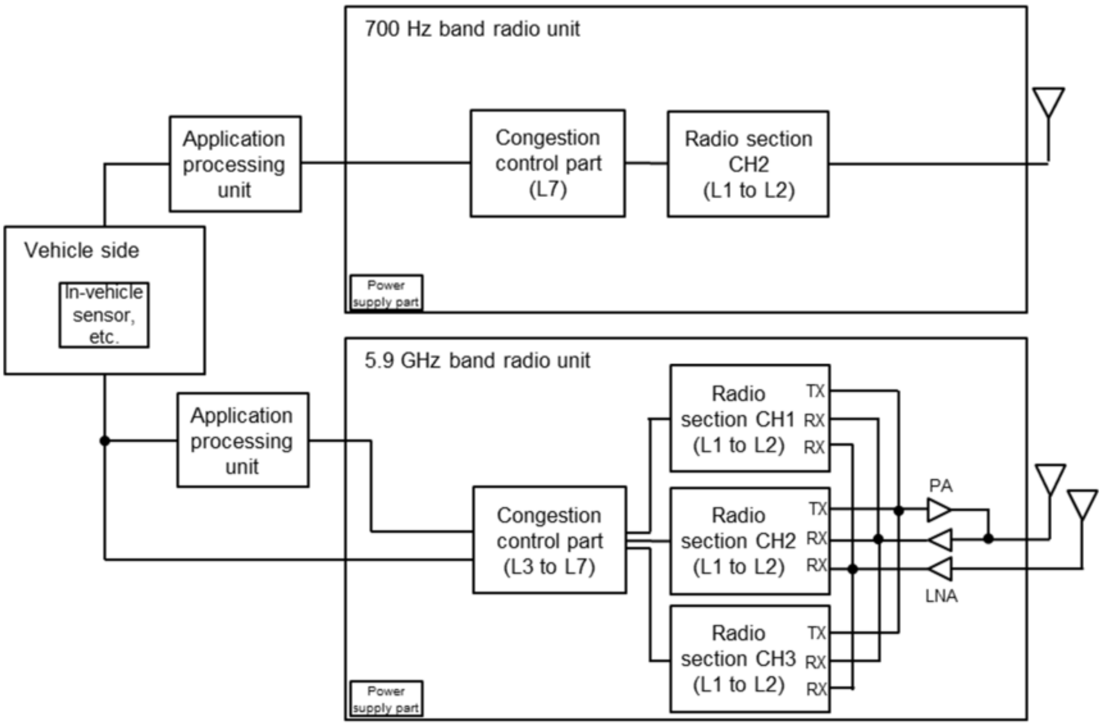



**Fig. 6.1.3-4 Equipment composition: Proposal 1, Implementation of 5.9 GHz band radio unit (no linkage)**

Equipment composition considering method of linkage to existing ITS: Proposal 2, Implementation of 5.9 GHz band radio unit (with linkage)

Equipment composition Proposal 2 is given in Fig. 6.1.3-5. Like Proposal 1, this is one of the proposals that anticipate the period of implementation of a new communication method (5.9 GHz) (corresponds to linkage method Proposal 2). To support linkage method Proposal 3, it would be necessary to add a control layer between the application and the communication control part of each radio unit to use both the 700 MHz band and 5.9 GHz band. In this proposal, unlike equipment composition Proposal 1, the composition would allow access to existing ITS and 5.9 GHz band communication layers from one application. For that reason, it is possible to switch the frequency used by each application depending on relative prevalence. On the other hand, applications would need an interface for each radio unit, so in previously implemented 700 MHz applications, it would be necessary to implement an interface with 5.9 GHz band radio unit that anticipates linkage, even before 5.9 GHz band radio units are implemented.

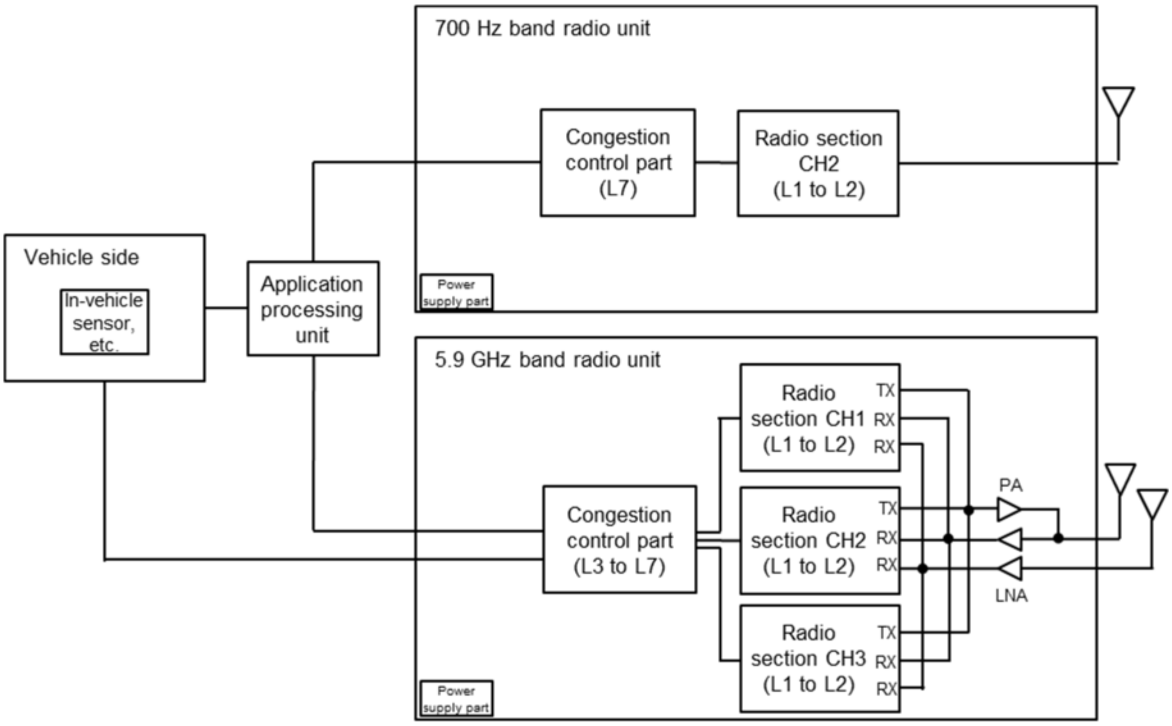



**Fig. 6.1.3-5 Equipment composition: Proposal 2, Implementation of 5.9 GHz band radio unit (with linkage)**

Equipment composition considering method of linkage to existing ITS: Proposal 3, After implementation of 5.9 GHz band radio unit (with linkage)

Equipment composition Proposal 3 is given in Fig. 6.1.3-6. Like equipment composition Proposal 2, the equipment composition diagram supports linkage method Proposal 2. This proposal anticipates the period after implementation of a new communication method in the above-mentioned roadmap and after equipment switching and the like have sufficiently advanced; existing ITS radio unit and 5.9 GHz band radio unit would be integrated into one unit. By achieving a single radio unit instead of the two required previously, it would enable power supply parts, control parts, etc., to share common modules, etc.; it is expected this would reduce the number of components and implementation space, making the equipment smaller and increasing flexibility in implementation. It is also expected it would reduce power consumption. On the other hand, it is expected it would be difficult to commonize PA, LNA, antennas, etc., because of their frequency characteristics, so equipment is composed with separate antennas for the 700 MHz band and 5.9 GHz band.

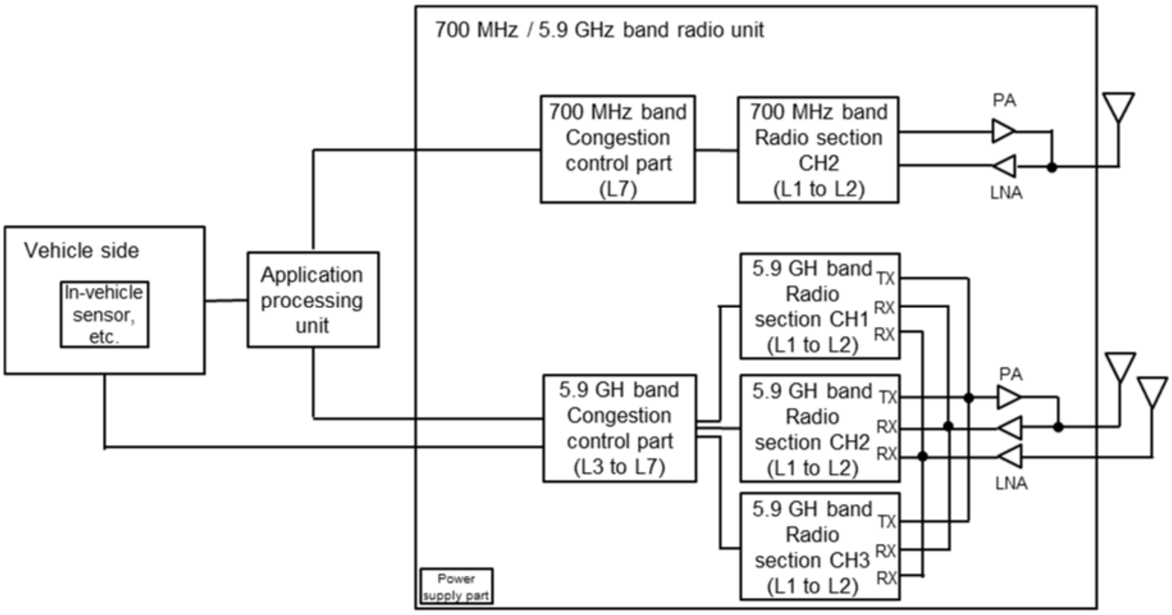



**Fig. 6.1.3-6 Equipment composition: Proposal 3, After implementation of 5.9 GHz band radio unit (with linkage)**

(3) V2X communication functions/characteristics/interfaces

Following are the results of organizing general requirements, wireless equipment technical requirements, and communication control part functions/characteristics/interfaces as V2X communication functions/characteristics/interfaces in the list of radio unit specification items.

(a) General requirements and wireless equipment technical requirements

Parameters for each item of general requirements and wireless equipment technical requirements to be applied in the next procedure were organized. First, for items governed by “Guidelines for Experiments of Communications System for Use Cases of Automated Driving on Expressways” (below, “ITS FORUM RC-015”), a guideline issued by the ITS FORUM, the values therein were applied. Next, for items not filled by the above procedure, the values used as evaluation conditions in Section 5.3 were applied. Other parameters are listed as “TBD.”

Results of organizing general requirements and wireless equipment technical requirements are given in Table 6.1.3-3 and Table 6.1.3-4. The “Reference source” column shows the literature referred to when finding each value. For parameters where there were multiple options, evaluation conditions were listed in the “Remarks” column for reference, to clarify the conditions under which evaluation was conducted in this project. Channel is listed as “TBD” because this item would be determined by the channel allocation. Items listed as “TBD” this time will need continuing study, but it is thought that antenna structure, gain, and polarization will be determined for example for each type of service provided. Moreover, polarization should ideally be the same in both RSUs and OBUs, since loss occurs between transmission and reception if each device has different polarization.

**Table 6.1.3-3 Results of study of general requirements and wireless equipment technical requirements: DSRC [12]**

| V2X communication functions/characteristics/interface details | | | Value | Quote source | Remarks |
|---|---|---|---|---|---|
| General requirements and wireless equipment technical requirements | General requirements | Data rate | Depending on the combination of modulation method and coding rate | – | – |
| | | Coding rate | Convolutional FEC R = 1/2, 2/3, 3/4 | ITS FORUM RC-015 | Evaluated with convolutional FEC R = 1/2 in reference document [1] |
| | | Channel | TBD | – | – |
| | | Modulation method | BPSK/OFDM, QPSK/OFDM, 16QAM/OFDM, 64QAM/OFDM | ITS FORUM RC-015 | Evaluation with QPSK/OFDM and 16QAM/OFDM in reference document [1] |
| | Transmission characteristics | Antenna power density | 10 mW/MHz | ITS FORUM RC-015 | – |
| | | Antenna power allowable deviation | Road side units: Upper limit 20%, lower limit 50%<br>In-vehicle units: Upper limit 50%, lower limit 50% | ITS FORUM RC-015 | – |
| | | Transmit spectrum mask | TBD | – | – |
| | | Leakage power when carrier is off | TBD | – | – |
| | | Transmission spurious | TBD | – | – |
| | | Frequency tolerance | Within $\pm 20 \times 10^{-6}$ | ITS FORUM RC-015 | – |
| | | Modulation accuracy | ■ Suppression of transmission center frequency component<br>According to the provisions of compliant document [1] "17.3.9.6.1 Transmitter center frequency leakage."<br>■ Transmit spectral flatness<br>According to the provisions of compliant document [1] "17.3.9.6.2 Transmitter spectral flatness."<br>■ Transmission modulation accuracy<br>According to the provisions of compliant document [1] "17.3.9.6.3 Transmitter constellation error."<br>BPSK, QPSK, 16QAM and 64QAM are selected in this system. | ITS FORUM RC-015 | – |
| | | Transmission timing accuracy | TBD | – | – |
| | Reception characteristics | Receiver sensitivity | According to the provisions of compliant document [1] "17.3.10.1 Receiver minimum input sensitivity."<br><br>BPSK, QPSK, 16QAM and 64QAM with "10 MHz channel spacing" are selected in this system. | ITS FORUM RC-015 | – |
| | | Adjacent channel rejection | TBD | – | – |
| | | Non-adjacent channel rejection | TBD | – | – |
| | | Limitation of secondarily emitted radio waves, etc. | TBD | – | – |
| | | Received maximum input power | TBD | – | – |
| | | CCA requirements | According to the provisions of compliant document [1] "17.3.9.6.3 Transmitter constellation error."<br>BPSK, QPSK, 16QAM and 64QAM are selected in this system. | ITS FORUM RC-015 | – |
| | Antenna | Antenna structure | TBD | – | – |
| | | Antenna gain | TBD | – | – |
| | | Antenna polarization | TBD<br>However, it is recommended to unify the polarization for both transmission and reception. | ITS FORUM RC-015 | – |
| | | Antenna installation | TBD | – | – |

Compliant document [1] IEEE802.11p-2010 [12]
Reference document [1] SIP Phase 1 "Investigation and study on message sets and protocols for automated driving support communication assuming a real environment" (FY2018)

**Table 6.1.3-4 Results of study of general requirements and wireless equipment technical requirements: CV2X [17]**

| V2X communication functions/characteristics/interface details | | | Value | Quote source | Remarks |
|---|---|---|---|---|---|
| General requirements and wireless equipment technical requirements | General requirements | Data rate | TBD | – | – |
| | | Coding rate | TBD | – | – |
| | | Channel | TBD | – | – |
| | | Modulation method | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.2.3.G." | ITS FORUM RC-015(*1) | – |
| | Transmission characteristics | Antenna power | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.2.2.G." | ITS FORUM RC-015(*1) | – |
| | | Antenna power allowable deviation | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.2.2.G." | ITS FORUM RC-015(*1) | – |
| | | Transmit spectrum mask | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.6.3.G." | ITS FORUM RC-015(*1) | – |
| | | Leakage power when carrier is off | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.3.3.G." | ITS FORUM RC-015(*1) | – |
| | | Transmission spurious | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.6.3.G." | ITS FORUM RC-015(*1) | – |
| | | Frequency tolerance | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.5.1.G." | ITS FORUM RC-015(*1) | – |
| | | Modulation accuracy | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.5.2." | ITS FORUM RC-015(*1) | – |
| | | Transmission timing accuracy | TBD | – | – |
| | Reception characteristics | Receiver sensitivity | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 6.5.1.G." | ITS FORUM RC-015(*1) | – |
| | | Adjacent channel rejection | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 7.5.1G." | ITS FORUM RC-015(*1) | – |
| | | Next adjacent channel rejection | TBD | – | – |
| | | Non-adjacent channel rejection | TBD | – | – |
| | | Limitation of secondarily emitted radio waves, etc. | TBD | – | – |
| | | Received maximum input power | According to the provisions of "3GPP TS36.101 V14.13.0 (2019-9) 7.4.1G." | ITS FORUM RC-015(*1) | – |
| | Antenna | Antenna structure | TBD | – | – |
| | | Antenna gain | Roadside unit: directivity 10 dBi or less, omnidirectional 6 dBi or less<br>In-vehicle units: 4 dBi or less | Evaluation conditions for this project | Compare the evaluation conditions of FY2021 review (*2) and select more precise communication parameters |
| | | Antenna polarization | TBD | – | – |
| | | Antenna installation | Road side units: 6.0 m or less<br>In-vehicle units: 4.1 m or less | Evaluation conditions for this project | Compare the evaluation conditions of FY2021 review (*2) and select more precise communication parameters |

*1 Value specified in "3GPP TS 36.101 E-UTRA User Equipment (UE) radio transmission and reception." [17]
*2 Ministry of Internal Affairs and Communications FY2021 frequency strain countermeasures technical experimentation office "Technical Study on 5.9 GHz Band V2X Communication System"; "Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation" in SIP Phase 2 automated driving (system and service expansion) FY2021 research and development; and "Evaluation Concerning 700 MHz Band ITS in Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation"

(b) Communication control part functions, characteristics, interfaces

Following are the results of organizing communication control part functions, characteristics, and interfaces as V2X communication functions/characteristics/interfaces in the list of radio unit specification items. Study results from Part 5 can be applied for most of the items in the scope of this study, so first the correspondences between communication control part function/characteristic/interface items and Part 5 study results are given in Table 6.1.3-5. Items which were not studied in Part 5 other than in overview were organized as follows. Concerning service primitives in Layer 5 to 7 functions, based on the communication sequence study results of Section 5.1.6, there are two types: periodic transmissions from the application and periodic transmissions from the upper layers, and based on that, these are each defined as a separate primitive and the minimum necessary parameters are listed. A layer management entity function is not necessarily needed to achieve the functions and operations of the protocol proposal studied in Section 5.1, but considering future expandability for layers with reference standards, such as Layer 1 and Layer 2, layer management entity function specifications were used as they appeared in reference standards.

**Table 6.1.3-5 Correspondences between V2X communication function/characteristic/interface items and Part 5 study results**

| V2X communication functions/characteristics/interface details | | | | |
|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 1 | Overview | — | — |
| | | Layer 1 Service interface | Service primitive | Function |
| | | | | Parameter |
| | | Layer 1 congestion control | Protocol data unit | Data format |
| | | | Sending/receiving procedure | — |
| | Function of Layer 2 | Overview | — | — |
| | | Layer 2 Service interface | Service primitive | Function |
| | | | | Parameter |
| | | Layer 2 congestion control | Protocol data unit | Data format |
| | | | Sending/receiving procedure | — |
| | Function of Layer 3 to 4 | Overview | — | — |
| | | Layer 3 to 4 Service interface | Service primitive | Function |
| | | | | Parameter |
| | | Layer 3 to 4 congestion control | Protocol data unit | Data format |
| | | | Sending/receiving procedure | |
| | Function of Layer 5 to 7 | Overview | — | — |
| | | Layer 5 to 7 Service interface | Service primitive | Function |
| | | | | Parameter |
| | | | Security primitives | Function |
| | | | | Parameter |
| | | Layer 5 to 7 congestion control | Protocol data unit | Data format |
| | | | Sending/receiving procedure | — |
| | Layer management Entity function | Layer management Service interface | Layer 1 | Function |
| | | | | Management Information Base (MIB) |
| | | | ⋮ | ⋮ |
| | | | Layer 7 | Function |
| | | | | Management Information Base (MIB) |
| | Security layer function | | | |
| | Other functions | Sending requirements | a-1-1 | Communication sequence |
| | | | | Usage service interface |
| | | | | Send parameter |
| | | | ⋮ | ⋮ |
| | | | g-2 | Communication sequence |
| | | | | Usage service interface |
| | | | | Send parameter |
| | | | Congestion control technology in the upper layer | — |
| | Between antenna and transmitter/receiver | Physical interface | — | — |
| | Between transmitter/receiver and congestion controller | Physical interface | — | — |
| | Between application and Layer 7 | Physical interface | — | — |

Correspondence with Chapter 5 study results

■For DSRC
- Table 5.1.4-13
■For CV2X
- Table 5.1.4-14

■For DSRC
- Table 5.1.4-5, 10
- Fig. 5.1.6-15,16,17
■For CV2X
- Table 5.1.4-6, 11
- Fig. 5.1.6-15,16,17

- Table 5.1.4-4, 9
- Fig. 5.1.6-15,16,17

- Table 5.1.4-15

- Table 5.1.4-3, 8
- Fig. 5.1.6-15,16,17

- Fig. 5.1.6-3 to 14

Based on the above results of organizing, the following part describes results of organizing into major items, such as "Layer 1 functions."

Results of organizing are given in Table 6.1.3-6-Table 6.1.3-13. Because reference is made in some cases to existing standards when noting function, characteristic, and interface specifications, places where it is expected that functions and operations will be the same as in reference documents are written in black, while those that are a change from the reference documents or are not included in reference documents are written in blue. Additionally, among the added functions, the wording "Other functions" was added to communication control items in each layer and those items that have not been studied to the point of detailed procedures are listed together there to avoid classifying them under an inappropriate item. Also, because the list of items was compiled systematically, items were added as necessary during organization.

Based on the results of Table 5.1.4-5, Table 5.1.4-6, Table 5.1.4-10, and Table 5.1.4-11, specifications were made to conform to ITS FORUM RC-015 for DSRC Layer 1 and CV2X Layer 1 to 2. For DSRC Layer 2, packet partitioning and priority control functions were added to ITS FORUM RC-015, while priority level, ending time, and channel identifier were added as MAC and LLC service primitive parameters.

For Layer 3 to 4, based on the results of Table 5.1.4-13, parameters concerning channel allocation and parameters for priority control must be delivered, but this can be achieved with service primitive parameters defined in reference literature, so the radio unit specification was set by listing the relevant primitives.

**Table 6.1.3-6 Results of study of communication control part functions, characteristics, interfaces: Layer 1 (DSRC) [12]**

| V2X communication functions/characteristics/interface details | | | | | Value | Remarks |
|---|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 1 | Overview | — | — | Compliant document [1] Part 1 ITS FORUM RC-005 reference method. However, the frequency band was revised to the 5.9 GHz band. | |
| | | Layer 1 Service interface | Service primitive (*1) | Request | ■ Request PHY-TXSTART<br>Function: Request to start sending MPDUs<br>Parameter: TX vector<br>■ Request PHY-DATA<br>Function: Transfer octets of data<br>Parameter: Data, user index (*2)<br>■ Request PHY-TXEND<br>Function: Complete current transmission of MPDU<br>Parameter: (none) | According to the provisions of compliant document [1] "4.2.2.1.4 PHY-TXSTART request."<br>According to the provisions of compliant document [1] "4.2.2.1.1 PHY-DATA request."<br>According to the provisions of compliant document [1] "4.2.2.1.6 PHY-TXEND request." |
| | | | | Confirmation | ■ Confirm PHY-TXSTART<br>Function: Confirm start of transmission<br>Parameter: TX status<br>■ Confirm PHY-DATA<br>Function: Confirm data transfer<br>Parameter: (none)<br>■ Confirm PHY-TXEND<br>Function: Confirm transmission completion<br>Parameter: Scrambler or CRC (*2) | According to the provisions of compliant document [1] "4.2.2.1.5 PHY-TXSTART confirm."<br>According to the provisions of compliant document [1] "4.2.2.1.3 PHY-DATA confirm."<br>According to the provisions of compliant document [1] "4.2.2.1.7 PHY-TXEND confirm." |
| | | | | Instructions | ■ Display PHY-CCA<br>Function: Notifies the current state of the media<br>Parameters: State, IP report (*2), channel list (*2)<br>■ Display PHY-RXSTART<br>Function: Signals that PLCP has received a valid start frame delimiter (SFD) and PLCP header.<br>Parameter: RX vector<br>■ Display PHY-DATA<br>Function: Confirm data transfer<br>Parameter: Data<br>■ Display PHY-RXEND<br>Function: Notifies that the currently received MPDU is completed<br>Parameter: RCPI, RX error | According to the provisions of compliant document [1] "4.2.2.1.10 PHY-CCA instructions."<br>According to the provisions of compliant document [1] "4.2.2.1.11 PHY-RXSTART instructions."<br>According to the provisions of compliant document [1] "4.2.2.1.2 PHY-DATA instructions."<br>According to the provisions of compliant document [1] "4.2.2.1.12 PHY-RXEND instructions." |
| | | Physical layer Convergence procedure sublayer | Protocol data unit | Data format | According to the provisions of compliant document [1] "4.2.3.1 Frame format." | |
| | | | Sending/ receiving procedure | Physical layer convergence procedure sublayer packet transmission processing procedure | According to the provisions of compliant document [1] "4.2.3.10 Physical layer convergence procedures." | |
| | | | | Physical layer convergence procedure sublayer packet reception processing procedure | According to the provisions of compliant document [1] "4.2.3.11 Physical layer convergence procedures." | |
| | | Physical medium dependent sublayer | — | — | According to the provisions of compliant document [1] "4.2.5 Physical media dependent sublayer." | |

Compliant document [1]:ITS FORUM RC-015 [12]
(*1) List only the primitives considered in this project
(*2) Valid only in certain cases

**Table 6.1.3-7 Results of study of communication control part functions, characteristics, interfaces: Layer 1 (CV2X) [12], [18]-[21]**

| V2X communication functions/characteristics/interface details | | | Value | Remarks |
|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 1 | Overview | Compliant Document [1] Part 2 Complies with LTE V2X (PC5) Reference Method (Compliant Documents [2] to [5]). | |
| | | Physical channel and modulation | According to the compliant document [2]. | |
| | | Multiplexing and channel coding | According to the compliant document [3]. | |
| | | Physical layer procedure | According to the compliant document [4]. | |
| | | Physical layer: Measurement | According to the compliant document [5]. | |

Compliant document [1]:ITS FORUM RC-015 [12]
Compliant document [2]:3GPP TS 36.211 [18]
Compliant document [3]:3GPP TS 36.212 [19]
Compliant document [4]:3GPP TS 36.213 [20]
Compliant document [5]:3GPP TS 36.214 [21]

**Table 6.1.3-8 Results of study of communication control part functions, characteristics, interfaces: Layer 2 (DSRC) [12]**

| V2X communication functions/characteristics/interface details | | | | | Value | Remarks |
|---|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 2 | Overview | — | — | Compliant document [1] unless otherwise stated<br>Part 1 Follows the ITS FORUM RC-005 reference method. | |
| | | Layer 2 Congestion control | Protocol data unit | Data format | According to the provisions of compliant document [1] "4.3.2 Protocol unit." | |
| | | Layer 2 (MAC) Service Interface | Service primitive | Request | ■ Request MA-UNIDATA<br>Function: Request to send MAC Service Data Unit (MSDU)<br>Parameters: Transmission source address, destination address, priority, end time, channel identifier, data | Compliant document [1]<br>Added parameters in red to the provisions of "4.3.3.2 MAC Interface Service Specifications." |
| | | | | Confirmation | — | |
| | | | | Instructions | ■ Display MA-UNIDATA<br>Function: Indicates arrival of MSDU<br>Parameters: Transmission source address, destination address, priority, data | |
| | | | Link address (MAC address) | — | According to the provisions of compliant document [1] "4.3.3.3 Link address (MAC address)." | |
| | | | Functionality of the MAC sublayer | — | According to the provisions of compliant document [1] "4.3.3.4 Functionality of the MAC sublayer." | |
| | | | Access control | — | According to the provisions of compliant document [1] "4.3.3.5 Access control." | |
| | | Layer 2 (MAC) Congestion control | Sending/receiving procedure | — | According to the provisions of compliant document [1] "4.3.3.6 Data transmission/reception control." | |
| | | | Other functions | — | ■ Packet division<br>TBD<br>■ Congestion control (priority control)<br>Perform processing based on the priority set for each message in the upper layer. | ■ Congestion control (priority control)<br>Based on the US specification and reference, it is assumed that the parameters necessary for priority control are passed from the upper layer to the lower layer |
| | | Layer 2 (LLC) Service interface | Service primitive | Request | ■ Request DL-UNIDATA<br>Function: Request to send MAC Service Data Unit (MSDU)<br>Parameters: Transmission source address, destination address, priority, WSM end time, channel identifier, data | Compliant document [1]<br>Added parameters in red to the provisions of "4.3.4.2 LLC Interface Service Specifications." |
| | | | | Confirmation | — | |
| | | | | Instructions | ■ Display DL-UNIDATA<br>Function: Indicates arrival of MSDU<br>Parameters: Transmission source address, destination address, priority, length, data | |
| | | | Types of LLC Procedures | — | According to the provisions of compliant document [1] "4.3.4.4 Types of LLC procedures." | |
| | | | LLC procedural elements | — | According to the provisions of compliant document [1] "4.3.4.5 LLC procedural elements." | |
| | | | LLC procedures | — | According to the provisions of compliant document [1] "4.3.4.6 LLC Procedures." | |

Compliant document [1]:ITS FORUM RC-015 [12]

**Table 6.1.3-9 Results of study of communication control part functions, characteristics, interfaces: Layer 2 (CV2X) [12], [23]-[25]**

| V2X communication functions/characteristics/interface details | | | Value | Remarks |
|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 2 | Overview | Compliant Document [1] Part 2 Complies with LTE V2X (PC5) Reference Method (Compliant Documents [2] to [4]). | |
| | | MAC protocol specification | According to the compliant document [2]. | |
| | | RLC protocol specification | According to the compliant document [3]. | |
| | | RDCP protocol specification | According to the compliant document [4]. | |

Compliant document [1]:ITS FORUM RC-015 [12]
Compliant document [2]:3GPP TS 36.321 [23]
Compliant document [3]:3GPP TS 36.322 [24]
Compliant document [4]:3GPP TS 36.323 [25]

**Table 6.1.3-10 Results of study of communication control part functions, characteristics, interfaces: Layer 3,4 [25]**

| V2X communication functions/characteristics/interface details | | | | | Value | Remarks |
|---|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 3, 4 | Overview | — | — | Broadcast type and direct communication are the main use cases, so there is no function other than specifying upper layer services | Assumed to have the same number of radio units (Layer 2 or lower) as the number of channel allocations |
| | | Layer 3, 4 Service interface | Service primitive (*1) | Request | ■ Request WSM-WaveShortMessage<br>Function: Request to send ASDU<br>Parameter: PSID, peer MAC address, user priority, end time, channel identifier, length, data | According to the provisions of compliant document [4] "7.3.2 WSM-WaveShortMessage.request." |
| | | | | Confirmation | ■ Confirm WSM-WaveShortMessage<br>Function: Notify data transmission result<br>Parameter: Result code | According to the provisions of compliant document [4] "7.3.3 WSM-WaveShortMessage.request." |
| | | | | Instructions | ■ Display WSM-WaveShortMessage<br>Function: Indicates arrival of ASDU<br>Parameters: PSID, peer MAC address, user priority, length, data | According to the provisions of compliant document [4] "7.3.4 WSM-WaveShortMessage.request." |
| | | Layer 3, 4 Congestion control | Protocol data unit | Data format | According to the provisions of compliant document [4] "8.3 WAVE Short Message (WSM) format." | |
| | | | Sending/ receiving procedure | Sending procedure | According to the provisions of compliant document [4] "5.5.2 WSM transmission." | |
| | | | | Receiving procedure | According to the provisions of compliant document [4] "5.5.3 WSM reception." | |

Compliant document [1]:IEEE1609.3-2010 [25]
(*1) List only the minimum required parameters

**Table 6.1.3-11 Results of study of communication control part functions, characteristics, interfaces: Layer 5 to 7 [12], [14], [16]**

| V2X communication functions/characteristics/interface details | | | | | Value | Remarks |
|---|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Function of Layer 7 | Overview | — | — | Security service primitives have similar functions in the reference document, with parameters<br>It indicates that the necessary functions considered in this project can be realized, and it is necessary to continue to consider whether to comply | |
| | | Layer 7 Service interface | Service primitive | Request | ■ Message send request<br>Function: Send UC messages<br>Parameters: Message, priority<br>■ Message trigger request<br>Function: Sends UC messages that are sent periodically by the upper layer<br>Parameter: Message, priority, upper layer communication parameters (transmission interval, timeout) | The name of each primitive is tentative. |
| | | | | Confirmation | TBD | |
| | | | | Instructions | ■ Received message display<br>Function: Pass incoming message to application<br>Parameter: message | |
| | | | Service primitive (Security) | Request | ■ Sec-SignedData.request<br>Function: Used by SDEE to require SDS to sign data<br>Parameters: Cryptographic material handle, data (*1), data type (*1), external data hash (*1,2), external data hash algorithm (*1,2), PSID, generation time setting (* 3), generation location setting (*4), end time (*1,2), signer identifier type, signer identifier certificate chain length (*1), maximum certificate chain length (* 1), signature with fast verification, elliptic curve point format, use of peer-to-peer certificate distribution, SDEE ID (*1)<br>■ Sec-SecureDataPreprocessing.request<br>Function: Used by SDEE to request that SDS perform pre-processing of secure data<br>Parameter: SDEE ID (*1), PSID, data, use of peer-to-peer certificate distribution<br>■ Sec-SignedDataVerification.request<br>Function: Used by SDEE to require SDS to verify signed data<br>Parameters: SDEE ID, PSID, content type, signed data, hash of external data (*1,2), hash algorithm of external data (*1,2), maximum length of certificate chain (*1), validity (Replay) (*3), validity (past generation time) (*4), validity period (*1), validity (future generation time) (*4), future data allowable period (*1) , generation time (*1), validity (end time) (*3), end time (*1), consistency (generation position) (*1,4), validity (generation position distance) (*3) , effective distance (*1), generation position (*1), allowable time for expired certificate revocation list (*1), validity (revoked certificate) (*4) | It is assumed that the same functions and parameters as the primitives specified in the reference document [1] are applied.<br>How to use security-related parameters other than PSID and data needs to be examined in the future along with detailed specifications. |
| | | | | Confirmation | ■ Sec-SignedData.confirm<br>Function: Returns the value calculated by the process specified in the corresponding request primitive<br>Parameters: Signed data, result code<br>■ Sec-SecureDataPreprocessing.confirm<br>Function: Returns the value calculated by the process specified in the corresponding request primitive<br>Parameter: Result code, content type (*1), service-specific permission (*1), assurance level (*1), earliest certificate revocation list time<br>■ Sec-SignedDataVerification.confirm<br>Function: Returns the result of the corresponding request primitive<br>Parameter: Result code | |
| | | Layer 7 Congestion control | Protocol data unit | Data format | TBD | |
| | | | Sending/ receiving procedure | Sending procedure | a) When sending the message received from the application as it is to the lower layer<br>b) When sending the message received from the application to the lower layer after adding the basic information of the vehicle<br>c) When the message received from the application is sent periodically in the upper layer until it is updated<br>d) When sending messages periodically in the upper layer regardless of the application | Detailed procedure needs further study |
| | | | | Receiving procedure | a) When sending a message received from a lower layer to an application | |
| | | | Other functions | — | ■ Congestion control (bandwidth control)<br>TBD<br>■ Multiplexing of information elements<br>Separate combined information elements when generating messages for multiple use cases simultaneously<br>Compliant document [2] "Appendix 1, Case 3 in Chapter 4," according to the consideration example of method 1<br>■ Split message<br>Divide into sizes that can be received by lower layers<br>■ Combine messages<br>Combine messages that have been split to a size that can be received by the lower layer<br>■ Continuous transmission control (applicable only for DSRC)<br>Compliant document [1] Part 1.2 According to the provisions of "4.4.2.1.3 Service content specifications".<br>■ Retransmit hazard information periodically<br>Targets hazard information and discards duplicates by comparing with received information<br>■ Periodic transmission of hazard information<br>Stores/updates the latest message that targets the hazard information, receives the message, and forwards it if it is within the area covered by the use case | ■ Split message<br>■ Combine messages<br>■ Retransmit hazard information periodically<br>■ Retransmit hazard information periodically<br>Details of the implementation method need to be considered in the future |

Reference document [1]:IEEE1609.2 [26]
Compliant document [1]:ITS FORUM RC-015 [12]
Compliant document [2]:ITS FORUM RC-017 [14]
(*1) Option
(*2) Not used for BSM (SAE J2945/1, SAE J3161/1)
(*3) For BSM (SAE J2945/1, SAE J3161/1), set to enabled
(*4) For BSM (SAE J2945/1, SAE J3161/1), set to disabled

**Table 6.1.3-12 Results of study of communication control part functions, characteristics, interfaces: Application**

| V2X communication functions/characteristics/interface details | | | | Value | Remarks |
|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Application features | Application features | Other functions | ■ Send message periodically<br>- Collect necessary information for each use case other than basic vehicle information<br>(Vehicles: Hazard information, etc. Roadside infrastructure: Traffic signal information, vehicle detection information, etc.<br>- Set each information element of the message<br>- Send periodically while updating information<br>■ Receive message<br>- Receive the information needed for each use case and make the decisions needed by the service<br>■ Priority setting, transmission timing determination (sender side)<br>- Determine transmission timing based on critical event determination, etc.<br>- Set priority for each message<br>■ Priority setting, transmission timing determination (receiving side)<br>- Perform processing as necessary based on the priority set on the sending side (notification to upper layer, etc.)<br><br>Below are the functions that target control/agreement use cases<br>■ Destination identification<br>- As a destination, it depends on the position, distance, etc.<br>Set range (for negotiation requests) or vehicle/roadside infrastructure ID<br>For control requests, negotiation responses, update requests, and update responses<br>■ Destination determination<br>- Based on the position and ID, determine whether the destination corresponds to the range based on the position and distance (in the case of a negotiation request), or the ID of the vehicle/roadside infrastructure (for control requests, arbitration responses, update requests, and update responses).<br>■ Request/response processing (sender side)<br>- After generating and sending a request message, wait for the reception of a response message<br>- After generating or sending a response message, wait for the next request message<br>- Perform state management<br>((Control request) -> negotiation request -> negotiation response -> Update request -> Update response -> ...)<br>■ Request/response processing (receiving side)<br>- After receiving a request message, generate and send a response message<br>- After receiving the response message, generate and send the next request message<br>- Perform state management ((control request) -> negotiation request -> negotiation response -> update request -> update response -> ...) | |

**Table 6.1.3-13 Results of study of communication control part functions, characteristics, interfaces: layer management entity [12]**

| V2X communication functions/characteristics/interface details | | | | Value | Remarks |
|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Layer management entity function | Layer 1 | Management primitives | According to the provisions of compliant document [1] "4.2.4.1 Management primitives." | |
| | | | Management Information Base (MIB) | According to the provisions of compliant document [1] "4.2.4 Physical layer management information base." | |
| | | Layer 2 | Management primitives | According to the provisions of compliant document [1] "4.3.5 Layer 2 layer management service interface." | |
| | | | Management Information Base (MIB) | TBD | |
| | | Layer 3 to 4 | Management primitives | TBD | |
| | | | Management Information Base (MIB) | TBD | |
| | | Layer 5 to 7 | Management primitives | TBD | |
| | | | Management Information Base (MIB) | TBD | |

**Table 6.1.3-14 Results of study of communication control part functions, characteristics, interfaces: other functions**

| V2X communication functions/characteristics/interface details | | | | | Value | Remarks |
|---|---|---|---|---|---|---|
| Congestion control part functions, characteristics, interfaces | Other functions | Sending requirements | a-1-1<br>a-1-2 | Communication sequence | Follow Fig.5.1.6-3 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | a-1-3 | Communication sequence | Follow Fig.5.1.6-4 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | a-1-4<br>a-2<br>a-3 | Communication sequence | Follow Fig.5.1.6-5 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | b-1-1 | Communication sequence | Follow Fig.5.1.6-6 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | c-1<br>c-3 | Communication sequence | Follow Fig.5.1.6-7 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | c-2-1 | Communication sequence | Follow Fig.5.1.6-8 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | c-2-2 | Communication sequence | Follow Fig.5.1.6-9 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | d-1~5 | Communication sequence | Follow Fig.5.1.6-10 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | e-1 | Communication sequence | Follow Fig.5.1.6-11 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | f-2 | Communication sequence | Follow Fig.5.1.6-12 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | g-1 | Communication sequence | Follow Fig.5.1.6-13 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | g-2 | Communication sequence | Follow Fig.5.1.6-14 | |
| | | | | Usage service interface | TBD | |
| | | | | Send parameter | TBD | |
| | | | Congestion control technology in the upper layer | — | Follow Section 4.2.3 | |

### 6.1.4 Radio unit specifications draft study issues

The following may be listed as future issues.

- **Continuous study of multi-channel support methods by quantitative evaluation**

Concerning the composition of a method for supporting multi-channel in the radio unit specifications [number of wireless parts (Layer 1 to 2) and communication control parts (Layer 3 to 7), etc.], it needs to be decided if there are problems with it being implementation-dependent, whether it is necessary to prescribe details, and how these will be handled. It is thought that to decide these things, a quantitative evaluation of performance requirements, cost, implementation conditions, etc., will be necessary.

- **Consideration of specifications for items whose priority has been lowered**

Upon discussion of the necessity, specifications will need to be decided for interface hardware specifications and non-communication functions (breakdown detection, power supply, etc.) and the like which are not items relating to communication standards that were the subject of priority study.

- **Detailed study of requirements of interface with vehicles**

It was assumed that the method of getting own-vehicle information would be indirect delivery through vehicle-side control equipment, etc., but it will be necessary to first organize requirements for messages such as message retrieval frequency and delay and then study the interface specifications in consultation with groups concerned.

## 6.2 FOTs (Field Operational Tests) on test course, etc.

This section describes the results of FOTs (Field Operational Tests) with actual equipment on a test course, etc. The following describes the process of testing (Section 6.2.1), and in accordance with that, the results of studying testing conditions and methods (Section 6.2.2), and results of evaluation with actual equipment indoors and outdoors, discussion, and organizing of the issues (Section 6.2.3 to 6.2.5).

### 6.2.1 Process of testing

Evaluation with actual equipment was done for the purpose of comparative analysis against results of communication performance evaluation done by channel allocation (Section 4.1) effectiveness verification and by simulation.

The study flow of FOTs (Field Operational Tests) on a test course, etc., is given in Fig. 6.2.1-1. First, the conditions and methods for imitating communication traffic on multiple channels were studied (Section 6.2.2). Next, in indoor testing, the characteristics of the impact of interference from adjacent channels were measured to confirm the testing conditions and appropriateness of the testing system (Section 6.2.3) and, on a test course, communication performance was evaluated in an environment that imitated communication traffic on multiple channels (Section 6.2.4).

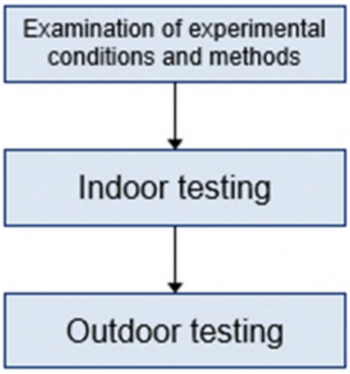



**Fig. 6.2.1-1 Study flow of FOTs (Field Operational Tests) on a test course, etc.**

### 6.2.2 Testing conditions and methods

(1) Organization of evaluation conditions

A comparison of evaluation conditions in this project and evaluation conditions from an FY2021 study (*) is given in Table 6.2.2-1. Similarly to the communication performance evaluation by simulation in Section 5.3, this evaluation anticipated multiple use cases existing together and the communication method used was CV2X (LTE V2X (PC5)). To evaluate the effectiveness of the channel allocation studied in Section 4.1, multiple communication channels were used, with bandwidth of 10 MHz and 20 MHz. In addition to PAR, delay was considered as an evaluation indicator. For outdoor testing, the 5.8 GHz band was used as an alternative frequency to the 5.9 GHz band and tests were arranged so there would be no impact on existing systems.

(*)“Study of Communication Systems for Realizing Use Cases for Cooperative Driving Automation” in SIP 2nd phase automated driving (system and service expansion) FY2021 research and development (written as “FY2021 SIP 5.9 GHz CV2X” in Table 6.2.2-1)

**Table 6.2.2-1 Comparison of evaluation conditions in this project and evaluation conditions from FY2021 study**

| Items | | Main business | FY2021 SIP |
|---|---|---|---|
| | | 5.9 GHz CV2X | 5.9 GHz CV2X |
| Operation modes | Communication channel | Multiple | Single |
| L1/L2 Related | Communication specifications | LTE V2X (PC5) | LTE V2X (PC5) |
| | Number of transmissions | Twice (Blind HARQ) | Once |
| | Antenna diversity | Present (1 transmission system, 2 reception systems) | Present (1 transmission system, 2 reception systems) |
| Radio wave propagation | Propagation environment | Test course | Test course |
| | Shadowing vehicle | Present | Present |
| Communication conditions | Evaluation case (SIP UC) | Multiple UCs | Multiple UC (c-1, c-2-2) |
| | Communication method | Road-to-vehicle/vehicle-to-vehicle | V2V |
| | | 1 to 1/N to N | 1 to 1/N to N |
| | Frequency | 5.8 GHz band | 5780 MHz |
| | Bandwidth | 10 MHz/20 MHz | 10 MHz |
| Evaluation index | Item evaluated | PAR, delay (99%) | PAR |

(2) Study of communication traffic imitation methods and multi-channel evaluation patterns

The following preconditions were used during the study of multi-channel evaluation patterns.

- Multiple channels at 5.9 GHz: 10 MHz × three channels (channel allocation Proposal 1), 10 MHz channel + 20 MHz channel (channel allocation Proposal 6)
- Concerning the placement of the three channels, a situation in which channels are adjacent to each other, which would create the most severe interference between channels, was evaluated

Study results of the testing methods are given in Fig. 6.2.2-1.

Experiment vehicles and interference vehicles were both equipped with radio unit and radio unit antennas. Hereafter, the channels used for transmissions from evaluation vehicles and from interference vehicles are referred to as “evaluation channel” and “interference channel,” respectively. “Interference vehicle” refers to a vehicle that transmits on the same or another channel as that used by the evaluation vehicle, in order to imitate use case communication traffic. By transmitting at short intervals in large packets in burst waves, depending on evaluation conditions, interference vehicles imitate communication traffic from tens to hundreds of OBUs anticipated for each use case. Within this environment, the evaluation vehicle communicated while driving, acquiring data such as PAR to distance.

The multi-channel evaluation patterns are given in the upper right of the figure. Evaluation patterns A and B feature single-channel conditions for comparison against multi-channel results, while evaluation patterns C, D, and E feature multi-channel conditions. In evaluation patterns A and B, the interference channel used is the same as the evaluation channel; use case communication traffic is added by burst transmission and the communication quality of the evaluation vehicle is evaluated. In evaluation patterns C, D, and E, the part in which communication traffic is added by burst transmission on the same channel as the evaluation channel is the same, but communication traffic from adjacent channels is also added.

In the case of burst waves, the amount of communication traffic that can be transmitted per installed radio unit used in this project is equivalent to at most 25% of the wireless resources occupation rate, but by providing four radio units that transmit interference waves on both the same channel and adjacent channels, conditions were imitated in which communication is congested. Communication traffic is provided as follows in 1:1 communication testing and N:N communication testing.

- 1:1 communication testing
  - ➢ Same channel: no transmission
  - ➢ Adjacent channels: transmit the maximum amount of communication traffic that can be transmitted by each radio unit
- N:N communication testing
  - ➢ Same and adjacent channels: imitate communication traffic on the relevant channel in simulation evaluation

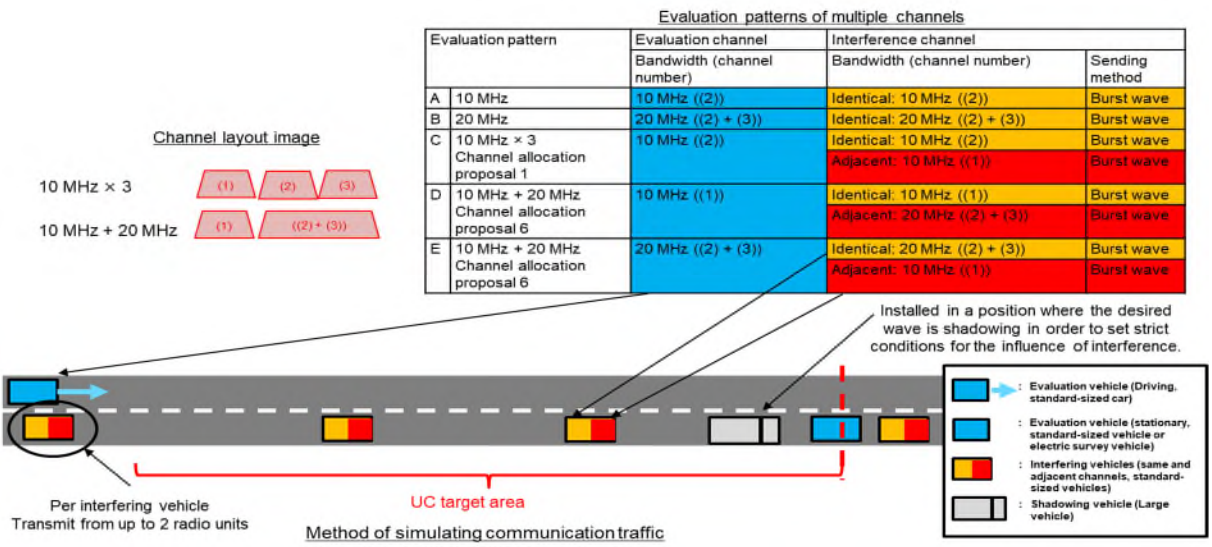



**Fig. 6.2.2-1 Study of test methods (N:N communication test)**

(3) List of items performed

A list of items performed is given in Table 6.2.2-2. In the table, conditions marked with the symbol − are not in the scope of testing, since they are combinations that do not occur in situations where channel allocation proposals in the scope of evaluation were considered.

**Table 6.2.2-2 List of test items**

| Items | Evaluation channel | Interfering channel: other channels | | Interfering channel: Co-channel | Combination of multiple UCs | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Expressway, merging section | | Prefectural and municipal roads, intersection | | |
| | | | | | Evaluation target | | | | |
| | System bandwidth | System bandwidth | Relationship with evaluation channels | System bandwidth | V2I | V2V | V2I | V2V | |
| N to N | 10 | | | 10 | ● | ● | ● | ● | Evaluation pattern A |
| | 20 | | | 20 | ● | ● | ● | ● | Evaluation pattern B |
| | 10 | 10 | Adjacent | 10 | ● | ● | ● | ● | Evaluation pattern C, channel allocation proposal 1 |
| | 10 | 20 | Adjacent | 10 | ● | − | ● | − | Evaluation pattern D, channel allocation proposal 6 |
| | 20 | 10 | Adjacent | 20 | − | ● | − | ● | Evaluation pattern E, channel allocation proposal 6 |

●: Implemented, -: Not implemented (not subject to measurement)

(4) Radio unit specifications and composition of measurement system

Radio unit specifications are given in Table 6.2.2-3.

The measurement system is given in Fig. 6.2.2-2. The equipment used were LTE-V2X (PC5) radio unit that are the subject of evaluation, PCs for controlling them, GNSS modules for measuring distances from reference points or between antennas, and a GPS receiving-type NTP server for time synchronization between the PCs of each vehicle.

**Table 6.2.2-3 Radio unit specifications**

| Items | LTE V2X (PC5) |
|---|---|
| | RSUOBU |
| Transmitting Frequency | 20 waves at 2.5 MHz intervals from 5775 to 5822.5 MHz/<br>8 waves at 2.5 MHz intervals from 5780 to 5797.5 MHz |
| Bandwidth | 10 MHz/<br>20 MHz or less |
| Transmission output | 200 mW or less |
| Modulation method | SC-FDM |
| Radio wave type | D7D, G7D, NON |
| Antenna gain | RSU: horizontal omnidirectional 5 dBi, directionality within 10 dBi<br>OBU: horizontal omnidirectional within 6 dBi |
| Antenna height | RSU: 5 to 6 m<br>OBU: 1.5 to 2 m |

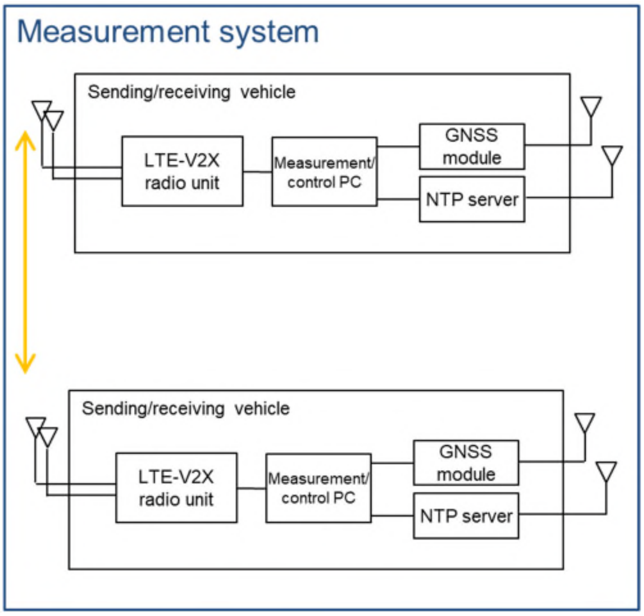



**Fig. 6.2.2-2 Composition of measurement system**

### 6.2.3 Indoor testing

This section describes results of indoor testing evaluation with actual equipment. This test evaluated interference suppression performance in an indoor imitation environment. When multiple channels are used, communication is impacted by interference from adjacent channels (and from channels adjacent to those), so the significance of this test is to confirm the actual value of equipment against this impact. Moreover, for outdoor testing, the 5.8 GHz band was used as an alternative frequency to the 5.9 GHz band, so interference suppression performance at both the 5.9 GHz band and 5.8 GHz band was evaluated and the appropriateness of usage with the alternative frequency was confirmed.

A testing overview, the measurement system, and the measurement conditions accompany each set of evaluation results. Moreover, in order to perform evaluation in the indoor imitation environment, radio units were connected to each other by wire and measurements were taken with each piece of equipment placed in a shield box so that the wrap-around of radio waves between pieces of equipment would not affect measurements.

(1) Measurement results (interference from other channels, V2V)

Results of evaluation of interference from other channels in V2V indoor testing are given in Fig. 6.2.3-1.

In the indoor testing, interference wave signals were combined with the desired wave signal while varying the level and the interference power at which the communication quality of the desired wave is within the target value (PER=$10^{-2}$) was measured.

Following is a description of the measurement conditions. The V2V communication use case chosen to be the subject of measurement was UC a-2, which, to cause severe conditions as interference impact, is predicted to have the greatest required communication range and smallest D/U of the V2V use cases, and the packet size and reception power at the specified point were set. Frequencies of the adjacent channels and channels adjacent to those were used as interference waves, and interference power with an upper limit of -25 dBm was applied to prevent equipment damage due to excess input. Moreover, the theoretical value of allowable interference power was found by calculating the interference power volume that could be allowed other than thermal noise, based on the reception power at the maximum communication range and on the required C/(N+I) found by desktop verification. The value in the case of the adjacent channels and channels adjacent to those were calculated by considering the amount of attenuation by detuning, which is found from the transmission characteristics and reception characteristics listed in the figure (*2).

Next, the measurement results are described. The allowable interference power of the vertical axis represents the interference power threshold for fulfilling the communication quality requirements; if interference power greater than this value is input, the communication quality requirements are not met. A comparison of measurement results and results of desktop calculations shows that there is an improvement of about 20 dB for adjacent channels. Data is not plotted for channels adjacent to those because no impact from interference was observed, even at the upper limit of -25 dBm. In other words, allowable interference power for channels adjacent to adjacent channels is even greater than -25 dBm. Furthermore, a comparison of results from 5.8 GHz and 5.9 GHz shows no great difference in allowable interference power between the two. Therefore, although 5.8 GHz was used as an alternative frequency to 5.9 GHz in outdoor testing, the impact of adjacent channels is predicted to be not very different than if measuring with 5.9 GHz.

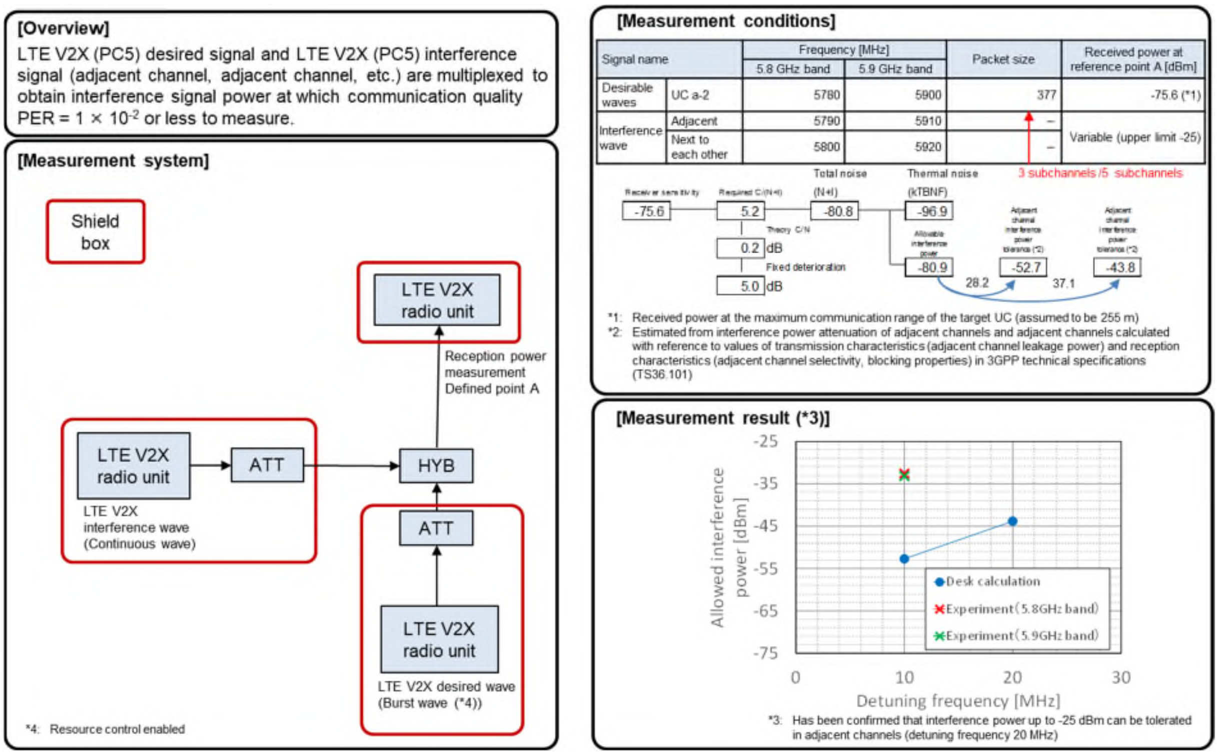



**Fig. 6.2.3-1 Indoor testing results: evaluation of interference from other channels, V2V**

(2) Measurement results (interference from other channels, V2I)

Results of evaluation of interference from other channels in V2I indoor testing are given in Fig. 6.2.3-2. The measurement method and measurement system are the same as with V2V, but when deciding the measurement conditions, UC b-1-1, a V2I use case, was anticipated and parameters were set accordingly.

Similarly to V2V, the measurement results with actual equipment confirmed improvement compared to desktop calculations for adjacent channels. Additionally, results of comparison of 5.8 GHz and 5.9 GHz were similar to those found with V2V, so it was judged that using 5.8 GHz as an alternative frequency would not be a problem.

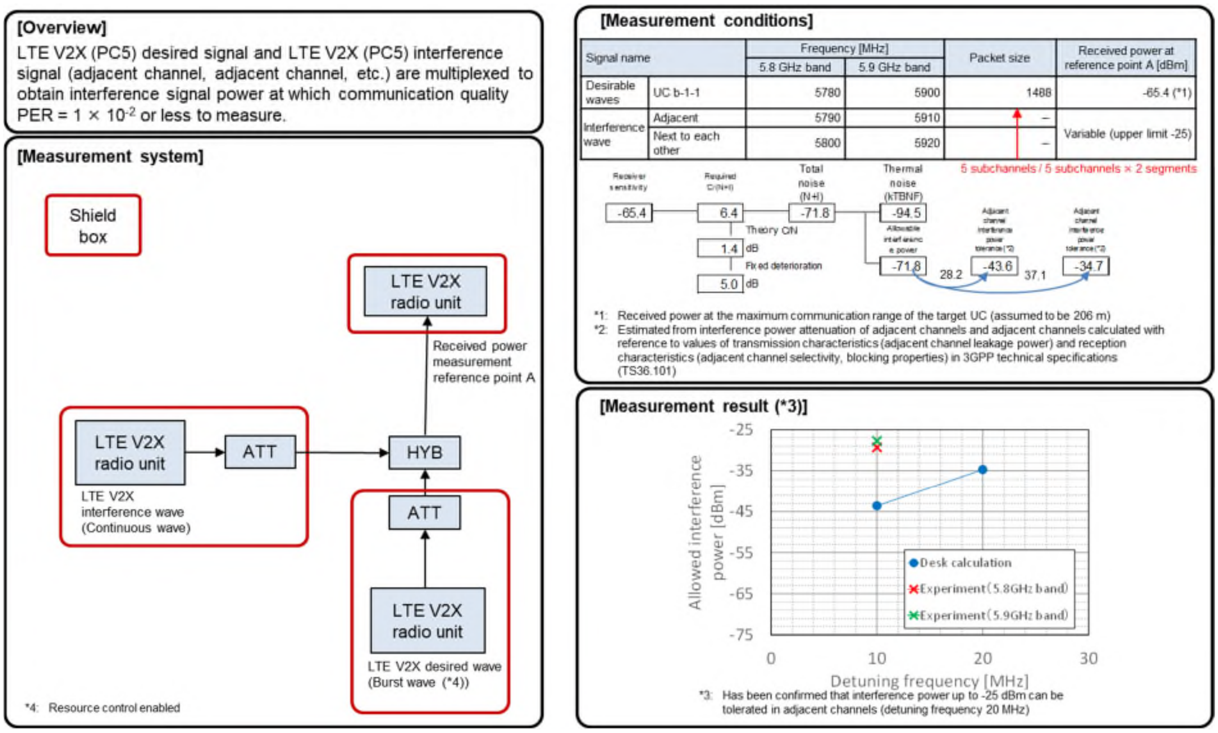



**Fig. 6.2.3-2 Indoor testing results Evaluation of interference from other channels, V2I**

### 6.2.4 Outdoor testing

(1) Testing location

Testing was conducted in the “V2X urban area” section of Japan Automobile Research Institute’s (JARI) Automated Driving Test Center (Jtown) in Tsukuba City, Ibaraki.

**Fig. 6.2.4-1 Testing location: “V2X urban area” section of Automated Driving Test Center (Jtown)**

(2) Vehicle placement

The vehicle placement at the “V2X urban area” section of Automated Driving Test Center (Jtown) is given in Fig. 6.2.4-2 and Fig. 6.2.4-3. The communication distance in the following description refers to the distance between antennas from an evaluation vehicle (fixed) to an evaluation vehicle (running).

To evaluate communication performance within the maximum communication range of the subject UC (below, “evaluation target area”), a position of approximately 400 m, where the communication distance is farther than the maximum communication distance, was used as a starting position of the evaluation vehicle. In addition, in order to evaluate under severe conditions when interference occurs, one interfering vehicle is placed at the maximum communication distance of the target UC, which is the position where the received power of the desired wave is the lowest in the evaluation target area.

Additionally, to imitate the shadowing loss that is considered in the desktop study, a large vehicle was used separately from the evaluation vehicle and interference vehicles. To cause severe conditions as interference impact, the large vehicle was placed so there would be shadowing of desired waves. Specifically, in V2V, it was placed behind a stationary evaluation vehicle. In V2I, on the other hand, even if the large vehicle was placed in the periphery of the vehicle from which radio waves were measured, the great height of the antenna meant that no shadowing occurred except in the periphery of the large vehicle. Therefore, the measurement was carried out by making the evaluation vehicle follow a large vehicle.

The numbers (1) to (4) in the figure were placed there to identify the multiple interference vehicles and correspond to (1) to (4) in the measurement conditions.


Source: Aerial photo from the Geospatial Information Authority of Japan (https://mapps.gsi.go.jp/maplibSearch.do#1), with features added to create image

**Fig. 6.2.4-2 Vehicle placement (V2V)**


Source: Aerial photo from the Geospatial Information Authority of Japan (https://mapps.gsi.go.jp/maplibSearch.do#1), with features added to create image

**Fig. 6.2.4-3 Vehicle placement (V2I)**

(3) Measurement conditions

An example of measurement conditions is given in Table 6.2.4-1. A data size was set for each interference vehicle to make it about the same as the communication traffic position distribution in the communication performance evaluation by communication simulation in Section 5.3. Additionally, based on the fact that the size of the data transmitted per vehicle is made larger to imitate the traffic of multiple vehicles, the following points were considered when calculating the size of data transmitted by each interference vehicle.

- Consideration of number of subchannels not used because of resource selection when size of packets transmitted per vehicle is considered
  [Following is a V2V example (size of packets transmitted per vehicle 377 bytes)]
  - 10 MHz
    All terminals are equal, requiring transmission on three out of five subchannels per vehicle, so the remaining two subchannels are not used for transmissions of other terminals either. Therefore, communication traffic was calculated on the assumption that subchannels would be occupied.
  - 20 MHz
    Transmission is on three out of 10 subchannels per vehicle. Depending on the subchannels selected, it is possible to transmit on two to three terminals per subframe, but to imitate severe conditions, it was assumed that transmissions could only be on two terminals at all times, and communication traffic was calculated on the assumption that the remaining subchannels would be occupied.

**Table 6.2.4-1 Measurement conditions Assuming N:N communication testing, V2V, expressway, evaluation pattern C [channel allocation Proposal 1 (multi-channel 10 MHz × 3 channels)]**

| Items | Value/specification | | |
|---|---|---|---|
| | Evaluation channel | Interference channel (identical) | Interference channel (adjacent) |
| Assumed UC | V2V UC | | |
| Data size | 377 bytes (*1) | (1) 2176 bytes<br>(2) 1088 bytes<br>(3) 1518 bytes<br>(4) 2725 bytes | (1) 2176 bytes<br>(2) 1088 bytes<br>(3) 2417 bytes<br>(4) 2725 bytes |
| Transmission interval | 100 ms | 20 ms | |
| Center frequency | 5790 MHz | 5790 MHz | 5800 MHz |
| System bandwidth | 10 MHz | | |
| Transmission power | 23 dBm | | |
| Antenna gain | 4 dBi | | |
| Antenna directivity | None | | |
| Cable/connector loss | 3.2dB | | |
| Antenna height | 1.5 m | | |
| Modulation method (encoding rate) | QPSK(0.5) | | |
| Number of transmissions | Twice (blind HARQ) | | |

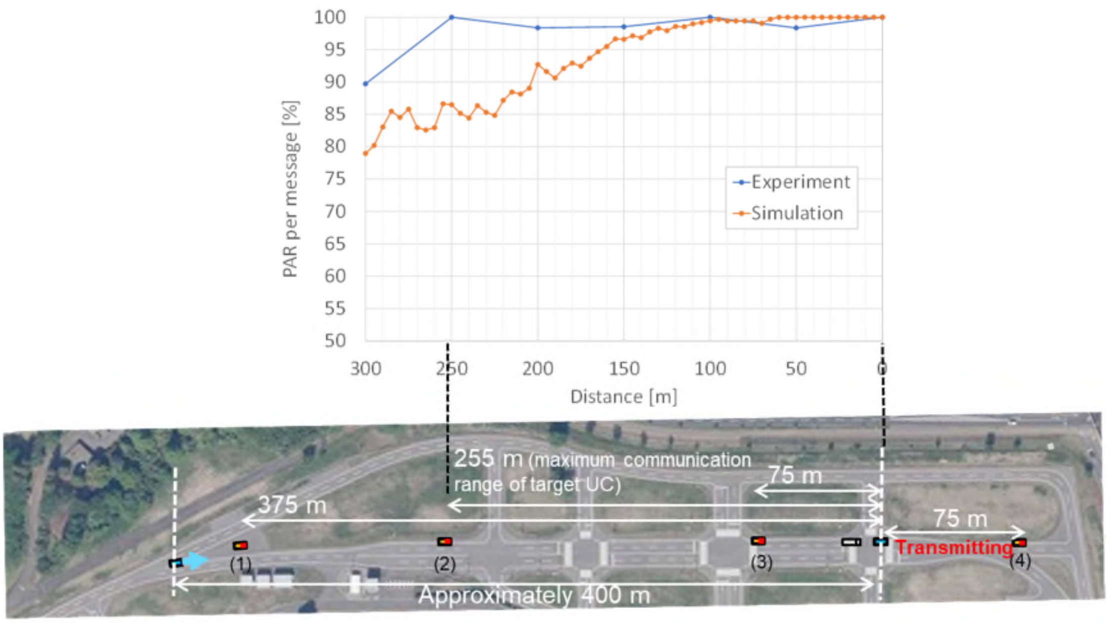
Adjust the data size for each vehicle to simulate the location distribution of communication traffic in the simulation evaluation

*1: Use of data size 3 subchannels / 5 subchannels when messages are shared for UC a-2 and e-1

(4) Testing results

An example of testing results is given in Fig. 6.2.4-4.

In the area within the maximum communication range, PAR = 98.4%. Compared to simulation results, communication quality was better at points with communication ranges of 100 m or greater. On the other hand, the results show that communication quality was worse than in the simulation at points with smaller communication ranges. A discussion of the causes of communication quality worsening at points with smaller communication ranges follows. In testing, there were situations where D/U grew smaller even in close proximity when a packet conflict happened because conditions were assumed that made D/U more severe and a large vehicle was placed in a position where only desired waves would be shadowed [supposing that packet conflict happened between the evaluation vehicle (transmitting side) at the 0 m position and an interfering vehicle at the 375 m position, it is possible that the receiving power for interference waves is larger than for desired waves starting from about the 50 m position].




Source: Aerial photo from the Geospatial Information Authority of Japan (https://mapps.gsi.go.jp/maplibSearch.do#1), with features added to create image

**Fig. 6.2.4-4 Testing results Assuming N:N communication testing, V2V, expressway, evaluation pattern C [channel allocation Proposal 1 (multi-channel 10 MHz × 3 channels)]**

A list of results from N:N communication testing outdoors that imitated communication traffic at merging sections on expressways and intersections on general roads is given in Table 6.2.4-2. For comparison, the table also gives PAR results of communication simulation that was conducted under the same communication traffic conditions imitated in outdoor testing.

**Table 6.2.4-2 Outdoor testing List of results**

PAR (top: experiment, bottom: simulation)

| Items | Evaluation channel | Interfering channel: other channels | | Interfering channel: same channel | Combination of multiple UCs | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Expressway, merging section | | General road intersection | | |
| | | | | | Evaluation target | | | | |
| | System bandwidth | System bandwidth | Relationship with evaluation channels | System bandwidth | V2I | V2V | V2I | V2V | |
| N to N | 10 | | | 10 | 96.0 | 92.1 | 60.2 | 80.7 | Evaluation pattern A |
| | | | | | 100.0 | 83.8 | 92.2 | 45.8 | |
| | 20 | | | 20 | 100.0 | 99.8 | 84.0 | 95.9 | Evaluation pattern B |
| | | | | | 100.0 | 96.6 | 95.3 | 66.7 | |
| | 10 | 10 | Adjacent | 10 | 95.7 | 98.4 | 100.0 | 88.7 | Evaluation pattern C, channel allocation proposal 1 |
| | | | | | 99.0 | 84.2 | 99.4 | 63.6 | |
| | 10 | 20 | Adjacent | 10 | 99.5 | - | 100.0 | - | Evaluation pattern D, channel allocation proposal 6 |
| | | | | | 99.7 | | 99.3 | | |
| | 20 | 10 | Adjacent | 20 | - | 100.0 | - | 96.6 | Evaluation pattern E, channel allocation proposal 6 |
| | | | | | | 91.5 | | 85.0 | |

### 6.2.5 Discussion and issues regarding testing results

This section discusses the testing results (Section 6.2) and describes the results of organizing the issues.
In the comparison of results in the single channel and multiple channels, the following trends were obtained. Concerning channel allocation, in both V2V and V2I communication, allocating V2V communication use cases to one channel of 20 MHz bandwidth resulted in better communication quality than allocating to two channels of 10 MHz bandwidth. Using fewer channels where information element multiplexing is possible in vehicle transmissions can multiplex more information elements and reduce security overhead (communication volume), which is thought to be an effective way to ensure communication quality within the channel and reduce interference to other channels. This trend is similar to the results of simulation evaluation.

However, a comparison of the results of single channel (20 MHz) and multi-channel (10 MHz + 20 MHz) at merging sections on expressways shows that communication quality was inferior in multi-channel when simulation was performed, but communication quality was about equal when testing was conducted. It is thought that the cause of inferior communication quality during simulation could be interference from the other channel (10 MHz), whereas in testing, the actual value of equipment against interference from adjacent channels is better than the desktop results, as was confirmed in indoor testing, which could explain the gap.

The following may be listed as future issues.

- **Verification on actual equipment when multi-channel transmitting and receiving were implemented using one radio unit**

During the FOTs (Field Operational Tests), validation was conducted using the same number of radio unit as there were channels when imitating multi-channel transmitting and receiving, but there is concern that when multi-channel on a single radio unit is achieved, communication performance could suffer from sharing an antenna with another channel and switching between transmitting and receiving, so it is thought necessary to verify this impact with actual equipment.

## 6.3 Organization of implementation issues and strategies to resolve them

This part describes the results of organizing the implementation issues and a study of strategies for resolving them.

Results of organizing implementation issues and strategies for resolving them are given in Table 6.3-1.

**Table 6.3-1 Results of organizing implementation issues and strategies for resolving them**

| Issues | Description | Strategies for resolving |
|---|---|---|
| Continuous study of multi-channel support methods by quantitative evaluation | It is necessary to decide whether to specify the details of the configuration of the multi-channel support method in the wireless device specifications. | Quantitatively evaluate performance requirements such as throughput, costs, implementation conditions, etc., and clarify the gaps in the system requirements for each configuration. |
| Updating wireless device specifications based on how to link with existing radio systems | If you need functions, interfaces, etc. for cooperation, it is necessary to replace the equipment, especially the 700MHz band wireless device that has been introduced in advance. | Clarify the performance and functional requirements necessary for coordination according to the channel allocation study results.<br>Based on the results, we will implement functions for cooperation in the 700MHz band wireless device prior to the introduction of the 5.9GHz band. |
| Detailed examination of interface requirements with the vehicle | As a method of obtaining own vehicle information, it is assumed that the information is passed through the control device on the vehicle side.<br>It is necessary to decide the applicable interface specifications in the future. | While considering flexibility and scalability for future additions and changes to UC, clarify requirements such as message information acquisition frequency and delay based on service requirements and service feasibility.<br>Based on the results, we will discuss and consider with related organizations. |
| Detailed determination of security specifications | Security specifications for domestic V2X systems have not yet been decided. | Considering trends in Europe and the United States, IEEE1609.2 (currently being revised) is considered to be one of the options for V2X security. It is necessary to obtain a consensus among users and stakeholders on how to apply it. |
| Promotion of standardization of upper layers of communication | Establish a forum for industry-academia-government to examine the details of the standard specifications for the upper layer of communication. In addition, standardization strategies should be considered. | Strengthen cooperation with organizations such as users and providers, who are stakeholders regarding standardization, and determine standardization strategies and objectives.<br>Furthermore, we will select the target standardization organization for the draft standardization and promote standardization. |

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[16]IEEE 802.11p-2010 IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments
https://standards.ieee.org/ieee/802.11p/3953/
[17]3GPP TS 36.101 Evolved Universal Terrestrial Radio Access(E-UTRA); User Equipment (UE) radio transmission and reception
[18]3GPP TS 36.211 Evolved Universal Terrestrial Radio Access(E-UTRA); Physical channels and modulation
[19]3GPP TS 36.212 Evolved Universal Terrestrial Radio Access(E-UTRA); Multiplexing and channel coding

[20]3GPP TS 36.213 Evolved Universal Terrestrial Radio Access(E-UTRA); Physical layer procedures
[21]3GPP TS 36.214 Evolved Universal Terrestrial Radio Access(E-UTRA); Physical layer; Measurements
[22]3GPP TS 36.321 Evolved Universal Terrestrial Radio Access(E-UTRA); Medium Access Control (MAC) protocol specification
[23]3GPP TS 36.322 Evolved Universal Terrestrial Radio Access(E-UTRA); Radio Link Control (RLC) protocol specification
[24]3GPP TS 36.323 Evolved Universal Terrestrial Radio Access(E-UTRA); Packet Data Convergence Protocol (PDCP) specification
[25]IEEE 1609.3-2020 IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services
https://standards.ieee.org/ieee/1609.3/10360/
[26] IEEE 1609.2-2016 IEEE Standard for Wireless Access in Vehicular Environments --Security Services for Applications and Management Messages
https://standards.ieee.org/ieee/1609.2/6038/

# 7. Exchange of opinions with concerned parties

In conducting this study, monthly meetings were held with concerned parties to exchange opinions with the ITS Forum and related organizations and institutions, results of the study were reported, opinions from all concerned parties were received, and those were reflected in this study. Meetings of the Radio System Technology TG of the Advanced ITS Info-communication Systems Committee of the ITS Info-communications Forum (hereinafter, the "TG") were attended, where the results of the study were reported and opinions from task group members were received, and those were reflected those in this study.

## 7.1 Meeting body

The meeting bodies and participating members are shown in Table 7.1-1.

**Table 7.1-1 Meeting body**

| No. | Meeting body | Participating members | When held |
|---|---|---|---|
| 1 | Study group on research findings | JAMA representatives, ITS Forum representatives, observers (Cabinet Office, Ministry of Internal Affairs and Communications, NEDO), Oki Electric Industry, NEC | Held once monthly |
| 2 | ITS Forum Radio System Technology TG/individual meeting | ITS Forum representatives, TG members, Oki Electric Industry, NEC | Held about once monthly |

## 7.2 Study group on research findings

The following is a summary of the results of holding/participation in study group on research findings and the contents of the report.

### 7.2.1 Results

The study group on research findings held during the period are shown in Table 7.2.1-1

**Table 7.2.1-1 Results of holding Study group on research findings**

| No. | Date held | Meeting |
|---|---|---|
| 1 | May 31, 2022 | 1st study group on research findings |
| 2 | June 30, 2022 | 2nd study group on research findings |
| 3 | July 29, 2022 | 3rd study group on research findings |
| 4 | Aug 30, 2022 | 4th study group on research findings |
| 5 | Oct 4, 2022 | 5th study group on research findings |
| 6 | Nov. 1, 2022 | 6th study group on research findings |
| 7 | Dec. 19, 2022 | 7th study group on research findings |

### 7.2.2 Report contents, comments/suggestions, and status of response

Main report contents, comments/suggestions, and status of responses for each time held/participated are shown in Table 7.2.2-1.

**Table 7.2.2-1 Report contents, comments/suggestions in study group on research findings**

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| Suggestions at 1st study group on research findings (5/31) | | | |
| 1 | • Explanation of details of implementation and overall policy | • What sort of traffic environment is assumed for traffic flow simulation? Please provide preconditions regarding the timing, percentage of vehicles equipped with ADAS systems, etc. In particular, please provide evidence (literature, etc.) regarding vehicle behavior.<br>• Regarding use cases for traffic flow simulation, please select them after considering what kind of communication protocols are assumed and how communication congestion will occur. | • Already explained in 2nd study group on research findings.<br>• Already explained in 2nd study group on research findings. |
| 2 | | • Regarding the SIP use cases (25 types) to be studied, please organize whether there are any use cases unique to Japan, and in addition, whether there are any protocols or message sets that have not been studied in other countries. | • Already explained in 2nd study group on research findings. (No major difference) |
| 3 | | • Wi-Fi6 (5 GHz band) will begin to be used, and we believe it will cause interference to V2X in the 5.9 GHz band. We believe it is necessary to identify global trends regarding interference countermeasures. What is the division of roles between V2N and V2I? | • Since the study of interference up to last fiscal year was based on use cases in Japan, implementation of investigations of interference countermeasures, etc., in other countries will be included in reports as future issues. |
| 4 | | • Please clarify what is expected as the output of this project. We would like to agree on what the final output will be before proceeding with the meeting discussion, so please organize and present it at the next meeting. | • Already explained in 2nd study group on research findings. |
| Suggestions at 2nd study group on research findings (6/30) | | | |

<table>
<tr><th>No.</th><th>Report contents</th><th>Related comments/suggestions</th><th>Response</th></tr>
<tr><td>1</td><td rowspan="6">• Section a Survey of international trends<br>• Section b Research aimed at developing communication protocol proposals<br>  • Proposal allocation of communication channels<br>  Comparison and organization of messages<br>  Concept of allocation proposal<br>  • Effect verification through traffic flow simulation<br>  Verification content, simulation content<br>• Section c Design of communication protocol proposal<br>  • Evaluation of communication performance by simulation<br>  Process of study<br>• Section d Proposing wireless device specifications<br>  • Examination of wireless device specifications</td><td>• Regarding the survey of trends outside Japan, please brush up taking into account on the addition of any omissions and the latest status of the study.</td><td>• Based on the conversations with experts, the materials have been brushed up and already explained at the 3rd study group on research findings.</td></tr>
<tr><td>2</td><td>• Please unify the use case and message comparison and organization tables and reorganize.</td><td>• Already reorganized and explained in the 3rd study group on research findings.</td></tr>
<tr><td>3</td><td>• Please clarify the concept of the channel allocation proposal.</td><td>• Materials have already been reorganized and sent by email.</td></tr>
<tr><td>4</td><td>• Please brush up the content described in “Organization of input/output of the project.”</td><td>• It will be revised based on suggestions in the meeting.<br>=> Explained in the 3rd study group on research findings.</td></tr>
<tr><td>5</td><td>• Please consider the purpose and content of communication simulation evaluation.</td><td>• Purpose and content will be organized and explained in the study group on research findings.<br>=> Already explained in 4th study group on research findings.</td></tr>
<tr><td>6</td><td>• Please also investigate specifications other than SAE J2945/1 and reflect in the draft items of wireless device specifications.</td><td>• Items to be investigated were added and reorganization done, and the results of the reorganization have already been explained at the 4th study group on research findings.</td></tr>
<tr><td colspan="4">Suggestions at 3rd study group on research findings (7/29)</td></tr>
<tr><td>1</td><td>• Section b Research aimed at developing communication protocol proposals<br>  • Allocation of communication channels<br>  Channel allocation proposal</td><td>• The concept of communication range in communication capacity estimation should be reviewed upon coordination with the ITS Forum.</td><td>• In coordination with ITS Forum, communication range in the communication capacity estimation will be the made to be communication requirements.<br>=> Already explained in 4th study group on research findings.</td></tr>
</table>

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| 2 | • Effect verification through traffic flow simulation<br>Status of verification (interim report)<br>• Section c Design of communication protocol proposal<br>• Design of communication protocol proposal<br>• Consideration of message proposal<br>Report on status of consideration/organization<br>• Evaluation of communication performance by simulation<br>Organization of evaluation conditions<br>• Section d Proposing wireless device specifications<br>• Examination of wireless device specifications<br>Draft items of specifications document | • Communication capacity estimation and required bandwidth estimation should be considered separately. | • Communication capacity estimation and required bandwidth estimation will be provided separately.<br>=> Already explained in 4th study group on research findings. |
| 3 | | • Regarding the use case/message comparison table, please add information such as whether there are differences in communication methods and message content to the extent known. | • Materials will be brushed up.<br>=> Already explained in 4th study group on research findings. |
| 4 | | • Regarding p. 8-9, the communication control flow diagram on the left and the protocol stack diagram on the right should be revised so that the corresponding parts of each layer match. | • Already explained in 4th study group on research findings. |
| 5 | | • Simulation conditions should be organized, including the type of diversity. | • Already explained in 4th study group on research findings. |
| 6 | | • Beginning next time, the description should indicate the overall process, the current progress, and the contents this time. | • Already handled in the 4th study group on research findings. |
| 7 | | • Next time, please show the plan for FOTs (Field Operational Tests). | • Already explained in 4th study group on research findings. |
| Suggestions at 4th study group on research findings (8/30) | | | |
| 1 | • Section b Research aimed at developing communication protocol proposals<br>• Proposal allocation of communication channels<br>• Upper layer communication (congestion) control method<br>• Effect verification through traffic flow simulation<br>• Section c Design of communication protocol proposal | • Please clarify the rationale for the parameters (vehicle gap) to be set at traffic flow simulations. | • Already explained in 5th study group on research findings. |
| 2 | | • Regarding the communication (congestion) control method, please organize a comparison table for each of the SAE and ETSI methods. | • Already explained in 5th study group on research findings. |
| 3 | | • Regarding the communication (congestion) control method, please organize verification details for results studied. | • Already explained in 6th study group on research findings. |

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| | • Design of communication protocol proposal<br>• Consideration of message proposal<br>• Evaluation of communication performance by simulation<br>• Section d Proposing wireless device specifications<br>• Examination of wireless device specifications<br>• FOTs (Field Operational Tests) on test courses, etc. | | |
| Suggestions at 5th study group on research findings (10/4) | | | |
| 1 | • Section b Research aimed at developing communication protocol proposals<br>• Allocation of communication channels<br>• Upper layer communication (congestion) control method<br>• Effect verification through traffic flow simulation<br>• Section c Design of communication protocol proposal<br>• Design of communication protocol proposal<br>• Evaluation of communication performance by simulation<br>• Section d Proposing wireless device specifications<br>• FOTs (Field Operational Tests) on test courses, etc. | • Regarding allocation of communication channels, various issues can be assumed in the implementation of multichannel to communication terminals. This should be clearly stated as a future issue to consider. | • Already explained in 6th study group on research findings. |
| 2 | | • At traffic flow simulation, please clarify whether sensing and processing delays on the vehicle side are taken into account as receiving opportunity. | • Receiving opportunity is set as 100 ms to 500 ms, and no values are placed as sensing and processing delays on the vehicle side. That will be added to the materials.<br>=> Already explained in 6th study group on research findings. |
| 3 | | • In the protocol study, basic policy should be presented on how 760 MHz should be handled. | • Additional study is needed taking into consideration coordination with 760 MHz after performing a study assuming 5.9 GHz. Basic policy will be added to the materials. |
| 4 | | • In outdoor tests, please add tests not only when the interfering channels are adjacent to each other, but also when they are apart. | • Based on the results of the indoor tests to be conducted first, items such as addition of conditions for outdoor tests will be studied. |

<table>
<tr><th>No.</th><th>Report contents</th><th>Related comments/suggestions</th><th>Response</th></tr>
<tr><td></td><td rowspan="2"></td><td></td><td>=> Already explained in 6th study group on research findings.</td></tr>
<tr><td>5</td><td>• The test conditions need to be determined by confirming the assumed transmission power density.</td><td>• After confirming the settings of the test machine, the conditions, etc., will be organized and added to materials.</td></tr>
<tr><td colspan="4">Suggestions at 6th study group on research findings (11/8)</td></tr>
<tr><td>1</td><td rowspan="7">• Section b Research aimed at developing communication protocol proposals<br>• Upper layer communication (congestion) control method proposal<br>Report on desktop verification<br>• Proposal allocation of communication channels (summary)<br>• Effect verification through traffic flow simulation<br>Report on additional verification<br>• Project results compilation policy (draft)<br>• Section c Design of communication protocol proposal<br>• Report on the communication protocol proposal and the status of desktop review<br>• Section d Proposing wireless device specifications<br>• FOTs (Field Operational Tests) on test courses, etc.<br>Progress report<br>• Results content (draft)</td><td>• Regarding communication channel allocation, please present the concept of frequency allocation.</td><td>• Already explained in 6th study group on research findings.</td></tr>
<tr><td>2</td><td>• Regarding communication (congestion) control, please confirm the rationale for setting parameters in SAE and ETSI.</td><td>• The basis for setting parameters in SAE and ETSI will be confirmed and presented.</td></tr>
<tr><td>3</td><td>• Regarding control based on the driving environment of communication (congestion) control, please organize the method of obtaining individual information, issues, etc.</td><td>• How to obtain individual information, issues, etc., will be organized.</td></tr>
<tr><td>4</td><td>• Regarding traffic flow simulation, what was the reason for implementing with the vehicle time gap reduced to 1.3 s?</td><td>• It was implemented as reference verification. This will be clearly stated.</td></tr>
<tr><td>5</td><td>• Regarding the communication (congestion) control method, what procedures will be used to develop specifications in the future?</td><td>• Procedures for future studies will be organized.</td></tr>
<tr><td>6</td><td>• Regarding the division of functions, processing flow, etc., of each layer in the protocol, please add a description of the receiving side as well.</td><td>• A description of the receiving side will also be added.</td></tr>
<tr><td>7</td><td>• Please organize and explain again points such as purpose of this project, its activities, and what should be done in the end.</td><td>• Explanatory materials will be added as a project overview.</td></tr>
</table>

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| 8 | | • That there is no description of the state where a request message is sent and a response is waited for, so please confirm. | • When organizing the overall communication sequence, consideration will be made for the transition thought to be necessary to return a response.<br>=> Already explained in 7th study group on research findings. |
| Suggestions at 7th study group on research findings (12/19) | | | |
| 1 | • Section a Survey of international trends<br>• Section b Research aimed at developing communication protocol proposals<br>• Section c Design of communication protocol proposal<br>• Section d Proposing wireless device specifications<br>• Summary report of final results of the study | • Please describe in the report of outcomes that there are implementation issues with multichannel at this time. | • That will be described in the report. |
| 2 | | • "Dynamic map" is a concept, so please describe the specific data collection sources anticipated, for example, fixed information on high-precision maps or dynamic information that can be distributed. | • The description will be corrected to be the appropriate data collection source. |
| 3 | | • Regarding traffic flow simulation, please note that automated vehicles should have approximately 2 seconds gap and that it is a prerequisite that they will not collide at sudden hard braking. | • That will be clearly stated as preconditions. |
| 4 | | • Please specify the meaning of symbols such as "○" and "△" in the individual tables in the materials. | • Meanings of "○" and "△" in tables will be added. |
| 5 | | • Please provide a separate venue to explain the transactions that were omitted. | • Explanation will be given at an opportunity provided separately. |
| 6 | | • If there are items that need further discussion at the ITS Forum, please summarize them in the report as action items. | • Items requiring further discussion will be summarized in the report as action items. |
| 7 | | • Regarding the configuration of OBU, please describe in the report as considerations issues related to expandability, taking into account the need to ensure continuity of service. | • That will be described in the report. |

### 7.3 ITS Forum

The following is a summary of holding and results of participation in meetings with the ITS Forum and the contents of the report.

#### 7.3.1 Results

Meetings participated in during the period are shown in Table 7.3.1-1.

**Table 7.3.1-1 Results of participation in ITS Forum meetings**

| No. | Date held | Meeting |
|---|---|---|
| 1 | May 16, 2022 | 160th Radio System Technology TG |
| 2 | June 13, 2022 | 161st Radio System Technology TG |
| 3 | July 11, 2022 | 162nd Radio System Technology TG |
| 4 | Aug 4, 2022 | 163rd Radio System Technology TG |
| 5 | Aug 18, 2022 | ITS Forum Radio System Technology Task Group - Contractors meeting |
| 6 | Sept 9, 2022 | 164th Radio System Technology TG |
| 7 | Sept 13, 2022 | ITS Forum Advanced ITS Info-communication Systems Committee Interim Report |
| 8 | Sept 30, 2022 | ITS Forum Radio System Technology Task Group - Contractors meeting |
| 9 | Oct 7, 2022 | 165th Radio System Technology TG |
| 10 | Nov. 1, 2022 | ITS Forum Radio System Technology Task Group - Contractors meeting |
| 11 | Nov. 10, 2022 | 166th Radio System Technology TG |
| 12 | Dec. 15, 2022 | ITS Forum Radio System Technology Task Group - Contractors meeting |
| 13 | Dec. 26, 2022 | 167th Radio System Technology TG |
| 14 | Jan. 23 and 24, 2023 | ITS Forum Advanced ITS Info-communication Systems Committee Report |

### 7.3.2 Report contents, comments/suggestions, and status of response

Main report contents, comments/suggestions, and status of responses of the ITS Forum are shown in Table 7.3.2-1.

**Table 7.3.2-1 Report contents, comments/suggestions to ITS Forum**

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| Suggestions at 160th Radio System Technology TG (5/16) | | | |
| 1 | • Explanation of details of implementation and overall policy | • Does the study of protocols assume standardization work? | • The image is of creating a draft protocol to contribute to standardization before entering the standardization process. If the process of standardization proceeds, it would be in the next fiscal year or later. |
| 2 | | • The scope is focused on V2I and V2V at 5.9 GHz, but V2N is not in the scope? | • V2N is not in the scope for this year. |
| Suggestions at 161st Radio System Technology TG (6/13) | | | |
| 1 | • Report of 1st study group on research findings | • At the Radio System Technology TG, a study is being conducted to determine whether or not it fits into the communication method, but no guarantee of service is made. Will an answer on service feasibility be answered in this project? | • Feasibility of communication will be confirmed by communication simulation. If not feasible, it will be raised as an issue. |
| 2 | | • How will coordination with the 700 MHz committee be done? | • Inquiries will be made as necessary. |
| 3 | | • It was mentioned that configuration of communication and communication (congestion) control will be studied, but how will cases where definitions of variables for communication parameters and variable names differ be handled? | • The effect in the communication simulation will be confirmed, and if there is an effect, it will be reflected in the draft protocol, but whether the detailed parameters can be determined has not yet been decided. |
| 4 | | • How will overseas collaboration proceed if the definition as a message field differs as a difference from overseas? | • A comparison of message sizes is assumed to be needed, and that will proceed in coordination with the Forum. |
| Suggestions at 162nd Radio System Technology TG (7/11) | | | |

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| 1 | • Report of 2nd study group on research findings | • Regarding allocation of channels, is it assumed that transmission and reception occur on three channels simultaneously? | • Separating channels for transmitting and receiving is not being considered. In the detailed study of allocation, restrictions that will prevent simultaneous transmission and reception are assumed to come up. |
| 2 | | • Is there a need to clarify where there is agreement with the Radio System Technology TG, such as frequency allocation using multiple frequency channels? | • Although there is a time gap between discussions at the SIP-adus project study group on research findings and the Radio System Technology TG, discussions will proceed while receiving comments from experts. |
| Suggestions at 163rd Radio System Technology TG (8/4) | | | |
| 1 | • Report of 3rd study group on research findings | • Regarding channel allocation, is not only 10 MHz bandwidth but also 20 MHz bandwidth, etc., being considered? | • It has been considered and reported at the 4th study group on research findings. |
| 2 | | • Is it necessary to be able to transmit and receive multiple channels at the same time, or is the operation of simultaneously receiving and transmitting on neighboring channels a degree of complexity for the terminal? When transmitting on one of the channels, other carriers may not be able to receive the signal due to intra-terminal interference. | • What sort of transmitting and receiving occurs will be considered. |
| 3 | | • Discussion of channel efficiency and spectrum efficiency may need to be considered together, such as interference at more than 250 m. | • This will be considered as needing discussion. |
| 4 | | • Will there be a quantitative evaluation of channel utilization efficiency in the simulation evaluation? | • To what extent that will be done needs to be confirmed. It will be in the form of confirming what interference looks like when two terminals approach each other and communicate. |
| 5 | | • Will the simulation be run again with feedback from the results of the actual equipment? | • Feeding back test results into the simulation is not being considered. |

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| 6 | | • Is doing everything at 5.9 GHz only being considered? | • It depends on the results of the channel allocation study. Discussion will be done taking into consideration the results this time in conjunction with coexistence with 700 MHz and the roadmap. |
| 7 | | • In simulation and confirmation with actual equipment, can it be assumed that the difference from last fiscal year is the use of 30 MHz?<br>• Will simulations be performed at 30 MHz bandwidth in addition to 10 MHz? | • Last year, one use case was evaluated at 10 MHz. This time, doing with multiple channels, etc., and what can be done if not all will be summarized.<br>• Simulation evaluation will be done in two stages, i.e., a single channel and a simultaneous three-channel simulation. Interference between channels will also be observed. Assumption did not cover to the point of using three channels in one vehicle at the same time, so it needs to be considered. |
| 8 | | • In addition to pass/fail simulations combining use cases, will evaluation be conducted to determine the critical point until communication (congestion) is controlled?<br>• Wouldn't it be better to consider capacity evaluation of the system and the discussion of message sharing in parallel? | • It also depends on the communication (congestion) control under consideration at NEC. First, consideration will be made in the case of message sharing with reference to the ITS Forum's communication requirements. Basic conditions need to be evaluated, and if they are not met, communication (congestion) control and the like need to be considered.<br>• We recognize that analysis is important because there are quantitative correlations. |
| Suggestions at Radio System Technology Task Group - Contractors meeting (8/18) | | | |
| 1 | • Q&A from the ITS Forum | • There has been talk that the U.S. FCC is considering a 20 MHz bandwidth at 5.9 GHz. Please check overseas trends and consider this as a proposal. | • It will be considered as a proposal upon checking overseas trends. |

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| 2 | | • Grouping messages by characteristics and considering a proposal would probably enable consideration of a wide range of proposals.<br>• a-1-3 and a-1-4 may be a series of sequences, and wouldn't it be better to make to be the same channel? | • At this time, a proposal is being considered with messages grouped by characteristics in the form V2I/V2V, broadcast/mediation and negotiation. If there is an excess or deficiency, additional consideration will be made.<br>• We would like to continue discussion as a point of discussion for the future. |
| 3 | | • What is the meaning of "△" in tables in materials summarizing coexisting use cases? | • Regarding merging assistance, a-1-3 is a must, and a-1-4 in not necessarily a must, so △ was used. |
| 4 | | • Shouldn't simulations be done this year too matching the conditions in which NEC implemented simulations for the SIP project last year? (Diversity, fixed degradation, antenna gain)<br>• Does the simulation take into account interference from OBU, etc.? | • Consideration will be done in the direction of matching simulation conditions, but more general ones will be selected.<br>• In section c, evaluation is performed taking into account packet arrival rate. Separate consideration is needed taking into account the effects of interference. |
| 5 | | • Regarding communication condition a-2, it is stated that it is assumed that 5% of the number of traveling vehicles change lanes. Is it correct that for one vehicle changing lanes, communication occurs with 73 vehicles, which is the requirement for a-2? | • The appropriateness of 5% will be studied. |
| 6 | | • Is it correct to those studies are being done under the assumption that the communication area of each SIP-UC alone can be satisfied in 5.9 GHz communication? | • Studies are being done on improving the level of achievement of communication (congestion) control in order to determine whether the communication area is satisfied, and the intention is to work to clarify issues. |

| No. | Report contents | Related comments/suggestions | Response |
| --- | --- | --- | --- |
| 7 | | • What is the use of spectrum efficiency and channel utilization in channel bandwidth calculation? | • Spectrum efficiency and channel utilization were calculated with reference to C2CCC values in order to calculate the bandwidth used. Since these figures are based on specific assumptions even for C2CCC and 5GAA, and they are difficult to define uniquely, they are first evaluated as figures for how much communication capacity is available when channels are allocated. |
| 8 | | • As congestion control, if the threshold is exceeded, does communication (congestion) control reduce the number of packets by lengthening the communication cycle or selecting message priority? | • A proposal for communication (congestion) control will be presented at the fourth study group on research findings. |
| 9 | | • The protocol stack needs to be organized for RC-017 to cover it.<br>• Where is congestion control specified? | • Organization will be done under that recognition.<br>• That for which the content is clear is specified in RC-017 and that for which it is not will be specified newly. |
| 10 | | • How should the suggestion that the radio can reach a wider range than 250 meters be handled? | • The radio wireless over-reach problem needs to be considered in system level simulation. In the calculation of communication capacity, it is necessary to consider under the assumption of 250 m based on communication requirements; and in the estimation of required bandwidth, it is necessary to consider it in the spectrum efficiency. |
| Suggestions at 164th Radio System Technology TG (9/9) | | | |
| 1 | • Report of 4th study group on research findings | • It is stated that communication (congestion) control applies to groups C and E. Is there any reason to limit group application? Can it also be applied to a-1-3? | • We do not intend to be particularly restrictive, and consider this to be a general discussion. |

| No. | Report contents | Related comments/suggestions | Response |
|---|---|---|---|
| | | • Communication (congestion) control for the first transmission of an event is considered to be inappropriate, and only periodic transmissions after the occurrence of an event should be subject to communication (congestion) control. | • We believe that understanding to be correct. |
| 2 | | • Why are the simulations and test in LTE-V2X and the proposed specifications in DSRC? | • Simulations and tests will be conducted in LTE-V2X. Other than that are for both. Comparisons of performance were made in last year's Ministry of Internal Affairs and Communications evaluation, and we plan to refer to those results as necessary. |
| 3 | | • For those that have an "X" in the simulation results, do you make any adjustments so they will be "○"? | • There is no overwhelming improvement from a perspective of the method, and we think improvements could be achieved with a review of sensitivity, etc. A bandwidth of 20 MHz could be considered, but distance bottlenecks could be a hinderance. In that case, we need to consider items such as whether to go 99% in integrated or how far to go. |
| Suggestions in ITS Forum Advanced ITS Info-communication Systems Committee Interim Report (9/13) | | | |
| 1 | • Interim report | • Considering future use cases/message expandability and flexibility, a measure to control at the upper layers as a single communication channel is also conceivable. In the above, it is necessary to consider control interfaces at the upper and lower layers. | • Already explained in 6th study group on research findings. |
| 2 | | • It is necessary to consider and verify communication congestion control functions that are consistent between communication layer and the application. | • Continued discussion will be had with the ITS Forum. |
| Suggestions in ITS Forum Advanced ITS Info-communication Systems Committee Interim Report (9/30) | | | |

| No. | Report contents | Related comments/suggestions | Response |
| --- | --- | --- | --- |
| 1 | • Report items of 5th study group on research findings Advance confirmation | • Regarding communication (congestion) control, it is understood that the main target is transmission from the vehicle, but will messages on the roadside infrastructure side be considered? | • First, communication (congestion) control in vehicles will be considered as a prerequisite, but after communication (congestion) control on the vehicle side is solidified, additional consideration will be given to application to the roadside. |
| 2 | | • Considering the structure of messages in ITS FORUM RC-017, it is inferred that the priority is assumed to change according to the message in order to have one-to-one correspondence between the event and the message content. | • Although further discussion is needed, the basic priority is determined for each message, but there are several messages tied to critical events, and the assumption is that the priority of those messages rises when there is a critical event. |
| 3 | | • Regarding 10 MHz + 20 MHz of channel allocation, the explanation this time was separated into V2V and V2I, but could there be other proposals? There is also the idea of separating cyclic and acyclic transmissions. | • This has been noted. |
| 4 | | • If multichannel, how is the influence of adjacent channels reflected? | • Issues need to be sorted out when implementing multichannel. |
| 5 | | • Is the explanation correct that continuous wave is a burst of 20 ms as a test condition? | • 20 ms is the transmission interval of a burst wave, while a continuous wave has no concept of a cycle. |
| 6 | | • In section b, it was understood that communication (congestion) control is mainly considered at the application layer, but in the processing flow on this page, communication (congestion) control is described not only at the application layer but also at Layer 2. Please explain the relationship. | • We have listed this as an option because in general communication (congestion) control overseas, control is performed at lower layers according to priorities determined at higher layers. We will make a decision in the future based on the results of the study of section b. |
| 7 | | • Which of the channel allocation proposals will be evaluated in the simulations and tests?<br>• Will simulations with communication (congestion) control be performed? | • Proposals 1 and 6 of the allocation proposals will be evaluated. |

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| | | | • Simulations with communication (congestion) control will not be conducted this fiscal year. |
| Suggestions at 165th Radio System Technology TG (10/7) | | | |
| 1 | • Report of 5th study group on research findings | • Is the concept of communication (congestion) control that is being studied in Europe and the U.S. insufficient? Please state the reason for arranging. | • We have determined that the two sides have different basic ideas, and are considering what they should be. |
| 2 | | • Is the purpose of traffic flow simulation for smoothness or for safety? Depending on the purpose, there is a possibility to confirm that which is not studied, and we believe that should be confirmed with automakers. | • At this time, no suggestions have been received from JAMA, but we will confirm. |
| Suggestions in ITS Forum Advanced ITS Info-communication Systems Committee Interim Report (11/1) | | | |
| 1 | • Report items of 6th study group on research findings Advance confirmation | • Comparing both the methods of vehicle density and communication status, we believe control based on communication status may be appropriate, given that the length of data communicated is variable. In addition, if considering only terminals, behavior changes when the adoption rate changes, so parameter settings need to be reviewed according to the adoption rate. | • Each method was studied and verified independently this time. Your point needs to be determined through various case studies. |
| 2 | | • There is an index that the 4 m position change in control by vehicle information meets the packet arrival rate index of integration at 5 m of travel in the 760 MHz discussion with JAMA, so relevance there needs to be considered. | • We are aware that the point above needs to be determined through various case studies. |

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| 3 | | • Won't the application of communication (congestion) control prevent communication requirements from being met? | • We believe that communication (congestion) control is based on the premise that communication requirements are satisfied according to use cases, and that communication (congestion) control is done within that range. Also, communication (congestion) control and priority control need to be considered as a set. |
| 4 | | • Regarding the allocation of communication channels, since it is said that mobile units cannot receive two channels at the same time, wouldn't it be easier to formulate control if the event system is always given priority in transmission and the basic information is dropped? | • We believe your point to be an allocation proposal equivalent to proposals 8 and 9. |
| 5 | | • A higher level of consideration is thought to be needed on how CPS should be implemented before it reaches a high adoption rate. | • For CPS, V2V and V2I penetration rates over time were recognized as needing to be perceived and studied over time. |
| 6 | | • The issue would be how much baseband receiving there is, but we believe sending has the problem whether it can or cannot be done at the same time. | • Issues from an implementation perspective will also be summarized. |
| 7 | | • It is assumed that a radio unit (RU) can support multiple channels, but is channel switching not assumed? | • It is a possible option, so we will identify and summarize the issues, including channel switching. |
| 8 | | • In addition to communicating the level of priority, valid times too need to be considered as a set, such as if information can be discarded if it does not reach the destination in a certain amount of time. | • This has been noted. |

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| 9 | | • In FOTs (Field Operational Tests), there was no interference from adjacent channels at all, but is it predict that there will be no interference based on the attenuation of the spectrum mask? | • It is known from indoor tests that there is impact if interference from adjacent channels is added above a certain level. However, due to the effects of attenuation by the mask, etc., the D/U did not see degraded communication quality under the conditions of the outdoor tests reported this time. We will continue to conduct tests under other conditions to confirm the impact. |
| Suggestions at 166th Radio System Technology TG (11/10) | | | |
| 1 | • Report of 6th study group on research findings | • What is the impact of not being able to 100% guarantee communication in traffic simulation? | • Simulation was conducted with a 100 ms to 500 ms reception delay. As a result, with ACC (Adaptive cruise control) driving, the impact of communication delay is negligible due to the propagation time of the deceleration behavior of the following vehicle (Vehicle 2 : 850 ms to Vehicle 9: about 1.5 s). |
| 2 | | • What is the interference caused by adjacent channels? | • The interference power allowed in the same channel (allowed interference power) is calculated, and the allowed interference power of adjacent channels is calculated based on that value from the value of the transmission/reception characteristics in 3GPP technical specifications. In the example indoor measurement results presented this time, the interference wave uses the entire 10 MHz bandwidth, but the desired wave is the packet size of the target use case, not a value using all the bandwidth. Since there are future plans to evaluate conditions that use all the bandwidth, we will continue to measure and organize the results. |

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| 3 | | • What has happened subsequently in consideration of message sets? | • Consideration will be done based on the protocol and explained at the 7th study group on research findings along with the evaluation results. |
| 4 | | • How will you proceed in studying the relationship between request and response and the need for state in regard to RC-017? | • We are considering conducting desktop studies by detailing communication sequences and organizing the issues. |
| Suggestions in ITS Forum Advanced ITS Info-communication Systems Committee Interim Report (12/15) | | | |
| 1 | Report items of 7th study group on research findings Advance confirmation | • Regarding communication channel allocation, we believe it would be easier to compare if there were also numbers normalized to 10 MHz when 20 MHz or 30 MHz. | • That will be added to the materials. |
| 2 | | Regarding, the upper layer communication control method, the description of "transmission timing" seems to be incorrect because the occurrence of events is being determined.<br>• Changes due to weather conditions, etc., affect the communication volume of all vehicles in the communication range, and the capacity of the system needs to be designed so that all communication can be realized even in poor weather conditions. Therefore, we believe the discussion to be about whether to "reduce the communication volume in good weather" rather than "increase the communication volume in poor weather."<br>• As for changing parameters, there is a method in which the vehicle can change parameters autonomously, but it is also possible to instruct parameter change in V2N, and it is possible to change parameter values without depending only on the driving environment. Can a statement be added that this needs to be considered in the future? | • A note on the meaning of "transmission timing" will be added and correction to the correct terminology will be considered.<br>• This was recognized as being a future issue to consider.<br>• This will be added as you suggested. |

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| 3 | | • Can you describe something about the relationship between sensitivity of the ride comfort evaluation and the safety evaluation in the traffic flow simulation? | • We will specify that the evaluation was made in two aspects this time: safety: deceleration and ride comfort: jerk. |
| 4 | | • It would be better to organize in sections c and d what is meant by application. | • We will check for contradictions in the definitions of words and in sections c and d. |
| 5 | | • In studying the message set proposal, we do not think it is necessary to describe the multiplexing of information elements in the summary in a case-specific manner. | • Based on this suggestion, we will revise the description to a more general expression. |
| 6 | | • In the examination of wireless device specifications, it is stated that application and sensor are connected However, we think it's more general to divide the interface between "application" and "vehicle side" and have sensors etc. in the vehicle side.<br>• It should not be necessary to limit just transmission/reception switching being realized on only one antenna system.<br>• There are various ways to realize the logic part, such as "using the CA function LTE-V2X," "using a pair of LTE-V2X and NR-V2X," and "installing multiple function blocks corresponding to one channel in the same device." We believe it would be better to raise the level of abstraction in the diagram so that such discussions can be held in the future.<br>• It is unclear what the terms "wireless unit," "tuner," and "RF" refer to. | • We will review the diagram to ensure that there are no misunderstandings.<br>• Based on this suggestion, we will revise the description.<br>• This has been noted.<br>• We will clarify the definitions of the terms and reorganize. |

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| 7 | | • It was mentioned that the adjacent channel was changed from continuous wave to burst wave in FOTs (Field Operational Tests) on test courses, etc., but some description of how the communication traffic fluctuates accordingly may be needed. | • We will add an explanation of the conditions of communication traffic or resource utilization rate in the burst wave evaluation. |
| Suggestions at 167th Radio System Technology TG (12/26) | | | |
| 1 | • Report of 7th study group on research findings | • Is there any relationship between the study of the communication control method and the study of the channel allocation proposal? | • The study this time summarizes each idea in a nearly independent manner. In the final determination of both, it is necessary to study them together, and they will need to be considered as one in the future. |
| 2 | | • In the communication control case study, was an allocation proposal decided on and implementation done? | • This time, implementation was done regardless of proposal. |
| 3 | | • There are concerns about the failing result with respect to communication performance evaluation by simulation. Is the cause known? Also, it is desirable to present what should be reviewed. | • We will organize the cause and the direction of review in the report summary. |
| Suggestions in ITS Forum Advanced ITS Info-communication Systems Committee Report (1/23, 24) | | | |
| 1 | Final report | • In ITU-R Working party 5A, materials that summarize the comparison results of the U.S., Europe, and Japan in a similar manner were presented, and that should be referenced. | • We will confirm. |
| 2 | | • In considering the proposed channel allocation proposals 1-9, have studies to distinguish between DSRC and C-V2X systems been included?<br>• Is it correct to understand that the channel allocation groups A to E are not divided per service, but by type of communication? | • Not included. This is a study from a technology-neutral standpoint.<br>• Basically, separation is by the type of communication, but proposals 8 and 9 also include classification from a service perspective. |

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| | | • There is a concept of dividing by requirements, such as those related to safety should be independent regardless of bandwidth because mixing channel allocation groups increases complexity.<br>• Is 760 MHz taken into account in the channel allocation table?<br>• C-V2X controls channels on a per-resource basis, but it is thought that there may be a time-axis direction a bit into the future. 760 MHz has V2I and V2V coexisting on the same channel, so there might be a way of using like that. | • Such implications are also included in the type, not in the continuity of the same broadcast, but in the emergency of the same broadcast.<br>• It is not taken into account, but the proposal to use 4 channels is a proposal to use 760 MHz in one of them, and only 5.9 GHz for others.<br>• This has been noted. This was recognized as being a future issue to consider. |
| 3 | | • It is interesting that in the traffic flow simulation results, a delay of a few 100 ms in communication has no significant impact on the behavior of the vehicle. Is the transmission interval 100 ms even in the case of platooning? | • We have excluded platooning from the scope of this study because it is a special case, and we will state that as being a presumption of the study. |
| 4 | | • As periodic communication this time, it is good that sending is done regardless of success or failure. However, we believe that with merging, if negotiation does not go well, success and failure will appear, but if there is enough time, the failure of the negotiation will affect the volume of traffic because negotiation will start again. | • This was recognized as being a future issue to consider. |
| 5 | | • Is it correct to recognize that security will be addressed between Layer 5 and Layer 7?<br>• Are we being told to multiplex and combine multiple services into one security control? | • That recognition is correct. |

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| | | • Are multiplexing and security included in the mission of the study this time?<br><br>• We thought it would be better to clearly state what about security was studied. | • When multiple use case messages are generated in the same channel, if they can be bundled into a single message rather than sent separately, we thought it would be possible to combine them by adding security information as a message from a single upper layer.<br>• Although the specifications of the contents were not covered in this study, the fact that 250-byte overheads of security signatures increase as communication capacity was reflected in the simulation evaluation.<br>• This has been noted. |
| 6 | | • The system configuration of vehicle-to-infrastructure (V2I) communication is written, but what is the positioning of these four patterns of roadside unit configuration?<br><br>• We thought it would be better to state that there would be four patterns, not simply in terms of services, but also in relation to the operators and their mode of operation. | • Roadside units are considered to provide different services depending on the location of installation, etc., and the configuration of each service is considered to be different. Therefore, we organized each of the minimum configurations to realize the use cases.<br>• Understood. |
| 7 | | • Although the application processors and the L7 communicatio n control section are logically independent, they may be imple mented in the same unit. It is better to write it as a supplemen t. | • Understood. |

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| 8 | | • Is it correct that outdoor communication tests reproduced shadowing loss by placing large vehicles?<br><br>• Why are the results better than the simulation? | • Partial reproduction was done. In simulation, a specific percentage of large vehicles are randomly generated, so shadowing occurs evenly regardless of desirable waves or interference waves. Since the number of communicating vehicles and large vehicles is limited in tests this time, the placement is adjusted so that desirable waves are shadowed to make the conditions severe enough as the impact of interference.<br>• Simulation is evaluated based on standard values, but the actual equipment is designed to satisfy the standard values, so reception sensitivity, etc., is improved. Also, in the radio wave propagation part, multipath fading due to reflections from buildings, etc., is considered to be partly due to the environment assumed in the desktop study model, which cannot be completely reproduced on the test course. Thus, an impact is assumed. |
| 9 | | • With chips such as for wireless LAN, it is possible to obtain channel use rate and the like to determine if frequencies are congested, and thus more accurately determine the radio wave frequency occupancy rate. We believed there is also an option to implement efficiently using information between layers through cross-layer control, including interaction with the chip, rather than just sending without looking. | • This has been noted. |

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| 10 | | • It is necessary to separate the types of information (content) and a method of control that fits them? We believed it would be good to divide and organize the in stages according to the nature of the content, such as “there will be problems if not delivered,” “best if delivered,” and “does not need to be delivered”. Also, we believe that the priority level and need for sending instantaneously are separate, and there may be a difference between priority level that can be used to block other messages and priority level (importance level) where delivery is a must, and such a control method may be possible. | • This has been noted. |
| 11 | | • Regarding priority control, once data is queued with ordinary wireless LAN, it is transmitted in order by CSMA/CA. Are you considering jumping over the transmission queue or changing the backoff for each priority level and making the backoff smaller for data that needs to be transmitted immediately? | • We have not gone that far in verification this time. In light of communication layer functions, we understood that it is necessary to consider whether control can be achieved at the upper level, including such control. |
| 12 | | • Even if a protocol is decided, it is possible that functions will be upgraded and parameters will be added over time. What are your thoughts on the protocol design in this area? | • We have not been able to go into the details of the format this time, but the content you raised will be noted as issues to be addressed. |
| 13 | | • Regarding negotiation, since agreement may be invalid or fail due to changes in vehicle behavior, communication may need to be redone or the status of agreement of surrounding vehicles may need to be ascertained. Has this been taken into account in the study? | • In desktop study, the communication sequence of the communication scenario proposal was detailed, but only for typical examples, and the ITS Forum has not yet detailed and reached a definitive decision assuming all cases. As for simulation evaluation, the communication capacity (amount of communication traffic) is reproduced, but the sequence is not completely reproduced, so we will organize the points you raised as issues to be addressed. |

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| 14 | | • It is mentioned that standardization is being considered overseas, but what are your thoughts on how to do this in the future, such as whether they will be different from each other, whether they will be aligned with overseas, or whether Japan will take leadership to propose better ones? | • The contractor cannot decide that, but based on your suggestion, we will consider including this as an issue to be addressed ahead of introduction. |
| 15 | | • It is mentioned that retransmission was compared by evaluation, but is retransmission done in other countries?<br>• It may be better to control whether or not to use retransmission by considering priority or importance. Also, in order to prevent communication congestion, when the channel use rate increases, the number of retransmissions may need to be considered along with various other controls. | • For CV2X, the specification exists, but we are aware that in both Europe and the U.S. a conclusion has not been reached on how many times the number of consecutive transmissions should be.<br>• All data was evaluated with the same number of consecutive transmissions this time, but based on your suggestion, this will be noted as an issue to be addressed. |
| 16 | | • Regarding multiple channels, there are concerns about whether processing can be done properly if a single radio unit (RU) handles three channels. What, for example, is the thought in the Europe and the U.S.? And when multiple channels are used, is that attempted using a single wireless unit?<br>• Wouldn't having more than one wireless unit increase costs? | • In the case of Europe and the U.S., specifications are defined considering both single tuner and multi-tuner. In the case of the U.S., it is possible to select the desired channel while switching channels even with a single tuner, and in Europe, the allocated channels are determined in order of priority, and only the channel with the highest priority is used for single tuner, but it is not recognized to what extent implementation is compliant with this.<br>• Your recognition of the situation is correct. We need to study not only the advantages but also the disadvantages in the implementation method, and we will organize the points you raised as issues to be addressed. |

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| 17 | | • If the 760 MHz and 5.9 GHz bands are used in the future, how will the existing 760 MHz system (ITS Connect) coexist, and how will the transition be made? We were concerned about backward compatibility when designing new protocols, such as, if a vehicle that does not support the 5.9 GHz band sends new information such as on merging at 760 MHz, will the ITS Connect receiving side ignore that and work without error. | • Based on your suggestions, we would like to include that it is necessary to organize issues such as operation and transition of existing systems when using both 760 MHz and 5.9 GHz bands. |

## 8. Summary

In the research and study in this project, the specifications of the radio Unit, including the communications protocols required for its introduction, were drafted, based on the roadmap that created the specific required specifications for the wireless communication technologies for the Use cases for Cooperative Driving Automation obtained from the SIP Phase 2 R&D. The aim was to accelerate the study and problem solving related to the introduction of V2X systems using the 5.9 GHz band radio waves and realize the implementation of Cooperative driving automation.

During the study of the communications protocol draft, the communications requirements of 5.9 GHz band V2X systems (communications content, communication channels, communication congestion control, etc.) were studied, taking into account international trends (relevant systems and standards, etc.). Further, during the design of the communications protocol draft and the drafting of the radio unit specifications, and based on the results of communication simulation evaluations that considered the impact of radio wave propagation characteristics and cross-communication channel interference, the communication procedures, communications protocol proposal of the protocol stacks, etc., and the draft message sets with commonization and expandability for multiple mixed use cases were studied and reflected in the draft radio unit specifications.

It is expected that research organizations and corporations will harmonize with those radio unit specifications including the formulated communication protocols, and begin study efforts towards the implementation of cooperative driving automation.