Study of utilization of new communication technologies including V2X technology to automated driving system of “Cross-ministerial Strategic Innovation Promotion Program(SIP) 2nd Stage Automated Driving System (Expansion of system and service)”

Final Report

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1．Object of study

- There are many initiatives which aim to utilize communication technologies to autonomous driving system.
- This study is intended to obtain trends of communication technologies expected to be commonly utilized to ITS and autonomous driving system. Object of study is as follows;

Object of study	Number of initiatives			
	Europe	U.S	Asia	Inter-national
① Initiatives for ITS and autonomous driving system ✓ Focus on the ongoing governmental and private projects which conduct research development and demonstration to utilize communication technologies to autonomous driving system. ✓ “Private project” means the one which multiple companies take part in. ✓ Initiatives and projects which focus on ITS and other peripheral functions related to autonomous driving systems are included.	Government:8 Private:9	Government:3 Private:1	Government:9 Private:9	–
② Standardization of communication technologies by standards bodies Focus on the bodies which deal with standardization of communication technologies utilized to autonomous driving system ✓ Initiatives which focus on ITS and other peripheral functions related to autonomous driving systems are included.	2	1	3	3
③ Cross-industrial research development of autonomous driving system Focus on cross-industrial bodies which various categories of business (auto manufacturer, carrier, electronic manufacturer etc.) take part in, and which deal with standardization of communication technologies utilized to autonomous driving system.	–	–	–	3

（→See after-mentioned **APPENDIX 2** for detailed object of study）

2．Use cases utilizing communication technologies

It is expected to utilize communication technologies to autonomous driving system

- To improve **safety, traffic smoothness** and **driving comfort** by collecting and providing such environmental information as vehicles, pedestrians and other situations, and to remotely manage commercial autonomous vehicles.
- To **remotely manage commercial autonomous vehicles**
- To **reload the map** which serves a platform of autonomous driving system

Group	Use cases	Project
Safety	Cooperative Adaptive Cruise Control	CITE project, CARMA, CONCORDA etc.
	Emergency electronic brake lump	CITE project, 5GAA, ITS Strategic Plan etc.
	Support for merging	5GCAR, C2-CCC, Technical Test for CC Society Realization
	Collision avoidance at the crossing	SIP/Large-scale Field Operational Tests, C-Road, ITS Strategic Plan
	Truck platooning	5G Operational Tests (Ministry of Internal Affairs and Communications)
Smoothness and comfort	Caution of emergency vehicle approach	Towards 5G initiative, MEC Project, CITE project, C-Road etc.
	Caution of accident	SCOOP@F, ITS Strategic Plan etc.
	Caution of congestion	CONCORDA, C-Road, SCOOP@F etc.
	Speed control information	CONCORDA, C-Road, ITS Strategic Plan etc.
	Traffic flow monitoring with probe data	ITS Strategic Plan, C-Road, SCOOP@F etc.
	Optimization of signal information	ITS Strategic Plan, C2-CCC etc.
	Provision of parking lot information and parking management	C-Road
Large-volume data	Map reloading	5GCAR, SIP/Large-scale Field Operational Tests
	Generation and provision of high-definition map	AECC
Commercial vehicle management	Remote management of autonomous vehicle	5G Operational Tests (Ministry of Internal Affairs and Communications)

3．Communication technologies expected to be utilized (1/3)

- The following **11 technologies** are expected to be utilized to autonomous driving.

		①DSRC (Japan)	②DSRC (Europe and U.S)	③700MHz帯高度道路交通システム	④60GHz帯無線
Summary		Developed for ITS service (V2I communication service). Utilized to ETC/ETC 2.0 in Japan	Developed for ITS service (V2I/V2V communication service). Utilization to ITS and autonomous driving is under study in Europe and U.S.	Developed for ITS service (V2I communication service). Utilized to ITS Connect and TSPS※2 in Japan. High diffraction due to using relatively low frequency band.	Developed for fast transfer of large-volume contents. Utilization to ITS and autonomous driving is under study in Japan. Standardization is under way in Europe for utilizing it to ITS.
Communications standards		ARIB STD-T75,T88,T110	IEEE802.11p	ARIB STD-T109	IEEE 802.11ad ARIB STD-T117
L1	Transmission rate	1Mbps or 4Mbps (depending on modulation)	3-27Mbps	3-18Mbps (depending on modulation)	Maximum 7.7Gbps
	Transmission range	A few m (ETC toll gate) A few dozen m (Main lane, notice beacon) ※1	A few hundred m (LOS environment) Below 100m (NLOS environment)	Depending on transmitted power and receiving sensitivity	10-200m
	Frequency band (allocated in Japan)	5.8GHz （5770-5850MHz）	5.9GHz （Undecided in Japan）	760MHz （755.5-764.5MHz）	60GHz （57GHz-66GHz）
	Bandwidth per CH	5MHz	10, 20MHz	9MHz	2GHz
	Number of CH	7ch for uplink and downlink	[Euro] 3ch (inc. 1 control channel) [U.S] 7ch (inc. 1 control channel)	1ch	4ch
L2	Multiple access	TDMA	CSMA/CA	[V2I]TDMA [V2V]CSMA/CA } Divide period of communication in terms of time	Hybrid of CSMA/CA＋TDMA
	Error correction	Turbo code	Convolution code	Convolution code	Low-density parity-check code（LDPC）
	Identifier	Link address (LID)	(unknown)	Link address（MAC address）	Link address（MAC address）
L3	Supposed IP communication	Supposed	Supposed	(unknown)	Supposed
L7	Configuration	Broadcast, Unicast	Broadcast, Multicast, Unicast	Broadcast	Broadcast, Multicast, Unicast
	Security	DSRC-SPF	IEEE Std 1609.2	(not disclosed)	Depending on application
Availability in Japan		Available	Unavailable (undecided on available period)	Available	Available
Communication object		V2I	V2V, V2I	V2V, V2I, I2I	V2V、V2I、I2I

※1 Carrier depends on RUS antenna output and type in accordance with services. OBE is directional antenna.
※2 Traffic Signal Prediction System

3．Communication technologies expected to be utilized (2/3)

		⑤Bluetooth	⑥Wi-Fi（wireless LAN）	⑦Infrared
Summary		Developed for close range wireless communication between digital equipment such as wearable device and wireless earphone.	Developed for device's wireless communication.	Developed for ITS service (V2I communication service). Utilized to VICS and DSSS in Japan
Communications standards		Bluetooth 5	IEEE 802.11 a/b/g/n/ac 2.4GHz band: ARIB STD-T66 5GHz band: ARIB STD-T71	UTMS Society of Japan B4-U-013-5-0
L1	Transmission rate	Maximum 2Mbps	A few dozen Mbps – a few hundred Mbps	1,024kbps (downlink) 64kbps/256kbps (uplink)
L1	Transmission range	Maximum 400m (slow mode)	Depending on transmitted power and receiving sensitivity	Maximum 5.34m (downlink) Maximum 3.5m (uplink)
L1	Frequency band（allocated in Japan）	2.4GHz (2402MHz-2480MHz)	2.4GHz (2400MHz-2497MHz) 5.2･5.3GHz (5150MHz-5350MHz) 5.6GHz (5470MHz-5725MHz)	—
L1	Bandwidth per CH	78MHz	20MHz (802.11a/b/g) 40MHz (802.11n) 80Mhz, 160MHz (82.11ac)	—
L1	Number of CH	—	—	—
L2	Multiple access	—	—	—
L2	Error correction	—	—	—
L2	Identifier	—	—	—
L3	Supposed IP communication	—	—	—
L7	Configuration	—	—	—
L7	Security	—	—	—
Availability in Japan		Available	Available (5.8 GHz band is not available)	Available
Communication object		V2I	V2I	V2I

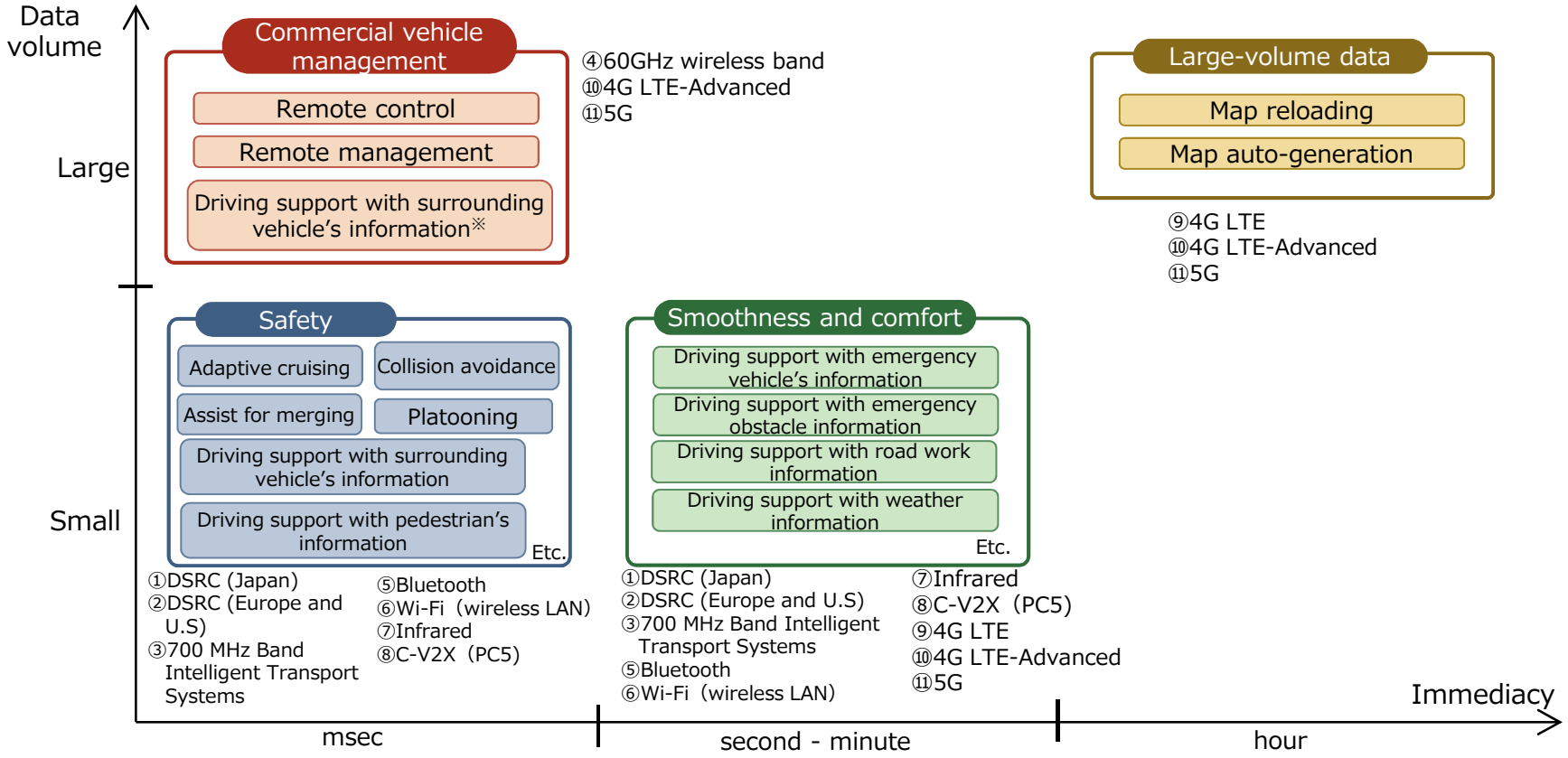
3．Communication technologies expected to be utilized (3/3)

		⑧C-V2X（PC5）	⑨4G LTE	⑩4G LTE-Advanced	⑪5G
Summary		Developed for terminal-to-terminal communication. Expected to be utilized to ITS and autonomous driving.	Developed for voice and data communication. Utilized to existing ITS service.	Developed for voice and data communication. Utilized to existing ITS service.	Developed for voice and data communication. Expected to be utilized to ITS and autonomous driving.
Communications standards		3GPP Release 14/15 (PC5)	3GPP Release 8-11	3GPP Release 12-14	3GPP Release 15
L1	Transmission rate	Maximum appx. 31Mbps※1	Over 100Mbps (downlink) Over 50Mbps (uplink) ※2	Over 1Gbps (downlink) Over 500Mbps (uplink) ※2	Over 20Gbps (downlink) Over 10Gbps (uplink) ※2
	Transmission range	Maximum 1.2 km	— (designed for broad area use)	— (designed for broad area use)	— (designed for broad area use)
	Frequency band (allocated in Japan)	5.9GHz (undecided on allocation in Japan)	700/800/900MHz, 1.5/1.7GHz, 2.0GHz, 3.5GHz Total 86 bands	700/800/900MHz, 1.5/1.7GHz, 2.0GHz, 3.5GHz Total 86 bands	3GHz, 26/28GHz etc. (3.7GHz, 4.5GHz, 28GHz)
	Bandwidth per CH	10, 20MHz	1.4,3,5,10,15,20MHz	1.4,3,5,10,15,20MHz※3	Maximum 100MHz※3※4 Maximum 400MHz※3※5
	Number of CH	Undecided due to no frequency band allocation in Japan	Depending on allocated bandwidth and the bandwidth per channel	Depending on allocated bandwidth and the bandwidth per channel	Frequency band will be allocated in Japan
L2	Multiple access	TDMA/FDMA utilizing sensing	OFDMA (downlink) SC-FDMA (uplink)	OFDMA (downlink) SC-FDMA (uplink)	TDMA/FDMA depending on base station scheduling
	Error correction	Turbo code	Turbo code	Turbo code	Low-density parity-check code (LDPC)
	Identifier	MAC address	MAC address	MAC address	MAC address
L3	Supposed IP communication	Supposed	Supposed	Supposed	Supposed
L7	Configuration	Broadcast	Broadcast, Multicast, Unicast	Broadcast, Multicast, Unicast	Only Unicast on Release 15
	Security	Security at application layer	(unknown)	(unknown)	3GPP TS 38.323, TS 33.501 etc.
Availability in Japan		Not available (Demonstrations are under way)	Available	Available	Not available (Demonstrations are under way)
Communication object		V2V,V2I,V2P	Used for various objects	Used for various objects	Used for various objects

※1 Maximum 3,963 Bytes/1ms ※2 Requirement for peak data rate
※3 Possible to bundle multiple bands by Carrier Aggregation
※4 Band range 1 (450MHz-6000MHz) ※5 Band range 2 (24250MHz–52600MHz)

4．Relationship between use case and communication technology

- On basis of analysis and results, we have specified four use cases; “Safety”, “Smoothness and comfort”, “Large-volume data” and “Commercial vehicle management”.
- From viewpoints of immediacy and data volume, it is thought that following communication technologies are required to realize each case.



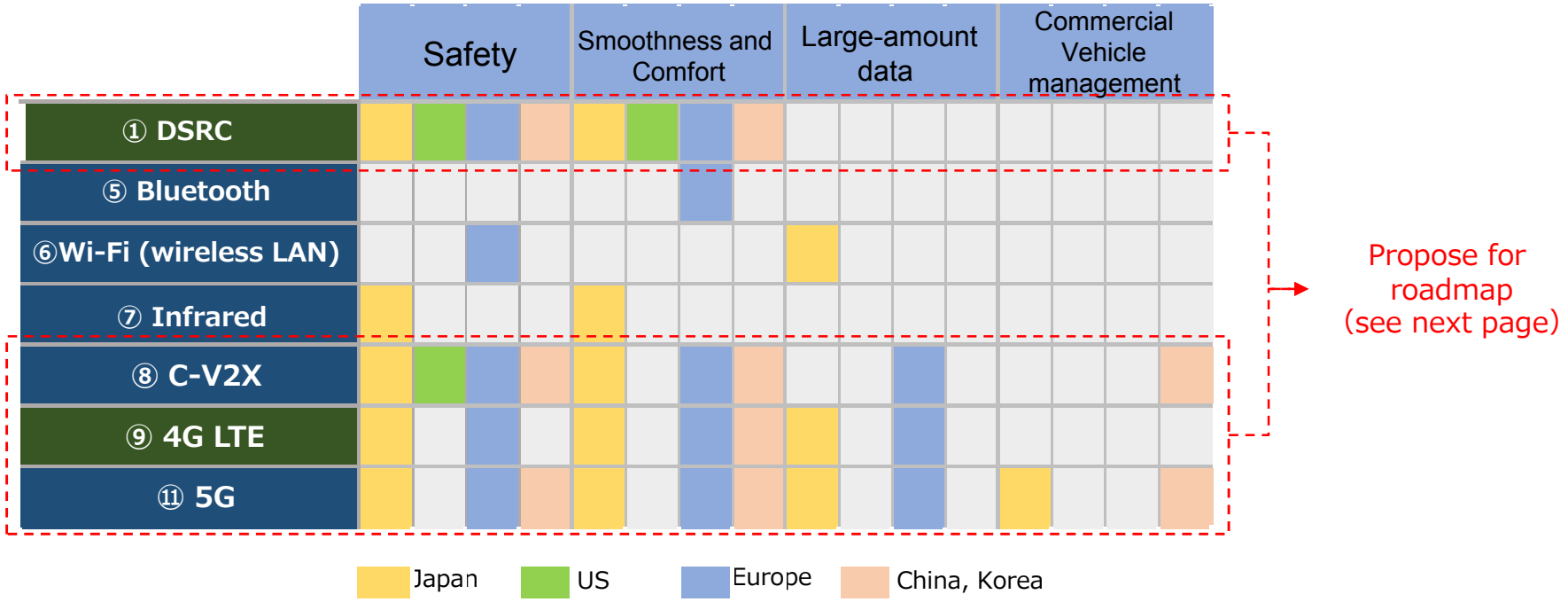
※ The case that video pictures are transferred by the surrounding vehicles.

5. Purpose of proposing roadmap

- Above studies show that utilization of communication technologies are expected at home and abroad to IST and autonomous driving system.
- Projects at home and abroad specify “use cases” as the expected manner of utilizing communication technologies and promote development and demonstration so that use case can be realized.
- It is thought that it is service provider (traffic controller/road administrator/private business) and OEM which develop these use cases into actual “service”.
- It is important to arrange communication technologies to be utilized to autonomous driving system and ensure the scope of choices to service provider and OEM.
- This study propose a roadmap which can contribute to **Japan’s planning to future research development and demonstration of communication technologies** so that these development and demonstration can be in step with, wherever possible, the status of global development for communication technologies.

6．Communication technologies for roadmap

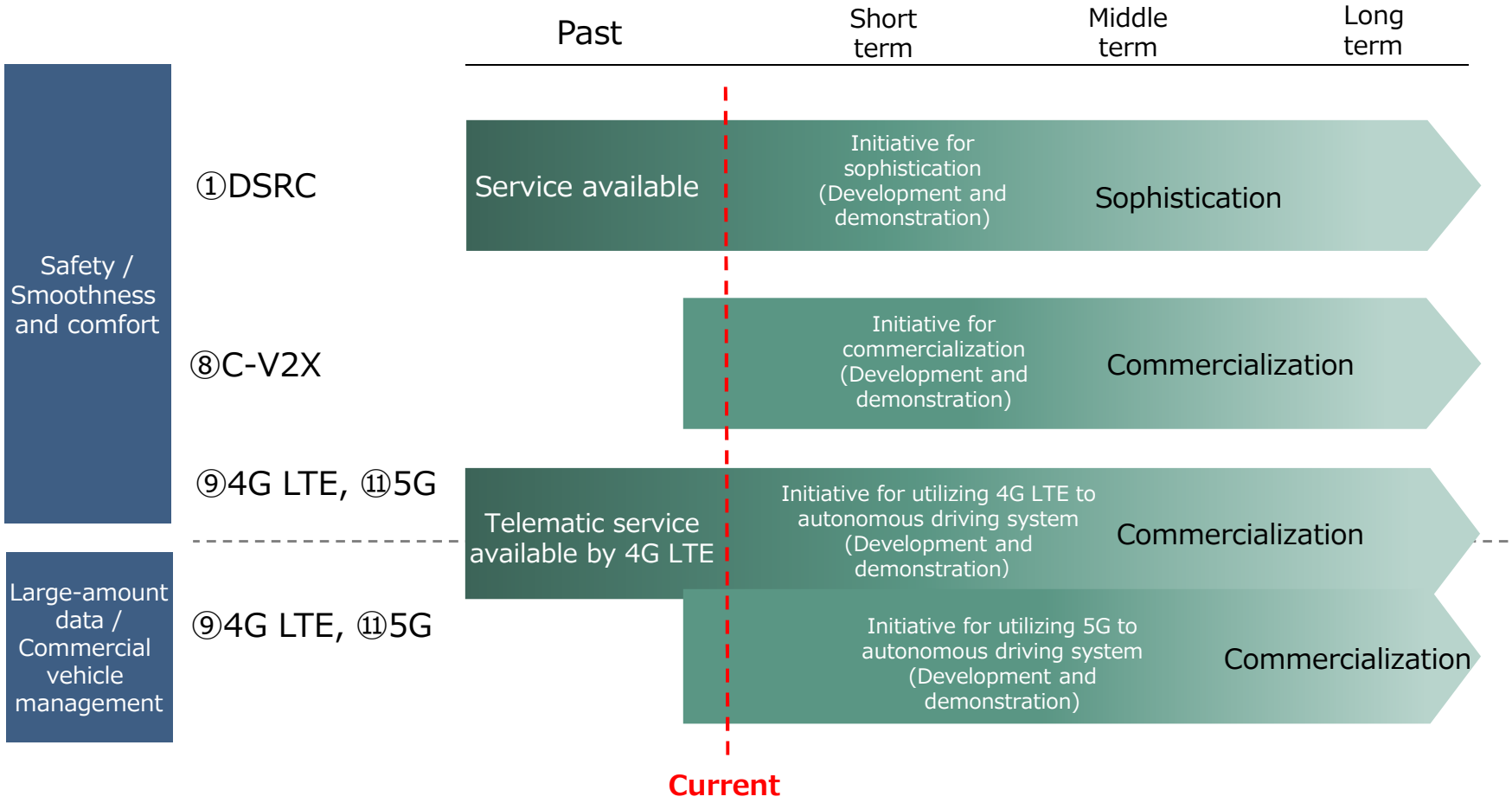
- In order to visualize trend of initiatives on autonomous driving system at home and abroad, we sorted out m by unit of country/regions (Japan, U.S, Europe and Asia (China and Korea)).
- We propose a roadmap for ① DSRC, ⑧ C-V2X, ⑨ 4G LTE and ⑪5G since their utilization to various use cases are internationally under study.



① DSRC: Including DSRC (Japan), DSRC(Europe and US), 700 MHz Band Intelligent Transport Systems and 60GHz wireless band.
⑨ 4G LTE: Including 4G LTE Advanced

7．Roadmap

- On the basis of “Safety” and “Smoothness and comfort” use cases, we propose a roadmap for initiatives for sophistication of ① DSRC , commercialization of ⑧ C-V2X and utilizations of ⑨ 4G LTE and ⑪5G.
- On the basis of “Large-amount data” and “Commercial vehicle management” use cases, we propose initiatives for utilizations of ⑨ 4G LTE and ⑪5G.



8. Point for future discussion

- We have proposed aforementioned roadmap which can contribute to planning development research and demonstration of communication technologies.
- In order to move this roadmap ahead, the following points are thought to be discussed among people involved.

(1) Discussion on priority of technology development

- It will be required to bring service provider and OEM into the discussion to prioritize technology development and demonstration on the basis of business model.

(2) Forethoughtful discussion on comprehensive selection of communication method

- Autonomous driving system will expect multiple communication technologies to be situationally utilized in accordance with each feature.
- It will be required to have a technically-crossover discussion such as the situational utilization of these technologies.
- Based on that, it will be required to forethoughtfully discuss the best combination of communication method for Japan.

APPENDIX 1 : ORGANIZATION OF CURRENT STATUS

1. Organization of current status

- Even now, vehicles are wirelessly connected for various uses.

Group	Use case	Summary	Medium
Safety	Heads-up (collision avoidance)	• Promote attention to driver by providing information of surrounding vehicles' location and speed, or by the warning tone in the case of collision risk against vehicles, pedestrians and obstructions.	Infrared, 700MHz*, DSRC (Japan)
	Cruise control	• Utilize V2V communication to cruise control by adjusting inter-vehicular distance and speed in accordance with the speed of precedence vehicle.	700MHz
Smoothness	Heads-up (safety driving)	• Promote attention to driver for law-abiding safety driving by providing information of limit line.	Infrared, 700MHz
	Traffic information	• Provide driver with information of traffic hinderance (accident, roadwork, frozen road etc.) traffic regulation (closure, speed limit, two-way traffic etc.) and congestion.	FM multiplex, Infrared, DSRC (Japan), 3G, 4G LTE, 700MHz
	Weather and disaster information	• Provide driver with weather and disaster information in case of heavy rain, earthquake, tsunami etc.	FM multiplex, DSRC (Japan)
	Signal information	• Promote driver by providing signal information.	Infrared, 700MHz
	Emergency calling	• Make an automatic or a manual emergency call in case of accident and breakdown. Some services transmit such information as speed, location, diagnosis at once.	3G、4G LTE
	Navigation	• Navigate driver to the best route by calculating required time using congestion situation and probe data. Some service provide navigation setting along with smartphone setting and voice recognition.	FM multiplex, Infrared, DSRC (Japan), 3G, 4G LTE
	Eco-drive assist	• Use signal information to recommend best driving speed and idling stop and notify indicated waiting time. Also, analyze brake operation to diagnose eco-drive.	Infrared, 700MHz, 3G, 4G LTE
Comfort	Remote maintenance	• Remotely diagnose vehicle and update software. Receive support information and advice from operator in the case of anomaly detection. Some services automatically reserve maintenance to repair plant.	3G, 4G LTE
	Remote control	• Remotely control vehicle such as start-up and turning air conditioner on. Control home monitor and appliances from vehicle using HEMS (Home Energy Management System).	3G, 4G LTE
	Entertainment	• Operate car navigation for streaming services and navigation services. Entertainment information includes applications such as news, event information, voice mail and advertisement optimized by location information.	3G, 4G LTE
	Sharing service	• Communicate smartphone application and on-board unit to search empty vehicles and open/close door.	3G, 4G LTE
	Fee collection	• Automatically collect fee on highway.	DSRC (Japan)
	Information of parking and others	• Provide information of parking lot and other facilities.	FM multiplex, Infrared, 3G, 4G LTE
	Telematic insurance	• An insurance service which utilizes driving data collected from CAN data to calculate insurance cost. Telematic insurance includes PAYD insurance, on the basis of actual driving distance, and PHYD insurance, on the basis of accident risk calculated by speed, steering operation etc.	3G, 4G LTE, Infrared
	Theftproof/detection	• Notify owner and security center in the case of abnormality. When vehicle is stolen, obtain its location information to forward it to police dispatch security guard. Remotely lock steering and engine reboot and slow down vehicle.	3G、4G LTE
Large-volume data	Map reloading	• Periodically or infrequently reload car navigation's map.	3G、4G LTE

* 700 MHz Band Intelligent Transport Systems

APPENDIX 2 : OBJECTS OF TREND SURVEY

1．Project on autonomous driving system

Region	Europe	U.S	Asia (Japan)
Governmental project	5G Test Network Finland* C-Road CONCORDA SCOOP@F L3Pilot* Connected Automated Driving ICT4CART* 5GCAR	ITS Strategic Plan (New York, Tampa, Wyoming) CARMA Smart City Challenge • Participant: 78 cities • Finalist: 7 cities; Columbus, Austin, Denver, Kansas City, Pittsburg, Portland and San Francisco • Columbus was selected.	SIP/Large-scale Field Operational Tests (Dynamic Map, Reduction of Pedestrian Accident, Next Generation Transport/advanced PTPS. Advanced PICS*) Autonomous Mobility 5G Operational Tests (Ministry of Internal Affairs and Communications) Joint Research of Technology Development for Next-Generation Cooperative Technical Test for CC Society Realization SIP Research Development (V2V, V2I Communication Technology) Joint Laboratory of Vehicle Infrastructure (China) Chongqing, Shanghai, Changchun (China)* Wuhan, Beijing (China)

* Projects without specific use cases or the disclosed documents regarding use cases and application or the ones which study information provision to other than driver are excluded from our sort-out of use cases.

1．Project on autonomous driving system

Region	Europe	U.S	Asia (Japan)
Private Project[*1]	MWC2017 C-V2X demonstration ConVeX Towards 5G initiative Bosch, Huawei, Vodafone demonstration CITE project V2V by LTE-V demonstration Deutsche Telekom demonstration 5G-Connected Mobility MEC	Ford, Qualcomm, Panasonic demonstration	LG, Qualcomm demonstration Apollo (Baidu) China Mobile, SAIC, Huawei C-V2X development Baidu, Panda Auto demonstration SAIC Motor, Nio demonstration[*2] Daimler, Bosch demonstration Fifth Generation Mobile Communication Promotion Forum (5GMF) C-V2X joint trial 5G Real-time traffic monitoring

*1: This classification is based on the regions of a company leading such project or area of demonstration.
Some companies outside the region may take part in the project.
*2: Excluded from our sort-out since it is supposed to deal with autonomous driving assistance application.

2．Standardization of communication technologies by standards bodies
3．Cross-industrial research development of autonomous driving system

Region	Europe	U.S	Asia (Japan)	International
②Standardization of communication technologies by standards bodies	ETSI TC ITS ★ SENSORIS ★	SAE: Connected Vehicles Steering Committee ★	ARIB ★★ TTC ★ ITS Forum ★	ISO/TC204 WG16, WG14,WG 18 ★ IEEE 1609 DSRC ★ 3GPP ★★
③Cross-industrial research development of autonomous driving system	–	–	–	5GAA AECC C2CCC*

★★　: Standardization of wireless system
★　: Standardization of wired or ITS communication system
No star　: Study of use case
*: We sort out use case and application in reference to the latest document.

APPENDIX 3 : CURRENT AND FUTURE TRENDS OF APPLICATION OF COMMUNICATION STANDARD

1．How to organize

- We organized present and future trend of utilization of each communication technology on the basis of “１．Object of study”, “２．Use cases utilizing communication technologies” and “3. Communication technologies expected to be utilized” from the following view points.

	Viewpoint
Communication Specification	• Whether communication environment is equipped, such as ✓ The region in question has the standard of such communication or its standardization is under way, including the one for utilizing to ITS and autonomous driving. ✓ Such communication technology is available in the region in question.
ITS Utilization	• Whether such communication is utilized to provide driver with information regarding safety or road traffic or service which contributes to comfort. • Vehicle control is not included.
Autonomous Driving Utilization	• Whether such communication is utilized to autonomous driving (SAE Level 1 or higher). • Included when it is clear that such communication is utilized to autonomous driving and information obtained through such communication is utilized to vehicle control.

2．Current and future trends of application of communication standard

- ①DSRC (Japan): Standardization has been completed in Japan. Commercially utilized to ITS. Utilization to autonomous driving system is under study.
- ②DSRC (Europe and U.S): Standardization has been completed in Europe and U.S. Commercially utilized. Utilization to ITS and autonomous driving system is under study.

①DSRC (Japan)

	Phase	Current	-2020	-2025
Euro	Specification			
	ITS utilization			
	Autonomous driving utilization			
US	Specification			
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Standardized, available		
	ITS utilization	Utilized (ETC2.0)		
	Autonomous driving utilization	Study(SIP)	Study (SIP 2nd stage)	
International standardization		Completed		

②DSRC (Europe and U.S)

	Phase	Current	-2020	-2025
Euro	Specification	Standardized, available		
	ITS utilization	Study (C-Road, CONCORDA)		
	Autonomous driving utilization	Study (CONCORDA)		
US	Specification	Standardized, available		
	ITS utilization	Study (ITS Strategic Plan)		
	Autonomous driving utilization	Study (CARMA)		
JPN*	Specification	Experimental use		
	ITS utilization	Study (SIP)		
	Autonomous driving utilization	Study (SIP)	Study (SIP Phase2)	
International standardization		Completed		

*5.8 GHz band is used in Japan.

2．Current and future trends of application of communication standard

- ③ 700 MHz Band Intelligent Transport Systems: Standardization has been completed in Japan. Commercially utilized to ITS. Utilization to autonomous driving system is under study. International standardization is under way.
- ④ 60GHz wireless band: Standardization has been completed in Europe and Japan for ITS use. Utilization to ITS and autonomous driving system is under study in Japan.

③ 700 MHz Band Intelligent Transport Systems

	Phase	Current	-2020	-2025
Euro	Specification			
	ITS utilization			
	Autonomous driving utilization			
US	Specification			
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Standardized, available		
	ITS utilization	Utilized (ITS Connect)		
	Autonomous driving utilization	Study(SIP)	Study (SIP 2nd stage)	
International standardization		Under way		

④ 60GHz wireless band

	Phase	Current	-2020	-2025
Euro	Specification	Available		
	ITS utilization	Standardized		
	Autonomous driving utilization			
US	Specification	Available		
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Standardized, available		
	ITS utilization	Study（CC Technical Test）		
	Autonomous driving utilization	Study（CC Technical Test ）		
International standardization		Completed		

2．Current and future trends of application of communication standard

- ⑤Bluetooth: Utilization to ITS is under study in Europe.
- ⑥Wi-Fi (wireless LAN): Utilization to ITS is under study in Europe and Japan.

⑤ Bluetooth

	Phase	Current	-2020	-2025
Euro	Specification	Available		
	ITS utilization	Study（SCOOP@F)		
	Autonomous driving utilization			
US	Specification	Available		
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Available		
	ITS utilization			
	Autonomous driving utilization			
International standardization		Completed		

⑥ Wi-Fi（wireless LAN）

	Phase	Current	-2020	-2025
Euro	Specification	Available		
	ITS utilization	Study（C-Road, CITE project)		
	Autonomous driving utilization			
US	Specification	Available		
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Available		
	ITS utilization	Study (Autonomous Mobility)		
	Autonomous driving utilization			
International standardization		Completed		

2．Current and future trends of application of communication standard

- ⑦ Infrared: Standardization has been completed in Japan. Commercially utilized to ITS. Utilization to autonomous driving system is under study.
- ⑧ C-V2X (PC5): Standardization has been completed. Utilization to autonomous driving system is under study mainly in Europe.

⑦ Infrared

	Phase	Current	-2020	-2025
Euro	Specification			
	ITS utilization			
	Autonomous driving utilization			
US	Specification			
	ITS utilization			
	Autonomous driving utilization			
JPN	Specification	Standardized /Utilized		
	ITS utilization	Utilized (DSSS)		
	Autonomous driving utilization	Study(SIP)	Study (SIP 2nd stage)	
International standardization				

⑧ C-V2X（PC5）

	Phase	Current	-2020	-2025
Euro	Specification	Standardized, available		
	ITS utilization	Study (CONCORDA, 5GAA)		
	Autonomous driving utilization	Study (CONCORDA)		
US	Specification	Standardization under study		
	ITS utilization	Study (Ford・Qualcomm・Pana)		
	Autonomous driving utilization	Study (Ford・Qualcomm・Pana)		
JPN	Specification	Experimental use		
	ITS utilization	Study	Study (C-V2X joint trial)	
	Autonomous driving utilization			
International standardization		Completed		

2．Current and future trends of application of communication standard

- ⑨ 4G LTE and ⑩ 4G LTE-Advanced: Widely used in various countries for mobile device and utilized to ITS. Utilization to autonomous driving system is under study in Japan.
- ⑪5G: Standardization is under way at 3GPP and other bodies. Utilization to ITS and autonomous driving system is under study in Europe.

⑨ 4G LTE ⑩ 4G LTE-Advanced

	Phase	Current	-2020	-2025
Euro	Specification	Available		
	ITS utilization	Utilized		
	Autonomous driving utilization			
US	Specification	Available		
	ITS utilization	Utilized		
	Autonomous driving utilization			
JPN	Specification	Available		
	ITS utilization	Utilized		
	Autonomous driving utilization	Study(SIP)	Study (SIP 2nd stage)	
International standardization		Completed		

⑪ 5G

	Phase	Current	-2020	-2025
Euro	Specification	Experimental use		
	ITS utilization	Study (C-Road, CONCORDA)		
	Autonomous driving utilization	Study (CONCORDA)		
US	Specification	Experimental use		
	ITS utilization	Study		
	Autonomous driving utilization	Study		
JPN	Specification	Experimental use		To be made available
	ITS utilization	Study (5G Trial)		
	Autonomous driving utilization	Study (5G Trial) Study (5GMF)		
International standardization		Completed		

APPENDIX 4: USE CASES TO BE CONSIDERED IN OUR STUDY

1．Use cases to be considered in our study

- Our study specifies the following use case groups and categories which communication technologies are expected to be utilized in autonomous driving system.

Group	Use case category	
Safety	1. Adaptive cruising (V2V) 2. Collision avoidance (V2V) 3. Assist for merging (V2V) 4. Assist for merging (V2I) 5. Driving support with surrounding vehicle's information (V2V) 6. Driving support with out-of-control vehicle's information(V2V)	7. Driving support with pedestrian's information(V2P) 8. Driving support with signal information (V2I) 9. Driving support with environmental information at crossing(V2V) 10. Driving support with environmental information at crossing(V2I) 11. Platooning by trucks (V2V)
Smoothness and comfort	12. Driving support with emergency vehicle's information(V2V) 13. Driving support with tram's information(V2V) 14. Driving support with information of obstacles(V2V) 15. Driving support with information of obstacles(V2I) 16. Driving support with information of road work(V2V) 17. Driving support with information of road work(V2I) 18. Driving support with information of traffic regulation(V2I) 19. Driving support with information of accident(V2V) 20. Driving support with information of accident(V2I) 21. Driving support with information of road surface condition(V2V) 22. Driving support with information of road surface condition(V2I)	23. Driving support with congestion information (V2V) 24. Driving support with weather information(V2I) 25. Driving support with disaster information(V2I) 26. Driving support with congestion information (V2I) 27. Driving support with hazards information(V2I) 28. Driving support with traffic sign information(V2I) 29. Driving support with speed limit information(V2I) 30. Provision of parking lot's information (V2I) 31. Rescue pressing(V2V) 32. Rescue pressing(V2N) 33. Optimization of signal timing (V2I) 34. Optimization of traffic flow (V2I) 35. Prioritization for public vehicles (V2I) 36. Caution to oversized commercial vehicle (V2I) 37. Self-parking (V2I)
Large-volume data	38. Map reloading(V2I)	39. Map auto-generation (V2I)
Commercial vehicle management	5. Driving support with surrounding vehicle's information (V2V)※ 40. Remote control (V2I)	41. Remote management (V2I)

※ The case that video pictures are transferred by the surrounding vehicles.