Cross-Ministerial Strategic Innovation Promotion Program (SIP) — Phase 2
/ Autonomous Driving (Expansion of Systems and Services) / A Study on 5.9GHz Band V2X Communication Protocol for Achieving Use Cases of Cooperative Driving Automation

FY 2022 Results Report Overview

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Scope

Overview

- In this study, based on the result of feasibility studies of communication technologies such as requirements for wireless communication technology applied to the cooperative automated driving Use cases, and on the output of Roadmap development, which defines concrete requirements for each Use cases and wireless communication technology including expectation to communication technologies to be developed for the future, the wireless device specification was prepared mentioning communication protocols required for the implementation of V2X system with radio wave in 5.9 GHz band (hereafter V2X system in 5.9 GHz band) in order to advance solving related issues and study.

Actions and Achievements

- The activities shown below were carried out with medium and long term perspectives in mind.

a) International standardization trends research

- We researched and analyzed standardization and institutionalization trends related to the V2X system in 5.9GHz band communication protocol, message sets, as well as relevant communication specifications in countries and regions including the U.S., Europe and China.

b) Research aimed at developing communication protocol proposals

- The V2X system with 5.9 GHz band communication requirements for the technological research of communication protocols was studied based on the communication requirements and message sets discussed through ITS Info-communication Forum, as well as on the result of the Roadmap development.

c) Designing communication protocol proposals

- Based on the evaluation results of the communication simulation, we designed the communication protocol for the V2X system in the 5.9 GHz band, which was concluded as communication protocol proposal mentioning communication procedures and protocol stack, along with message sets.

d) Proposing wireless device specifications

- Taking into account functions required for practical implementation and cooperation with existing wireless systems, we developed a specification for on-board unit and roadside unit using V2X system in 5.9 GHz band then clarified issues for implementation and counter measures to solve the issues.

International standardization trends research

International standardization trends research

- Standardization trends related to communication specifications by standardization bodies in Europe, US, and China regarding communication protocols.

[Standardization organization specifications, etc. in regions subject to study]

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

SAE: Society of Automotive Engineers, US
ETSI: European Telecommunication Standards Institute
CCSA: China Communication Standards Association

International standardization trends research

Result 1/2

- Consideration and standardization of new services are progressing in Europe and US
  - In addition to services that use basic messages such as BSM and CAM/DENM, messages that contribute to the safety of pedestrians, etc. (VRUs) are also standardized in SAE and ETSI.
  - As cooperative recognition, standardization of messages for sharing sensing data (CPS/CPM) and messages for vehicle driving adjustment is also progressing.
  - It is necessary to continue to investigate trends related to such services and consider the necessity of such services.
- Standardization of communication and control has been established
  - Standards for LTE-V2X and DSRC (802.11p) have been developed, but the use of new communications such as NR-V2X and 802.11bd is still under development, and it is necessary to grasp trends such as standardization in the future.
  - In addition, due to changes in needs due to new services (for example, an increase in communication traffic due to the application of VRUs to a VRU, an increase in communication volume due to data sharing, etc.), it is expected that the study and standardization of control methods will continue, and it is necessary to pay close attention to such trends.
- Comparison with SIP use cases and message specifications (shown on the next page)
  - There is no significant difference in the concept of use case classification and message specification.

International standardization trends research

Result 2/2

- Comparison with SIP use cases and message specifications
  - However, messages related to negotiation are under consideration in Europe and the United States, and additional studies are required regarding future communication specifications.

Japan(SIP)		US		Europe	
Use case	Message	Use case	Message	Use case	Message
a-1-1	Message of location information	(Under consideration)	(Under consideration)	○	○
a-1-2	Message of location information	(Under consideration)	(Under consideration)	○	○
b-1-1(V2I)	Message of signal information	○	○	○	○
c-1	Message of c-1	○	○	○	○
c-2-1(V2V)	Message of c-2-1	○	○	○	○
c-2-2(V2I)	Message of c-2-2	○	○	○	○
c-3	Message of c-3	○	○	○	○
e-1	Message of e-1	(Include in BSM)	○	○	○
a-1-3	Message of location information Message of negotiation/update	(Under consideration)	(Under consideration)	○	(Under consideration)
a-1-4	Message of negotiation/update	(Under consideration)	(Under consideration)	○	(Under consideration)
a-2	Message of negotiation/update	(Under consideration)	(Under consideration)	○	(Under consideration)
a-3	Message of negotiation/update	(Under consideration)	(Under consideration)	○	(Under consideration)

○ : Equivalent to or equivalent to the content of the SIP use cases.

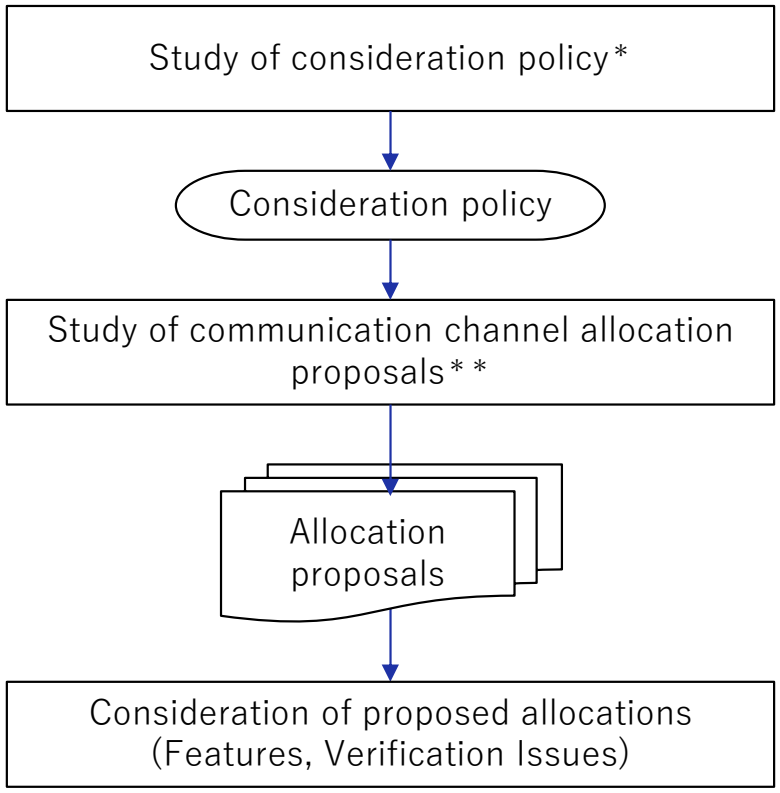
Research aimed at developing communication protocol proposals

1) Communication channel allocation

Research aimed at developing communication protocol proposals

Communication channel allocation

Study procedures



*Based on the results of the International standardization trends research.

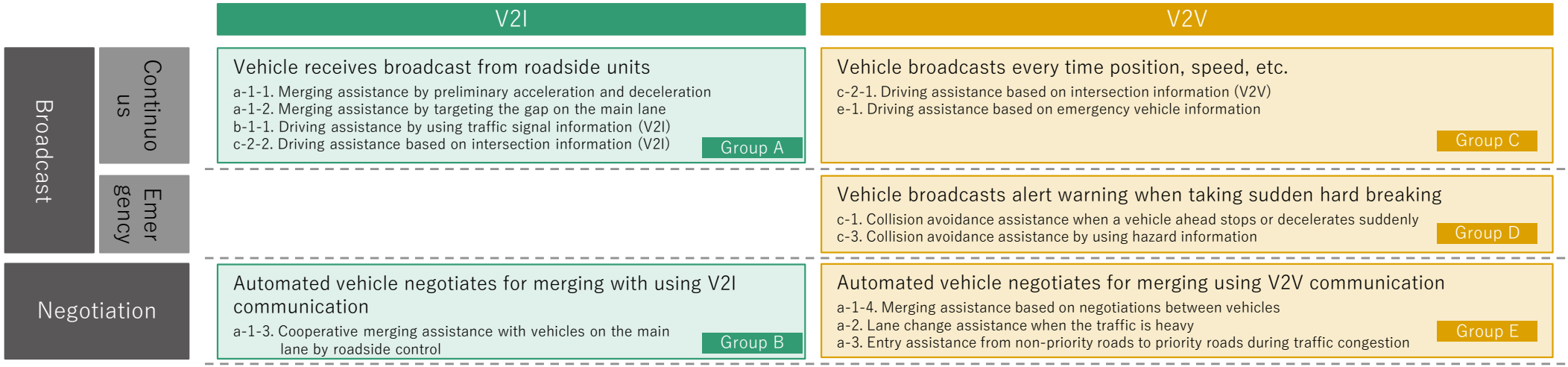
**Reflected the results of the ITS Forum RC-017 message structure review.

Research aimed at developing communication protocol proposals

Communication channel allocation

Basic Concept

- Since V2I use cases and V2V use cases are different situations, in principle, use different channels.
- Since negotiation involve a large number of exchanges (sometimes variable), in principle, a channel different from the broadcast is used.
- Since emergency events (sudden braking, etc.) that occur in the vehicle should be communicated reliably, in principle, use a different channel.

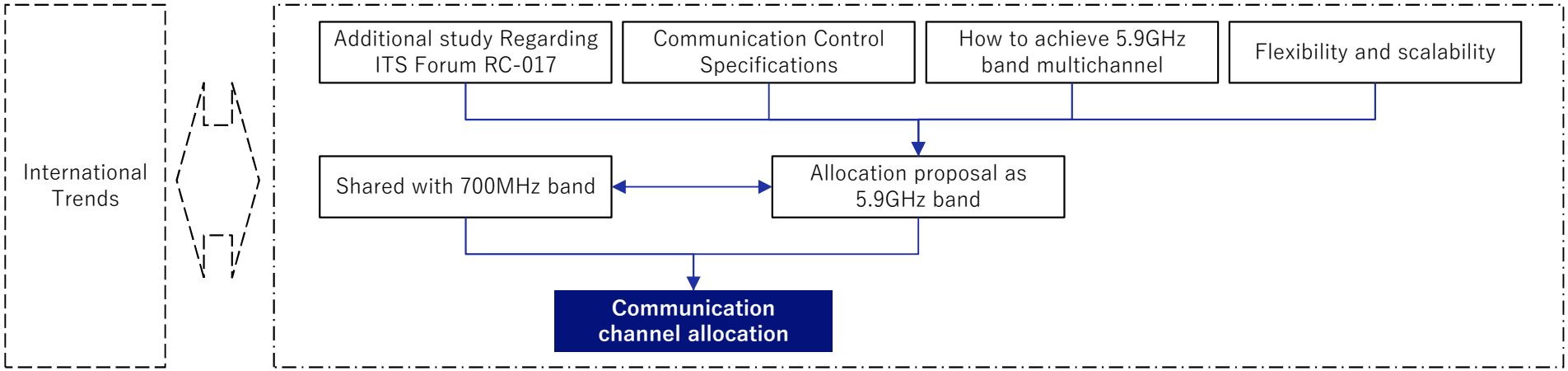


Research aimed at developing communication protocol proposals

Communication channel allocation

Result

- The proposal is shown in the table on the following page.
- Points for future continuation
  - Results of additional study of communication requirements (cycle, quality, etc.) taking into account the simultaneous occurrence of multiple use cases and cooperation between use cases, etc.
  - Communication control specifications (transmission control, priority)
  - How to realize 5.9 GHz band multichannel in radios
  - Shared with 700MHz band intelligent transportation system
- **Future study procedures**

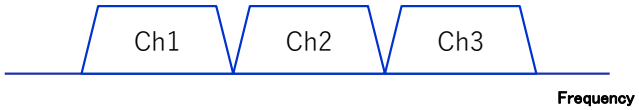


Research aimed at developing communication protocol proposals

Communication channel allocation

Proposal 1/3

[Prpposal1~4]

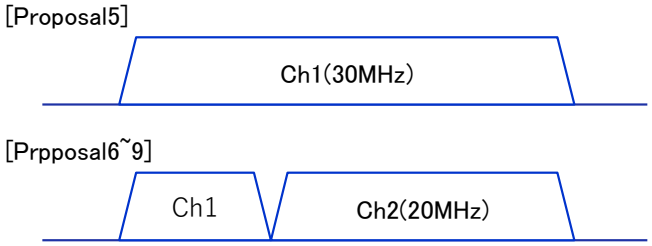


Type	Group	Proposal1	Proposal2	Proposal3	Proposal4
V2I	A : Broadcast from roadside units	Ch1(10MHz)	Ch1(10MHz)	Ch1(10MHz)	Ch1(10MHz)
	B : Negotiation from roadside units			Ch2(10MHz)	
V2V	C : Broadcast from vehicle (continuous)	Ch2(10MHz)	Ch2(10MHz)	Ch1(10MHz)	Ch2(10MHz)
	D : Broadcast from vehicle (emergency)	Ch3(10MHz)		Ch3(10MHz)	Ch3(10MHz)
	E : Vehicle-to-vehicle negotiation	Ch2(10MHz)	Ch3(10MHz)	Ch4(10MHz)	Ch4(10MHz)
Way of thinking	Feature(PROS/CONS)	- Allocate vehicle emergency messages to Ch3. - Ch2 communication traffic increases. - When the number of adjustment vehicles is large, Ch1 communication traffic increases.	- Vehicle-to-vehicle negotiation allocated to Ch3. - Possibility of communication of Ch2 Group C,D. - When the number of adjustment vehicles is large, Ch1 communication traffic increases.	- Road-to-vehicle negotiation, vehicle emergency messages, and vehicle-to-vehicle negotiations are allocated to Ch2, 3, and 4, respectively. - Ch1 communication traffic increases.	- Allocate each V2V message to Ch2, 3, and 4. - When the number of adjustment vehicles is large, Ch1 communication traffic increases.
	Issues	- Optimization of communication control for Group C, E. - Send/receive sequence from roadside units. (when the number of adjustment vehicles is large)	- Optimization of communication control for Group C, E. - Send/receive sequence from roadside units. (when the number of adjustment vehicles is large)	- Optimization of communication control for Group A, C.	- Send/receive sequence from roadside units. (when the number of adjustment vehicles is large)

Research aimed at developing communication protocol proposals

Communication channel allocation

Proposal 2/3



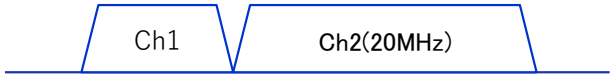
Type	Group	Proposal5	Proposal6
V2I	A : Broadcast from roadside units	Ch1(30MHz)	Ch1(10MHz)
	B : Negotiation from roadside units		
V2V	C : Broadcast from vehicle (continuous)		Ch2(20MHz)
	D : Broadcast from vehicle (emergency)		
	E : Vehicle-to-vehicle negotiation		
Way of thinking	Feature(PROS/CONS)	– Flexibility and extensibility for future use cases and messages. – High spectral efficiency can be expected. – Increasing complexity of communication control in the upper layer. – C-V2X's 30MHz band is applicable to NR-V2X.	– Channel separation by V2I and V2V. – Allocate 20MHz to V2V. – Ch2 can be expected to improve spectral efficiency. – Increasing complexity of communication control in the upper layer of Ch2. – When the number of adjustment vehicles is large, the communication volume of Ch1 is large.
	Issues	– Common specifications for communication control specifications for roadside systems and in-vehicle systems. – Study to maximize channel utilization rate.	– Communication control specifications for V2I and V2V, or common specifications. – When the number of adjustment vehicles is large, the send/receive sequence from the roadside unit.

Research aimed at developing communication protocol proposals

Communication channel allocation

Proposal 3/3

[Prpposal6~9]



Type	Group	Proposal7	Proposal8	Proposal9
V2I	A : Broadcast from roadside units	Ch2(20MHz)	Ch2(20MHz)	Ch1(10MHz)
	B : Negotiation from roadside units	Ch1(10MHz)		
V2V	C : Broadcast from vehicle (continuous)	Ch2(20MHz)	Vehicle base information : Ch1(10MHz) Other information : Ch2	Vehicle base information : Ch2(20MHz) Other information : Ch1
	D : Broadcast from vehicle (emergency)		Ch2(20MHz)	Ch1(10MHz)
	E : Vehicle-to-vehicle negotiation	Ch1(10MHz)		
Way of thinking	Feature(PROS/CONS)	– Separated broadcast, negotiation and allocated to Ch2,1. – Spectral efficiency can be expected to increase as Ch2. – Complexity of communication control in the upper layers of Ch1 and 2.	– Easy to migrate between use cases. – Allocation with room for event-related messages. – High spectral efficiency can be expected as Ch2. – Increasing complexity of communication control in the upper layer of Ch2.	– Easy to migrate between use cases. – High spectral efficiency can be expected as Ch2. – Increasing complexity of communication control in the upper layer of Ch2. – When the number of adjustment vehicles is large, Ch1 communication traffic increases.
	Issues	– Communication control specifications for V2I and V2V, or common specifications. – Send/receive sequence (when the number of adjustment vehicles is large)	– Communication control specifications for V2I and V2V, or common specifications. – Send/receive sequence.(when the number of adjustment vehicles is large)	– Communication control specifications for V2I and V2V, or common specifications. – Send/receive sequence (when the number of adjustment vehicles is large)

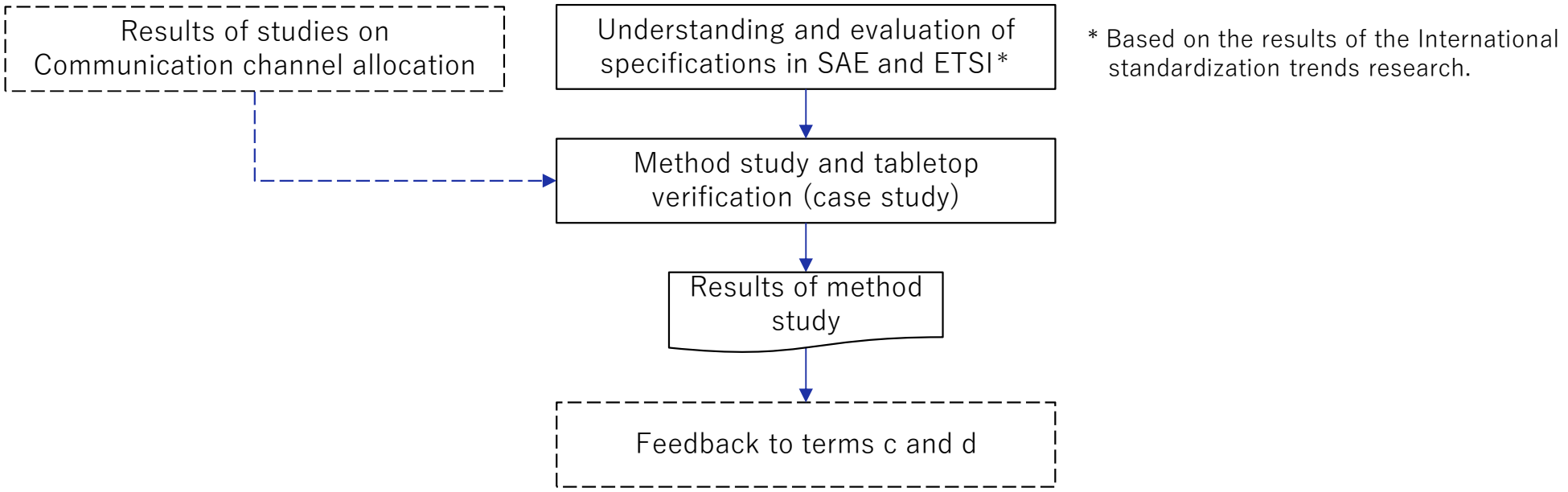
Research aimed at developing communication protocol proposals

2) Communication congestion control methods at upper layers

Research aimed at developing communication protocol proposals

Communication congestion control methods at upper layers

- Study procedures



* Based on the results of the International standardization trends research.

Research aimed at developing communication protocol proposals

Communication congestion control methods at upper layers

Result 1/2

- Referring to the specifications of the United States (SAE) and the Europe (ETSI), we devised a communication congestion control method at the upper layer as an ideal state.
- The next page shows an image of realizing communication congestion control based on case studies for each functional requirement.

Specifications		Proposed	SAE(BSM)	ETSI(CAM)
Transmission timing control	Vehicle information	○	N/A	○
	Critical events	○	○	N/A
	Driving environment	○	N/A	N/A
	Surrounding vehicle density	○	○	N/A
	Surrounding communication status	○	N/A	△(DRSC only)
Priority control		○	○	○
Transmit Power control		(Future consideration)	△(DRSC only)	N/A

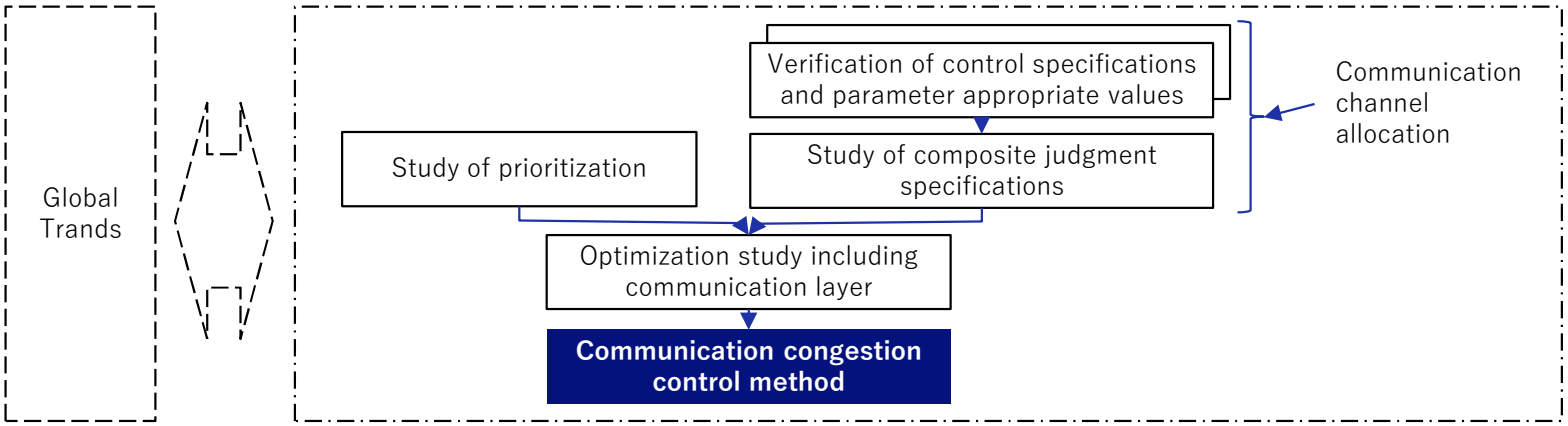
○ : Full function, △ : Limited function

Research aimed at developing communication protocol proposals

Communication congestion control methods at upper layers

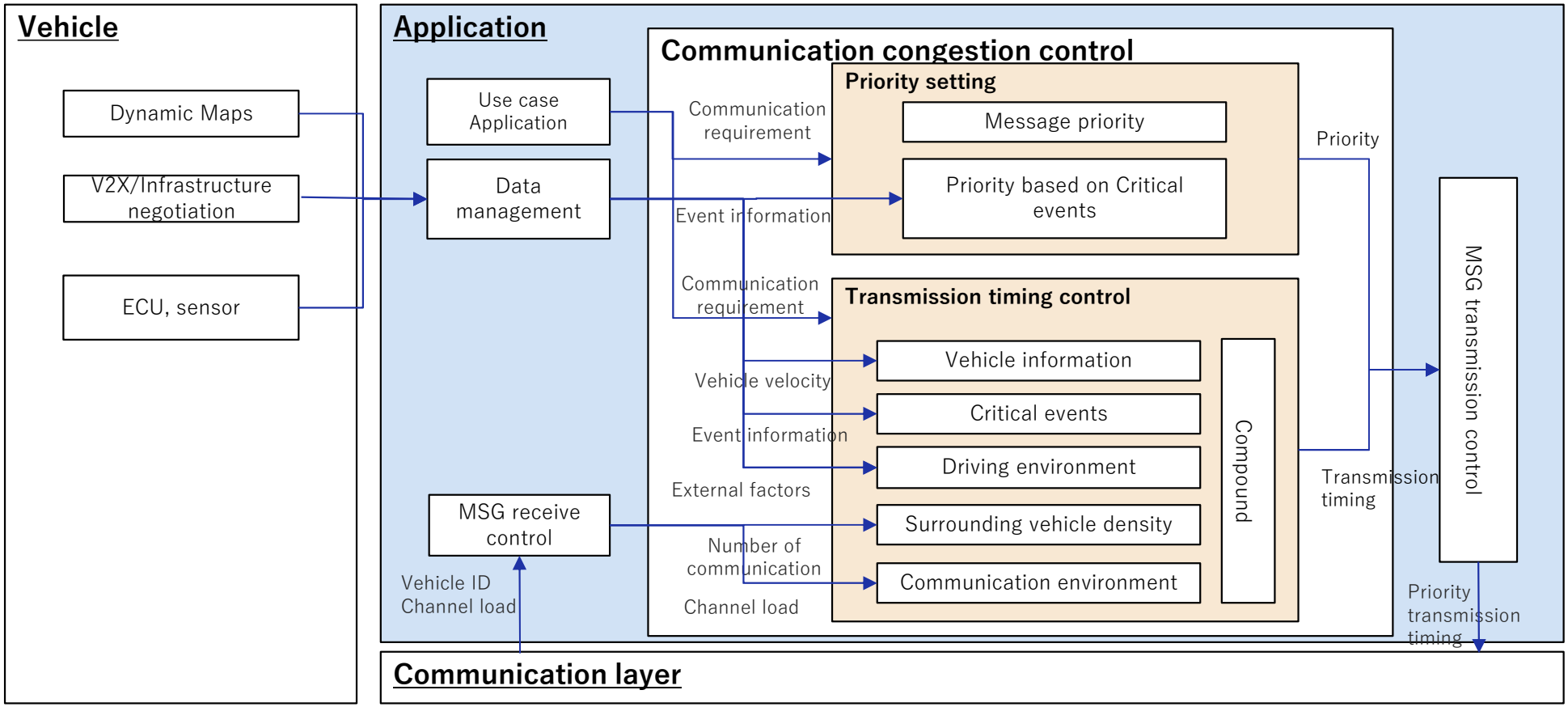
Result 2/2

- Through verification of the transmission timing judgment requirements, it was confirmed that the communication volume can be suppressed under the following vehicle density condition for each judgment requirement.
  - 20km/h～70km/h, distance between vehicles per second
- Matters requiring further consideration
  - Verification of control specifications and parameter appropriate values through various case studies.
  - Study of composite decision specification for multiple transmission timing control requirements.
  - Overall optimization study including communication control at the communication layer.
- **Future study procedures**



Research aimed at developing communication protocol proposals

Communication congestion control realization image(Function block)



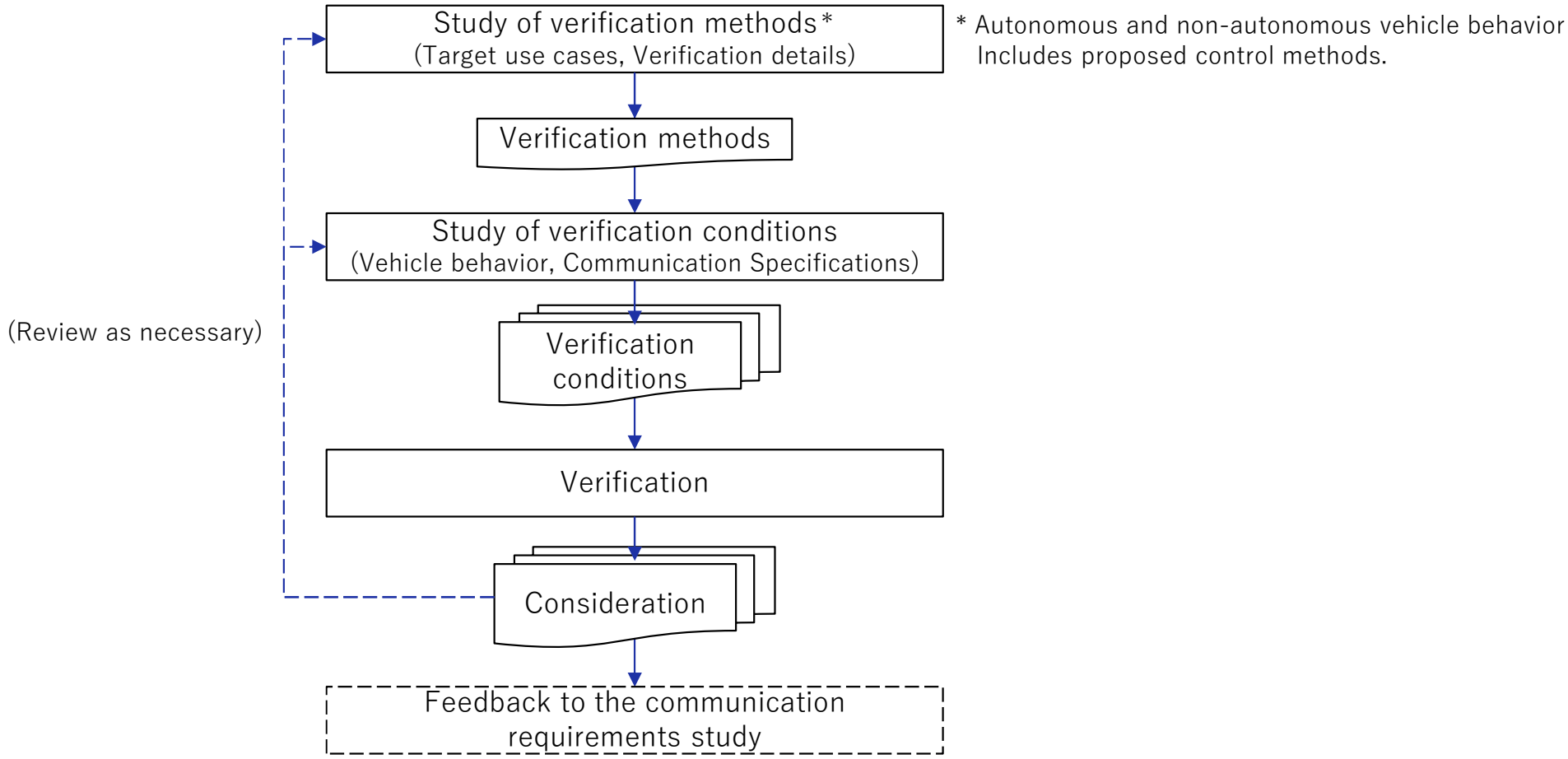
Research aimed at developing communication protocol proposals

3) Traffic flow simulation-based effectiveness evaluation

Research aimed at developing communication protocol proposals

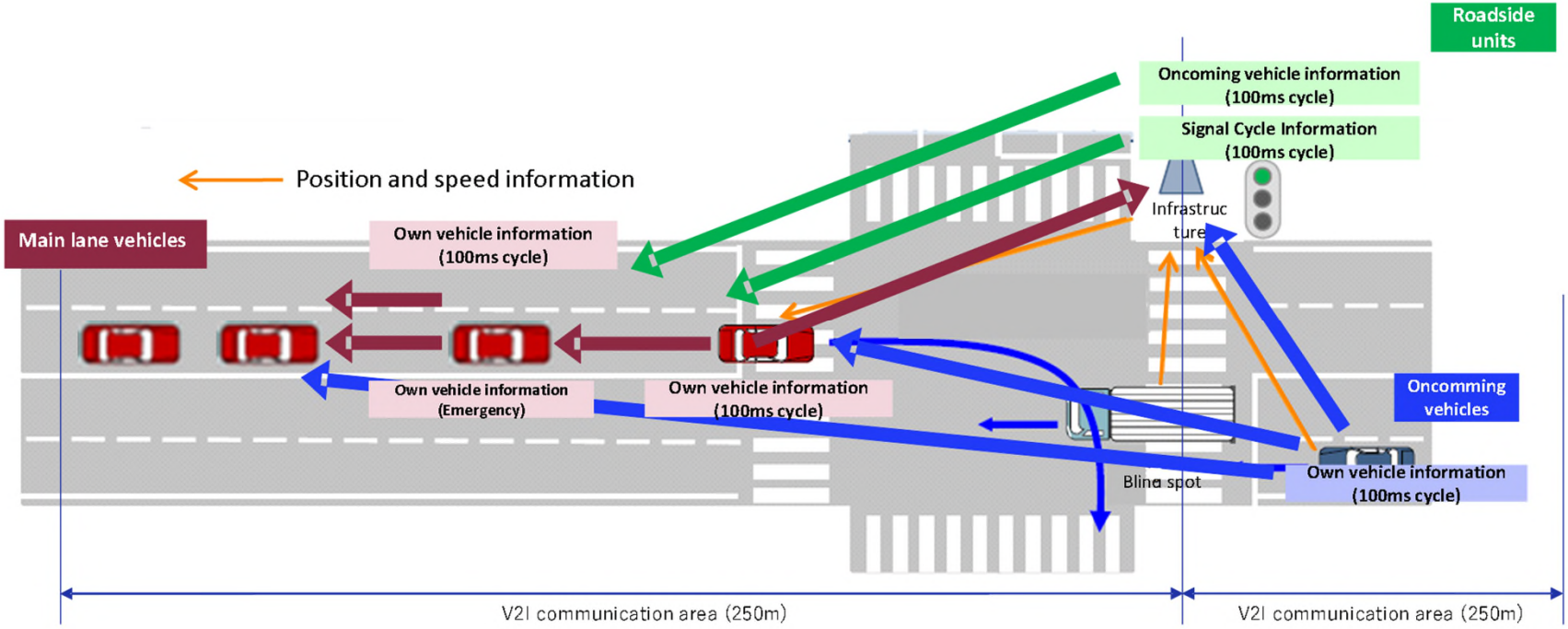
Traffic flow simulation–based effectiveness evaluation

Study procedures



Research aimed at developing communication protocol proposals

- Traffic flow simulation–based effectiveness evaluation
  - Use cases to validate
    - c-1 : Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly
    - Notification from the leading vehicle to the following vehicle encourages early deceleration. At that time, the vehicle behavior (deceleration, jerk) of the following vehicle was evaluated.



Example of communication around an intersection

Research aimed at developing communication protocol proposals

Traffic flow simulation-based effectiveness evaluation

Result

- 5.9GHz band V2X System Effects
  - In addition to “deceleration” as safety, evaluation was conducted from the viewpoint of “jerk” as riding 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 with and without communication, there was a more marked difference in “jerk” than in ”deceleration”.
- Effects of differences in communication specifications (reception timing)
  - The difference in message reception timing (several hundred ms) did not have a significant effect on vehicle behavior.
  - In the assumed delay range of the reception timing(100～500ms), when the delay increases to 500 ms, deceleration propagation occurs due to following the preceding vehicle. Therefore, the vehicle immediately after the leading vehicle has a reduced effect of preliminary deceleration.
  - After the second unit, no change due to differences in reception timing is 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.

Research aimed at developing communication protocol proposals

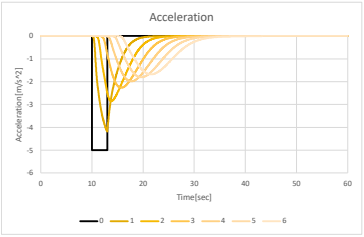
Traffic flow simulation–based effectiveness evaluation

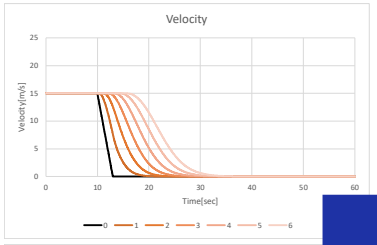
- Example of validation results (No communication / With communication)
  - "With communication" achieved a gradual deceleration, and the effect of communication was confirmed.

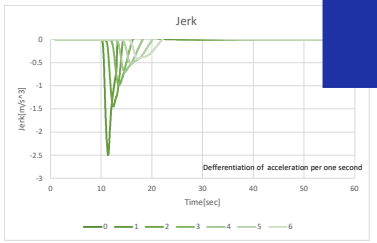
[Case0 : No communication]

	1st	2nd	3rd	4th	5th	6th
Transmission timing[ms]	n/a	n/a	n/a	n/a	n/a	n/a

All autonomous driving (1st ～ 6th)





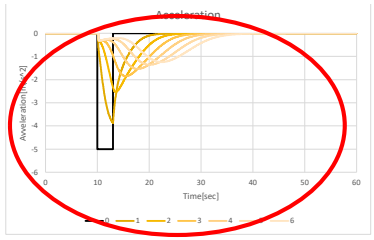


[Case1 : With communication]

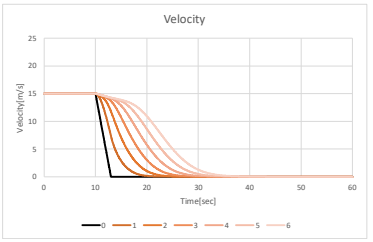
	1st	2nd	3rd	4th	5th	6th
Transmission timing[ms]	100	100	100	200	200	200

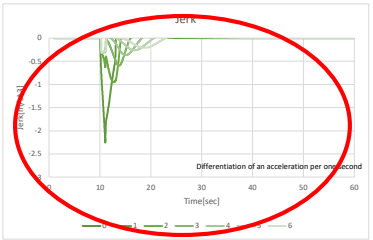
All autonomous driving (1st ～ 6th)
Upon receipt of information, initiate a preliminary slowdown.
The deceleration starts before it reacts to the deceleration of the preceding vehicle.
Therefore, there is a margin of time until the peak of the deceleration is reached.

Since each vehicle slows down to open the space between the vehicles, the peak is generally larger for the vehicle behind it. However, since the time is also shifted backwards, the amount of change in deceleration is small.



The acceleration curve of the following vehicle becomes smoother. (Improvement)





The peak of jerk of the following vehicle is reduced and the curve becomes smoother. (Improvement)

c) Designing communication protocol proposals

1) Developing communication protocol proposals

1) Developing communication protocol proposals
Summary

- Based on communication scenarios for SIP use cases (ITS FORUM RC-017), communication protocol proposals in 5.9 GHz band were developed, and protocol stacks, communication control flow and communication specifications (function, behavior, interface, etc.) were compiled as outline proposals.
- 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.
- Based on the assumption that security services similar to those in the European and U.S. specifications (electronic signature method) would be provided, interfaces and procedures between layers were studied and compiled. Detailed specifications of the security services need to be further discussed.
- 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.
- Proposed ways to cooperation with 700 MHz band ITS was organized in a way that does not change the existing protocol stacks. Based on SIP roadmap of V2X communication methods for cooperative driving automation and a technology adoption situation, it is necessary to study the channel allocation method including 700 MHz and 5.9 GHz bands for each SIP use case in the future.
- Future issues include:
  - Review of this study reflecting the communication scenarios to be revised and international trends.
  - Study of interface specifications with non-communication functions (control systems, etc.).
  - Study of detailed procedures including state transitions, exception handling, etc.

Summary of communication protocol proposals

Layers	Main specifications	Notes
Application	- Generate messages and send periodically. - Destination identification, request/response processing (for control/agreement use cases) - Transmission control (Priority setting, transmission timing control)	Add functions required by control/agreements to European and U.S. specifications.
Higher layers (Layer 5-7)	- Broadcast communication (destination unspecified) - Generate vehicle basic information and send periodically. - Retransmit hazard information periodically. (*) - Forward the hazard information. (*)	Same as European specifications. (If U.S. specifications are applied as an alternative, (*) is handled by the application.)
Network and transport layers (Layer 3-4)	- Broadcast communication (destination unspecified) - No forwarding/routing control	Same as U.S. specifications. (As an alternative, it is possible to apply European specifications.)
–	Channel allocation	Assume static allocation.
Physical and data link layers (Layer 1-2)	Base on Guideline for experiments of communications system for use cases of automated driving on expressways (ITS FORUM RC-015).	Same as European and U.S. specifications.

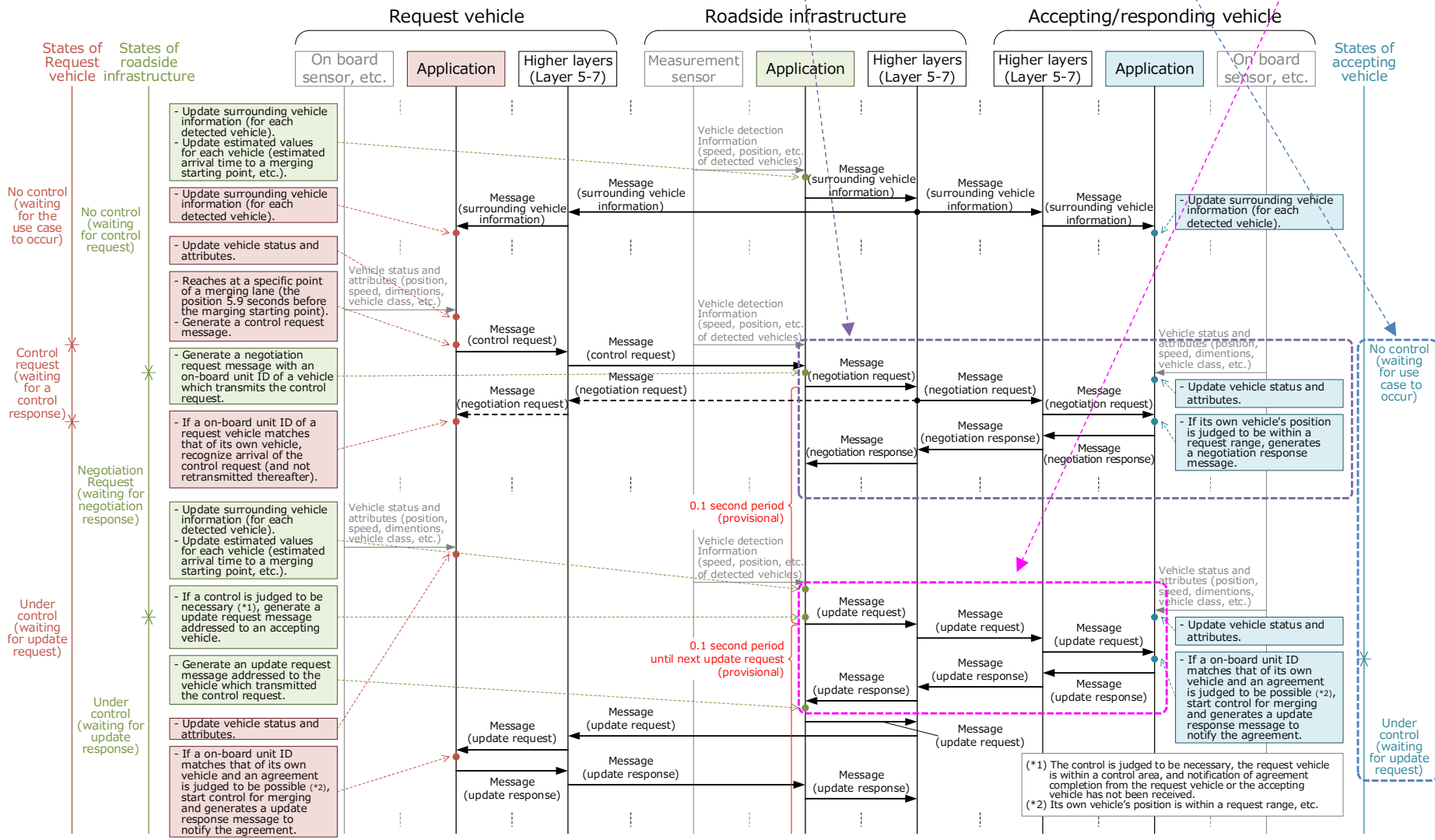
1) Developing communication protocol proposals

Example of desk study - Application to communication scenarios for SIP use cases -

- Add new functions for control/agreement use cases. (Destination identification, request/response processing)
- Further study of detailed specifications is needed. (Destination identification method, state transition, etc.)
- Future confirmation of overseas standardization trends is also needed.

Message content	Vehicle detection Information (sensor information, speed, position, etc. of detected vehicles)
Information element	**Use case specific Information (Negotiation 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 or aperiodic	**Periodic**
Transmission period	**0.1 second**
Forwarding	**No**

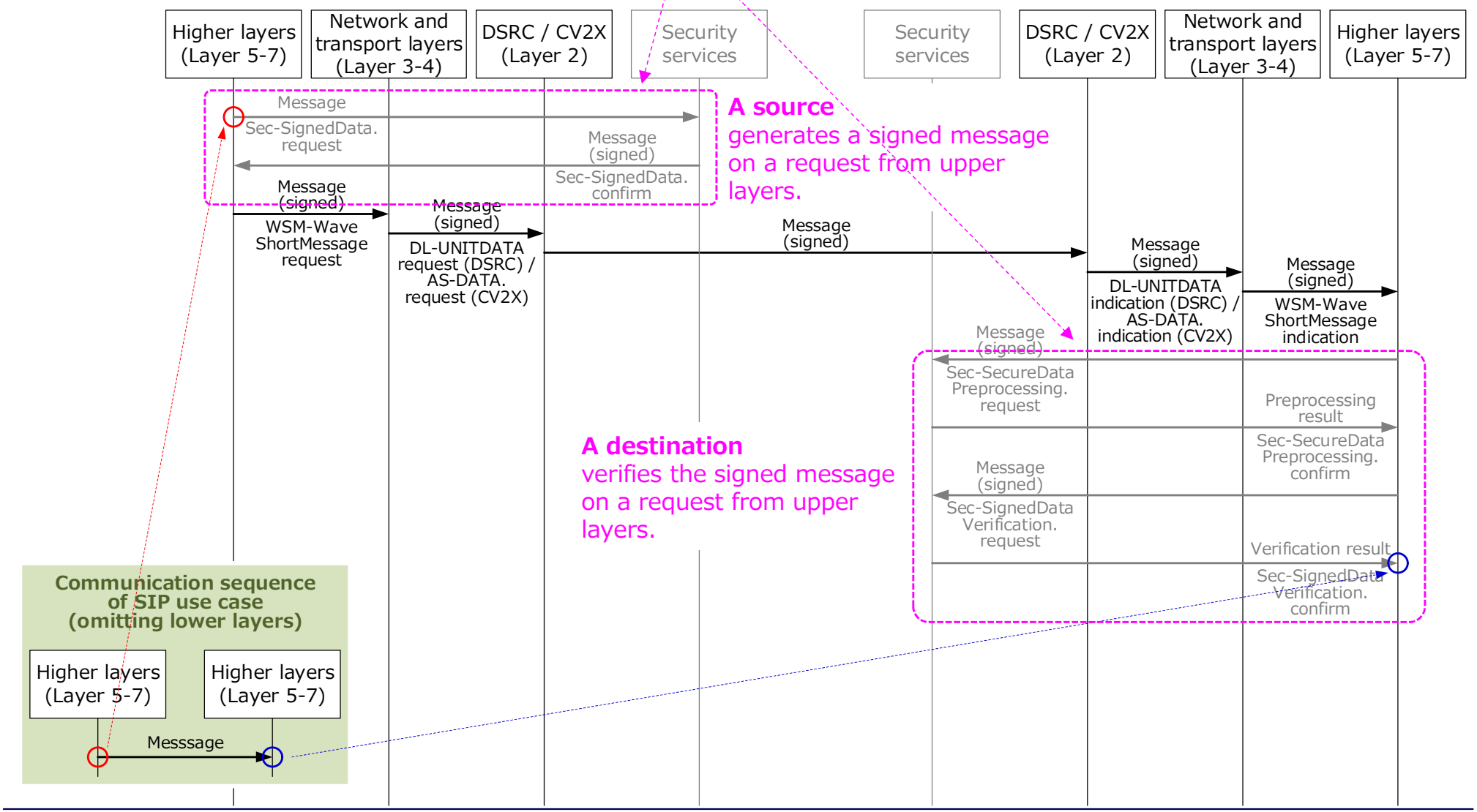
Information on driving targets (target speed, lane, vehicle interval, reply request range, etc.)		
Use case specific information (Negotiation information)		
a. Merging/lane change assistance		
Cooperative merging assistance with vehicles on the main lane by roadside control		
a-1-3		
Control request	Negotiation request, Update request	Negotiation response, Update response
V2I	I2V	V2I
Non-specific vehicles or specific vehicles		Roadside infrastructure
Aperiodic		
–		
No		



1) Developing communication protocol proposals

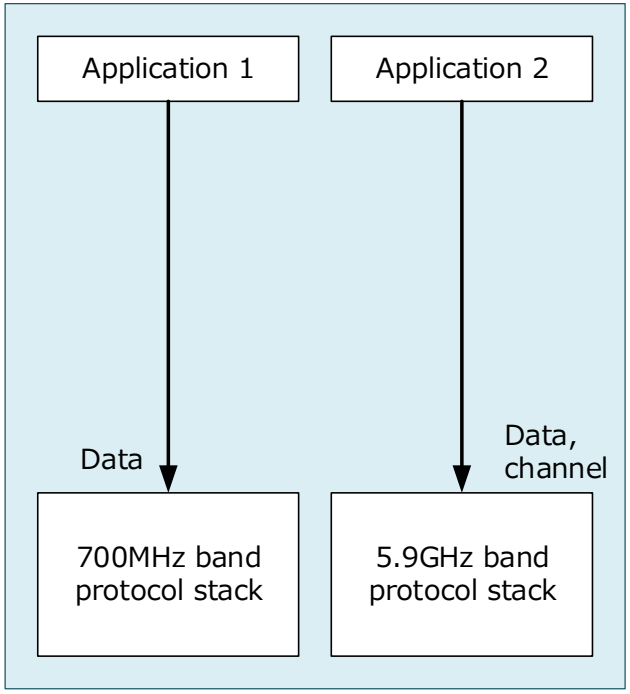
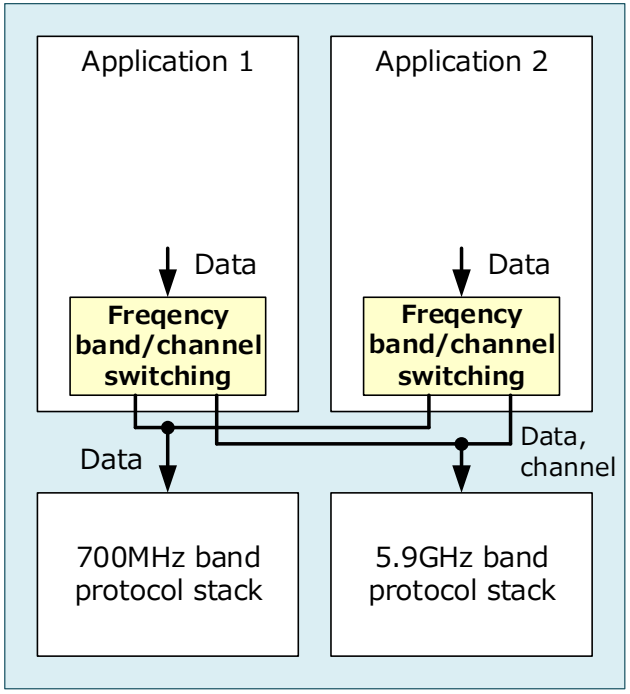
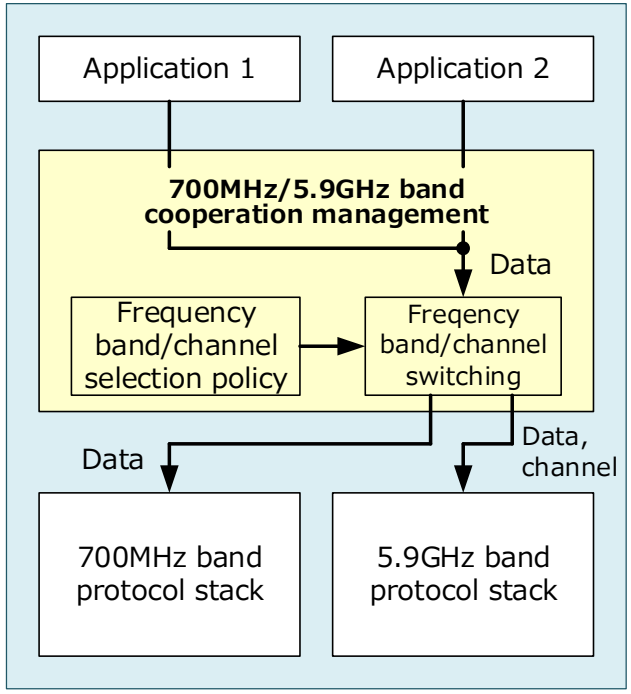
Example of desk study - Procedure between layers -

- Based on the assumption that security services similar to those in the European and U.S. specifications (electronic signature method) would be provided, **procedures between layers were studied and organized**.
- Detailed specifications of the security services need to be further discussed.
  * In this study, **message sizes added by security services (overhead) is reflected in the communication simulation**.



1) Developing communication protocol proposals
Proposed ways to cooperation with 700 MHz band ITS

- Propose proposals in which protocol stacks (**layer 7 or lower**) for each frequency band **exist side by side and applications choose** between them.
- Based on SIP roadmap and a technology adoption situation, it is necessary to study the channel allocation method including 700 MHz and 5.9 GHz bands for each SIP use case in the future.

Proposal	Proposal 1	Proposal 2	Proposal 3
Way to cooperation	**Predefine the frequency band (without cooperation).**	**Select the frequency band by applications.**	**Select the frequency band by non-application.**
Merit	No need to modify existing applications.	Capable of switching frequencies used by applications according to a technology adoption, etc.	Capable of determining frequencies for an entire system considering frequency utilization efficiency.
Issue	Way to handle review of the frequencies used by applications	Consideration of how to distribute frequencies used by each application	Consideration of a management layer for sharing 700 MHz and 5.9 GHz bands
Structure			

c) Designing communication protocol proposals

2) Developing a message set proposal

2) Developing a message set proposal
Summary

- Regarding message structure of SIP use cases, based on the results of the study by ITS Info-communications Forum (ITS FORUM RC-017), information elements, the use cases that use them and their size were organized considering commonality among the message used in each use case.
- By conducting this study using the above organized results as preconditions for 1) and 3), consistency with the channel allocation and the communication protocol proposals was confirmed.
- Based on the developed communication protocol proposals, a study of information elements multiplexing was conducted. It was confirmed that combining multiple information from different destinations or use cases into a single packet and reducing the security overhead can be expected to reduce the communications traffic.
- Future issues include:
  - Review of this study reflecting the message structure to be revised.
  - Study and evaluation of detailed procedures for the information elements multiplexing.

Organized result of a message set proposal (Summary)

Classification by function	Use case	No.	Message name	Communication Method	Data size [bytes]									
									(4) Use case specific information					
					Total	Security overhead	(1) Message information	(3) Vehicle basic 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 Update request	I2V	**298**	250	18					30			
			Negotiation response Update response	V2I	**329**	250	18	31				30			
	Merging assistance based on negotiations between vehicles	a-1-4	Negotiation request Update request	V2V	**329**	250	18	31				30			
			Negotiation response Update response	V2V	**329**	250	18	31				30			
	Lane change assistance when the traffic is heavy	a-2	Negotiation request Update request	V2V	**329**	250	18	31				30			
			Negotiation response Update response	V2V	**329**	250	18	31				30			
	Entry assistance from non-priority roads to priority roads during traffic congestion	a-3	Negotiation request Update request	V2V	**329**	250	18	31				30			
			Negotiation response Update response	V2V	**329**	250	18	31				30			
b. Traffic signal information	Driving assistance by using 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		
	Collision avoidance assistance by using 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) Developing a message set proposal
Case studies of information elements multiplexing method

- **Consider reducing communications traffic by combining multiple information** from different destinations or use cases into a single packet and reducing security (electronic signatures) overhead.
- Studies were conducted for roadside infrastructures and vehicles, respectively (and the results were reflected in communication simulation evaluation).
  - When **roadside infrastructures** send negotiation/update requests to multiple vehicles for UC a-1-3 (cooperative merging assistance with vehicles on the main lane by roadside control)
  - When **vehicles** send messages of multiple use cases on the same channel

A multiplexing method (proposal) for roadside infrastructures

No multiplexing of information elements

Security overhead (250 bytes)	Message information (18 bytes)	Negotiation information addressed to vehicle 1 (30 bytes)

Security overhead (250 bytes)	Message information (18 bytes)	Negotiation information addressed to vehicle 2 (30 bytes)

⋮

Multiplexing of information elements

Security overhead (250 bytes)	Message information (18 bytes)	Negotiation information addressed to vehicle 1 (30 bytes)	Negotiation information addressed to vehicle 2 (30 bytes)	…

A multiplexing method (proposal) for vehicles

No multiplexing of information elements

Security overhead (250 bytes)	Message information (18 bytes)	Vehicle basic information (31 bytes)	Negotiation information for UC a-2 (30 bytes)

Security overhead (250 bytes)	Message information (18 bytes)	Vehicle basic information (31 bytes)	Hazard information for UC c-1 (39 bytes)

⋮

Multiplexing of information elements

Security overhead (250 bytes)	Message information (18 bytes)	Vehicle basic information (31 bytes)	Negotiation information for UC a-2 (30 bytes)	Hazard information for UC c-1 (39 bytes)	…

Target use cases

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
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					
			Location information	I2V	100ms	1	**5244**	250	18		1	4975					
	Cooperative merging assistance with vehicles on the main lane by roadside control	a-1-3	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

(*1) Provisional (*2) Number of controlled vehicles

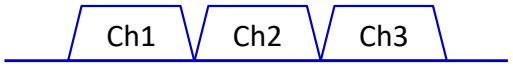
c) Designing communication protocol proposals

3) Simulation-based communication performance evaluation

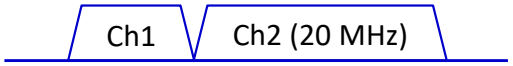
3) Simulation-based communication performance evaluation
Summary

- Under mixed environments of SIP use cases (and interference sources) at an expressway merging section and a general road intersection, communication performance was evaluated using CV2X (LTE V2X) when multiple channels were allocated within a 30 MHz bandwidth and messages (information elements) of the multiple use cases were 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 effectiveness of a communication control method, communication performance was evaluated when transmission periods of vehicles were extended. It was confirmed that communication quality could be improved in situations where the communication was congested and a required PAR could not be achieved.
- 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).
- Future issues include:
  - Comparison of single channel and multi-channel performance in the same bandwidth.
    (For example, for NR V2X, is it better to use one channel with a bandwidth of 30 MHz or to divide the bandwidth into two or more channels?)
  - Verification of the effectiveness of channel allocation methods other than methods of allocating channels on a per-service basis.
    (For example, when multiplexing information elements, channel utilization efficiency may be improved if a channel is divided by source rather than by use case. Such as, dividing between transmissions of roadside infrastructures (I2V) and those of vehicles (V2I and V2V).)
  - Detailed evaluation of communication control methods considering time variation of the transmission periods, priority, etc.

Proposal 1 (3 channels of 10MHz)



Proposal 6 (1 channel of 10MHz and 1 channel of 20MHz)



Summary of evaluation conditions (combinations of use cases, channel allocations)

Expressway merging section

Classification by function	Use case	Communication method	Channel allocation	
			Proposal 1	Proposal 6
a. Merging/lane change assistance	a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control	V2I	Ch1 (10 MHz)	Ch1 (10 MHz)
e. Lookahead information: emergency vehicle notification	e-1. Driving assistance based on emergency vehicle information	V2V	Ch2 (10 MHz)	Ch2 (20 MHz)
a. Merging/lane change assistance	a-2. Lane change assistance when the traffic is heavy			
c. Lookahead information: collision avoidance	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly		Ch3 (10 MHz)	

General road intersection

Classification by function	Use case	Communication method	Channel allocation	
			Proposal 1	Proposal 6
b. Traffic signal information	b-1-1. Driving assistance by using traffic signal information (V2I)	V2I	Ch1 (10 MHz)	Ch1 (10 MHz)
c. Lookahead information: collision avoidance	c-2-2. Driving assistance based on intersection information (V2I)			
e. Lookahead information: emergency vehicle notification	e-1. Driving assistance based on emergency vehicle information	V2V	Ch2 (10 MHz)	Ch2 (20 MHz)
a. Merging/lane change assistance	a-2. Lane change assistance when the traffic is heavy			
c. Lookahead information: collision avoidance	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly		Ch3 (10 MHz)	

3) Simulation-based communication performance evaluation
Example of transmission conditions (Information elements multiplexing)

- Based on the study in 2), **reduce communications traffic** by **combining multiple information** from different destinations or use cases **into a single packet** and reducing security (electronic signatures) overhead.
- Conducted for roadside infrastructures and vehicles, respectively.
  - When **roadside infrastructures** send negotiation/update requests to multiple vehicles for UC a-1-3 (cooperative merging assistance with vehicles on the main lane by roadside control)
  - When **vehicles** send messages of multiple use cases on the same channel

For the expressway merging section

Source	Classification by function	Use case	Message name	Communication method	Multiplexing of information elements (conditions for this evaluation)								No multiplexing of information elements (reference)
					Multichannel (channel allocation proposals)				Single channel (conditions for comparison)				
					Proposal 1 (10 MHz x 3 Ch)		Proposal 6 (10 + 20 MHz)		10 MHz		20 MHz		
					Channel	**Data size [bytes]**	Channel	**Data size [bytes]**	Channel	**Data size [bytes]**	Channel	**Data size [bytes]**	**Data size [bytes]**
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 Update request (*2)			**718 (x 4)**		**718 (x 4)**		**718 (x 4)**		**718 (x 4)**	**718 (x 4)**
			Control request	V2I		**329**		**329**		**398**		**398**	**329**
Vehicle			Negotiation response 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 Update request										**329**
			Negotiation response Update response										
	c. Lookahead information: collision avoidance	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly	-		Ch3	**338**							**338**

(*1) Its data size is for 50 km/h and 1 second vehicle interval (for 100 km/h and 2 seconds vehicle interval, 708 bytes).
(*2) Its data size is for 50 km/h and 1 second vehicle interval (for 100 km/h and 2 seconds vehicle interval, 718 (x 2) bytes if multiplexing information elements and 298 (x 16) bytes if not multiplexing them). The notation "718 (x 4)" indicates that 718 bytes are transmitted 4 times.

3) Simulation-based communication performance evaluation
Example of simulation results

A comparison of channel allocation methods showed:

- Communication quality was generally better when V2V use cases were assigned to one channel (Proposal 6) than when they were assigned to two channels (Proposal 1) within a 20 MHz bandwidth.
  -> Because information elements on the same channel was multiplexed, a smaller number of channels means fewer packets per bandwidth, reducing transmission frequency and security overhead (communications traffic).
- Compared to single channel cases (up to 20 MHz bandwidth), the result did not necessarily show an improvement in the communication quality.
  -> When vehicles transmissions are distributed across the multiple channels due to the multiple channel allocation, information elements can not be multiplexed across the different channels, increasing the number of packets per bandwidth.

Verification of effectiveness of a communication control method (when transmission periods of vehicles were extended) showed:

- It was confirmed that communication quality could be improved in situations where the communication was congested and a required PAR could not be achieved.

For the expressway merging section (in the case of 100 km/h and 2 second vehicle interval)

100 ms for roadside infrastructure (unchanged), 200 ms for vehicle (changed from 100 ms)

Communication method, etc.	Use case	Message name	Required communication distance	Single channel: 10 MHz (a) PAR per message	(b) Delay (99th percentile)	(c) Availability for each use case	(d) Time to reach required PAR	Single channel: 20 MHz (a)	(b)	(c)	(d)	Multichannel (communication channel allocation proposals): Proposal 1 (10 MHz x 3 Ch) (a)	(b)	(c)	(d)	Proposal 6 (10 MHz + 20 MHz) (a)	(b)	(c)	(d)	Verification of effectiveness of a communication control method (when transmission periods of vehicles were extended): Proposal 1 (10 MHz x 3 Ch) (a)	(b)	(c)	(d)	Proposal 6 (10 MHz + 20 MHz) (a)	(b)	(c)	(d)
I2V (main lane)	a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control	Location info.	222.2 m	100.0%	49.0ms	O	100ms	100.0%	46.0ms	O	100ms	98.0%	-	X	200ms	97.6%	-	X	200ms	99.0%	-	X	200ms	99.7%	50.0ms	O	100ms
		Negotiation req. Update req.	222.2 m	99.0%	50.0ms	O	100ms	100.0%	45.0ms	O	100ms	96.4%	-	X	200ms	98.7%	-	X	200ms	98.9%	-	X	200ms	99.0%	-	X	200ms
V2I (main lane)		Negotiation resp. Update resp.	222.2 m	42.0%	-	X	900ms	86.8%	-	X	300ms	54.4%	-	X	600ms	43.1%	-	X	900ms	78.9%	-	X	400ms	76.9%	-	X	400ms
I2V (merging lane)		Location info.	66.7 m	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms
		Negotiation req. Update req.	66.7 m	99.7%	46.0ms	O	100ms	100.0%	44.0ms	O	100ms	100.0%	46.0ms	O	100ms	100.0%	46.0ms	O	100ms	99.8%	46.0ms	O	100ms	99.8%	46.0ms	O	100ms
V2I (merging lane)		Negotiation resp. Update resp.	66.7 m	95.6%	-	X	200ms	100.0%	46.4ms	O	100ms	96.4%	-	X	200ms	96.1%	-	X	200ms	98.2%	-	X	200ms	97.6%	-	X	200ms
V2V (without forwarding)	a-2. Lane change assistance when the traffic is heavy	-	255 m	50.5%	-	X	700ms	86.5%	-	X	300ms	60.3%	-	X	500ms	81.1%	-	X	300ms	84.2%	-	X	400ms	91.5%	-	X	200ms
	e-1. Driving assistance based on emergency vehicle information	-	150 m	84.0%	-	X	300ms	98.8%	-	X	200ms	89.8%	-	X	300ms	95.5%	-	X	200ms	95.6%	-	X	200ms	97.9%	-	X	200ms
V2V (with forwarding)	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly	-	250 m	98.7%	103.6ms	X	200ms	100.0%	58.2ms	O	100ms	100.0%	65.1ms	O	100ms	100.0%	70.8ms	O	100ms	100.0%	88.5ms	O	200ms	99.9%	82.8ms	O	200ms
		-	1000 m	100.0%	152.7ms	O	200ms	100.0%	128.7ms	O	200ms	100.0%	152.8ms	O	200ms	100.0%	133.1ms	O	200ms	100.0%	173.3ms	O	200ms	100.0%	136.7ms	O	200ms

* Coloring of the above table depends on values of (d) (time to reach required PAR). : 100 ms : 200-300 ms : 400-600 ms : 700-1200 ms : 1300- ms

d) Proposing wireless device specifications

1) Examination of wireless device specifications

1) Examination of wireless device specifications
Item extraction

- In order to comprehensively organize the items, refer to existing wireless device specifications and extract the functions, characteristics, interfaces, etc. required for V2X communication.
  - Domestic: 5.8GHz Band DSRC Roadside unit standards
  - Overseas: SAE J2945/1 etc.
- Prioritize the items necessary for creating communication standards, and only list items such as security, functions other than communication, hardware specifications for interfaces, etc.

Comparison between item proposals and existing specifications

Item proposals of wireless device specifications for V2X system in the 5.9GHz band	5.8GHz Band DSRC Roadside unit standards	SAE J2945/1 On-Board System Requirements for V2V Safety Communications
1. Scope - Purpose - Scope of application, prerequisites (Target use cases, requirements, etc.)	1-1 Scope of application of this standard 1-5 Prerequisites for roadside units	1.SCOPE 4.2 V2V Safety Features 5.1 V2V Over-the-Air Data Description
2. V2X system overview - System configuration - Equipment configuration	1-4 Roadside unit overview 1-1 Internal configuration	4.1 V2V System Overview
3. V2X communication function, characteristics, and interface details - General requirements and technical requirements for wireless device - Communication control section functions, characteristics, interface	2-3 Functions and characteristics of the antenna part 2-4 Functions and characteristics of transmitter and receiver 2-5 Functions and characteristics of the communication control section 2-10 Interface	5.2 System Interfaces 6.1 Standards Profiles 6.3 BSM Transmission Requirements on Channel vChannelNumber

1) Examination of wireless device specifications

Summary of results

- Based on the results of extracting the items, we compiled a proposal for wireless device specifications by organizing the specifications corresponding to the communication protocol proposal, etc.

Wireless device specifications for the V2X system in the 5.9GHz
Item list
1. Scope - Purpose - Scope of application, prerequisites (Target use cases, requirements, etc.)
2. V2X system overview - System configuration - Equipment configuration
3. V2X communication function, characteristics, and interface details - General requirements and technical requirements for wireless device - Communication control section functions, characteristics, interface

V2X communication function, characteristics, and interface		
General requirements and technical requirements for wireless device	General requirements	Data rate
		Coding Rate
		Channel
		Modulation method
	Transmitter characteristics	Antenna power
		Antenna power permissible deviation
		Transmit spectrum mask
		Leakage power during carrier off
		Transmitter spurious
		Frequency permissible deviation
		Modulation accuracy
		Transmission timing accuracy
	Receiver characteristics	Receiver sensitivity
		Adjacent channel rejection
		Non-adjacent channel rejection
		Secondary emitted radio wave strength
		Receiving maximum input power
	Antenna	Antenna structure
		Antenna gain
		Antenna polarization
		Antenna installation

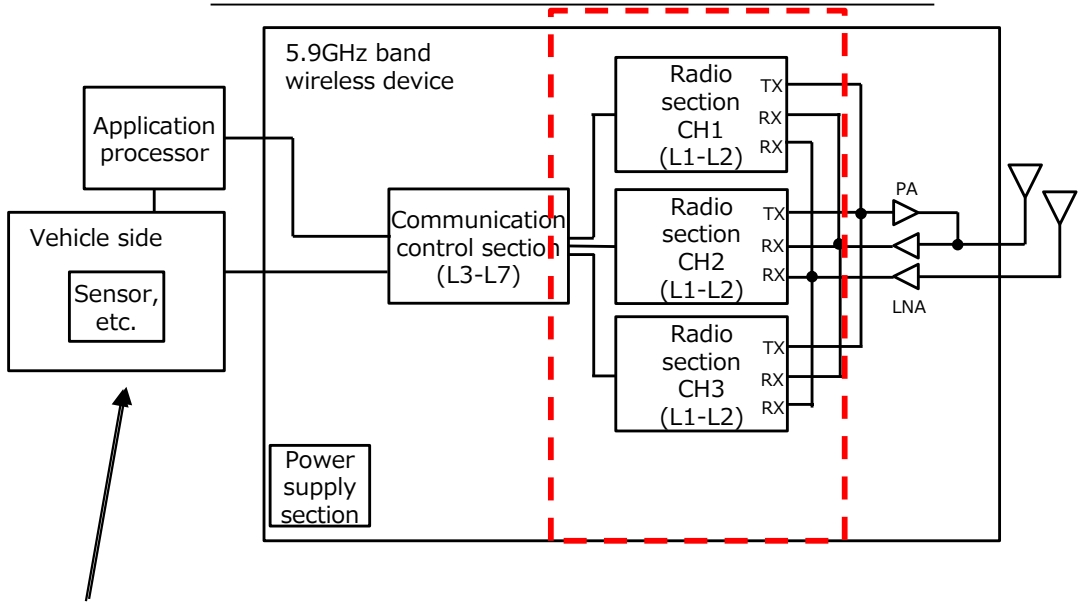
V2X communication function, characteristics, and interface			
Communication control section functions, characteristics, interface	Layer 1 functions	Overview	–	–
		Layer 1 Service interface	Service primitive	Functions
				Parameters
		Layer 1 communication control	Protocol data unit	Data format
			Transmit/receive procedure	–
	⋮	⋮	⋮	⋮
	Layer 7 functions	Overview	–	–
		Layer 7 Service interface	Service primitive	Functions
				Parameters
			Service primitive (Security)	Functions
				Parameters
		Layer 7 communication control	Protocol data unit	Data format
			Transmit/receive procedure	–
	Layer management Entity functions	Layer management Service interface	Layer 1	Functions
				Management information base(MIB)
			⋮	⋮
			Layer 7	Functions
				Management information base(MIB)
	Security layer functions			
	Other functions	Transmission requirements	UC a-1-1	Communication sequence
				Interface of service in use
				Transmission parameters
			⋮	⋮
			UC g-2	Communication sequence
				Interface of service in use
				Transmission parameters
			Congestion control	–
	Between antenna section and transmission/receiving section	Physical interface	–	–
	Between transmission/receiving section and communication control section	Physical interface	–	
	Between application and layer 7	Physical interface	–	

: Out of scope

1) Examination of wireless device specifications
Example of results: 2. V2X system overview - Equipment configuration -

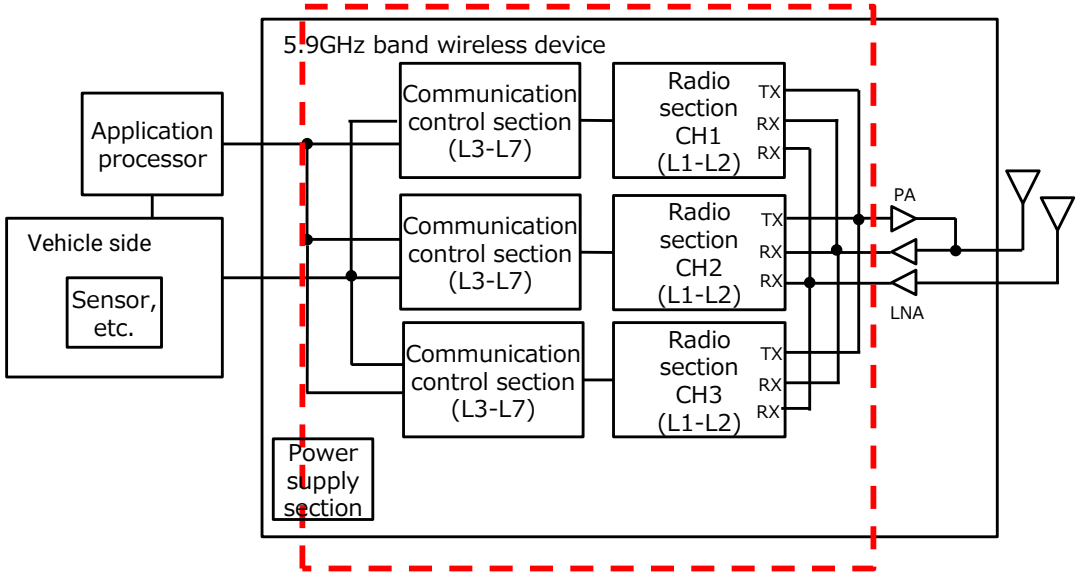
- Based on the functions and operations related to channel allocation in the communication protocol proposal (assumed to have the same number of radio sections (Layer 2 or lower) as the number of allocated channels), organize the equipment configuration that supports multi-channels.
  - It is necessary to have a radio sections or a radio sections + communication control sections (L3 to L7) for the number of allocated channels

Equipped with radio sections for the number of allocated channels



※As a method of obtaining own vehicle information, it is assumed that the information is passed through the control device on the vehicle side.

Equipped with radio sections and communication control sections for the number of allocated channels

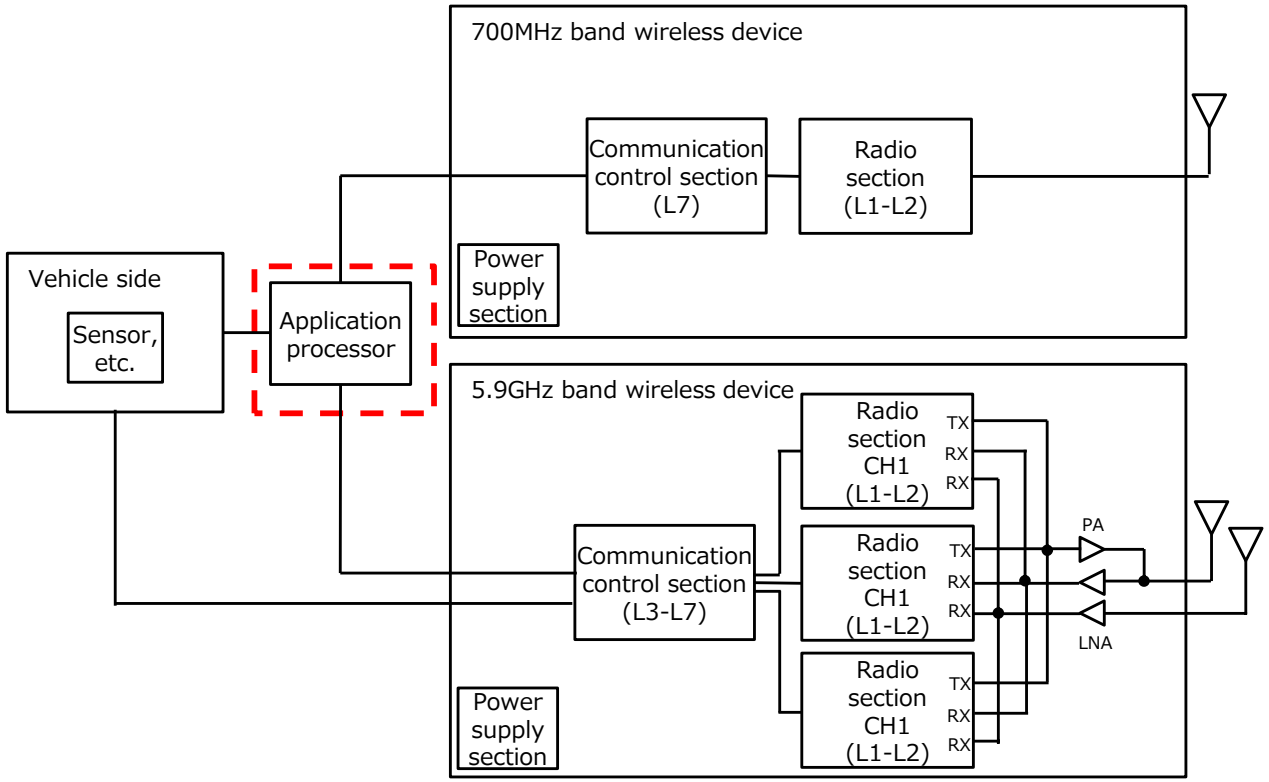


: Implement according to the number of allocated channels

1) Examination of wireless device specifications

Example of results: 2. V2X system overview - Equipment configuration -

- Equipment configuration that takes into the method of cooperation with the existing ITS:Proposal2 Introduced 5.9GHz band wireless device
  - Corresponds to proposal 2 for cooperation with 700 MHz band ITS in c)
  - Each application can select the frequency used depending on the situation of spread because one application is configured to be able to access communication layers of existing ITS and 5.9GHz band.



1) Examination of wireless device specifications
Summary

- Regarding the system configuration, device configuration, functions/characteristics/interfaces, we compiled a proposal for wireless device specifications by organizing the specifications corresponding to the communication protocol proposal, etc.
- Based on the SIP roadmap of V2X communication methods, the equipment configuration proposal was organized by considering the method of cooperation with the existing ITS radio equipment for each period of introduction and post-introduction of the 5.9 GHz band wireless device.
- Future issues include:
  - Continuous study of multi-channel support methods by quantitative evaluation
  - Consideration of specifications for items whose priority has been lowered
    - Hardware specifications for interfaces
    - Functions other than communication (Fault detection, power supply, etc.)
  - Detailed examination of interface requirements with the vehicle

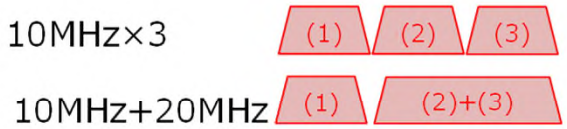
d) Proposing wireless device specifications

2) FOTs on test courses, etc.

2) FOTs on test courses, etc.
Content of implementation

- Conduct FOTs (Field Operational Tests) on a test course under conditions where multiple use cases coexist
  - Conducted communication performance evaluation when using multiple channels and 20MHz bandwidth, and verified the effect of channel allocation
  - Uses CV2X (LTE V2X (PC5)) communication equipment

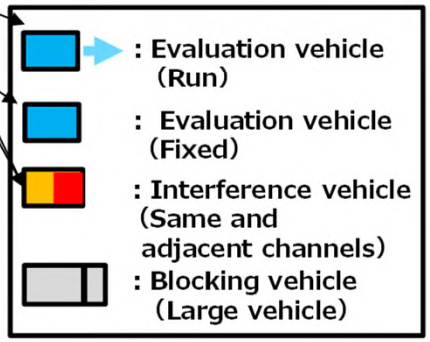
Channel layout image



Evaluation patterns of multiple channels

Evaluation pattern		Evaluation channel Bandwidth	Interference channel Bandwidth	Interference channel transmission method
A	10MHz	10MHz	Same: 10MHz	Burst wave
B	20MHz	20MHz	Same: 20MHz	Burst wave
C	10MHz×3 Proposal1	10MHz	Same: 10MHz	Burst wave
			Adjacent: 10MHz	Burst wave
D	10MHz+20MHz Proposal6	10MHz	Same: 10MHz	Burst wave
			Adjacent: 20MHz	Burst wave
E	10MHz+20MHz Proposal6	20MHz	Same: 20MHz	Burst wave
			Adjacent: 10MHz	Burst wave

Japan Automobile Research Institute (JARI) Automated Driving Test Center Jtown V2X Urban Area



Vehicle placement

Source: Created by processing aerial photographs of the Geospatial Information Authority of Japan (https://mapps.gsi.go.jp/maplibSearch.do#1)

2) FOTs on test courses, etc.
Summary

- Under the evaluation conditions of this demonstration experiment (using a separate wireless device respectively for multi-channel transmission (or reception)), it was confirmed that the effect of channel allocation showed the same tendency as the simulation.
- Future issues include:
  - Verification of degradation factors when multi-channel transmission/reception is realized with a single wireless device

List of results

PAR (upper row : Experiment, lower row : Simulation)

Evaluation channel	Interference channel : Other channel		Interference channel : Same channel	Combination of multiple use cases				Notes
				Expressway merging section		General road intersection		
				Evaluation target				
System bandwidth	System bandwidth	Relationship with evaluation channel	System bandwidth	V2I	V2V	V2I	V2V	
10			10	96.0	92.1	60.2	80.7	Evaluation pattern A
				100.0	83.8	92.2	45.8	Single channel (10MHz)
20			20	100.0	99.8	84.0	95.9	Evaluation pattern B
				100.0	96.6	95.3	66.7	Single channel (20MHz)
10	10	Adjacent	10	95.7	98.4	100.0	88.7	Evaluation pattern C
				99.0	84.2	99.4	63.6	Multiple channel (Proposal1:10MHz×3Ch)
10	20	Adjacent	10	99.5	-	100.0	-	Evaluation pattern D
				99.7		99.3		Multiple channel (Proposal6:10MHz+20MHz)
20	10	Adjacent	20	-	100.0	-	96.6	Evaluation pattern E
					91.5		85.0	Multiple channel (Proposal6:10MHz+20MHz)

d) Proposing wireless device specifications

3) Clarification of issues and its solutions for implementation

3）Clarification of issues and its solutions for implementation

Issues	Content	Solutions
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. 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. 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. 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. Furthermore, we will select the target standardization organization for the draft standardization and promote standardization.

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.