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A Guide to Using SDV Connectivity to Support Vehicle Services

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1 Introduction

1.1 Disclaimer

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1.2 Scope of Application

This book presents the concept and perspective of the utilization of connectivity in SDVs that support vehicle services, and provides a guide for effective operation.

Note: This article is not intended to summarize any specific use case or specification.

1.3 References

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1.4 Terminology

No.	term	explanation
[SDV/ Vehicle Architecture / Operation]		
1	CASE	The acronym stands for Connected, Autonomous, Shared & Services, and Electric. More recently, we have also developed a focus on Customer Value, Autono-XaaS (a combination of autonomous driving with AR/VR and AI technologies), and Solutions (Solutions that combine each area and technology), Energy & Resource (energy and resource recycling) [1].
2	ECU (Electronic Control Unit)	A physical electronic control unit to manage each part of the vehicle. There are many of them in the in-vehicle system, and they are mainly linked by communication cables such as CAN and Ethernet.
3	E/E Architecture (Electrical/Electronic) Architecture)	A configuration that combines electricity (physical electrical wiring configuration such as power supply, wiring, fuses, relays, etc.) and electronics (ECU, sensors, actuators, various control modules, etc.) in the vehicle. SDV is making it possible to dynamically update software inside the E/E configuration.
4	E/C (Electronics & Cloud/Communication/Customer experience)	The concept of adding elements such as "cloud," "communication," and "user experience" to the conventional E/E configuration. We believe that this is an important framework for considering business, service, and technological development in anticipation of the future automobile society.
5	E2E (End-to-End) Communication)	The entire chain of communication from the vehicle to the cloud/server and the user. Balancing stability and security is an issue.
6	Car-Life Cycle	In general, the life stages of a car are planned / designed / developed / manufacturing process ~ warehousing ~ export ~ destination storage ~ dealer shipment ~ sale to the user ~ personalization ~ vehicle service period ~ maintenance ~ sale ~ used car market distribution ~ sale to the second owner ~ scrapped car.
7	Log Collection	The act of recording and collecting the operational status of the vehicle, communication behavior, and the situation at the time of an abnormality. It is important information at the development stage and market operation, and is useful for improving the quality of services and supporting maintenance.
8	Migration	The process of gradually migrating or upgrading existing vehicle services, application systems, and network configurations to new specifications and environments. The SDV era requires flexible and strategic updates while ensuring service continuity and compatibility.
9	OTA (Over-the-Air)	A technology that uses external wireless communication to update the vehicle's software and settings. It is extremely important as a basic function of SDV.
10	Personalization	Individualize the in-vehicle environment and functions according to the user's gender, age, and individual usage habits. It will be realized in cooperation with OTAs by SDV .
11	Scalability	The ability of a system or network to flexibly up/down (vertically) or scaling up or down (horizontally) or scaling up or down (horizontally) in response to changes in load or scale (scale up/down/scale out/scale in). In the development and operation of SDV, it is an important design perspective from both the vehicle side and the external system side.
12	Security requirements	Technical and operational conditions necessary to protect the confidentiality, integrity and availability of data.

	Requirements)	
13	SDV (Software-Defined Vehicle)	The concept of a vehicle that is structured around software. An architecture/system concept for updating and personalizing vehicle functions later by OTA and other methods. This paper focuses on "connectivity" as a central element that underpins SDV.
14	SLA (Service Level Agreement)	An agreement on the quality of service (availability, response time, recovery time, etc.) between a provider of a telecommunications service or cloud service and a user. For mission-critical applications such as vehicle services, it is important for OEMs to enter into agreements with mobile carriers from the perspective of ensuring stable communication in both normal and abnormal conditions.
[Communication technology/Network technology]		
15	Access Point	A point of connection for Wi-Fi services. There are many types of Wi-Fi, such as public Wi-Fi and corporate Wi-Fi, and the authentication method with the vehicle is an issue.
16	Best-Effort Communication)	Situational communication methods with no performance guarantees. Current cellular communication and Wi-Fi are best-effort, and vehicle services require special consideration between external wireless communication functions and application functions.
17	CAN (Controller Area Network)	A message protocol or communication cable by which ECUs communicate with each other. It is used to promote functional coordination between conventional ECUs.
18	Captive Portal	After connecting to Wi-Fi, a screen requesting authentication procedure is automatically displayed on the web browser. Although it is common in public Wi-Fi, it is considered to be an authentication method that requires ingenuity to be used with non-interactive devices in the vehicle.
19	DBC file (DataBaseCAN file)	A definition file that describes the message definitions on the CAN bus. It includes the name, position, range of values, etc. of the signal. It will be the setting base for tools and simulators.
20	Cellular Communication	This is one of the forms of external wireless communication of vehicles using the mobile keyalia system . There are 5G and 4G LTE, which are important for the stable operation of vehicle services.
21	Communication requirements Requirements)	The communication conditions required for a particular service or application to work, such as latency, bandwidth, and security.
22	Connectivity	A broad concept of how a vehicle connects and communicates with other devices and systems. In this paper, it is defined as one of the central elements of SDV.
23	Connected	It refers to a state in which the vehicle is permanently or intermittently connected to an external network or system at a certain time of day. It enables Internet connection, linkage with the cloud and other vehicles, and is one of the network conditions that is a prerequisite for providing services in SDV. "Connected" refers to mechanisms, means, and capabilities, while "connected" refers to the resulting state.
24	DNS (Domain Name System)	How domain names are translated to IP addresses. When switching the external network route, it is a factor that causes the connection server to change.
25	EAP (Extensible Authentication Protocol)	It is an authentication framework used when connecting to a network such as Wi-Fi, and there are various authentication methods. (for example, EAP-TLS/EAP-TTLS/PEAP/EAP-SIM/EAP-AKA/EAP-AKA'). Vehicle is out As a method for automatically connecting to the Wi-Fi access point of the department, it is an important element for corporate use and secure public Wi-Fi connection.
26	External wireless communication	A means of communication for the vehicle to access the internet and cloud/servers. Cellular communications and

	(External Wireless Communication)	Wi-Fi is the main means.
27	External Monitoring	To determine whether the vehicle is ready to communicate with the external network (observability). Specifically, ICMP and DNS communication, TLS connection status, and whether there is a response at the application layer are checked regularly. It is an indispensable design element for the stable and continuous provision of SDV services from the viewpoint of assigning meaning and judging the network state during normal times and abnormal times.
28	External Network Path	It refers to the network route or medium used by the vehicle to communicate with the outside world. Specifically, it includes cellular communication (4G/5G), Wi-Fi (STA mode), satellite communication, etc. It is a core element of connectivity in SDV, and is the basis for stable and continuous service provision by making it possible to redundant/switch communication means in both normal and abnormal times.
29	Hotspot 2.0	A technology that allows you to automatically and securely connect to a network based on prior authentication information in a public Wi-Fi service. It is based on IEEE 802.11u and provides secure authentication using EAP methods (EAP-TTLS, EAP-SIM, etc.). Wi-Fi STA connection in vehicles is also expected to be a means of connecting to an access point without user operation, and will be one of the practical options for mobility.
30	ICMP (Internet Control Message Protocol)	A communication protocol for error notification and reachability check in an IP network. A typical use case is to check communication by ping. In vehicle systems, it is used to monitor the E2E communication status with external systems (external monitoring), and is one of the indicators to determine whether the network route is normal.
31	IP Communication (Internet Protocol) Communication)	The concept of IP-based communication between inside and outside the vehicle . It is used as a data communication protocol for E2E security and external network routes.
32	MPTCP (Multi Path TCP)	A communication technology that bundles multiple network routes and treats them as a single TCP communication path. It can be applied to simultaneous use of Wi-Fi and cellular.
33	MQTT (Message Queuing Telemetry Transport)	A lightweight asynchronous communication message application protocol. SDV is mainly used for log collection and service control.
34	NFC (NearField Communication)	It is a type of short-range wireless communication technology that exchanges data within a few centimeters. In vehicles, it is expected to be used as a connection support technology that minimizes human interaction, such as registering Wi-Fi access point information and pairing with user terminals. In particular, it is positioned as a means of reducing the input burden on the vehicle by setting up automatic connection.
35	OpenRoaming	A roaming standard for public Wi-Fi services promoted by the WBA (Wireless Broadband Alliance). Based on the pre-authentication information of the general public, individuals, and corporations, it provides a mechanism that allows seamless and secure automatic connection between different Wi-Fi networks. Using authentication methods such as EAP-TLS, it allows smartphones and vehicles to connect across multiple access points without user interaction. It is attracting attention as a means of reliable Wi-Fi connection in mobility environments.
36	PDN Session (Packet Data Network) Session)	A unit of session in the wireless layer for IP communication in cellular communications. It is related to connection establishment and network status.

37	QR-Code	It is a matrix-type two-dimensional barcode that can compactly store and display URLs and authentication information. In a vehicle, it may be used as a means of registering Wi-Fi access point information. Although there is an advantage that direct input by the user can be omitted, it may be pointed out that there are issues in terms of the presence or absence of a QR code display medium and security in vehicle use.
38	QUIC (Quick UDP Internet Connections)	A UDP-based transport protocol developed by Google. Built-in TLS 1.3 to achieve both security and communication speed.
39	RSRP / RSRQ (Reference Signal Received Power / Quality)	Indicators of radio strength and quality of cellular communications. It is used to determine whether or not communication is possible and to switch to NW.
40	Throughput	The amount of data that can be sent and received in a given amount of time. One of the performance evaluation indicators for external wireless communication.
41	TLS (Transport Layer Security)	A standard technology that enables encrypted communication between the application layer and the transport layer. TLS 1.3 supports high-speed and asynchronous communication.
42	Wi-Fi STA (Station Mode)	The mode in which the vehicle connects to the access point as a client. It is expected to be used for high-capacity communication at specific points and while the vehicle is stopped.
43	WPS (Wi-Fi Protected Setup)	A method for simple connection to a Wi-Fi network, and a connection method that eliminates the need for manual SSID/password input by pressing a button or entering a PIN code. In the past, it attracted attention as one of the methods for connecting vehicles to access points, but as of 2025, there are many cases where it is not recommended to use it from the viewpoint of security vulnerabilities, and it is generally not suitable for automotive applications.
[Others]		
44	GUI (Graphical User Interface)	An interface that can be navigated visually by the user. In a vehicle, it refers to a screen displayed / operated on a touch panel or display such as a navigation system. It is one of the means of direct communication between the vehicle and the user, such as manual input of Wi-Fi access point information, but since the configuration differs depending on the OEM, it may be a problem for general-purpose operation and automation.
45	IF (Interface)	Contacts and specifications for connection and cooperation between systems, devices, and software. In vehicle systems, it is treated as a broad concept that includes everything from the physical connection between ECUs (connectors, buses) to the data linkage between software (APIs and protocols). In this paper, it is repeatedly used as a boundary element to achieve design consistency and connectivity between the components of SDV (vehicle, communication, cloud, and user).
46	MNOs, Mobile Network Operators	Operators that provide mobile communications services (cellular communications). It is characterized by the fact that it owns its own communication infrastructure (base stations, core networks, etc.), and is the main connection destination when the vehicle connects to the outside world by cellular communication. Vehicle services are also affected by national and regional contracts/regulations (e.g., roaming restrictions), making them an important player in the communication design of SDVs.
47	MVNO (Mobile Virtual Network Operator)	A mobile virtual network operator. It refers to a company that does not own its own wireless communication infrastructure (base stations, etc.) and provides its own communication services by renting lines from MNOs. MVNOs are notable for their ability to offer flexible pricing designs and contract structures, and may be deployed in vehicle systems for specific use cases (e.g., development applications, leased lines for specific functions, etc.). However, the communication quality (throughput and latency) depends on the MNO, so it is not suitable for mission-critical vehicle service applications

		It is necessary to carefully consider when using it in.
48	OEM (Original Equipment Manufacturer)	In the automotive industry, it is common to mean a finished vehicle manufacturer (Nissan, Toyota, Honda, etc.). In this paper, it is treated as an entity that plays a role as a designer/operator of services and systems in software-defined vehicles (SDVs), and is a central player in connectivity strategy and communication design.

1.5 Copyright Notices

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2 Readers and Areas Covered by this Paper

This paper is mainly aimed at those involved in the development and operation of services, systems, and various functions that utilize external wireless communication in services using vehicles. Since the keywords "CASE (Connected, Autonomous, Shared & Services, Electric)" were widely shouted around 2016, about 10 Years passed. During this period, the use of external wireless communication in the field of vehicle control and infotainment has greatly expanded both in Japan and abroad. Under such circumstances, a new concept called Software-Defined Vehicle (SDV) has emerged, and it is expected that the use of external wireless communication will increase further in the future[2]。 In addition, we believe that the overlap between areas related to vehicle motion control and comfort areas such as entertainment will increase the complexity of the entire system.

Table 2-1 below briefly defines the main terms used in this paper.

Table 2-1 Definitions of Basic Terms Used in This Paper

No.	term	definition
1	service	A service using a vehicle based on the premise of utilizing external wireless communication
2	system	The entire management mechanism, including the update function established to maintain/update the service
3	Users (end users or related systems)	This includes users who enjoy services through vehicles and other systems that are linked to the systems that make up the service.
4	Connectivity	Comprehensive connectivity concept, how a vehicle connects/communicates with other devices and systems
5	Connected	The vehicle is physically and logically connected to the internet and other devices

Against this background, this paper is organized and presented as a "guidebook" on the viewpoints and ways of thinking that should be kept in mind when introducing and using external wireless communication in the development of services using vehicles. 1

2.1 What part of SDV is it to follow?

Since General Motors launched OnStar in 1999, vehicle services utilizing external wireless communication have already been around for more than a quarter of a century. However, even as of 2025, it is difficult to say that the benefits of connectivity are being fully realized in vehicle services as a whole. This is due to the fact that robustness and cost-efficiency have been emphasized in conventional vehicle service design. As a typical example, many ECUs and external wireless communication devices use hardware with limited computing power and storage capacity based on the premise of an embedded OS, which is a limitation on the utilization of connectivity.

On the other hand, some emerging OEMs are actively adopting an approach that flexibly utilizes external wireless communications, such as applications on smartphones. In the market as a whole, it is expected that the use of connectivity in vehicle services and the architecture of the vehicle itself will expand in the future, and the market size will grow steadily as a result [3].

1 This article is not a document that summarizes a specific use case or specification.

In addition, it is already widely recognized that use cases in vehicle services such as infotainment will change significantly due to advances in connectivity, with "autonomous driving functions" as a turning point [4]. However, connectivity itself is a "means of conveying information" and does not directly add value in itself [5]. At the moment, many OEMs are not fully aware that connectivity is a "distribution channel for transporting information," and they have not yet changed their strategic efforts or the design philosophy of their vehicle service systems.

Under these circumstances, cellular communications (especially 5G), which is one of the representative communication methods , have not been able to fully realize the expected high-performance/high-efficiency communication services (such as a significant decrease in the unit price per bit compared to 4G LTE).
Against this background, the JASPAR Connectivity Working Group has defined the "connectivity" of SDVs that support vehicle services as shown in Table 2-2 below. This paper is intended to provide a step-by-step guide on how to use it.

Table 2-2 Connectivity Definitions

No.	substance
1	Ability to be " connected " when you need it, as much as you need it, and when you can
2	Flexible× stable, and continuously × ability to perform secure " connected " for use
3	Ability to streamline the profitability of SDV systems operating vehicle services

2.2 SDV Concept and World Vision Using External Wireless Communication

One of the envisioned world visions utilizing the SDV concept is to standardize hardware (HW) as much as possible. This applies to model years (MY), models and grades, and even between old and new automotive HW architectures (common physical interfaces). Then, by software (SW), for example, functions are configured / set for each vehicle model, and the vehicle service system aims to spread from inside the vehicle to the outside of the vehicle. In fact, some OEMs have already introduced such initiatives .
This approach essentially ensures that there is a new timing for SW updates during development testing, during the manufacturing process, and even just before the vehicle is shipped2. In addition, it is expected that OTA (Over-The-Air) updates of SW and firmware for personalization will be carried out after sales, for example. As a result, it is predicted that the type of data / timing / method of transmission / reception required will be more diverse than ever in the life stage 3 of the vehicle. As a result, the system design to realize these goals is expected to become more diverse. In addition, if the services used are different, it may be necessary to optimize the operation / mechanism not only for individual applications but also for the service system as a whole. This paper provides guidelines for the development and operation of services, systems, and various functions with a view to business issues regarding the connectivity of vehicle services built on the premise of SDV. Specifically, Connect

2 The exchange of data during the manufacturing process and warehouse inventory is expected to be completely different from the data communication service using external wireless communication of ordinary vehicles, and in particular, the use of Wi-Fi, which exists as the company' s equipment, is considered to be a case where a high degree of freedom in system design is required.
3 In general, the life stages of a car are as follows: manufacturing process ~ warehousing ~ export ~ destination storage ~ dealer shipment ~ sale to the user ~ personalization ~ vehicle service usage period ~ maintenance ~ sale ~ used car market distribution ~ sale to the second owner ~ scrapped car.

We will discuss "who", "what", "timing", and "how" to use tivity to get closer to the definition of SDV connectivity mentioned above.

3 Vehicle Service and External Radio Communication

3.1 Current vehicle-oriented services and external wireless communication

This section describes the relationship between vehicle services and external wireless communication based on the premise of SDV. Communication services/scenes that utilize external wireless communication of vehicles can be broadly classified into three categories, as shown in Table 3-1 below.

Table 3-1 Classification of Services/Scenes Using External Wireless Communication of Vehicles

No.	substance	
1	For Consumers/Individuals	Personalized, personalized services
		Packaged Services
		Specific Content Serving Services
2	For Corporate Clients	
3	For system control and maintenance/management	

Table 3-2 below shows specific use cases.

Table 3-2 Use Cases and Examples of External Wireless Communication

No.	use case	Scenes in which external wireless communication is used
1	Autonomous driving [6] (privately owned, commercial, shared mobility)	A scene in which an autonomous vehicle exchanges necessary information with the outside world in response to changing road conditions
2	Vehicle Monitoring	Scenes where it is necessary to grasp the operating state (engine, battery, tire pressure, etc.) for car maintenance
3	Remote control of the vehicle	Event operation scene from the external system side (server, user device)
4	traffic	Traffic congestion, accidents, construction sites, and scenes that require information that contributes to safety and security
5	weather	Scenes that require weather information, such as rain, snow, or fog
6	map	A scene that reflects the latest map information, or an application of it
7	voice	Telephone (VoLTE, VoNR), VoIP applications
8	entertainment	Scenes for audio/video streaming, gaming, concierge, internet connection, etc.

In the future, we believe that keeping in mind the efficiency of all parts of vehicle service and vehicle development will be the basic concept of working on SDV. In a manner similar to an IT system, a vehicle service system is expected to be operated while migrating (migration/renewal work) on both the vehicle side and external systems other than the vehicle (such as the company's own system). In vehicle services, the use of external wireless communication is indispensable for collecting logs, updating various SWs, and updating services to suppress the decrease in residual value. In addition, the design and condition of the server system facing the vehicle (OEMs often use cloud servers) should also be considered as a factor that has a significant impact on vehicle service and external wireless communication.

Based on the above, in order to form a vehicle service, it is necessary to divide the service system into a two-tier structure consisting of a network platform and a service platform (although it is physically divided into two main parts: the vehicle side and the external system side), and take a bird's-eye view of the entire system.

3.2 Connectivity for Healthy Businesses and Long-Term Service Platforms

Falling into a situation where only certain companies (suppliers, IT vendors, operators, etc.) are responsible for system development and operation may hinder sound business activities. In order to avoid such a situation, it is essential to have specific and clear requirements and requirements for network platforms and connectivity. These requirements and requirements need to be reviewed as appropriate and the specifications should be added/modified according to the situation. These efforts have been cultivated over a long history in the field of IT systems. This is due to the high operational efficiencies and flexibility (e.g., scale-up and scale-out) that can be achieved by utilizing a software-defined approach.

In the case of vehicles, since they are basically linked to external systems through external wireless communication, we believe that having multiple "distribution channels for carrying information" will increase convenience. Especially in the field of mobility, the connection status of external wireless communication fluctuates greatly depending on the location and time, and it is not uncommon for the connection to be temporarily interrupted. In such a situation, the problem may be solved by switching from the external wireless communication path (external NW route) in use to another external NW route (or the communication status can be changed to In some cases, it may be useful to reset once and try a new connection.) We believe that this kind of flexible connectivity behavior directly contributes to the "stability" and "continuity" of vehicle services.

3.3 Opportunities to use external wireless communication to obtain vehicle services

The environment for external wireless communication (radio wave resources, etc.) is a highly public resource, and companies that use it are required to have a responsible awareness of "appropriate use of public assets." First of all, this point should be clarified. When a vehicle uses external wireless communication, it is necessary to fully understand the characteristics of the data distribution channel (external network route) and use it appropriately according to the situation, and it is important to consider the following factors (see Table 3-3).

Table 3-3 Factors to Consider When Using External Network Routes

No.	element	summary
1	security	Protection of communication contents, prevention of unauthorized access, etc.
2	Transmission speed	The amount of data per unit of time required for continuous data communication, etc.
3	Response Time	The range of delays allowed

Arranging/designing these elements and optimizing them in a well-balanced manner will lead to efficient use of external wireless communications. In addition, the opportunities and requirements for the use of external wireless communication vary greatly depending on the type of mobility. For example, the following differences occur between privately owned vehicles and commercial vehicles, or shared mobility such as ride-sharing and shared cars (see Table 3-4). Based on these characteristics, implementations that satisfy different communication requirements4 for each type of mobility are required.

Table 3-4 Types of Mobility and Usage Patterns of External Wireless Communication

No.	Types of Mobility	Viewpoint of using external wireless communication
1	Privately owned vehicles	Emphasis on personalized service for drivers
2	Commercial Vehicles	Improvement of operational efficiency and automation of maintenance management are required.
3	Shared Mobility	Flexible connectivity and high uptime in multi-user environments are required.

There are a plurality of options for external wireless communication used by the vehicle service as shown in Table 3-5 below. In order to realistically implement the concept of "connectivity" defined in this paper, these are a list of communication methods that are considered to be effective now and in the future.

Table 3-5 External Wireless Communications (External Network Routes) listed in "Choices"

No.	External NW route seen from the vehicle	summary	supplement
1	Cellular Communications	5G NSA SA, 4G LTE, 3G, C-V2X, etc.	An external network route commonly used by OEMs for vehicle service . OEMs often use SLAs (Service Level Agreements) with mobile carriers .
2	Wi-Fi STA Mode [5]	Wi-Fi 6, Wi-Fi 5 (11ac), etc.	Connects to an access point (AP) that is attached to a private home (e.g., a garage) or a confined area (e.g., a factory [7]). Or you may connect to a public wireless LAN (AP) in town.
3	Cooperation between V2V and fixed stations	A mesh network consisting of a combination of vehicle-to-vehicle (V2V) and fixed stations (cellular base stations, Wi-Fi access points, etc.)	• Mesh network Cooperation between vehicle-to-vehicle communication and fixed stations requires the development and selection of vehicle-to-vehicle communication devices, communication connection methods, and application protocols. However, it is undeniable that if only a specific vehicle manufacturer is working on it, the effect will be limited. • Use of existing devices (e.g., Wi-Fi Direct) By using devices that are already installed in the vehicle, there is no need to introduce new devices, which may lower the hurdle to implementation. This approach is expected to create an environment in which many vehicles can participate in the mesh network.

4 Communication requirements refer to the conditions and performance criteria required for a particular application or system to function through communications. This includes the type of data, the timing of communication, and the level of security. On the other hand, communication requirements vary widely depending on the service and purpose to be realized. Although there are standard standards, specifications, and performance values, it is necessary to consider that the expected performance varies depending on the conditions set. We believe that communication requirements should be stipulated including these.

5 Cellular communication is a matter of course, but the usable bands (2.4 GHz band, 5 GHz band, etc.) in Wi-Fi STA mode have different usage rules depending on the country, so "build a vehicle network platform" That would be the point above.

4	Miscellaneous	NTN[6], LPWA[7], Bluetooth (e.g., tethering to personal smartphones), etc.	This type has an area coverage that is completely different from that of conventional external wireless communication. An external wireless communication type that requires a remarkably small current consumption. There are options other than the above, such as a type that provides an opportunity to use external wireless communication across another device.

The key to future connectivity design will be how to concretely create "opportunities for use" of external wireless communication in vehicle services by combining the characteristics of each mobility and multiple external network routes. In particular, when considering communication requirements, it is necessary to clarify the purpose for which the external network route will be used, and to select an appropriate method after grasping the necessary performance and constraints from various perspectives.

Table 3-6 below shows the "element axes" that should be considered in order for vehicles to effectively utilize external wireless communication. In order to maximize "No. 1: The ability to be 'connected' when necessary, as much as necessary, and when possible," it is essential to first organize according to the purpose of use and consider the means to achieve it. As a result, "No. 2: Ability to implement flexible×, stable, and continuously × secure 'connected' according to the application" should be seen as a more realistic and implementable form.

Table 3-6 Element Axes Required to Effectively Utilize External Wireless Communication Opportunities in Vehicles

purpose

- **Web-based communication scenarios**
- **Communication scenarios for IoT**
- **Communication scenes for real-time data, etc.**

Viewpoint (Communication Requirements)	means		
	Communication Protocols (1)	Communication Protocols (2)	・・・
Communication speed	・・・	・・・	・・・
Responsibility (Delay)	・・・	・・・	・・・
Stability, reliability	・・・	・・・	・・・
Continuity (data communication resume time)	・・・	・・・	・・・
Security	・・・	・・・	・・・
Resource usage on embedded systems	・・・	・・・	・・・
Scalability	・・・	・・・	・・・
Communication costs	・・・	・・・	・・・
・・・	・・・	・・・	・・・

On the other hand, it is necessary to take into account that the use of external wireless communications may change depending on the laws of the country and the instructions of the government, regardless of whether the OEM is aware of it or not. Table 3-7 below lists the information confirmed by WG officials as of December 2024, but it is an execution method that uses external wireless communication for vehicle services.

6 Non-Terrestrial Network
7 Low Power Wide Area

As long as this is the case, we should be fully concerned that there may be changes in the network platform of vehicle services.[8]

Table 3-7 Examples of Requests Not Related to Technical Challenges for External Wireless Communication

<table>
<tr><th>No.</th><th>example</th><th colspan="2">substance</th></tr>
<tr><td>1</td><td>Illinois Vehicle Code Amendements (HB2245) [8]</td><td colspan="2">In the event of an emergency, such as a hijacking or kidnapping, tracking data must be provided to the authorities.</td></tr>
<tr><td>2</td><td>Australia
SURVEILLANCE DEVICES ACT 2004 No. 152, 2004 - SECT 39 [9]</td><td colspan="2">The Surveillance Device Act (same as above,
you will be required to provide tracking data).</td></tr>
<tr><td>3</td><td rowspan="2">Legislation aimed at improving data portability9</td><td>EU Data Law [10]</td><td>All IoT data, including Connected Car, can be disclosed to the user or to a third party with the user 's consent.</td></tr>
<tr><td>4</td><td>U.S. Right-to-repair [11]</td><td>Equipment should not be repaired only by the manufacturer, but should also be repaired by a third party after sharing relevant data.[10]</td></tr>
</table>

3.4 Security Requirements and Supplements from the Viewpoint of External Wireless Communication

The security requirements for vehicle services based on SDV must first be considered for data communication in E2E (end-to-end11) (see Figure 3-1). On top of that, it is important to divide the network platform and the service platform into two layers (including the configuration and arrangement of functions that meet security requirements) and take appropriate measures for each.

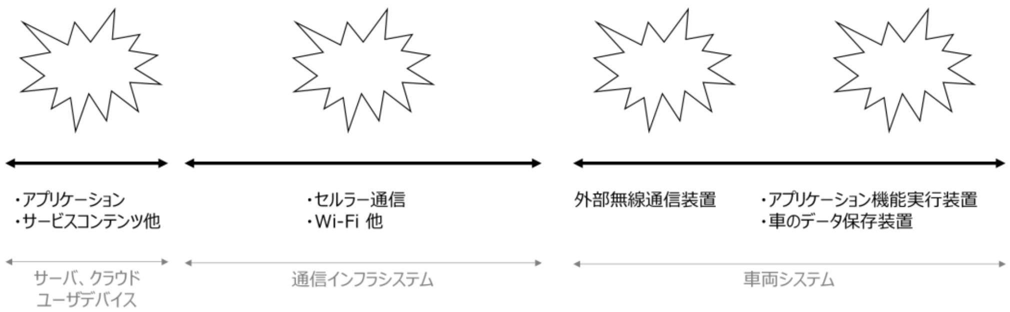


Figure 3-1 E2E Journey and Security Section When Vehicle Services Use External Wireless Communication

3.4.1 External wireless communication function and basic security design of the vehicle

8 In the event of an unexpected request, it is possible to rewrite the SW instead of directly implementing it in the HW each time or considering hard coding in SW, of course, "change the settings" I think it is necessary to have a system in advance that can respond flexibly.
9 Examples of a growing trend from the perspective of liberalization of data utilization.
10 There are many opinions that equipment manufacturers are unequal, and they are conflicted, and enforcement has been postponed (as ofDecember 2024).
11 For example, the journey from the terminal operated to execute the service to the server where the content is located.

We believe that vehicle communication functions should be designed to meet security requirements mainly in Layer 1 ~ Layer 4 (network layer) of "inside outside" (see Figure 3-2). In particular, it is necessary to consider the direction of external wireless communication (external NW route). Specifically, the contents of Table 3-8 are cited.

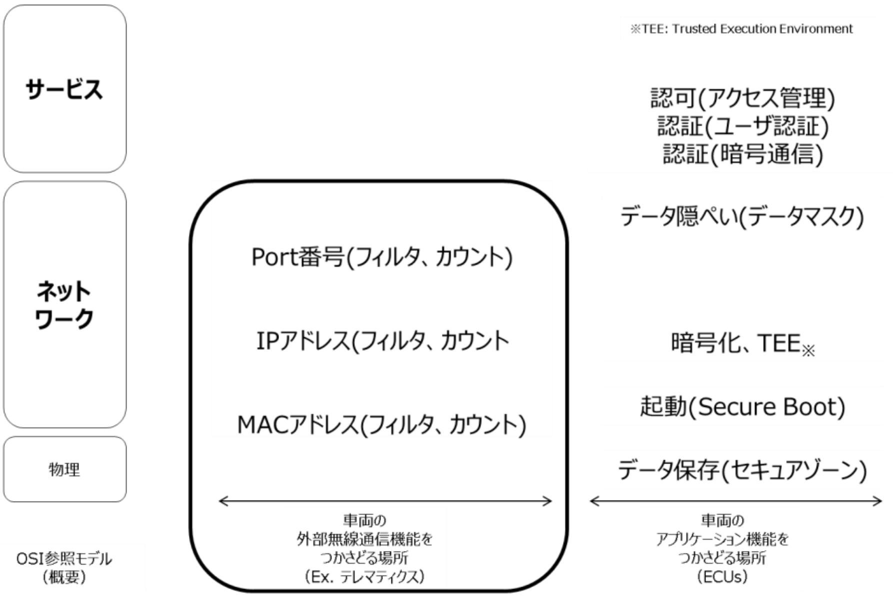


Figure 3-2 Scope of security mainly supported by the vehicle's external wireless communication function

Table 3-8 External Network Route Considerations When Considering Security Design

No.	item	substance
1	Communication in the Downlink (DL) direction	Communication that involves "writing" in the storage area of the vehicle may require higher security hardness
2	Communication in the uplink (UL) direction	When uploading data from inside the car to the outside of the vehicle, flexible security settings may be allowed compared to the DL direction

In addition, it is recommended to make a clear distinction between data communication related to system control and non-system communication, as the security requirements that must be addressed are different.

3.4.2 Security Features of External Network Routes

It is necessary to understand the security characteristics of the external network route and use it appropriately based on it. For example, if an OEM has a contract with a mobile carrier and uses a closed network with a high level of security, it is necessary to organize the purpose of use. Specifically, it is necessary to consider the following studies as shown in Table 3-9.

Table 3-9 Summary of Cases When Using the Closed Network of a Mobile Carrier on an External Network Route

No.	substance
1	Distinguish between communication requirements that require the use of a closed network and those that do not.

2	Optimize the way you access your company's external system (Internet) according to the contents of the contract[12]

3.4.3 Consideration of Vulnerabilities Over Time

It is necessary to take into account that the external wireless communication capabilities of the vehicle's embedded systems may develop vulnerabilities over time. This includes the contents of Table 3-10.

Table 3-10 Time Lapse and Vulnerability Response

No.	item	substance
1	OSS (Open Source Software)	Overall, continuous updates are required
2	OS and device driver SW	Since there is a potential security risk in the OS and device drivers used in ECUs, it is necessary to update them on an irregular basis.
3	Cryptographic Communication Protocols	TLS 1.2 (as of January 2025) is often used in vehicles as well as in general and personal mobile services, but support for the next version is required as appropriate

We believe that appropriate monitoring and countermeasures against these vulnerabilities will ensure the long-term security of the system.

3.4.4 Supplement on External Radio Communication for Vehicle Services

1. Progress and Market Trends of 5G Infrastructure Development 5G infrastructure development is being promoted in countries around the world as the core of mobile carrier communications that support all aspects of life, such as mobile services for general and personal users (for smartphones, etc.) and vehicle services. However, there are differences in progress depending on the region, and the current situation is that the development of the project has been delayed, especially in regional and emerging regions. Although relatively dense areas in Japan are expanding (as of 2025), there are many cases where development is limited mainly in urban areas in other countries, and even in Japan, there are many areas where 5G services are not yet developed in rural areas and depopulated areas. This uneven coverage is a major challenge in ensuring communication continuity in vehicle services (for reasons described later). Especially in areas where cellular communication is out of range, the use of alternative routes such as Wi-Fi and satellite communication as a complement is becoming increasingly important. In addition, the deployment status of 5G is not only a large area, but also a performance issue such as communication speed and low latency. In order to solve these issues, it is necessary for countries and telecommunications carriers to work together to promote more efficient and comprehensive infrastructure development.

2. Current status and market trends of conventional V2X V2X (Vehicle-to-Everything) technology has attracted attention as a technology that aims to improve transportation efficiency and safety by exchanging information between the vehicle and the surrounding infrastructure and other vehicles. At one time, there were high expectations centered on V2V (vehicle-to-vehicle communication) and V2I (vehicle-to-infrastructure communication), and many OEMs have considered it. However, at present, the growth of the market is not good, and there are several issues to be addressed in terms of widespread use. Its main linchpin

12 Since there are different types of cellular communications, such as closed networks and public networks (the way of saying it may differ depending on the mobile carrier), it is recommended to carefully check the communication quality that can be performed and the content that can be executed (QoS).

This is due to the fact that in order for the effects of V2X to be exerted in society as a whole, extensive infrastructure development and standardization are required. Even if a particular OEM implements V2X technology in vehicles on its own, it will have a limited effect on the entire social system. For example , in use cases such as improving traffic management using V2I communication or giving priority to emergency vehicles, it is difficult to maximize the benefits of V2X technology if the infrastructure is not in place. Therefore, in order to promote the social implementation of V2X, it is essential for the national government and government agencies to take the lead in planning and promoting infrastructure development and standardization. For example, it will be necessary to unify communication protocols, upgrade transportation infrastructure in cities and regions, and develop regulations on privacy and security. By overcoming these issues, it is expected that V2X technology will be put to practical use in society as a whole, and that it will have real effects such as improving transportation efficiency and safety.

3. Importance of flexible and stable communication Based on the content so far, it is not the "maximum output of 13" of external wireless communication that is important for communication in vehicle services . Rather, it is important to have a wide range of wireless coverage, including cellular communications, and a mechanism for effectively using multiple external network routes. The ability to use external wireless communication flexibly, stably, and continuously through such a system is the key to supporting the "quality" of vehicle services. In situations where cellular communication is unstable, a mechanism that can immediately switch to Wi-Fi or satellite communication will be a great advantage for vehicle services that require real-time performance. In addition, the use of such flexible external network routes makes it possible to provide "execution opportunities" for vehicle services in various environments such as rural areas and highways, as well as urban areas.

3.5 External wireless communication for mobility used even in normal times and abnormal times

Peacetime refers to a situation in which vehicle services are operating as usual. On the other hand, an abnormal time refers to a situation in which the communication infrastructure is lost immediately after a cellular communication system failure or natural disaster occurs.

3.5.1 Strategic Use of External Radio Communications in Peacetime

In order to maximize the utilization rate of vehicle services, OEMs are required to strategically consider the use of "distribution channels (external network channels) that carry information " and select and utilize them appropriately according to the situation and communication requirements. This initiative not only enables existing use cases for vehicle services more effectively, but also has the potential to create new business opportunities. Table 3-11 below shows specific examples of strategic external NW route use.

Table 3-11 Examples of Strategic Use of External Wireless Communications in Peacetime

No.	substance
1	External network routes for service operations provided by OEMs
2	External network route[14] used by the user in combination with a smartphone contract, etc.

13 Performance values spoken of in QoS (Quality of Service) such as throughput .

14 As an example of normal use using the GSMA SGP.32 mechanism , we assumed a situation in which the mobile carrier and contract details connected to each user are automatically switched in the same way that the seat position is optimized for each user when boarding a general or personal vehicle. For example, the connection destination may be dynamically adjusted depending on the father who needs to communicate as little as text data, the mother for whom voice calls are important, or the son or daughter who needs large amounts of data communication.

3	Sharing or lending of external NW routes with third parties[15]

3.5.2 Use of external wireless communication in the event of an abnormality

If the external network route used during normal times is lost, the vehicle's external wireless communication device switches to another available external network route (mobile carrier B, Wi-Fi, etc.). It is possible to continuously perform vehicle services by temporarily flowing data.[16] However, the implementation of this method is expected to face the challenges shown in Table 3-12 below.

Table 3-12 Issues for Flexible Use of External Wireless Communication in the Event of an Abnormality

No.	substance
1	Establishment of execution rules for the communication requirements of the OEM itself and the legal entities with which it cooperates
2	Selection and control of priority services (prioritization of communication requirements)
3	Arrangements with mobile carriers in anticipation of emergencies
4	Consistency and identification of economic rationality combined with peacetime use

3.5.3 Monitoring of External Network Routes and Decision on Usage

The external wireless communication device or the application function execution device of the vehicle system needs to autonomously determine whether the external NW path in use is normal or abnormal. For this reason, a mechanism is required for the vehicle itself to recognize the loss status of the external NW path. In order to achieve this, it is necessary to continuously carry out a certain level of external network monitoring (external monitoring) in some way during normal times.[17]

15 Image of the use of GSMA SGP.32. While there is a high degree of certainty on the technical side, there are many challenges in terms of operations (demarcation of responsibility, profile management, SIM lifecycle agreement, understanding of laws and regulations and mobile carrier policies). However, it is a realistic case as an effective use of SDV connectivity.

16 As an example of the use of the GSMA SGP.32 mechanism in the **event of an abnormality**, we assumed a situation in which external wireless communication is possible on a separate line even if the conventional line is not available. However, in order to realize this mechanism, it is necessary for mobile carriers to make appropriate preparations. To this end, it is important to work across different industries and with the same perspective to solve problems.

17 External monitoring does not need to be performed on all external network paths at all times. The important thing is to grasp the status of the establishment of E2E (end-to-end) in some way based on a specific purpose. As a result, if the communication status can be confirmed with a higher degree of accuracy, it will be easier to trust the reachability of data flowing in both directions.

4 Service system configuration and key points from the perspective of SDV connectivity

Cybersecurity standards and national trends that must be kept in mind when shaping vehicle services are still in flux and changing every day [12] [13] [14]. Under these circumstances, it is necessary to realize a flexible and adaptable system configuration [15]. As mentioned in Chapter 3, when configuring a vehicle service system (SDV system), it is important to separate the network platform from the service platform and clearly divide the security requirements that each performs. This approach makes it possible to form a system configuration that can flexibly respond to the evolution of the times, changes in technology, and new issues over time (see Figure 4-1).

1. Separation of roles between platforms
   - The network platform basically supports processing up to the network layer (Layer 1~4)[18]. In this range, it mainly acts like a firewall, SrcIP (source IP)/SrcPort (source port), DstIP (destination IP)/DstPort (destination port) and other information. This system ensures proper communication between the inside and outside of the vehicle and ensures safety.

   - The service platform is responsible for data protection, access control, and user authentication on a per-service basis. In this layer, detailed control is performed according to the security requirements of vehicle services to ensure the reliability and safety of various services.
2. Adapting to the evolution of the times
   - As technologies and standards evolve, it is better to aim for a design that allows each platform to be updated independently. As a result, we believe that it will be possible to quickly introduce new technologies while reducing the overall system modification cost.
3. Responding to issues over time
   - With a view to long-term operation, it is necessary for the entire system to continuously take measures against vulnerabilities. For example, the standardization of security policies across platforms and the establishment of a regular update process are some of the challenges.

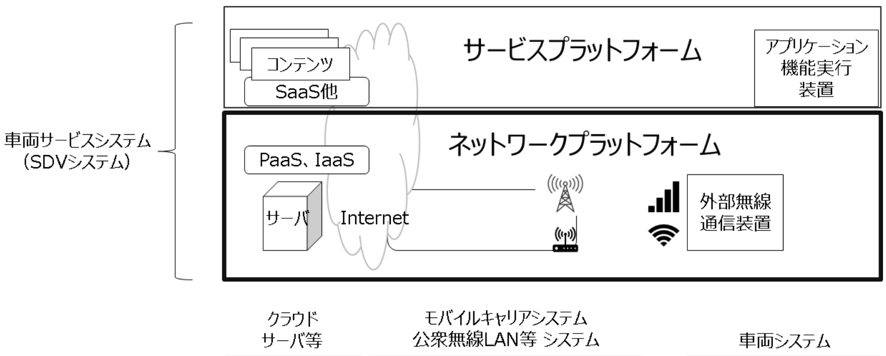


Figure 4-1 Images of each platform of the vehicle service system (SDV system)

18 The external wireless communication device mainly processes data traffic up to L1 ~ L4, but the part related to the control that it scopes may be required up to L7 separately.

4.1 Vehicle System Architecture and External Radio Communication

JASPAR's Next-Generation High-Speed LAN WG provides over-the-air (OTA) in-vehicle systems It is assumed that application functions can be updated or upgraded, and that the operation and behavior of the in-vehicle network can be flexibly rewritten. In addition, by preparing multiple settings in advance, it is considered to be in the optimal state according to the expected event [16]. Connectivity is required to take into account the conditions and influences not only inside the vehicle but also outside (servers, communication infrastructure, etc.), and to establish a network platform for vehicle services. At this time, it is necessary to consider the following disturbances (see Fig. 4-2~4-3).

(1) Limitations on best-effort performance due to out-of-range range and field environments (2) Congestion or failure of communication infrastructure (3) Termination of cellular communications (2G, 3G, 4G LTE) services (4) Gaps in user experience quality due to the evolution of the times (response performance, etc.) (5) OS over time and vulnerabilities in various chipsets (6) Other1 (lead time required for external internal mediation, rapid data entry, repeated physical IF UP/DOWN, etc.) (7) Other 2 (OTA failure, misconfiguration, file error, etc.) (8) Other 3 (physical line defect, unstable power supply)

As can be said for the entire vehicle service system, at a minimum, what and how to behave in response to "unexpected events" (OS behavior, high-priority SW, the minimum communication protocol to be used) and think that it is necessary to be prepared. By taking measures to this extent, we believe that we will be able to provide services continuously, and as a result, we will contribute to expanding contact points with users and improving profitability.

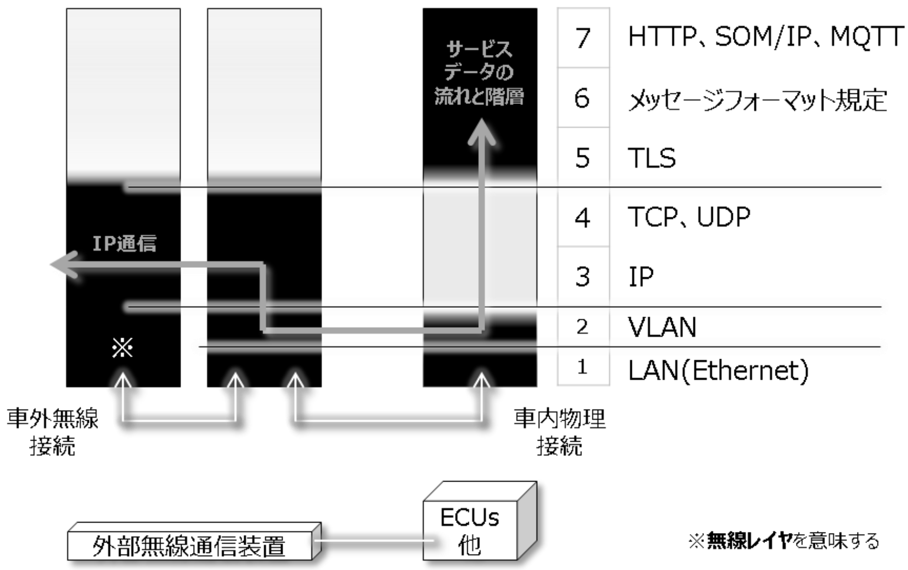


Figure 4-2 Data path [19] when using the in-vehicle system and external wireless communication

19 CAN (Control Area Network) belongs to Layer 1~2 in the OSI reference model , but the logical network cannot be configured.

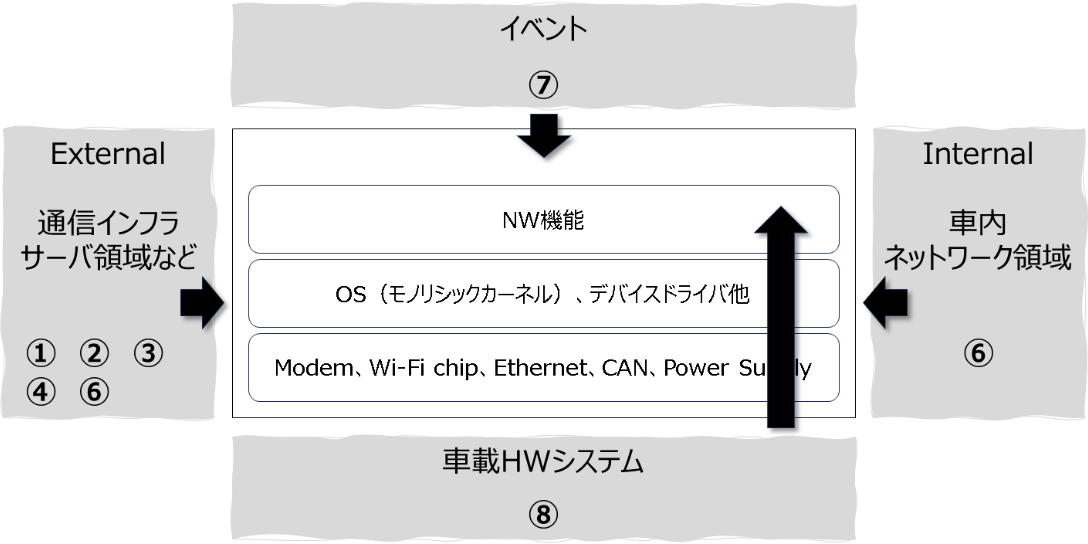


Figure 4-3 Disturbances that the vehicle's external radio communication device must consider

4.2 External Wireless Communication Issues Required to Be Solved by Vehicle Service Systems

1. The Current State of 5G Cellular Communications As of 2025, demand for 5G cellular communications remains sluggish, even in the general and consumer mobile markets. This impact has also spilled over into the automotive market, where the market as a whole is currently not fully benefiting from the features and opportunities offered by 5G. For example, chipmakers and equipment manufacturers are actively promoting the adoption of 5G, but there are only a limited number of use cases that can be effective, and mobile carriers have not found a sufficient return on investment for the roadmap presented by 3GPP[20] (see 3.4.4). For this reason, there is an impression that the market for 5G-A (Advanced), which is the next-generation standard for 5G, is lacking.

2. Wi-Fi Market Trends and Utilization On the other hand, Wi-Fi seems to be receiving a favorable market response. Wi-Fi 7 compatible products will be introduced to the market from around 2024, and use is being considered for smart city projects and factory equipment-related use cases. This is largely due to the new features offered by Wi-Fi 7. In particular , the contents of Table 4-1 are expected to greatly expand the possibilities of Wi-Fi use in vehicles [17].

Table 4-1 Features of Interest in Wi-Fi 7

No.	item	
1	MLO（Multi-LinkOperation）	A mechanism that improves the stability and speed of communication by using multiple communication links at the same time (a mechanism that allows the use of 2.4 GHz, 5 GHz, and 6 GHz in a bundle)
2	MRU（Multi-ResourceUnit）	A mechanism for flexibly dividing channel resources for efficient use
3	Preamble Puncturing	A mechanism that makes the most of the available bandwidth while avoiding specific frequency bands that are experiencing interference or interference. This makes it possible to use even limited frequency resources

20 3GPP ： 3rd Generation Partnership Project

		Achieve high-speed and stable communication

We believe that these technologies have the potential not only to improve the efficiency of communication in a single vehicle, but also to enable efficient data communication in the entire fleet of vehicles.

4.2.1 Challenges to Countries, Laws, and Restrictions (Rules)

As mentioned in Section 3.3, the opportunities for the use of external wireless communications in which vehicle services can be used differ in each country and region. By being flexible in responding to the directives of local governments and agencies, you will have a better chance of maintaining the uptime of the service systems you have or are trying to implement. In particular, it is necessary to prepare in advance on the vehicle side. The following are examples of possible situations:

1. Designation of a mobile carrier by the local government Local government or agency may require the use of a specific mobile carrier (e.g., MNO). For example, even if you are using the roaming service of a certain mobile carrier locally, you may suddenly need to switch to the local mobile carrier. We believe that it is necessary to have a mechanism that can respond quickly to such changes in regulations.

2. Communication Standards and Interoperability There are global standards such as 3GPP for external wireless communication, but in some layers and some systems, the operation specifications of each mobile carrier are different, and the operation may differ (in fact). Therefore, a vehicle service that has been confirmed to be feasible on a mobile carrier in your home country may not be able to perform in the same way on a mobile carrier in another country. It is important to consider these differences in interoperability during design/implementation and testing.

3. Risk of changes in mobile carrier plans due to differences in countries and cultures Due to differences in countries and cultures, even plans that were once held by mobile carriers and OEMs may change. In view of this risk, it is no longer mandatory for OEMs to use external network routes (public networks such as Wi-Fi) that do not depend on mobile carriers .

4.2.2 Realistic external wireless communication performance level required by the service

The contents of Table 4-2 below visually represent the performance required by general use cases by taking the communication speed (bps) on the vertical axis and the delay time (ms) on the horizontal axis, with advanced autonomous driving as a turning point . According to one survey, the external wireless communication performance required for vehicle services (use cases) is mostly up to 5G in the case of cellular communications, and it should be noted that Wi-Fi satisfies the performance. The following reasons are cited behind the lack of progress in the use of 5G in vehicle service use cases.

1. Performance Fulfillment by Existing Technologies and Technologies Embedded in Lifestyles Many use cases that use external wireless communication in vehicle services are fully satisfied by the connection stability provided by 4G LTE and the high-capacity communication performance provided by Wi-Fi. This limits the need for more 5G performance.

2. Characteristics of Use Cases With the exception of highly automated driving, most vehicle services only require stability and moderate communication speeds during connectivity, and there are few situations where they can fully benefit from the ultra-high speeds and low latency provided by 5G.

For the time being, in the selection of external wireless communication in vehicle services, cellular communication performance up to 4G LTE and 5G, as well as performance such as Wi-Fi, should be appropriately utilized. It is necessary to prepare a data communication execution environment according to the use case. We believe that it is necessary to acquire the ability to streamline the profitability of SDV systems that operate vehicle services.

Table 4-2 Realistic External Wireless Communication Performance Levels Required by Services

Wireless communication speed (bps)		Latency(ms) [21]			
		Cellular Communications			Wi-Fi STA
use case	UL Communication Needs	**Less than 1ms** (machine-to-machine control)	**Less than 10ms** (Human machine-to-machine communication)	**10ms or more** (Areas where latency is not important)	**No latency constraints**
Multiple 4K video uploads	100Mbps more than	**6G**			· Driving road data/vehicle data **· OTA** · High-resolution 3Dmap · Operation evaluation · Fault diagnosis **- DL type content**
		- Ultra-high-speed data transmission and reception for dynamic maps - Dynamic replacement of algorithms	No expected use cases	No expected use cases	
4K video calls or multiple FHD video uploads	25Mbps less than	**5G-Advanced**	**5G**	**4 G LTE**	
		- High-speed data transmission and reception for dynamic maps - Dynamic replacement of algorithms	**- Game streaming - Remote monitoring** · Partial remote driving (assistance for autonomous driving)	- Reporting and data collection in the event of an accident	
FHD Video Calling	5Mbps less than	No expected use cases	**4G LTE (1 band, initial or higher)**		
			· HMI · Cooperation with smartcities · Navigation function	**· Remote control of vehicles** (Remote engine start , body operation , valet parking, etc.)	

4.2.3 Status and Challenges of External Wireless Communication (Cellular, Wi-Fi, etc.)

In the establishment and operation of vehicle services, the issues that connectivity needs to address are as follows.

1. Actual performance of external wireless communication achieved by vehicle service

21 Round-trip time between external wireless communication equipment and mobile carrier system base station

External wireless communication is generally provided on a best-effort basis, but in a mobility environment, it is necessary to execute services while moving, and services are required to be established even in situations where the communication environment is even more unstable. It will be necessary to devise a technical solution to deal with this.

2. Challenges related to UL service from the perspective of the vehicle In cellular communications, data communications for general and personal mobile devices such as smartphones account for most of the system resources of mobile carriers. For this reason, DL (downlink) is usually prioritized in mobile carrier systems, and the utilization rate of UL (uplink) is kept low. On the other hand, in vehicle services, there is an increasing demand for data communication in the UL direction (e.g., vehicle status data and log uploads). In order for a service to run properly under these circumstances, it is necessary to carefully consider when to perform communication [18] [19].

3. Regional differences in the quality of mobile carrier systems There are significant differences in the quality of mobile carrier systems in each country and region [20].
   - In Japan, wireless cells are installed in detail according to the location of movement, and the success rate of communication connection is very high.
   - On the other hand, the success rate of communication connections in North America is about 90%, and in Europe it is about 80%, which is higher than in Japan.

   OEMs need to take into account these differences in cellular communication quality and design various contents to provide vehicle services in different communication environments and with the same system.[22]

4. Vehicle Systems and External Wireless Communication Devices and Communication Requirements In vehicle systems, there is a wide range of data sent and received through external wireless communication. Specifically, the following data will be included.
   - Service data (e.g. content data)
   - Control data (e.g. monitoring/management data)
   - Failure analysis data (e.g., debug logs)
 - Data for next-generation vehicle development (e.g., vehicle operation history) These data are very different from the situation of general/personal mobile (although some of this is also done for general/personal mobile) and have vehicle-specific requirements. Under these circumstances, the vehicle's external wireless communication must function as a network device to manage a wide variety of communication requirements on the premise of best-effort performance. In other words, it is essential to support the network platform that supports vehicle services as a fundamental technology from the vehicle side.

5. Misunderstanding between different ECUs and in-vehicle switches In vehicle systems, it is common to have multiple ECUs working in tandem, but ECUs A clear interface specification is essential for coordination. In particular, when each ECU is designed and provided by different suppliers, the type of HW, SW, and OS used and their configurations are often different.

22 In addition, it is necessary to have a mechanism that can be scaled over time by changing configurations and settings.

There are a wide range of factors that need to be adjusted. For example, even if the same OS is used, there are many cases where the functions and libraries available are different due to different OS versions, and communication and operation between ECUs are not performed properly. Even these elementary incompatibilities can have serious consequences for the entire system. Therefore, it is extremely important to coordinate and align the elements in each layer, such as the HW configuration, device driver, OS version, library configuration, and communication message format, to be used in advance. In particular, in situations where external wireless communication is used, inconsistencies in coordination between ECUs can lead to instability in communication functions and performance itself, so it is necessary to clarify the linkage specifications (IF specifications, etc.) from the initial development stage.

6. Management and control of multiple external network routes (see 3.3) (details will be described later)

7. Operation of external wireless communication performance according to the lifetime of the vehicle In the operation of vehicle services, the external wireless communication function is affected by the evolution of the times and the passage of time, as mentioned at the beginning of Chapter 4. Cellular communication (3G, 4G LTE) In response to the end of the service (sunset), it is predicted that a fundamental change (scale-up) will be required in the future to change the external wireless communication performance of the vehicle.

4.2.4 Example of Service System and Migration Utilizing SDV Connectivity

Based on the content of SDV connectivity described so far , we will turn our attention to services that run on a network platform. Even in the event of a transition of system functions due to HW switching (HW architecture change or scale-up) or SW update, existing services will continue to operate. Predict the form of the service system that can be migrated. Fig. 4-4~4-6 below illustrates the flow of "vehicle remote control" (door lock/unlock, etc.) system and application (APP) data that is commonly present in vehicle services. In the conventional vehicle service system, processing is performed in the order of smartphone (APP), → server (APP), → vehicle (APP) (see Figure 4-4). In the development of APP functions for conventional vehicle services, individual development is often required according to differences related to HW as shown in Table 4-3below[23]. In addition, in order to add value to the model and grade of the vehicle, additional differential development has also occurred.

Table 4-3 Differences Derived from HW Generated in Application Function Development for Conventional Vehicle Services

No.	substance
1	Differences in HW architecture
2	Differences in HW functions, performance, and physical IF
3	Different CAN messages for different vehicles (e.g. DBC files)

In light of these issues, we predict the shape of the system shown in Figure 4-5 from the perspectives of "Service Operation × SDV× Vehicle Development × Changes in the Times/ OEM Strategy × Utilization of Connectivity ". With this system, we believe that the situation where APP development was required each time due to the difference in vehicle HW will be greatly improved. Applores like this

23 Some OEMs may create new HWs, which often disrupts the planned development schedule.

By taking this approach, it is predicted that it will be possible to realize an environment that can be operated with a unified service system even in the HW architecture of new and old vehicles.

Table 4-4 When reviewing the placement of "application functions" on vehicle services based on the assumption of SDV (see Figure 4-5)

No.	substance
1	Centralization of the area of APP development (APP development is completed on smartphones and servers, eliminating the need for individual development on the in-vehicle side)
2	The server bundles vehicle-specific CAN messages and sends them to the vehicle as IP data
3	The vehicle converts the received IP data into CAN and forwards the message to the body unit appropriately

Furthermore , as one of the destinations of the SDV service system , the system shown in Figure 4-6 will promote the conversion of CAN to IP. Reduce message translation overhead and E2E through IPv4 to IPv6 support It shows that it is possible to improve the responsiveness of We believe that such a migration (migration/renewal work) can be expected to further improve the performance and operational efficiency of the service.

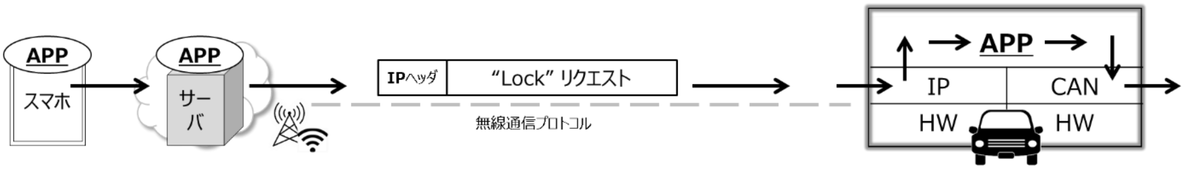


Figure 4-4 Conventional "Vehicle Remote Control Service System"

Figure 4-5 APP processing is up to the server. Vehicles are only IP to CAN GW

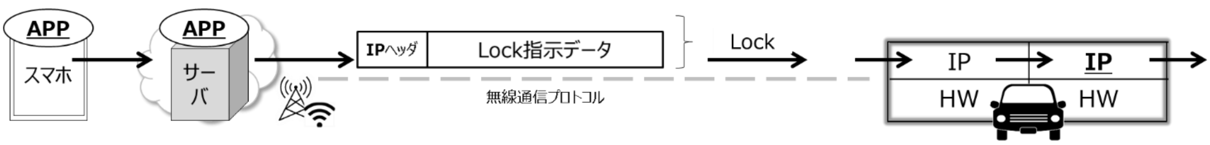


Figure 4-6 In the end, the in-vehicle processing is only IP data transfer (firewall processing)

4.2.5 Predictions for Highly Automated Driving Using External Wireless Communication (Connectivity Perspective)

If there is a highly autonomous driving system using external wireless communication (5G-A or later), the system architecture from the connectivity perspective (see Figure 4-7) and the communication requirements up to Lv3 and Lv4 and beyond (Table 4-5), and predict the communication requirements required for highly automated driving as shown in Table 4-6 below.

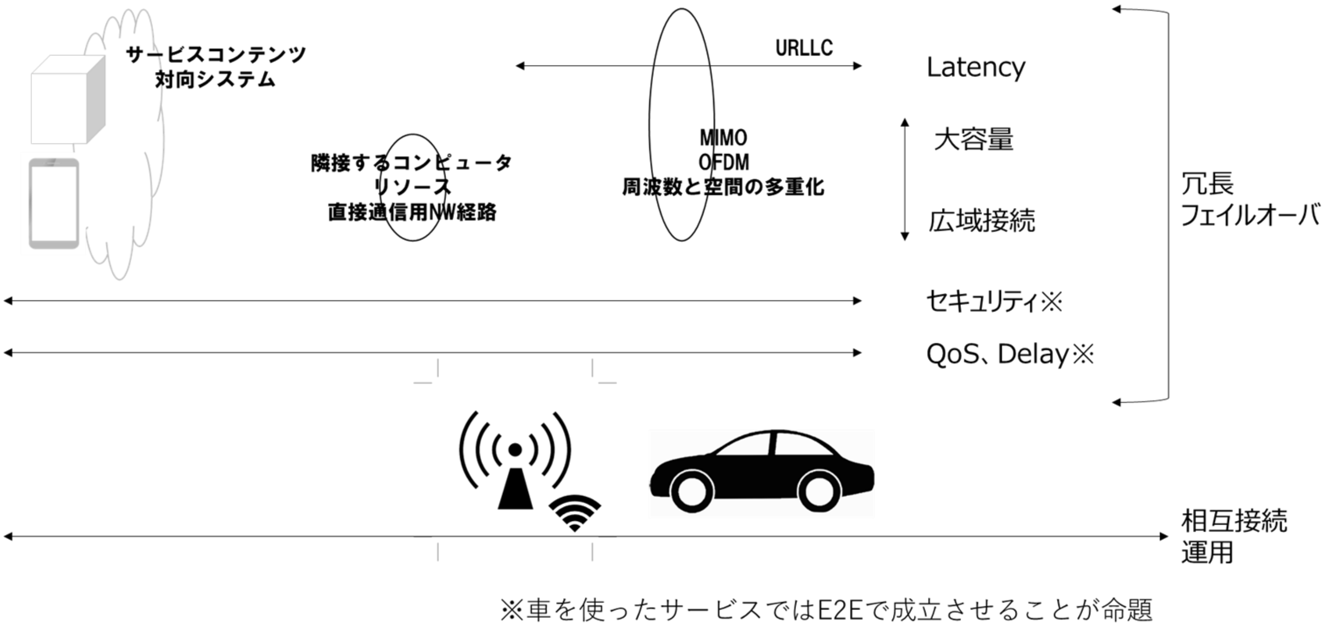


Figure 4-7 System architecture for advanced autonomous driving from a connectivity perspective

Table 4-5 Comparison of Communication Requirements for Autonomous Driving Lv3 and Lv4

● Must (conditions necessary for competition) ○ Nice to have (nice to have) * Requirements for emerging companies

classification	Services that require external wireless communication	~ Level 3		Level 4 ~	
		On the road	At a stop	On the road	At a stop
Data collection and distribution for ADAS/AD improvement	Accident Reporting/Data Collection	•	-	•	-
	Collection of driving road data for specific situations (severe conditions and near-misses)	-	•	-	•
	OTA	-	•	-	•
Entertainment Infotainment	Game Streaming	o	-	•	-
	HMI (Communication, Image, and Speech Recognition)	o	-	•	-
	Enhanced navigation functions (real-time peripheral information, etc.)	o	-	•	-
	Cooperation with smart cities (e.g., coordination with facilities and other means of transportation)	o	-	•	-
Driver Assistance Functions	Remote Monitoring	o	-	•	-
	Partial remote control (sending signals from the outside and instructing in-vehicle autonomous driving intelligence)	o	-	o	-
	Operation evaluation function	-	-	-	-
Autonomous driving assistance	High-resolution 3D maps	-	o	-	o
	Transmit and receive data for dynamic maps (e.g., road surface condition monitoring)	○ /	o	○ /	o

	Dynamic Algorithm Replacement		-		-
other	Fault Diagnosis		o		o
	Remote engine start/body operation/valet parking, etc.		o		o

Table 4-6 Communication Requirements for Highly Automated Driving

NO.	item	substance	Communication requirements
1	Updating the Autonomous Driving Algorithm	Changes to image recognition models, dynamic path planning, changes to AI, etc.	If necessary, download hundreds of MB ~ several GB of data
2	OTA Updates	Updates to the vehicle control system, new features, etc. are basically the same as past OTAs	Downloading tens of MB ~ tens of GB of data
3	Updating high-precision map data	Updating high-precision map data adapted to each region	Download tens of MB ~ tens of GB of data as needed each time
4	Share traffic and sensor data	Dynamically changing traffic and weather data updates	Periodic and event-in-event DL /UL with ~several KB of data

5 Appearance of external wireless communication generated by the vehicle at the time of execution

5.1 Situations when performing external wireless communication

Since the vehicle's external wireless communication is carried out in a mobility-specific environment, it may face situations where communication is more difficult than that of a typical user device. Table 5-1 below shows the specific scenes in which the signal becomes weak and interrupted, or the scene in which data cannot flow well even if the signal is good (mainly in the case of cellular communication). There are many more scenes like this than those mentioned in 4.2.3.

Table 5-1 Scenarios Encountered When Mobility Performs External Radio Communication[24]

No.	Scenes where data does not flow well	reason
1	Population is concentrated	· Congestion due to simultaneous connections · Radio frequency interference (many peripheral devices)
2	· Thepopulationisnotconcentrated · Roads along the coastline · Forests and valleys (buildings, natural environment)	Lack of cellular coverage
3	· Tunnelentrance/exit · Near the entrance/exit of underground parking lots	· It cannot be switched immediately to the handover destination · There is no cellular repeater etc.
4	When you are surrounded by trucks while traveling	· Surrounded by tall metal shields, the visibility of radio waves deteriorates significantly.
5	Heavy rain, heavy snow, dense fog	· Radio waves with high frequency bands are attenuated.
6	other	- Device performance (e.g., scheduling limitations) - Insufficient battery / unstable · Lead time for encrypted communication connection - Limits on available frequencies and execution throughput (e.g., roaming areas)

5.2 Mobility uses cellular communication continuously to perform services

In the graph below (Figure 5-2), time is shown on the horizontal axis, and throughput and packet loss are shown on the vertical axis. Such a situation occurs when the mobile device continuously communicates data using cellular communication. In reality, it can be seen that the data is not flowing continuously, and intermittent communication data flow occurs[25]. What I have discussed in Chapters 3 and 4 is also closely related to this situation. The usable environment for external wireless communication in mobility (see Figure 5-1) is formed by the overlap of many factors.

24 Scenes where you may behave differently when using cellular communication while moving.

25 There are several reasons why this condition occurs. (1) Since the Modulation and Coding Scheme (MCS) changes dynamically according to the radio quality, the throughput that can be achieved on the radio layer is constantly fluctuating. (2) RB (Resource Block) according to the number of devices connected to a base station The allocation size fluctuates, which also affects the throughput on the radio layer. From the application point of view, these changes do not appear to be preliminarily operated or disseminated, and the execution communication environment appears to have changed suddenly. As a result, the main reason is that the application is not able to respond linearly in real time, making it difficult to flow the right amount of data at that moment. In some cases, it may cause an event such as unplugging and unplugging the Ethernet cable. If the Ethernet cable is unplugged, data cannot be flowed.

Figure 5-1 Environment when using cellular communication to link data with the outside world in mobility

In such a situation, it is important that the external wireless communication function located between the outside of the vehicle and the inside of the vehicle accurately transmits the communication status outside the vehicle to the vehicle so as not to interfere with the execution of the application. By establishing this mechanism, the application execution side will be able to clearly determine "when to communicate data with the outside" (see 4.1, details will be described later). In addition, various communication requirements arise when the vehicle and the external system are linked with data (see 4.2.3, details will be described later). However, because the available throughput reaches its limit quickly (and reverts), there is always a limit to the number of services that can be run and the amount of communication capacity that can be run (Figure 5-3 Reference). In order to establish connectivity, it is necessary to carefully consider "who", "what", "when", and "how" data communication should be performed, and put it into practice. However, this alone is not sufficient, and in the end, it is necessary to dynamically implement network control such as priority control. This makes it possible to efficiently utilize limited resources and ensure the stability of the network platform that supports vehicle services.

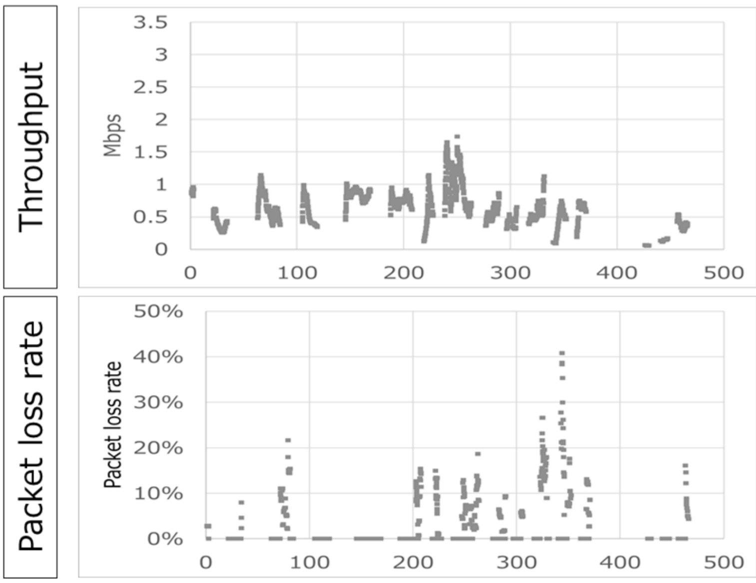


Figure 5-2 Situation when data is continuously uploaded over cellular communication in mobility (in fact, there are many times when it is extremely intermittent and stopped as shown in the figure)

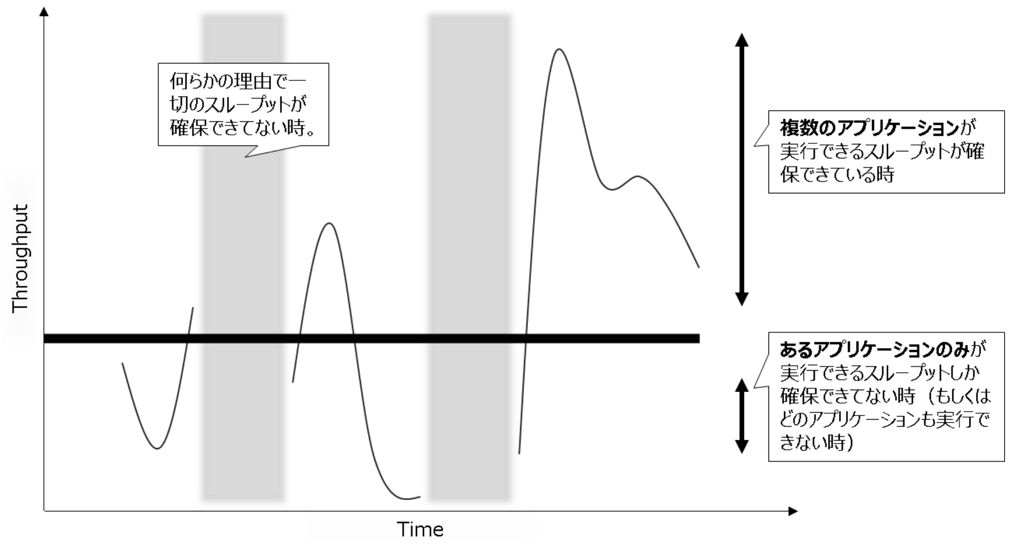


Figure 5-3 Actual Availability of Available Throughput and Situations in which Priority Control is Required

5.3 Cases in which vehicle service developers/operators use external wireless communication

In this section, we will describe the "data monitoring" and "log collection" that are basically performed by the developer and operator of the vehicle service. In order to ensure the profitability of vehicle services and realize sustainable service operations, these activities are necessary consistently from the development stage to the post-market launch. Especially in the future, the importance of data monitoring and log collection is expected to increase even more. These data are expected to be used not only to maintain and improve the experience value of users who use the service, but also to be used as a foundation for the development of next-generation vehicles, migration of existing services, and development of new services. Based on what has been described so far, Table 5-2 below describes in detail what should be considered for connectivity on the vehicle side in data monitoring and log collection. By considering such contents, we believe that it is possible to maximize the value of vehicle services.

Table 5-2 Vehicle-Side Connectivity Considerations for Data Monitoring and Log Collection

No.	Items to consider	substance
1	Management/Control of External Network Routes (see 3.3)	A) Seamless switching between 5G 4G LTE 3G, cellular Wi-Fi B) Implement and manage/control multiple external network routes as options. • Multi-mobile carriers, Remote SIM Provisioning (GSMA SGP.02, SGP.32, etc.), MVNOs, roaming connectivity services, etc. • Public Wi-Fi (e.g. Wi-Fi), other unlicensed bands • Vehicle-to-vehicle (V2V) and fixed stations (cellular, Wi-Fi APs) coordination and use (information bucket relay) • Non-Terrestrial Networks, etc.
2	Ingenuity for the exchange of application data between the vehicle and the external system	A) Encryption and compression methods B) How the data is processed (e.g., masking personal information) C) How to DL/UL little by little while dividing the file (so that you can resume sending and receiving data from the middle) D) Primary storage (cache) on the vehicle side or external system side, and DL /UL at the appropriate time (see 8.2 Annotation)

3	How to Align and Synchronize Data	A) Error detection and correction method B) Timestamp check method C) Timing synchronization (e.g., Time-Sensitive Networking) methods
4	Ways to keep data exchanged (4.1 Reference)	A) Bridging the gap between the outside and inside of the vehicle (judgment on (1) and the execution of (2) and (3). (1) Monitoring the status of the outside of the vehicle (electric field strength/quality, mobile carrier system connection status, DNS resolvability, etc.) (2) Transmitting the information described in (1) above to the vehicle (3) In response to (1) above, control of data communication generated from inside and outside the vehicle [26] B) Utilization of external monitoring (1) As a result of E2E 's NW monitoring, the above No. Execute control of 1 (2) Identification of the primary cause by external monitoring and early recovery C) Initialization and recovery of communication status by turning off/on the communication modem function

26 a) Control the amount of data sent and received according to the amount of available throughput, b) Control the priority of the data to be sent and received, c) Network control with QoE (Quality of Experience) as the target value , etc.

6 What should the external wireless communication function in the vehicle do to establish a network platform?

In this section, we will describe the role that the external wireless communication function of the vehicle should play, considering what should be done at which layer of the OSI reference model. Developers and operators of vehicle services need to build a network platform based on the following contents (see Figure 6-1).

Figure 6-1 What to Do About Network Platforms[27]

6.1 Organizing information on services running on the network platform

In constructing a network platform for vehicle services, it is necessary to clearly organize the target service information that operates on it. Specific examples are shown in Table 6-1 below.

Table 6-1 Service Information to Run on a Network Platform

No.	What you'll need	point of view	supplement
1	Scenes, Use Cases	• Scene, use case information • Service System Overview • List of systems/people, sequences, and data	-
2	Data Characteristics Information	• When dealing with UL and DL files (in some cases, split files) • When working with real-time data • When handling short data (a story that can be sent and received in a short period of time)	• How reliable is it necessary to get to where the data is (e.g., time efficiency is inefficient if interrupted, data communication costs will increase due to rework, etc.) • How long is it required to view the data continuously (e.g., the value of the target service will decrease if it does not continue)? • How much time constraint is required for interactive interaction?

27 Bundle individual communication requirements that occur in the application function @ service platform with the network platform for overall optimization (communication requirement definition).

			If the time is long, the value of the target service will decrease, etc.)
3	Data prioritization	• Control vs. infotainment vs. etc. • Data expiry date (e.g., safety-related data, settlements, bug analysis, data that becomes irrelevant over time, data that you want to UL at any time , etc.) • Spatial constraints (data density, distance to subject, size of the area to be understood)	• Prioritization determined from external circumstances (scenes) (see 4.1) • Prioritization determined from the internal situation (vehicle condition) • Prioritization determined by countries, laws, and restrictions (rules) • Prioritization based on arbitrary XX triggers by the user
4	Choosing a Network Route	• No. For reasons 1~3, select the NW (cellular, Wi-Fi, etc .) to be used. • Selection of NW based on the content of the cellular line contract (assuming that when multi-mobile carriers exist, there will be a difference in what can and cannot be done due to contract differences) • In addition , the characteristics of the external NW route are set to No. To add to the premise of the contents of 1~3	• OEMs can either use a fully outsourced network (mobile carrier) to send and receive information from the vehicle, or a partially in-house network (local 5G, Wi-Fi, or the OEM owns the Strategically decide whether to become an MVNO and own some of the telecommunications facilities. • Determine the NW path for the performance (QoS, etc.) that is realistically required • Ensuring stability, reliability, and continuity • Management of communication costs in consideration of operational status

6.2 Communication requirements for operating on network platforms[28]

Based on the information in Table 6-1, define the communication requirements and network specifications (network configuration, traffic routes, etc.) of a certain application function . The definition of the communication requirements in Table 6-2 below is a task to concretize the contents of the table shown in 3.3 (see Figs. 6-2~6-3). In this paper, we will use the case of vehicle log collection to give a specific example (some vague expressions and figures are given for the sake of this article).

Table 6-2 Things to Organize for Effective Vehicle Log Collection Cases

Communication requirements			Candidate Communication Protocols	
item	Content 1	Contents 2	MQTToverQUIC（IETF[29]Draft）	MQTT (Conventional)
Communication speed	Information of several KB ~ tens of KB can be sent intermittently*1	-	~ ○	○ ~

28 Like MQTT, which is often used for log collection, there are communication requirements and NW requirements (QoS values, etc.) that are considered separately for each Layer7 protocol. On the other hand, in order to form a network platform that operates stably, it **is actually necessary to bundle** such individual communication requirements and network requirements and design them for the purpose of overall optimization (if we organize the communication requirements for log collection only, It cannot be said that it has become a communication requirement to work on a network platform).

29 IETF ： Internet Engineering Task Force

Responsibility (Delay)	For cellular communication, RSRQ -20dB Must be able to achieve within 10 seconds (e.g., 90% of the fastest to 90% of the total number of attempts) *2	All time zones*3		~ ○
Stability, reliability	Mobility characteristics include the ability to transmit data intermittently and continuously*3	It can operate continuously as long as there is no failure of the external system.		o
Continuity	In a cellular communication environment, Even if you switch to Wi-Fi STA, etc., it will basically resume immediately (within 1 second depending on the conditions, etc.) *4*5	Even if the external network route is disrupted, data can be temporarily retained and retransmitted at a certain level (see note 8.2)*6		~ ○
Security	Encrypted communication that can still be used in the future	The security level is such that the corporation will have no problem in the future.	(TLS1.3)	○ (TLS 1.2)
Resource usage on embedded systems	Lightweight	-	Handling small amounts of traffic	Fewer session management, less traffic handling
Scalability (see Chapter 8)	What can be considered in the application architecture for scale-out/scale-in?	The priority of processing within the application function must be in some form that can be considered.		
Communication costs	Be able to call appropriately if necessary	Effective data transmission and reception (e.g., avoiding the tendency of frequent retransmission data)	○ ~	~ ○
. . .	. . .	. . .	. . .	. . .
Expected results	-	-	Everyday use	Limited Use
remarks	-	-	-	Fallback use, when stopped and Wi-Fi connected

[Supplement] *1 It is necessary to collect reference data and **formulate a place to perform the test** *2 Consider the location of the server function to be placed **opposite** (domestic or overseas, west coast or east coast, etc.) *3 When moving and stopping Separate considerations (see Figure 7-5) *4 It is necessary to consider what kind of NW route configuration to execute under **what vehicle condition. *5 Not a basic scene.** Clarify the case *6 When returning to an environment where external wireless communication is possible, actively try to restore immediately.

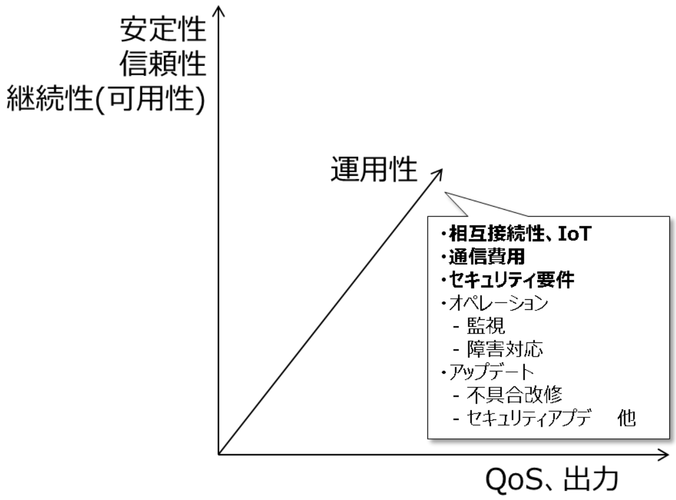


Figure 6-2 "Axis of consideration" for communication requirements running on the SDV network platform

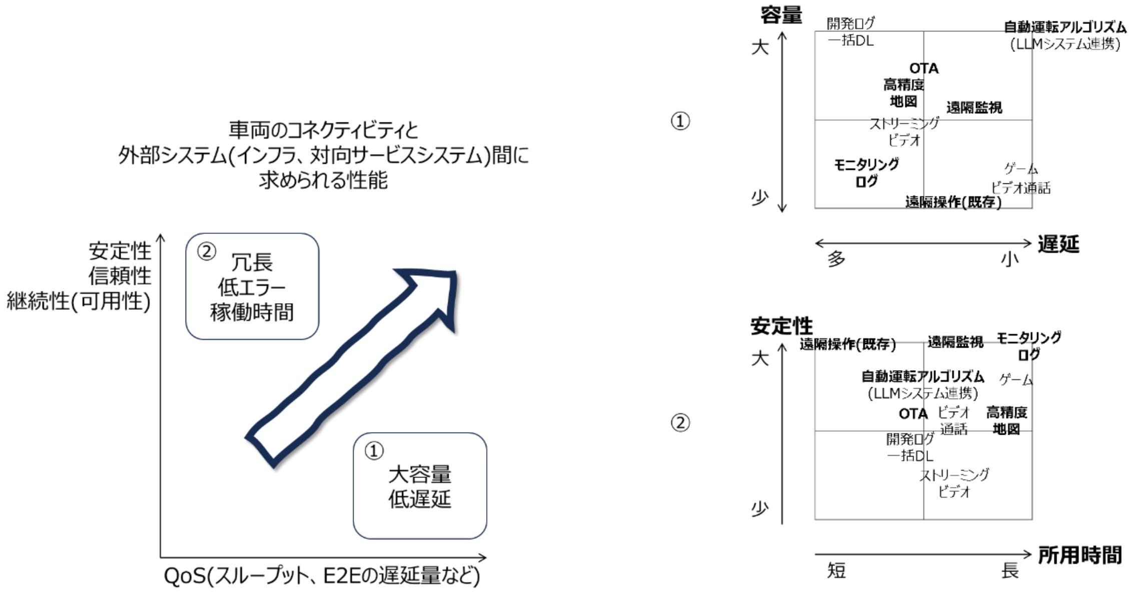


Figure 6-3 Vectors and weights to be observed in terms of execution performance in order to assemble communicationrequirements(Whatcommunicationrequirementsareimportant?) ）

Once the communication requirement definition is clarified, the specifications of the network are examined. However, in practice, in most cases, communication requirements can be achieved with existing network platforms, and it is rare to build a completely new network platform. Therefore, it is necessary to consider not only new communication requirements but also existing communication requirements, and proceed with the study in a way that establishes the whole thing.

When designing a new network platform, it is important to aim for a network platform that can be scaled from the beginning, as described in 4.2.4. In order to achieve this, it is necessary to consider the possibility that the network configuration, traffic routes (data paths), and specifications of some network software (NW-SW) will change over time. The specific method of examining the network specification is beyond the scope of this paper.

6.3 Control details of the external wireless communication functions of the vehicle constituting the network platform

In contrast to the contents and specifications defined so far (Table 6-2), the external wireless communication function of the vehicle controls and executes the contents shown in 5.3 in order to establish a network platform. The speech bubbles in Figure 6-4 below show what is targeted in each layer, and the bold arrows briefly express the execution order and the relationships between the callouts.

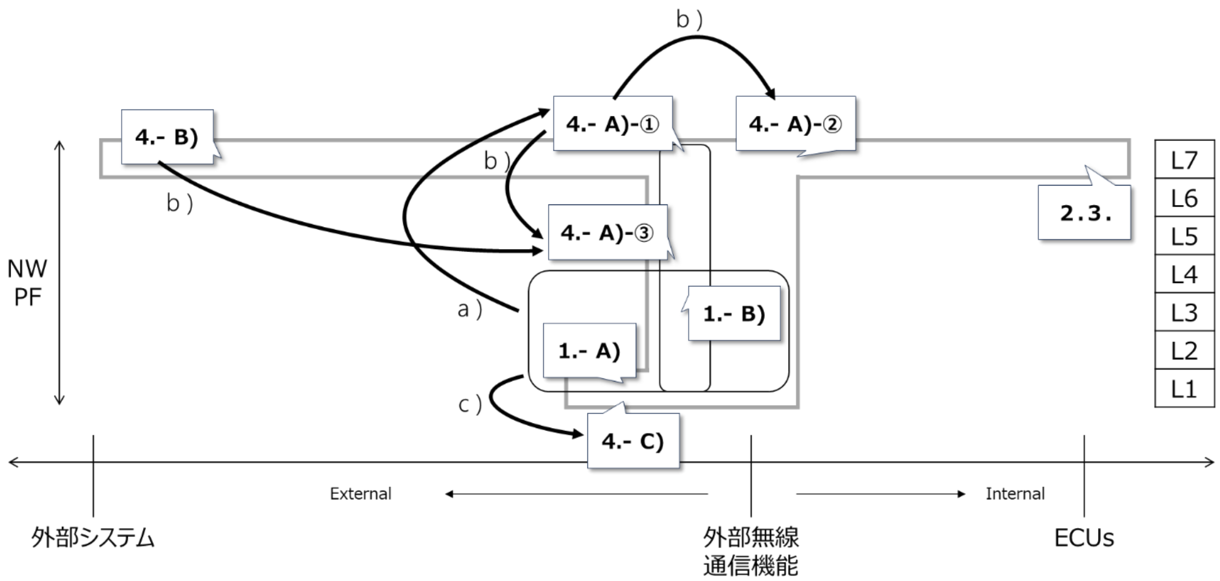


Figure 6-4 Control details of the external wireless communication function of the vehicle (Contents and operation coordination of Table 5-2 are illustrated)

7 Vehicle services performed on a network platform

7.1 "Secure communication" from the vehicle system to the external system

3.4 on what was mentioned in 3.4 and 4.2, the following points are described.

1. Challenges and Responses in Vehicle Systems Vehicles are embedded systems, so resources are extremely limited. However, as the number of opportunities to use external network routes increases in the future, the importance of security measures will increase further, and at the same time, changes in the methods of response will be required. In order to respond to this change, it is important to keep the security measures on the vehicle side simple (lightweight). Further, it is required to maintain an appropriate mechanism on the premise [30][31] of linkage with an external system. As a result, it is possible to construct a system that can respond flexibly while maintaining security even with limited resources (see Figure 7-1).

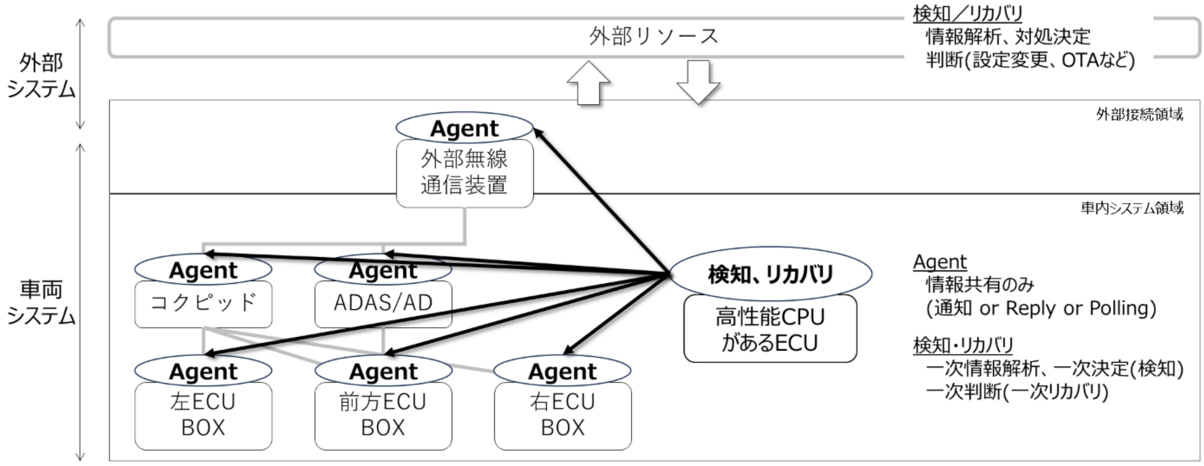


Figure 7-1 Vehicle System with External Wireless Communication and Security Posture

2. Necessity of backup line When security measures are required at a high level (stable and continuous cooperation with external systems is strongly required), securing a backup line is considered essential. For example, in an environment where autonomous driving services of Level 4 or higher are operated, it is necessary to reliably transmit at least "what is happening" information to a distant place in the event of an emergency. In order to achieve this, it is important to continue to secure opportunities for the use of external network routes, and it is expected that backup lines will be required as a means of ensuring redundancy. However, as mentioned in 3.5, it is a prerequisite to ensure economic rationality by considering the balance between utilization in normal times and in abnormal times. In the design of backup circuits, it is essential to consider not only redundancy, but also trade-offs with cost and operational load.

30 It is not always a prerequisite to cooperate with external systems. Although it is necessary for the vehicle side to take minimum measures against unexpected events, it is important to cooperate when necessary, as much as necessary, and when it can be done as a connected ability for efficient vehicle service.

31 Until there is a major change in vehicle services (such as up to Autonomous Driving Level 3), or until rules from national agencies become explicit, the conventional Whitelist-type firewall is basically the way it has been done in the past. It is assumed that the mechanism "only" will continue (see 3.4).

7.2 The function of the application on the vehicle system "connects to an external system"

1. Vehicle status when application function connects to external system The state of the vehicle when the application function connects to or during connection to an external system (see Table 7-1) varies. The application function on the service platform utilizes the information obtained from the (IF) with the network platform and appropriately controls the behavior of the application function while cooperating with the external wireless communication function (see Figure 4-3 in 4.1). We believe that it will be possible to ensure the stability and continuity of vehicle services.

Table 7-1 Condition in which the vehicle is placed

No.	State 1	State 2	State 3
1	At a stop	IG OFF/ Power OFF	Presence or absence of people: Parking (home, external parking lot, multi-storey parking lot, roadside strip), etc.
		IG ON/ Power ON	Same as above
2	On the road	IG ON/ Power ON	Condition of people in the car Urban, rural, special terrain (coast, mountainous, tunnel) General roads, highways, traffic jams, etc.
		-	-

2. Mechanism of application function connection to external system By following (1) ~ (9) in Figure 7-2 below, the application function on the vehicle system can link data with the external system. In addition, in order to continue to select the optimal external network route at all times, it is necessary to properly implement seamless switching (routing operation, etc.) in the external wireless communication function (see Figs. 7-3 and 5.3).

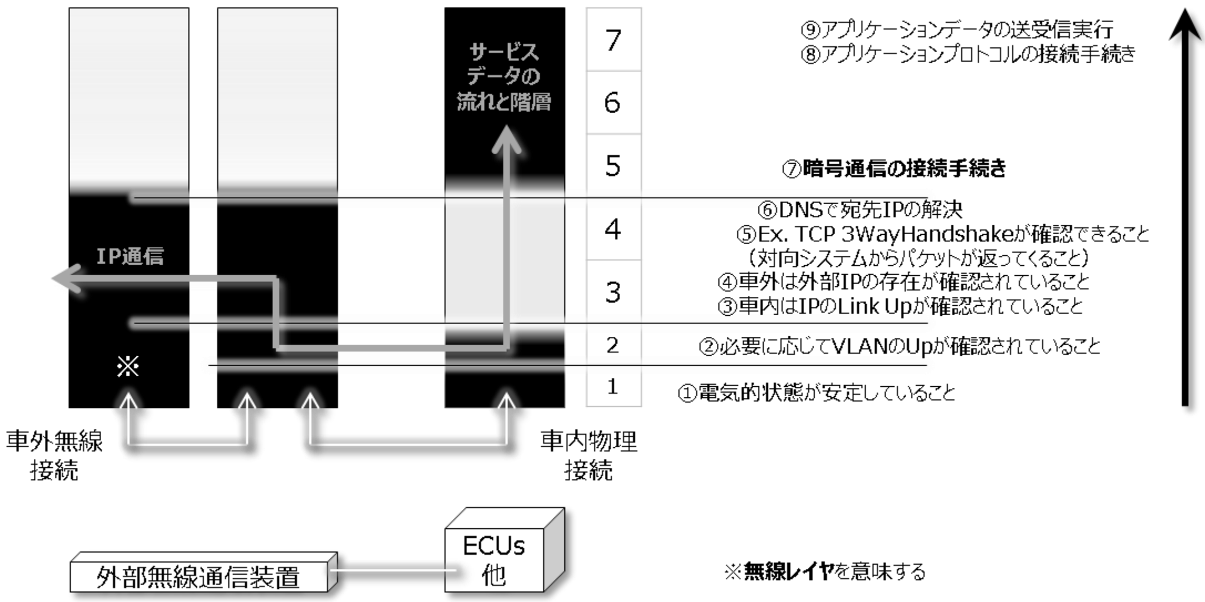


Figure 7-2 How the application function on the vehicle system interlocks data with the external system

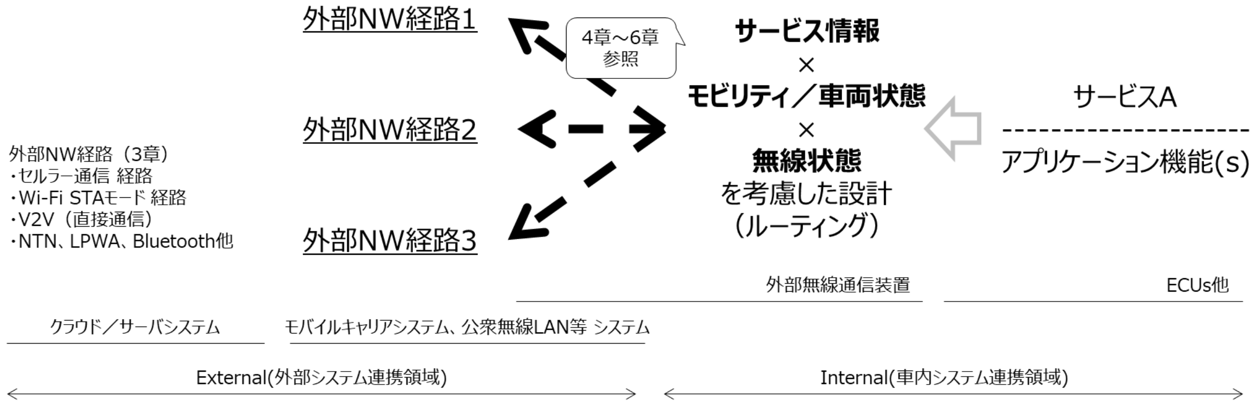


Figure 7-3 Determination of the external network path that the application function takes to link data with the external system

3. Consideration of lead time for encrypted communication connection procedures When using the vehicle's external wireless communication function to link with an external system, see Chapter 4 and 5 It is necessary to take into account the requirements described in the chapter. In particular, the time required for the connection procedure of encrypted communication that occurs at the time of the first connection or when the connection is resumed affects the execution time of the data communication service, so it is necessary to carefully consider it. Naturally, the connection time and success rate of the encrypted communication are greatly dependent on the execution environment 32 of the external wireless communication as well as the data communication of the application function (see FIG. 7-4). For this reason, it is necessary to connect to encrypted communication 33, especially during poor wireless communication quality (RSRQ)

32 Although the environment for performing external wireless communication has been described here, it is affected by the stability of the power supply in the vehicle system, for example (see Figure 4-3).

33 Just because it's stopped doesn't mean it's stable. If the train stops in an area with poor radio communication quality (RSRQ), the encrypted communication connection often takes longer or is not successful. When you are on the move, the time it takes to connect to encrypted communication often varies because there are places where the wireless communication quality is poor and there are places where it is good.

Time needs to be given due consideration. By optimizing the connection procedure and examining a mechanism to suppress delays, we believe that more stable operation of vehicle services will be possible (see Figs. 7-5, 5.3, and 6.3).

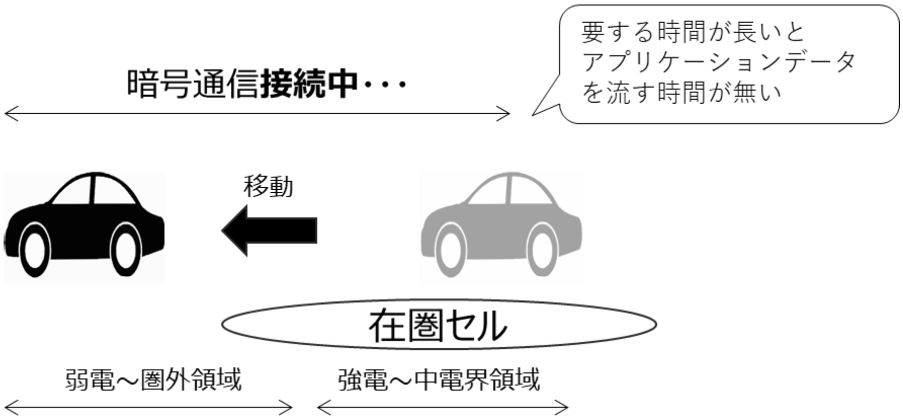


Figure 7-4 What Happens During Mobility Radio Communication (E.g., Encrypted Communication Connection)

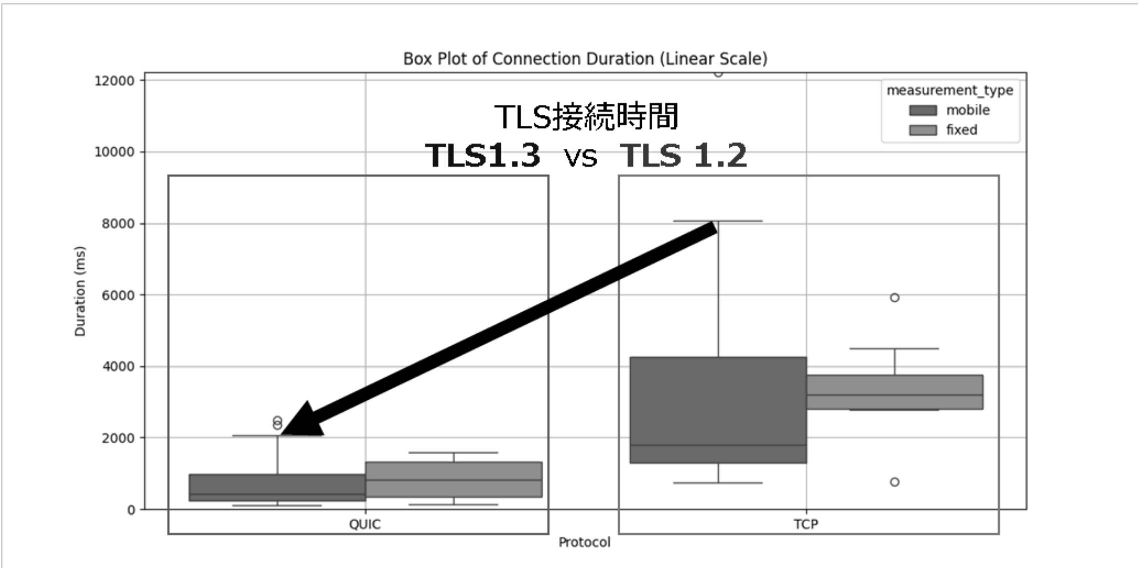


Figure 7-5 Reducing the time it takes to connect to an encrypted connection is essential for improving the uptime of application functions

7.3 Vehicle systems and external systems "react to events in tandem"

7.3.1 From the Vehicle System Side

5 Given what has been said in Chapter 5, and taking into account the factors in Chapter 6, the application functions on the vehicle system are

7.2 process described in 7.2 must be executed continuously34 . In this case, 6.3 of the external wireless communication function that controls the network platform from the vehicle's point of view is required to appropriately manage the state of the vehicle, the IP state inside and outside the vehicle , and the feasible communication requirements (see 6.2) (see Figure 6-4). In addition, in order to maintain E2E system linkage stably and continuously at a higher level, it is not possible to use external monitoring (see 3.5.3) according to the purpose.

34 If for any reason you start the work of returning, you will have to start over from the beginning, depending on the situation.

It is lacking. Table 7-2 below shows the contents that should be continuously observed through the control function of 6.3 in order to respond to events that occur during linkage with external systems (including both inside and outside the vehicle).

Table 7-2 Contents to be observed by external monitoring (reference)

No.		substance
0		External wireless communication function, monitoring of vehicle status from the viewpoint and information linkage with the vehicle system via IF[35]
1		Observation of cellular communication modems, Wi-Fi chips, and information recognized by the OS
	1	In order to communicate with cellular, is it now in the area or out of range? (Figure: 7-6 Reference)
	2	Current state of the PDN session for cellular communication[36] (see Figure 7-7)
	3	Are you currently connected to a Wi-Fi access point? (Figure: 7-8 Reference)
	4	The current state of the IP of the external wireless communication device (UP/DOWN) given to cellular communication and Wi-Fi STA
2		Observation of E2E ICMP communication status (e.g., whether communication with DNS server is possible)
3		Observation of DNS resolution status (resolution success/failure, time exceeded, etc.)
4		Observation of E2E TLS connection status (e.g., connection establishment status)
5		Observation of the connection status of E2E application protocols
	1	HTTP: Request/response status, file upload success/failure, etc.
	2	MQTT: Status of data probe transmission/reception, whether remote operation can be executed, etc.

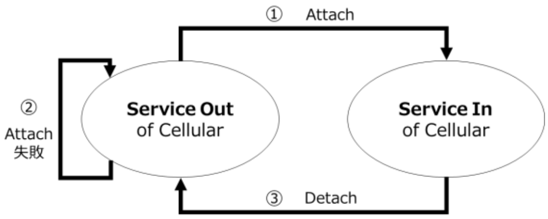
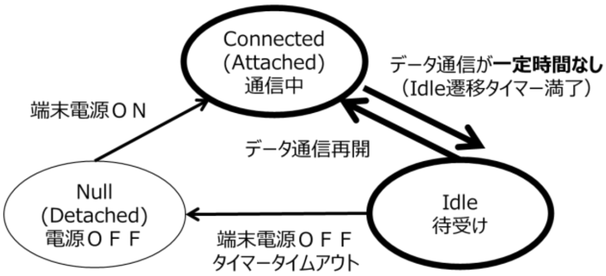


Figure 7-6 State Change of Cellular Communication Connection (Overview)



状態	無線区間の接続	セッション	主な状態
Null	なし	なし	電源OFF
Idle	なし	あり	待受け
Connected	あり	あり	データ送受信中

Figure 7-7 State Transitions for Cellular Communication Connections

35 In order for external monitoring to be effective on a vehicle system, it is necessary to superimpose it on the vehicle status information and to link it with the equipment that performs the application function.
36 For example, a failure to retrieve a paging message due to a Tracking Area Update (TAU) failure can result in a PDN session timeout or a forced disconnect .

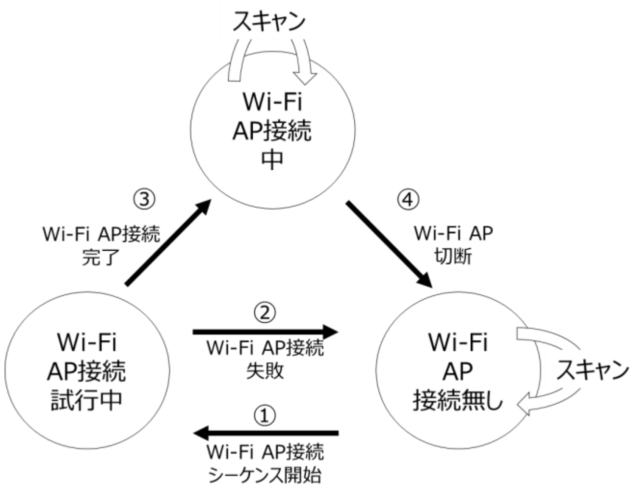


Figure 7-8 State Transitions When the Wi-Fi STA Connects to an External Access Point

7.3.2 From the external system side

In this paper, we have mainly discussed the viewpoint of stable connection from the vehicle system side to the external system and continuous operation as a network platform. However, it should not be forgotten that there are cases where the vehicle system is approached from the external system side.

In the previous section (7.2), we described the case where the vehicle is not able to connect to the external system through external radio communication and the application on the vehicle system does not work as expected. Similarly, there may be cases where the application function on the external system side cannot be linked with the vehicle system and does not function as expected. For example, suppose that the external wireless communication device on the vehicle side is suddenly disconnected from the cellular communication system while the application function on the external server is sending a remote control command to the vehicle. At this time, the application on the external system cannot grasp that the cause of the communication disconnection is in the wireless layer (especially between the vehicle and the cellular network), so it repeats the retry until a response is received from the vehicle side.[37], the process goes into a waiting state. The problem here is that even though the vehicle and the external system are restored as a new connection, the past execution history (retry state and standby state) is not updated, and the state of the vehicle system and the external system is inconsistent. This can lead to applications on external systems making incorrect decisions and causing unexpectedbehavior.[38] In order to respond to such a phenomenon, it is important to design a management function that takes into account the state synchronization of both E2E. We believe that it is necessary to develop a mechanism that allows the vehicle system and external systems to appropriately grasp and share each other's status in the network platform and the service platform.

37 Be sure to include, at least as a basic design element.

38 In this case, a common case is that the result of the remote control executed by the user is not returned, but the state of some function that has been executed since then is "updated" (the "some" state is updated because the background processing performed by the application on the smartphone is "resumed"). From the user's point of view, there are cases where the unfinished state continues to remain, leading to dissatisfaction.

7.4 Points to Consider for Automotive Network Platforms

Based on the content of Chapter 7 so far , while taking full advantage of the power of connectivity, 6.2 and You are expected to do what is indicated in 6.3. In this section, we reaffirmed the "connectivity" of SDVs that support vehicle services, and briefly summarized the design policy of the network platform from the perspective of the vehicle (see Table 7-3).

Table 7-3 Design Policies for Automotive Network Platforms

No.	SDV Connectivity	Design Principles
1	Ability to " connect " when you need to, as much as you need it, and when you can	To determine the behavior of the network platform from the vehicle perspective, clarify: (1) When is it impossible to communicate? (2) What are the minimum communication requirements that should be secured? (3) When is the appropriate communication timing (timing of using external NW routes)?
2	Flexible× stable, and continuously × ability to perform secure " connected " for use	To get the most out of No.1, consider the following points: (1) Equipped with an in-vehicle HW system (E/E) that can operate stably and an external wireless communication device, it is resistant to disturbances, does not become busy even when the load is concentrated, and can quickly recover. Construct the configuration (2) Clearly define the information to determine whether or not data communication can be performed (3) Design that can appropriately change the behavior of the network platform from the vehicle's point of view (4) Establish a mechanism to select the optimal external network route
3	Ability to streamline the profitability of SDV systems operating vehicle services	Efficiently create opportunities for the use of connectivity (No. 1) and make effective use of them (No. 2). As a result, it will contribute to improving the profitability of vehicle services.

8 Vehicle services operated on a network platform

This chapter predicts what changes will be required to the network platform in the future for the operation of vehicle services based on SDV (see Chapter 3).
It is important for users of vehicle services (general/individual, corporations, etc.) to minimize discomfort and misalignment with changes in the times and the surrounding environment through service updates (see Chapter 4). Once an automotive HW is introduced to the market, it is difficult to change it thereafter. On the other hand, IoT devices (such as smartphones) that users use on a daily basis can be updated / changed relatively easily according to trends. As a result, there is a gradual gap between vehicle services that become "outdated" (e.g., slow response times) for the user. Therefore, in the operation of vehicle services (updates, refurbishments, etc.), it is necessary not only to evolve them, but also to aim for "optimization" by suppressing or stopping some other functions as necessary in order to ensure stable operation of high-priority services within limited HW resources.

Based on this situation, the following describes the envisioned state of vehicle service operation from the perspective of a network platform.

8.1 Scaling Up and Down the Network Platform

1. Scale up/down on the vehicle system side

The network platform on the vehicle side is expected to scale up and down in the following ways:

1. In the case of scale-up, increase the processing capacity of the CPU (number of logical cores, etc.), improve network performance by improving QoS (see Figure 6-2), and expand the opportunities (processing volume) to use external wireless communications. It also includes adding/expanding the available external network routes (e.g., adding mobile carrier communication lines, adding Wi-Fi STAs, etc.).
2. In the case of scale-down On the other hand, limit the opportunity to use external wireless communication, or temporarily limit or stop the amount of communication and the number of connections to be processed at the same time. This reduces the weight of the process and concentrates it only on high-priority processing.

In addition, when the embedded device of the vehicle system is to be fundamentally scaled up, it is recommended to replace the device itself. In particular, it is highly likely that equipment replacement will be required due to the termination of mobile carrier communication services mentioned in 4.1 or the use of Wi-Fi STA to demand more powerful and stable throughput.

2. Scale up/down on the external system side (server, user device)

On the external system side, it is assumed that scale up / down will be implemented according to the performance and communication requirements required by the service to be executed (in the case of the cloud type, it may be implemented dynamically). Here, we have summarized the events and risks that may occur on the network platform at that time.

1. Changing the communication protocol due to the installation/termination of the application or the SW update of the ECU When the communication protocol is changed, the firewall on the external system side and the vehicle side It may be necessary to change the configuration or update the routing table.

2. Special requirements for small-start operation of the service During the initial operation phase, if the service is to be operated only on a specific vehicle or a specific external network route (e.g., Wi-Fi STA only), it may be necessary to monitor individual vehicles and collect dedicated logs.

3. Risks associated with migrating server environments (e.g., relocating/consolidating cloud environments) Server migrations can cause overload on unexpected network routes. In addition, it may be necessary to change the destination (URL) or update the TLS certificate on the vehicle side.

8.2 Network Platform Scale-Out/Scale-In

In the previous section (8.1), we mainly talked about scaling up and down the vehicle system. On the external system side, it is common for the scale to be adjusted in stages according to the service to be executed. This is due to the shift of external systems such as servers to the use of cloud services, and this trend is expected to continue in the future. However, depending on the application and requirements, it is thought that a hybrid configuration with an on-premise server will coexist.

On the other hand, since the vehicle side is an embedded system, the upper limit of available resources is strict, and it is not easy to scale out. On the other hand, on the external system side, it is necessary to flexibly scale out and scale in according to the amount of communication and the number of connections, thereby improving the operational efficiency of the network platform and appropriately contributing to the improvement of the quality of the entire vehicle service.

1. <u>Applicability of scale-out/scale-in on the vehicle system side</u>

Although there are not many opportunities for scale-out/scale-in to be directly performed in vehicle systems, we believe that it can be applied from the following perspectives.

   1. Dynamic management of application functions Since the vehicle is an embedded system, there are limitations on the functionality and performance of the application that can be executed over time. Therefore, the priority of the application is set, and the execution target is adjusted as necessary (scale-in: limit). On the other hand, we believe that it is possible to operate close to scale-out, such as enabling additional functions when certain conditions are met.

   2. Control log collection and use of asynchronous communication protocols Log collection is essential for the operation of vehicle services, but due to the limitations of mobility and vehicle systems, it is difficult to keep all logs transferred to the outside world at all times. Therefore, it is considered realistic to classify the transfer target into always-on logs and event-trigger-based logs, and to optimize resources by controlling the transfer timing. In such cases, asynchronous message application protocols such as MQTT (Message Queuing Telemetry Transport) are effective. It is assumed that by placing a broker on each side of the vehicle and the external system and having a cache structure, it will be possible to flexibly scale-out/scale-in[39] [21].

39 a) When the vehicle is out of range, the data is cached in the buffer area of the external radio communication device. b) Automatically transmit the accumulated data when the external network route is restored. c) Due to the limited buffer capacity, old and low-priority data are sequentially discarded and high-priority data is stored. It is conceivable to implement such a mechanism.

2. Operation by scale-out/scale-in on the external system side

In vehicle services, it is important to be able to use external networks "when you need them, as much as you need them, at the right time," but in order to make this opportunity effective, the external system side is required to operate by scale-out/scale-in. The scale-out / scale-in of the network platform of the external system occurs due to factors as shown in Table 8-1 below.

Table 8-1 Triggers for Scale-Out/Scale-in in External System Network Platforms

No.	substance
1	Changes in the number of users and frequency of communication[40]
2	System architecture changes (e.g., multi-site)
3	Strategic initiatives for OEMs (e.g., service changes, expansion of regions, etc.)

Based on these diverse backgrounds, we have organized the following two ways of thinking about scale-out/scale-in on the external system side.

1. Fixed Resources (Long-term Operation) We believe that the system resources used by OEMs for the development and operation of their own services will be used over the long term as an infrastructure that supports the sustainable provision of vehicle services. Examples include analysis and operation platforms used for vehicle log collection, state management, user analysis, and development support for next-generation models.

2. Liquid Resources (Short-term Operation) On the other hand, system resources related to the provision of services for users have the property of being dynamically adjusted according to usage conditions and service quality requirements. It is expected that there will be a scene where resource adjustment to ensure response performance, multi-site configuration to avoid loss of usage opportunities, and design of redundant network routes (cloud infrastructure, external network routes, etc.) are required. In addition, in the future, there is a possibility that there will be an increase in scaling in relatively short cycles using cloud resources for applications such as AI processing and user data analysis, especially for initial deployment.

Chapter 8 discusses how to address scalability in the operation of vehicle services from the perspective of network platforms. However, from the viewpoint of vehicle service and application function, the requirements shown in Table 8-2 should also be considered for the design of the network platform.

Table 8-2 Requirements for Network Platform Design from an Application Perspective

No.	substance
1	Neutrality (see 3.2)
2	Locality and interoperability (see 4.2.1)

40 Estimating performance on what scale is also an important point for scaling on the external system side. For example, when it comes to multi-site, the thickness and quality of the NW connecting them are the subject of consideration.

3	Availability (Stability/Continuity)
4	Observability (ensuring feasibility through external monitoring mentioned in 3.5.3)
5	portability

At this time (January 2025), these topics are not covered in this article, and are limited to relevant references [22].

9 Vehicle's External Radio Communication Function

As the final chapter of this paper, this chapter focuses on the external wireless communication function itself installed in the vehicle, based on the relationship between vehicle services and connectivity in the SDV era. Again, the vehicle is essentially an embedded system, and it does not have an interface for the user to operate and configure arbitrarily, as is the case with smartphones. Therefore, it is necessary to recognize in advance that the external wireless communication function cannot be easily operated and controlled by others like general ICT devices . Behind the highly flexible service design and execution environment provided by SDV, it is necessary to design and operate communication functions based on these physical and logical constraints.

9.1 The vehicle uses cellular communication

3 3 provides an overview of the relationship between vehicle services and external wireless communication, and Chapter 4 summarizes considerations from the viewpoint of network configuration and security. Chapter 5 presents communication challenges in the physical environment specific to mobility and their countermeasures, and Chapters 6 and beyond provide technical guidance and implementation perspectives based on the SDV network platform, as well as SDV I described the nature of connectivity in the world. Based on this premise, this section positions the basic concept of the use of cellular communication in vehicles. Normally, this section would delve into detailed design theories and utilization strategies for cellular communications, as well as control specifications according to communication characteristics, but these will be summarized more comprehensively in the next edition and later.

In this section, from the perspective of connecting to 9.2 (Wi-Fi STA utilization) and 9.3 (combined use of cellular and Wi-Fi STA), the role of cellular communication in the vehicle is confirmed, and multiple external networks are discussed. It is only summarized as a basic position in dealing with routes.

9.2 The vehicle communicates using Wi-Fi STA

In order for the Wi-Fi STA of the external wireless communication device to connect to the Wi-Fi access point, Wi-Fi can be automatically connected without user intervention. We believe that it is necessary to utilize the service. This is because it is important to secure opportunities for vehicle services to communicate "stably" and "quickly", especially when the vehicle is stopped, and it is necessary to demonstrate high performance within a limited time while the vehicle is stopped. Table 9-1 below summarizes the typical Wi-Fi services on the market and their authentication methods as of March 19, 2025 ◦ Wi-Fi is basically classified as a public network, but in order to handle it for corporate use, the security strength and operability of the authentication method are important factors [23].

Table 9-1 Wi-Fi Services and Authentication Methods

No.	Authentication method	Wi-Fi services deployed in the market					
		Open Roaming	Hotspot2.0	Eduroam Cityroam	Google Orion Wi-Fi	Carrier Wi-Fi	Public Wi-Fi
1	EAP-TLS	o	o	o	o	×	
2	EAP-TTLS	o	o	o	o	×	o
3	PEAP	×	×	o	o	×	o
4	EAP-SIM	×	o	×	×	o	×
5	EAP-AKA	×	o	×	×	o	×

	EAP-AKA’						
6	Captive Portal	×	×	×	×	×	o
	For Corporate Clients (Reference)		o			o	

Furthermore, in order to enable vehicles to connect to more external access points, it is also necessary to design an interface that allows the general public, individuals, and corporations to register the Wi-Fi access point information of the connection destination in advance. For example, a mechanism that can automatically connect to a pre-registered SSID like a smartphone is an example. Table 9-2 below summarizes the expected input means and their characteristics.

Table 9-2 Methods for Entering Wi-Fi Access Point Information

NO.	Input method (example)	merit	demerit	For Consumers/Individuals	For Corporate Clients
1	In-vehicle GUIs (e.g., infotainment systems)	Direct input is possible	Different OEMs have different UIs and a high user load	o	×
2	Information transfer via NFC	No manual input required (initial setup required)	NFC-enabled devices are required for both parties (sender and receiver)		?
3	Smartphone app/cloud linkage	The user is familiar with the UI and can operate intuitively.	Requires a dedicated app and cloud capabilities on the OEM side		
4	SIM-based authentication	No manual input required	Limited to compatible Wi-Fi access points	o	o
5	QR-Code	No manual input required	QR codes must be present at the connection destination (in many cases, they are not provided)	o	?
6	WPS（ Wi-Fi ProtectedSetup ）	No manual input required	Limited to WPS-enabled APs, security concerns (as of 2025)	×	×

The use of these connection methods and execution contents is considered to be determined by the communication, security, and application requirements described in Chapters 3 and 6.

In addition, it is very important to be able to secure communication by Wi-Fi STA as a means of maintaining vehicle service even in situations where cellular communication is not available . For this reason, OEMs are required to consider the design as shown in Table 9-3 below so that the Wi-Fi STA function can be implemented as universally as possible .

Table 9-3 Design Considerations for Generalizing the Wi-Fi STA Function

No.	substance
1	Generic deployment on HW architecture (elimination of HW architecture, differences, effects, etc.)
2	System design including external influences (disturbances) (see Chapter 4)
3	After the sequence at startup, clarification of "what determines that the function is normal"
4	Parameters should not be hard-coded, but should be designed flexibly to be managed by configuration files.

We believe that these are the keys to the reliable and sustainable use of Wi-Fi STA as one of the external network routes in the network platform of SDV.

9.3 The vehicle communicates using a combination of cellular and Wi-Fi STA

As mentioned in Section 7.2, when a vehicle switches between multiple external wireless networks (e.g., cellular and Wi-Fi STA), each communication path is configured through a different physical/logical layer, which causes the effects described in Table 9-4 below.

Table 9-4 Main Events That Occur When Cellular Communications and Wi-Fi STA Are Used Together for External Connections

No.	Main events	Chain-descending events (examples)
1	The IP address used by the external wireless communication function is switched.	- Disconnect/re-establish TCP session (new)- Re-establish TLS connection (new)
2	DNS resolution results may differ	- Changing the connection destination server - Re-authentication in the application layer (mainly new) - File re-download occurs

In addition, due to the switching of the network route, there will be a period of time when the network will temporarily "appear to be unresponsive" from the service platform on the vehicle side. Specifically, when a low-level network platform is in the process of switching, there are cases where there appears to be no response from an external system, for example, for a few seconds to a dozen seconds.[41] In order to minimize the impact of such switching, it is necessary for the external wireless communication function to grasp the status of the communication path in real time and utilize it for control (see 5.3 and 6.3). Table 9-5 below shows the lower layer points to be observed in each connection state in cellular communication and Wi-Fi STA.

Table 9-5 Lower Layer States to Observe During Data Communication Using Cellular Communication/ Wi-Fi STA

No.	For cellular communications	When communicating using Wi-Fi STA
1	- [42]	Is the signal level at which the Wi-Fi STA can connect to the access point?
2	Signal level at which "application data" can be flowed	Wi-Fi STA is connected to the access point by "application

41 Basically, unless specially created, the other party will appear unresponsive from the application's point of view while performing the connection procedure in NW-PF, new TLS connection, and DNS resolution.
42 The mobile carrier system is basically treated as a black box in this paper.

	Or? Is the RSRQ value appropriate?[43], etc.)	Is the signal level capable of flowing "data data"? [44]
3	Is it an IP communication environment that can flow "application data"? (Chapter 4, See Chapter 5)	Is the Wi-Fi STA an IP communication environment that allows "application data" to flow through the access point ? (See Chapters 4 and 5)
4	When driving and stopping, should No. 2 be designed differently (e.g., thresholds) or the same design?	Do you want No. 1 and No. 2 to be designed differently (e.g., thresholds) or the same design?

As mentioned in Chapter 7.2, application functions need to go through multiple layers to connect to external systems. Therefore, there is a possibility that the processing of the upper layer (application layer) will be re-executed due to changes in the IP address or DNS resolution result. Therefore, the design of external NW channels (= distribution channels) will be more strategic.

Against this background, the importance of communication protocol design based on the premise of simultaneous and selective use of multiple external network routes increases. Table 9-6 below shows the expected countermeasures.

Table 9-6 Example Communication Protocols for Enabling Multiple External Network Routes to Be Used Together

No.	way	Protocols used	summary
1	Utilizing communication protocols based on the premise of using multiple routes	MultiPathTCP （ RFC[45]8684 ）	· Abstraction of TCP and IP layers by utilizing MultiPathTCP · HTTP/2 running on Multi Path TCP supports cellular communication paths and Wi-Fi STA routes operate as a single TCP network[46]
2	Leverages asynchronous communication protocols	MQTToverQUIC （ IETFDraft ）	- Supports UDP-based TLS 1.3 communication and is resistant to changes in connectivity (see 7.2) - High flexibility in the application layer[47]

In this way, the combination of multiple routes in external wireless communication of vehicles requires consistent network design and control including the upper layer. The network function (router function) to realize connectivity in SDV is also required to be configured so that it can seamlessly switch and use cellular communication and Wi-Fi STA routes. Figure 9-1 below is an example of a network configuration in which the router function to satisfy these requirements is abstracted on an SW basis and can be controlled separately from the physical device.

The purpose of this is to flexibly respond to changes in the situation as described in Chapters 3 and 4, and to improve operability by setting and parameterizing the configuration described in Chapter 6.

43 Since the physical values of the radio (RSRP, RSSI, RSRQ, etc.) may not be easily seen, what constitutes the appropriate signal level for the radio? is a point of discussion.

44 It is important to note that the signal level at which the Wi-Fi STA can connect to the access point is different from the signal level when application data is flowing after connection.

45 IETF-administered/revised Request for Comments (RFC).

46 The Wi-Fi STA route generated by the state of the vehicle is used as a dual active when the connection is made. However, it is basically necessary to provide Multi Path TCP client and server functions on the vehicle side and the server side.

47 Application protocols (such as HTTP/2) that have been commonly used so far are TCP-based synchronous communication, and when data is sent from a vehicle, it has the characteristic of stopping (waiting) until a response is received from the server. On the other hand, asynchronous communication protocols such as QUIC allow **other communication and processing to proceed in parallel without waiting for a response**, avoiding processing blocks due to latency. As mentioned in Section 7.2, synchronous communication certainly provides high reliability, but the flexibility of asynchronous communication can be a significant advantage, as responsiveness is equally important in vehicle services .

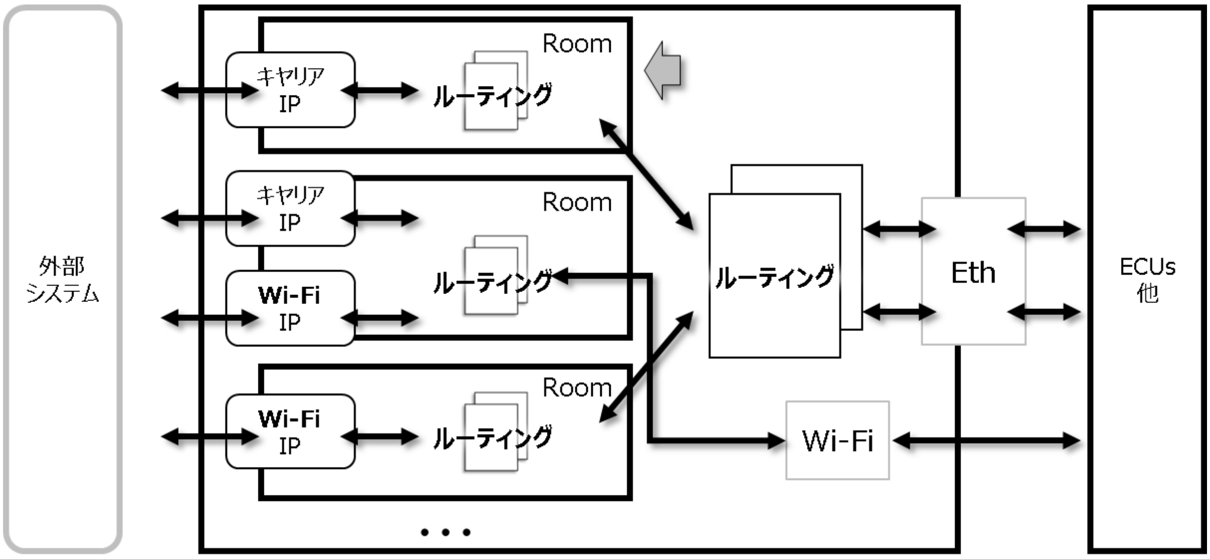


Figure 9-1 Configuration image of the NW function (router) for SDV connectivity

10 Afterword

In the future, vehicle service systems are expected to evolve as integrated systems (SDV systems) that are composed of multiple domains such as "users," "clouds/servers," "communications," and "vehicles" based on the premise of software-defined vehicles (SDVs). In this paper, we have focused on "communication" or connectivity, and from the perspective of the JASPAR Connectivity WG, we have presented a "way of thinking" from the design, implementation, and operation of the system, along with realistic recognition of issues.

As we've said repeatedly, connectivity doesn't create value on its own. It functions within the SDV system as a whole through collaboration with other domains, and it is this "harmony" that creates value. In particular, communication in a mobility environment is based on a best-effort approach, and it is difficult to design based on guaranteed communication quality. Based on these characteristics, how to combine and optimize communications and services is an important issue in both design and operation.

In the past, vehicle system design focused on the perspective of "E/E (Electrical & Electronic)", but in the future, "E/C (Electronics & Cloud/Communication/Customer experience)" This cross-sectional perspective is indispensable. The concept of E/C is not limited to the development of services after mass production, but also includes the possibility of bringing new value such as remote development linked to the cloud from the early stages of development and multi-site/distributed debugging. In order to achieve this, it is necessary not only to achieve technical consistency, but also to create a collaborative system and operational design that transcends the barriers between organizations. In particular, for mass-produced vehicles with large shipments and severe cost constraints, designing the optimal balance between hardware resources and communication load on the vehicle side will be an important theme in the future.

In addition, as services that provide experience value, such as personalization, are evolving, continuous collection and utilization of post-shipment data is directly linked to the improvement of service quality and the sophistication of risk detection and avoidance. Connectivity is also indispensable here, and it is necessary to incorporate it into the premise from the early stages of design. Over-the-air (OTA) functions are indispensable as the basic functions that support the SDV system and E/C infrastructure, but we believe that their essence extends beyond "renewal" to "collaboration" and "evolution."

We believe that the essence of connectivity in the SDV era is that vehicles continue to cooperate with the external environment through connectivity, and services continue to flexibly respond to changes in users and society . And that such connectivity will blend into everyday life as a natural and "sophisticated" existence for users and designers. That is what we at JASPAR Connectivity WG are aiming for.

We sincerely hope that this article will provide you with a small but solid hint in the field of design, implementation, and operation of those who will lead the E/C era, and will help shape the mobility society of the future.