“The Cross-ministerial Strategic Innovation Promotion Program (SIP) Second Phase/ Automated Driving (Expansion of Systems and Services)/ Research and Development on the Provision of Signal Phase and Timing (SPaT) Information using Cloud and other technologies toward Social Implementation”

Progress Report for Fiscal Year 2022
Overview

UTMS Society of Japan
NIPPON SIGNAL CO., LTD.
OMRON Social Solutions Co., Ltd.
Panasonic Connect Co., Ltd.
(Company name changed on April 1, 2022.
Formerly Panasonic System Solutions Japan Co., Ltd.)

March 2023

[List of Themes for FY2021]

a) Examination of the social functional requirements (the need) of the SPaT Information Center
b) Examination of the technical requirements of the SPaT Information Center
c) Examination of the implementing entities of the SPaT Information Center
d) Examination of the integrated delivery of information other than SPaT information (traffic regulation information, etc.)
e) Examination of linking SPaT information and high-precision three-dimensional maps
f) Verification of the improvement in accuracy of SPaT information
g) Examination of reducing communication delays of SPaT information
h) Examination of reducing the functions of the National Police Agency's SPaT information aggregation system

* The contents indicated by the symbols a) through h) in the following documents are as above.

1. Assignment of Themes (for fiscal year 2021)

Theme 1 “R&D for the social implementation of the provision of SPaT information using cloud and other technologies [Examination of the social functional requirements (the need) of the SPaT Information Center] ”

[UTMS Society of Japan]

a, c

Theme 2 “R&D for the social implementation of the provision of SPaT information using cloud and other technologies (Examination of the technical requirements of the SPaT Information Center)”

[Panasonic System Solutions Japan Co., Ltd.]*

b, h

(*) Company name changed to Panasonic Connect Co., Ltd. on April 1, 2022

Theme 3 “R&D for the social implementation of the provision of SPaT information using cloud and other technologies (Examination of the integrated delivery of information other than SPaT information (traffic regulation information, etc.)”

[NIPPON SIGNAL CO., LTD.]

d, g

Theme 4 “R&D for the social implementation of the provision of SPaT information using cloud and other technologies (Examination of the verification of the improvement in accuracy of SPaT information and the examination of reducing communication delay of SPaT information)”

[OMRON Social Solutions Co., Ltd.]

f, g

1. Assignment of Themes (for fiscal year 2022)

The following are items that have been added as a result of the contract change

Theme 5 **“Examination of equipment and software to be installed in the prefecture where the FY2022 FOT is implemented”**
[OMRON SOCIAL SOLUTIONS Co., Ltd.]

Theme 6 **“Creation of an environment for verifying the provision of SpaT information connected to the National Police Agency's SPaT information aggregation system, and implementation of the verification, etc.”**
[Panasonic Connect Co., Ltd.]

Theme 7 **“Establishment of a network between the National Police Agency and prefectures, creation of a verification environment for the provision of SpaT information in the system at prefectural police, and implementation of verification, etc.”**
[NIPPON SIGNAL CO., LTD.]

Theme 8 **“Creation of an environment for the verification of SPaT information provision in the system at prefectural police, and implementation of the verification, etc.”**
[OMRON SOCIAL SOLUTIONS Co., Ltd.]

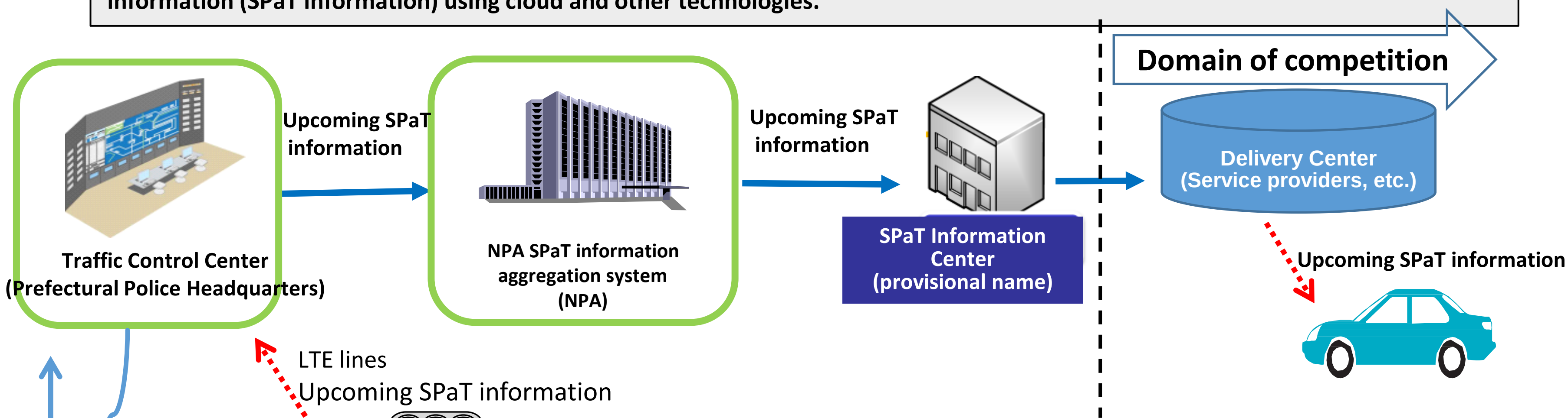
2. History of the project

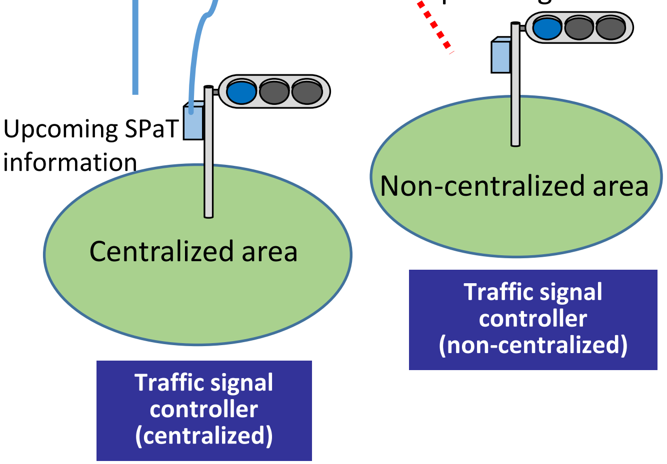
Research name	Before FY 2018	FY 2018	FY 2019	FY 2020	FY 2021	FY2022
R&D on the provision of SPaT information using cloud and other technologies **[R&D on the provision of SPaT information using methods other than V2I communication via ITS roadside radio units and others]** **(V2N)**	Understanding the trends of technology development by private sector automakers and others **Expectations for lower costs**	• **Basic research including overseas situation** • **Proposal of SPaT information provision methods**	• **Refinement of functional requirements** • **Plant-level verification** • **Selection of SPaT information provision methods**	• **Refinement of functional requirements** • **Examination of measures to address issues** • **Building and verification of a model system** • **Development of specifications for the system to be built for verification for next year and beyond**	• **Examination of social requirements, technical requirements, etc. of the SPaT Information Center** • **Examination of the linking and integration with other information** • **Examination of the improvement of measures to address issues**	**Model project and verification**
[Reference] R&D on the enhancement of technologies to provide SPaT information toward the realization of automated driving (V2I)	• Practical application of TSPS using infrared beacons • Practical application of DSSS using ITS roadside radio units	• Basic research including research on overseas situations • Preparation for the next fiscal year	• Refinement of functional requirements • Development of measures to address issues • Plant-level verification • Comparison and examination including other methods • Specification based on the above		• Continued efforts toward widespread use by promoting cost reduction	

3. Overview of the research

[Overview]

Automated driving for Universal Services in the Phase 2 of the Cross-ministerial Strategic Innovation Promotion Program (SIP) stipulates, aiming to be competitive in the fierce international competition of automated driving, the establishment of the world's most advanced core technologies (such as technologies for collecting and distributing road traffic information, including traffic signal and probe information), which requires cooperation among automobile manufacturers, and the establishment and social implementation of a foundation for the realization of automated driving (equivalent of SAE Level 3) on ordinary roads. As part of these efforts, this project will conduct research and development for the social implementation of the provision of traffic signal information (SPaT information) using cloud and other technologies.



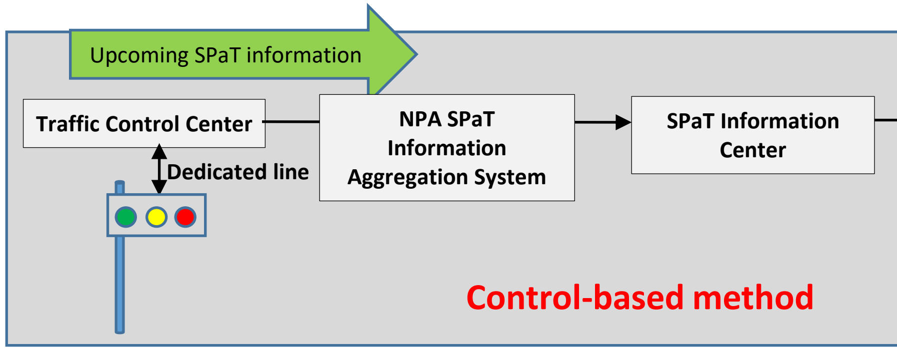


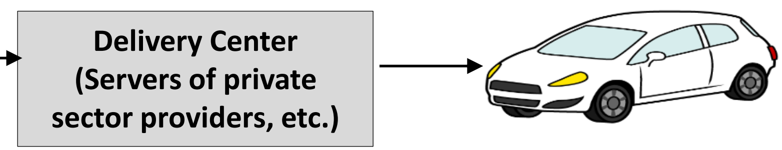
Name	Role
Prefectural Police Headquarters Traffic Control Center	Generates upcoming SPaT information based on command information from traffic lights and sends the generated information to the NPA SPaT information aggregation system. Manages information used for linking with dynamic maps.
National Police Agency SPaT information aggregation system	Collects upcoming SPaT information from traffic control centers across the country and sends the collected information to the SPaT Information Center.
SPaT Information Center	Sends SPaT information to providers' delivery centers.

4. SPaT information provision methods

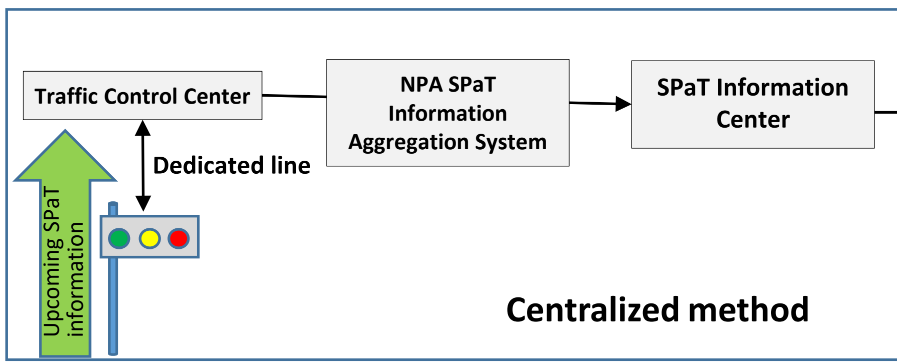
The R&D studies and develops methods for providing upcoming SPaT information, which is generated by traffic control centers or traffic signal controllers, aggregated temporarily to the NPA SPaT information aggregation system via LTE lines, etc. and then provided to delivery centers. Based on the results of the examinations carried out in fiscal 2020, the R&D will focus on the examination of the control-based method and explores the centralized and controller-based methods as complementary to the control-based method.

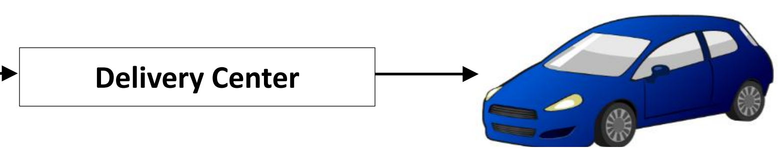
* SPaT Information Center and Delivery Center are provisional names.





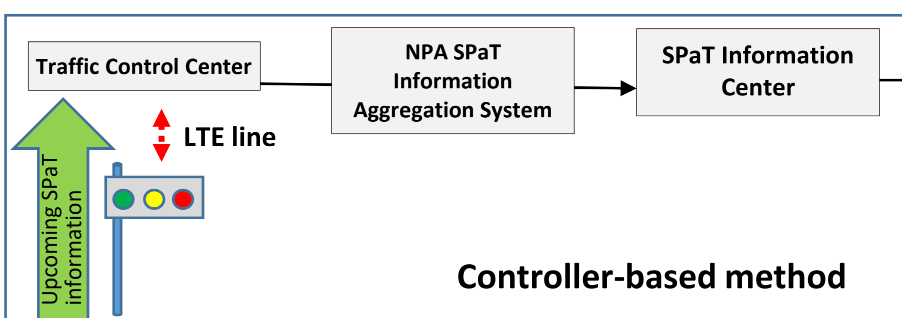
The method by which upcoming SPaT information is created at traffic control centers.

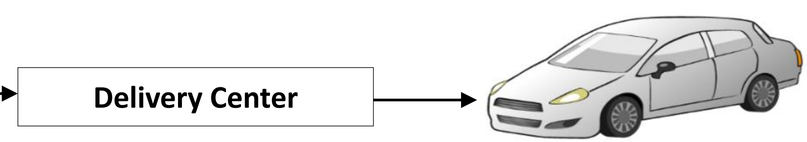




The method by which upcoming SPaT information is created by traffic signal controllers.

★ Applicable to traffic signal controllers that are remotely controlled from traffic control centers





The method by which the current traffic light information and upcoming SPaT information are created by traffic signal controllers at each intersection.

★ Applicable to independently operating traffic signal controllers

5. Implementation system (FY2021)

UTMS Society of Japan a, c

(Takes charge of the operation of both committees)

Panasonic System Solutions Japan Co., Ltd. b, h

Submit results of examination and verification

SPaT Information Center Examination Committee

The National Police Agency, transportation infrastructure manufacturers, vehicle manufacturers, traffic information providers, communications carriers, etc.

[Deliberation issues]

a. Examination of social functional requirements (the need) of the SPaT Information Center

b. Examination of technical requirements of the SPaT Information Center

c. Examination of the implementation entity of the SPaT Information Center

h. Examination of reducing the functions of the National Police Agency's SPaT information aggregation system

To be confirmed through deliberations
Overlap areas are confirmed by both sides

NIPPON SIGNAL CO., LTD. d - g

Verifies the control-based method and centralized method

OMRON Social Solutions Co., Ltd. f, g

Verifies the control-based method and controller-based method

Committee to examine technology for providing SPaT information utilizing cloud and other technologies

The National Police Agency, transportation infrastructure manufacturers, vehicle manufacturers, map-related companies, communications carriers, etc.

[Deliberation issues]

d. Examination of the integrated delivery of information other than SPaT information (e.g., traffic regulation information, etc.)

e. Examination linking SPaT information and high-precision three-dimensional maps

f. Verification of the improvement in accuracy of SPaT information

g. Examination of reducing communication delays of SPaT information

5. Implementation system (FY2022)

UTMS Society of Japan a, c
(Takes charge of the operation of the committee)

Panasonic Connect Co., Ltd. b, h
(Verifies information delivery environment

Submit results of examination and verification

NIPPON SIGNAL CO., LTD.
Verifies information generation environment (for the centralized method)

OMRON Social Solutions Co., Ltd.
Verifies information generation environment (for the control-based system, controller-based method)

SPaT Information Center Examination Committee

The National Police Agency, transportation infrastructure manufacturers, vehicle manufacturers, traffic information providers, communications carriers, etc.

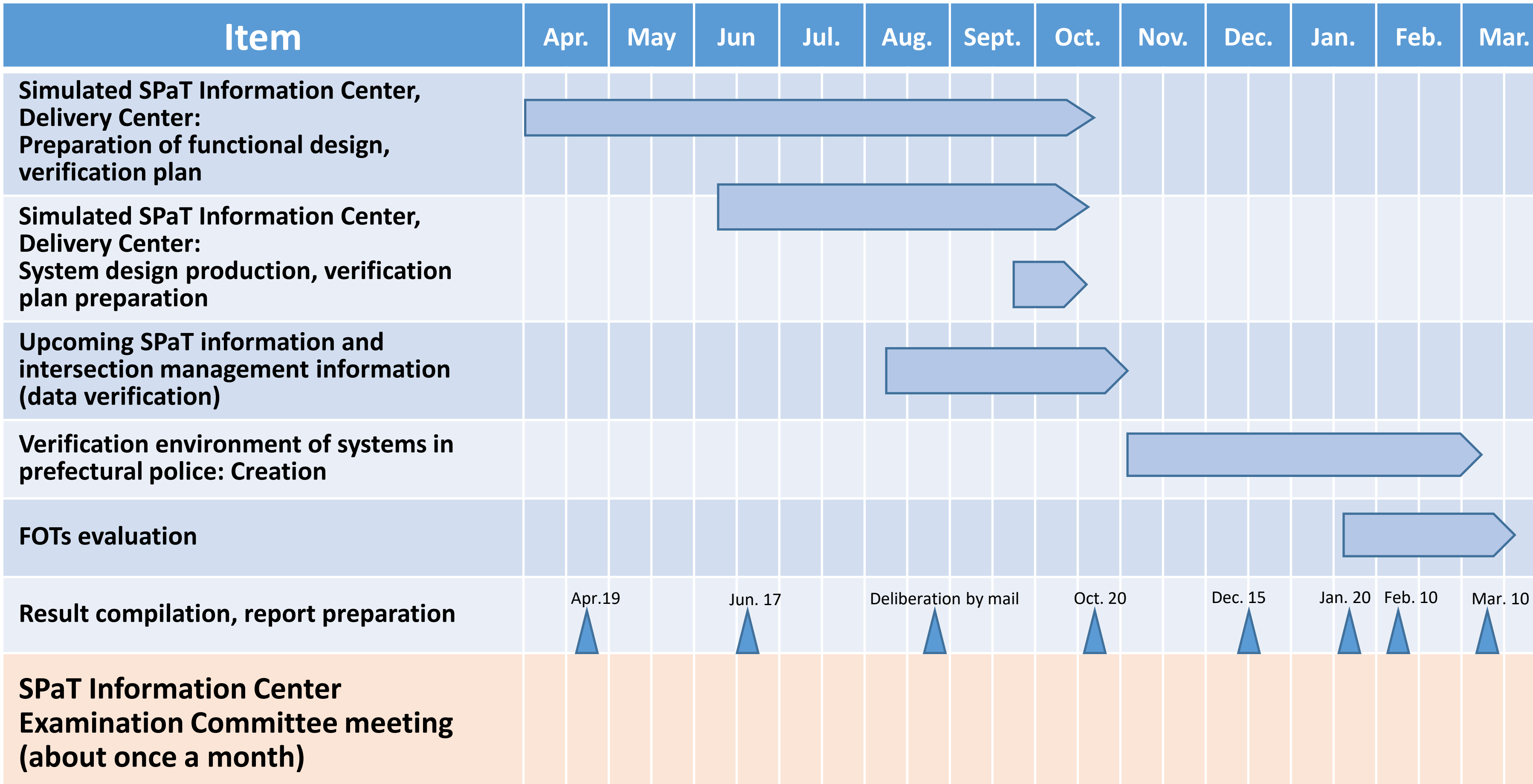
[Deliberation issues]

- Confirmation and evaluation for the Nara Prefecture FOTS（Field Operational Tests）
- Examination of issues

6. Schedule of the research and development (FY 2021)

Item	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
a. Examination of social functional requirements (the need) of the SPaT Information Center								
b. Examination of technical requirements of the SPaT Information Center								
c. Examination of the implementation entity of the SPaT Information Center								
d. Examination of the integrated delivery of information other than SPaT information (e.g., traffic regulation information, etc.)								
e. Examination of linking SPaT information and high-precision three-dimensional maps								
f. Verification of the improvement in accuracy of SPaT information								
g. Examination of reducing communication delays of SPaT information								
h. Examination of reducing the functions of the National Police Agency's SPaT information aggregation system								
[Preparation of the integrated report]								
SPaT Information Center Examination Committee meeting (about once a month)		Sept. 17	Oct. 14	Nov. 11	Dec. 9, Dec. 23	Jan. 14	Feb. 10	Mar. 8
SPaT Information Provision Technology Examination Committee meeting (about once a month)		Sept. 17	Oct. 14	Nov. 11	Dec. 9, Dec. 23	Jan. 14	Feb. 10	Mar. 8

6. Schedule of the research and development (FY 2022)



Various examinations and factory-level verifications

7. Results and issues against the R&D goals (1/2)

Establishment of SPaT information provision environment for the practical application of automatic driving

SPaT information generation environment

- **V2I method** — Cleared JAMA requirements
- **V2N method** — Cleared JAMA requirements + reduced installation cost

Priority goal (1)
Verification of the control system to resolve issues

[Implemented] [Future issues]

	Item	Result	[Implemented]	[Future issues]
f	Control-based method	Cost advantageous method Performance issues exist => Verified whether they can be solved	○	Completion of technical examination Examination of installation guidelines (ease JAMA requirements, expand applications to driver assistance)
f	Centralized method	Highly feasible method Remaining issues exist=> Improved the performance to increase the perfection level	○	FOTs in a final form
f	Controller-based method	Method for non-centralized intersections Remaining issues exist=> Improved the performance to increase the perfection level	○	FOTs in a final form

SPaT information delivery environment

- **SPaT information aggregation system** — Examined in FY2020
- **SPaT Information Center** — Examined under this theme

	Item	Result	[Implemented]	[Future issues]
h	Reduction of system functions	Functions overlap with the SPaT Information Center and performance issues exist => Reduced functions, and identified performances and solved issues in a rapid and fully integrated manner	○	FOTs in a final form
a	Identification of needs	Clarified social roles Organized operations such as construction, maintenance, management, procedures, etc.	○	
b	Examination of technical requirements	Functional and non-functional requirements necessary for the operation, security and other specifications, and connection specifications with external centers	○	
c	Examination of implementing entities	Requirements for the implementing organizations (operational methods, systems, etc.)	○	

Priority goal (2)
Establishment of a rational delivery environment

7. Results and issues against the R&D goals (2/2)

Issues in implementing the system

Information to be delivered

Delivery method

[Results] [Future issues]

d Examination of the integrated delivery of traffic regulation information, etc.

Identified use cases for regulation information in automated driving, and examined delivery message specifications and functions of traffic control centers for delivery

Results: ○

e Examination of linking SPaT information and high-precision three-dimensional maps

Linking SPaT information with dynamic maps is an issue.
=> Examined issues in linking signal information and maps and measures to address them, and examined delivery message specifications and functions of traffic control centers for the delivery of such information

Results: ○

Future issues: Development of specifics of the linking method, and determination of function placement

g Examination of reducing communication delays of SPaT information

Communication delay issues have emerged in the control-based method, centralized method, and center-to-center communications under the FY2020 theme.
→Analyzed issues from SPaT information delivery origins to delivery destination, and examined mitigation measures.

Results: ○

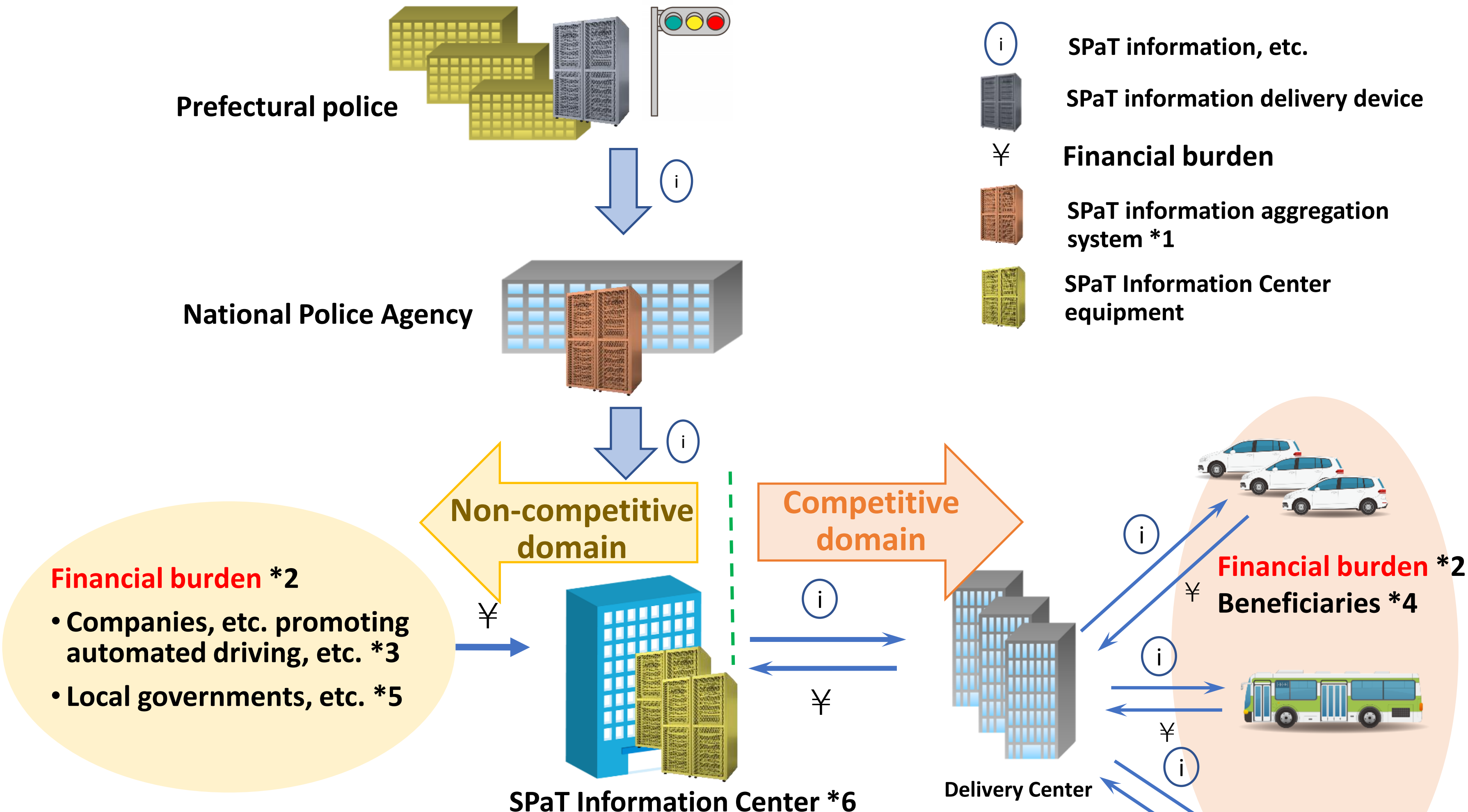
Future issues: FOTs in a final form

Identification of the relationship between the physical distance of each center and delay times

8. Overall picture of the SPaT Information Center project (assumption)

a

(UTMS Society of Japan)



*1 SPaT information aggregation system: Its functions including its technical perspectives need to be discussed in the process of starting operation

*2 Financial burdens: The allocation of the burden of initial and maintenance costs needs to be discussed, and the burden here is limited to those necessary for the operation of the SPaT Information Center.

*3 Companies, etc. promoting automated driving, etc.: OEMs and other companies promoting automated driving

*4 Beneficiaries: Including not only vehicle operators but also data users such as MaaS operators, etc.

*5 Local governments: Prefectural police are not included. They are, for example, prefectures, cities, towns, and villages that operate buses, etc.

*6 SPaT Information Center: Specified as a conceptual positioning, and the decentralization of functions to regions, etc. need to be discussed in the future.

8. Social requirements needed to be met by the SPaT Information Center

a

(UTMS Society of Japan)

Item	Necessary social requirements	Issues
Operation of an organizational entity	• Managerial planning function • Function to secure financing	• Securing of human resources (those with experiences in financing including the securing of payments from beneficiaries, and with the ability to think from a public perspective) • Smoothness of communication with related organizations
Relaying of SPaT information	• Relay-related operational functions • Recovery response function at the time of an event	• Securing of human resources (those with experiences in operations) • Experiences of similar tasks
Installation, preservation, management, repair and operation of the SPaT Information Center	• Planning and design of signal information center facilities and related ordering functions • Security management functions • Handling of routine failures • Support for delivery centers	• Securing of human resources (field engineering and dynamic database specialists) • Experiences of similar tasks • Ensuring of a nationwide system
Technical connection to the delivery center	• Functions to implement the installation, etc. of connection equipment, etc. (including the construction works of the SPaT Information Center facilities), etc.	• Securing of human resources (those with technology management skills) • Experiences of similar tasks
Procedural connection to the delivery center	• Acceptance (confirmation of terms and conditions) function • Fee (to be borne by beneficiaries) collection function	• Securing of human resources (those with customer service experiences) • Experiences of similar tasks
Technical support to the delivery center	• Technical support including the confirmation of specifications, standards, etc.	• Securing of human resources (those with knowledge of newly developed SPaT information provision technology)

※ **Human resources shown in red** should be secured by the SPaT Information Center. Operations and facility-related personnel can be outsourced.

8. Conditions for implementing entities of the SPaT Information Center

(UTMS Society of Japan)

C

Relationship with the Road Traffic Law

From the perspective of being responsible for SPaT information, etc., which requires higher reliability than conventional traffic information, it is necessary to satisfy at least Article 38-7, Paragraph 2 of the Enforcement Regulations of the Road Traffic Law.

"aims to contribute to the safety and smoothness of traffic on roads by providing information on road traffic..... and has the necessary and appropriate organizations, facilities and capacity to conduct affairs pertaining to the provision of traffic information prescribed in paragraph (1) of the same Article." (Article 38-7, Paragraph 2 of the Enforcement Regulations of the Road Traffic Law)

Fulfillment of social requirements

Need to fulfill the necessary social requirements

Items among the functional requirements for which it is appropriate to seek a technical solution, such as facility development, technical support, etc., can be entrusted to other organizations

Matters to consider

- Limiting the number
- Utilization of existing organizations
- Participation of experienced organizations

- Due to the nature of the operation of relaying between the police and the competitive domain, it is appropriate that the least possible number of organizations be responsible for the SPaT Information Center from the perspective of the burden on the police side, maintenance of security, nationwide uniformity, and operational feasibility (if possible, a single organization with a nationwide and 24-hour system that can guarantee neutrality and fairness and manage all functions in an integrated manner while taking into consideration regional decentralization of the functions).
- Due to the nature of supporting automated driving, management certainty to ensure sustainability is important, and one of the most promising ways to achieve this is to expand the operation of an existing organization that has a certain track record.
- The need to secure human resources for planning, management decisions, etc. requires the participation of organizations with experience in the field of traffic information.

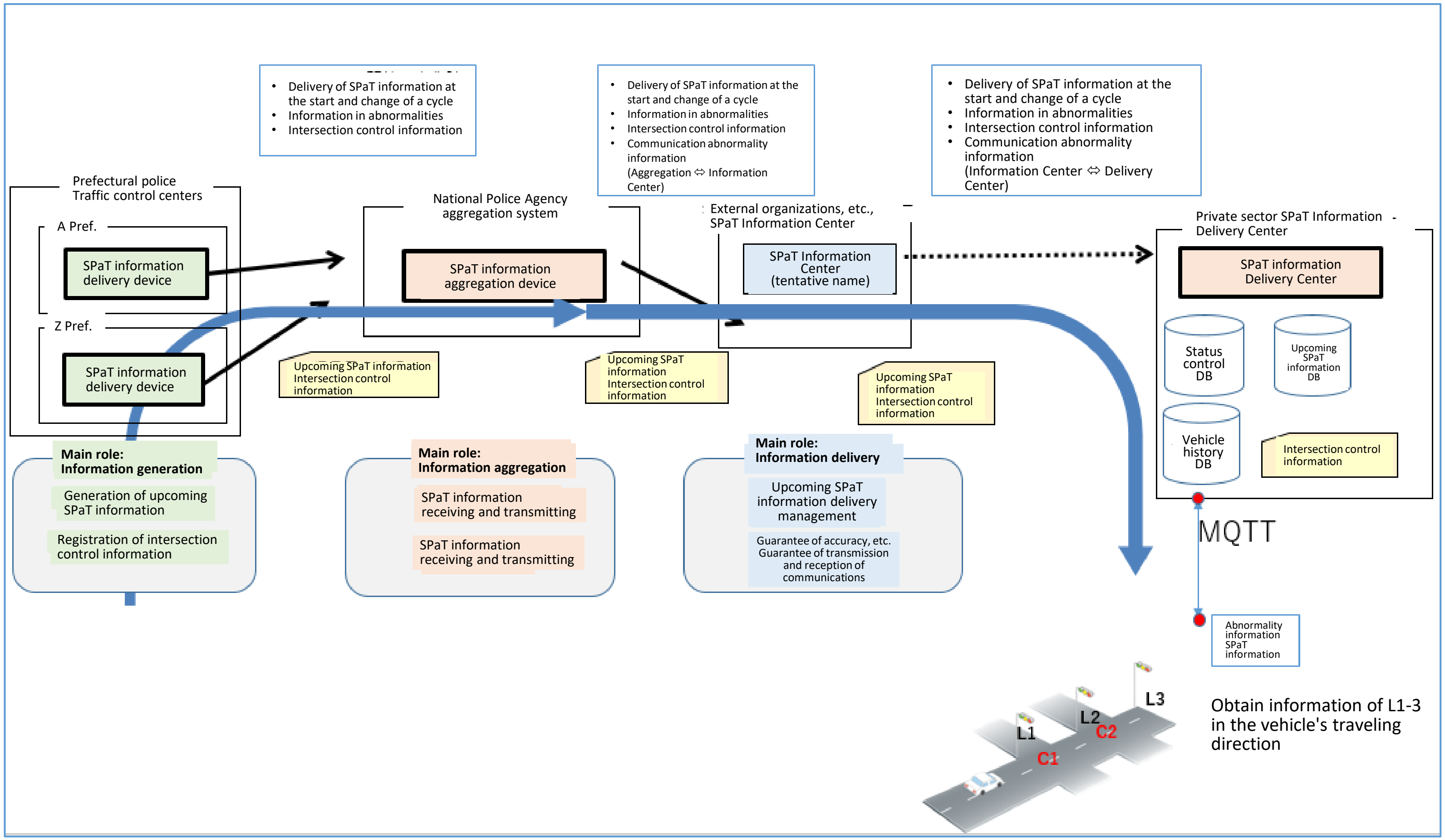
9. Overall configuration and necessary functions for the technical requirements of the SPaT Information Center

b

(Panasonic System Solutions Japan Co., Ltd.)

[Technical requirements of the SPaT Information Center, etc.]

- **Specification of a system for the SPaT Information Center that aggregates SPaT information provided from the Prefectural Police traffic control centers through the NPA SPaT information aggregation system and transmits the information to the SPaT Information Delivery Center.**
  (Draft specifications for the signal information aggregation system have already been prepared in FY2021)
- **Redesign of roles among each of the above devices**



9. Examination of configuration and functional placement for the technical requirements of the SPaT Information Center

(Panasonic System Solutions Japan Co., Ltd.)

b

(1) Examination of hardware configuration

- Organization of hardware configuration (roles of each device)
- Calculation of resource capacity (memory, hard disk) (per day, per month)
- Hardware and its functional requirements for SPaT information aggregation devices and the SPaT information Center's system devices
- Examination of technical (performance) requirements

(2) System configuration (the consistency of device placement and function)

- Verification of minimum required system configuration (monitoring, storing of communications logs, databases)
- Examination of the utilization of theory and devices (the following items should be considered)
- Data management consistent with the operation of intersection control information
- Method of transmitting error information between upcoming SPaT information and devices
- Examination with consideration to the system neutrality requirements of the software for building databases needed for other than OS and middleware.

(3) Examination of reports (the reference system)

(4) Network environment and non-functional requirements

9. Identification of functions specified in the technical requirements of the SPaT Information Center

b, h

(Panasonic System Solutions Japan Co., Ltd.)

Examination of the functions of the SPaT information aggregation system and the Signal Information Center and determination of functional ite

Division of system functional roles

A proposed division of system functions that will serve as a premise for examining the requirements for the SPaT information aggregation system and SPaT Information Center system, in order to realize the service of providing SPaT information.

	Cooperative domain			Competitive domain (private sectors)
System	Prefectural police/Traffic control system	National Police Agency/ SPaT information aggregation system	SPaT Information Center/ SPaT Information Center System (tentative)	Delivery Center/Delivery Center System (tentative)
Main devices	SPaT information delivery device	SPaT information aggregation device	SPaT information provision device (tentative)	SPaT information delivery server (tentative)
Division of system functions	● Generation of SPaT information ● Registration of intersection control information	● Aggregation of nationwide information and integration of routes	● Ensuring of consistency of rules and regulations for SPaT information, etc.	● Management of delivery of upcoming SPaT information
	● Management of communications, etc. ● Historical records inquiry	● Communications monitoring (communication error response) ● Historical records inquiry	● Delivery management and inquiry	-
	● Management of provision of upcoming SPaT information (Ensuring of consistency of upcoming SPaT information)	● Various verifications of FOTs (Including the time of launching the service)	● Management of information provided	-

[Legend]

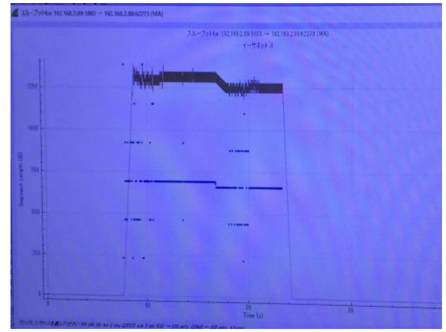
● Red: Functions that were shifted from those in the FY2020 specifications.

10. Performance measurement (performance improvement and bottleneck factors)

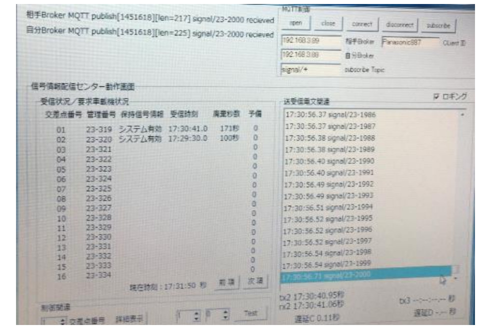
(Panasonic System Solutions Japan Co., Ltd.)

Traffic control center

SPaT information delivery device

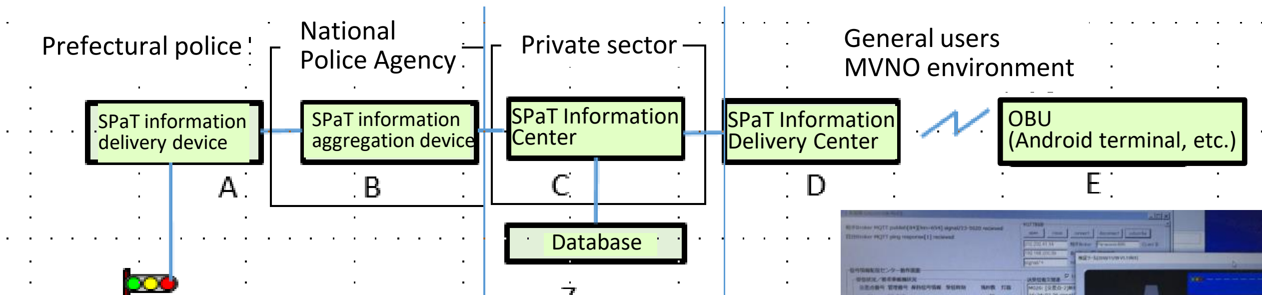


12.5 Mbps bandwidth with USB-LAN, etc.



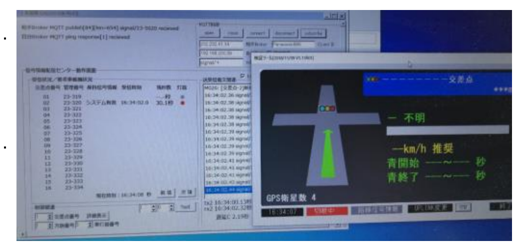
SPaT Information Delivery Center

Terminal control unit



Pseudo signal controller with 0.1 sec. processing

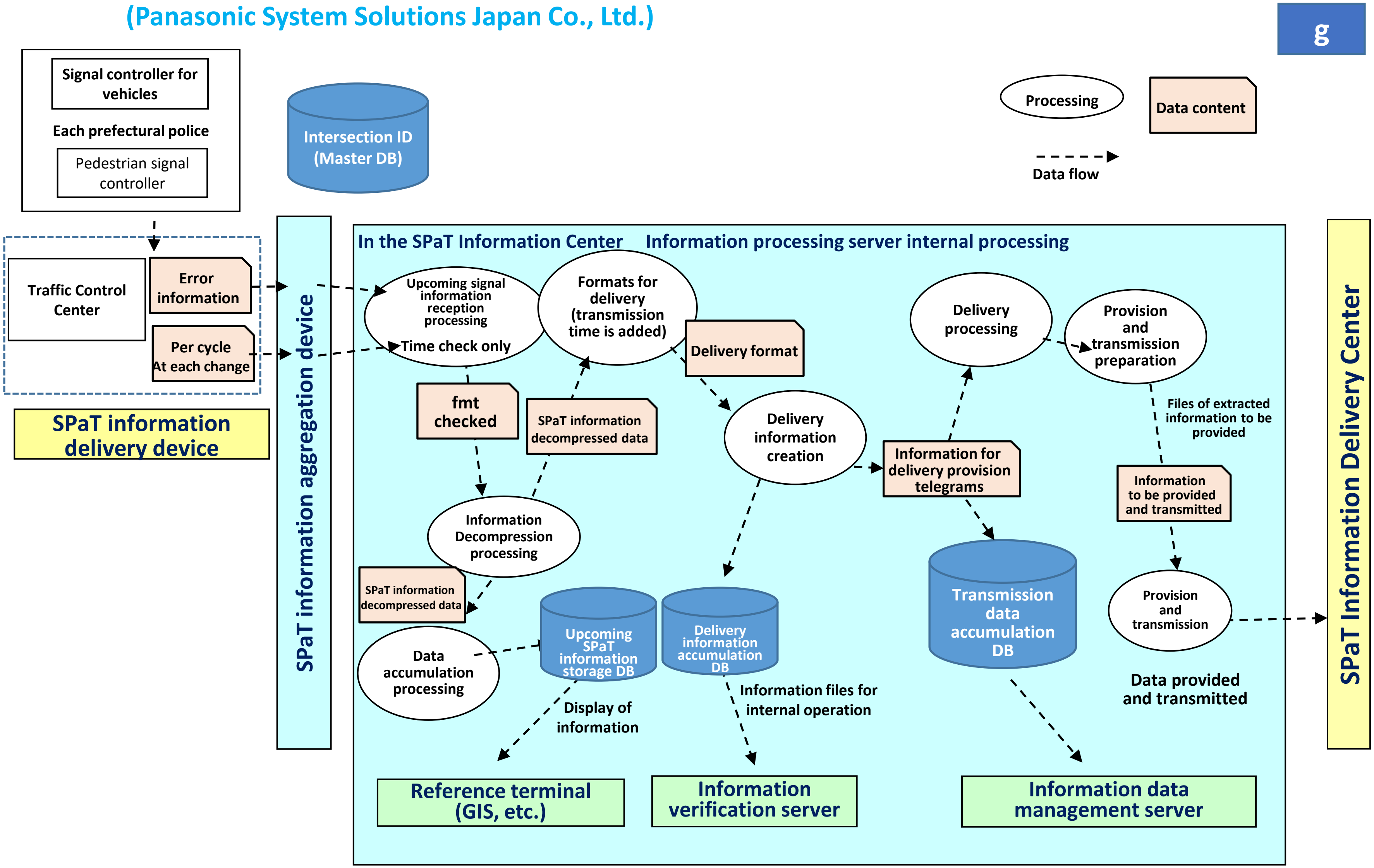
Simulation of the number of simultaneous communications
4000 intersections with the cycle length of 60 sec.
100 intersections (99.99%)



Aging data during the packet communication over a general public network will be obtained.
Obtained the number of retransmissions

10. Examination of internal processing to reduce delays, etc.

(Panasonic System Solutions Japan Co., Ltd.)



(1) Creation of an environment for measuring the performance of the header load processing section
(2) Revision of the number of simultaneous communication processing
(3) Time check processing
(4) No retransmission processing

10. Performance measurement results

(Panasonic System Solutions Japan Co., Ltd.)

g

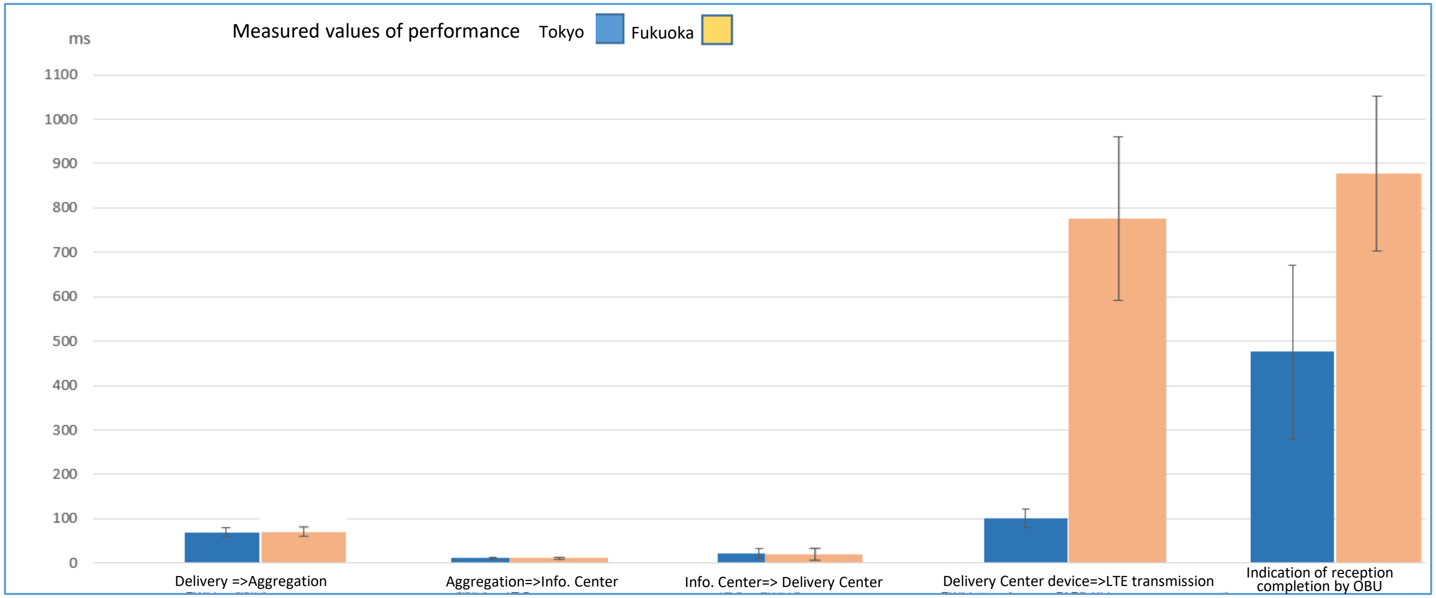
Measurement environment

Between the simulated SPaT information delivery device (for each prefectural police) and the simulated SPaT information aggregation device Bandwidth: 12.5 Mbps
Cycle length: 100 sec Size of upcoming SPaT information: 585 bytes Number of simultaneous communications: 256 intersections
Location: In Fukuoka and Tokyo Measured at the same time period from 17:00 to 19:30

- In FY2020, verification was conducted between two devices. In FY2021, a simulated environment closer to the actual environment was created by such means as placing four devices (the generation device, aggregation device, and the devices for the SPaT Information Center and Delivery Center) in different segments.

Results
Fukuoka Maximum 2.63 sec. Average 0.87 sec.
Tokyo Maximum 1.57 sec. Average 0.47 sec.
(Connectivity environment with PULL communication)

- As the processing time of the SPaT Information Center, delivery took 30 to 60 ms including communication time.
- Communication delays increase as the distance between the prefecture where the center is installed and the OBU increases.

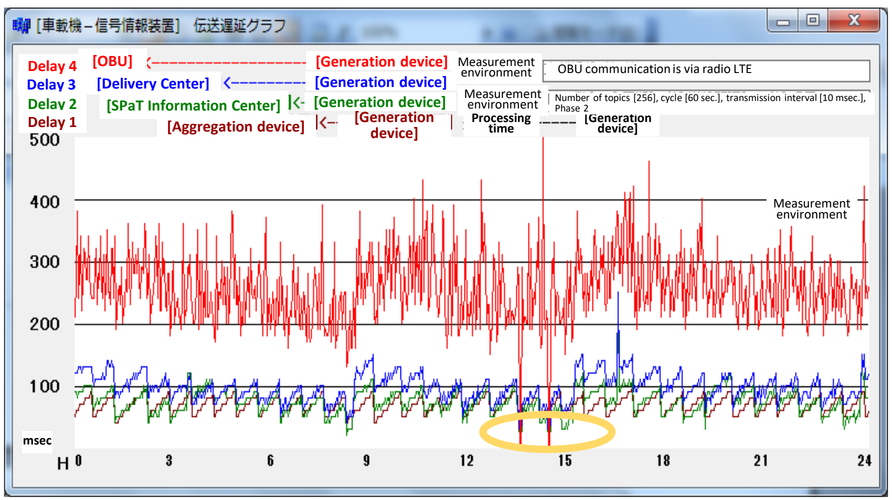


10. Performance measurement results

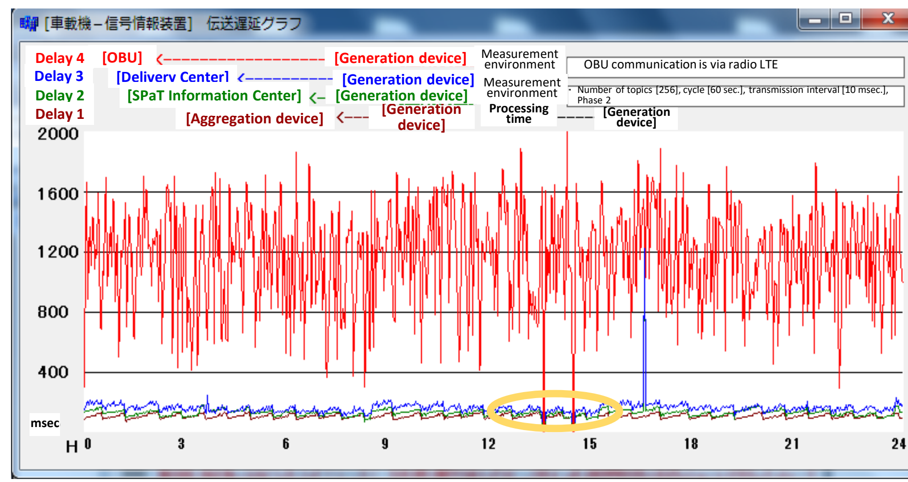
(Panasonic System Solutions Japan Co., Ltd.)

g

- In FY2020, the performance was evaluated by evaluating the delay time until writing data to the database and the delivery time from the Delivery Center to the simulated OBU, respectively, and then evaluating the results of the addition of both times. The result was a delay of around 2 to 3 seconds.
- In FY2021, the delay was reduced to 200 ms - 500 ms by setting up calls through the MQTT-PING data propagation result communication between the OBU and the Center at 1 second intervals in parallel with database writing.



Continuous operation with MQTT-PING at every 1 sec.



Continuous operation without MQTT-PING

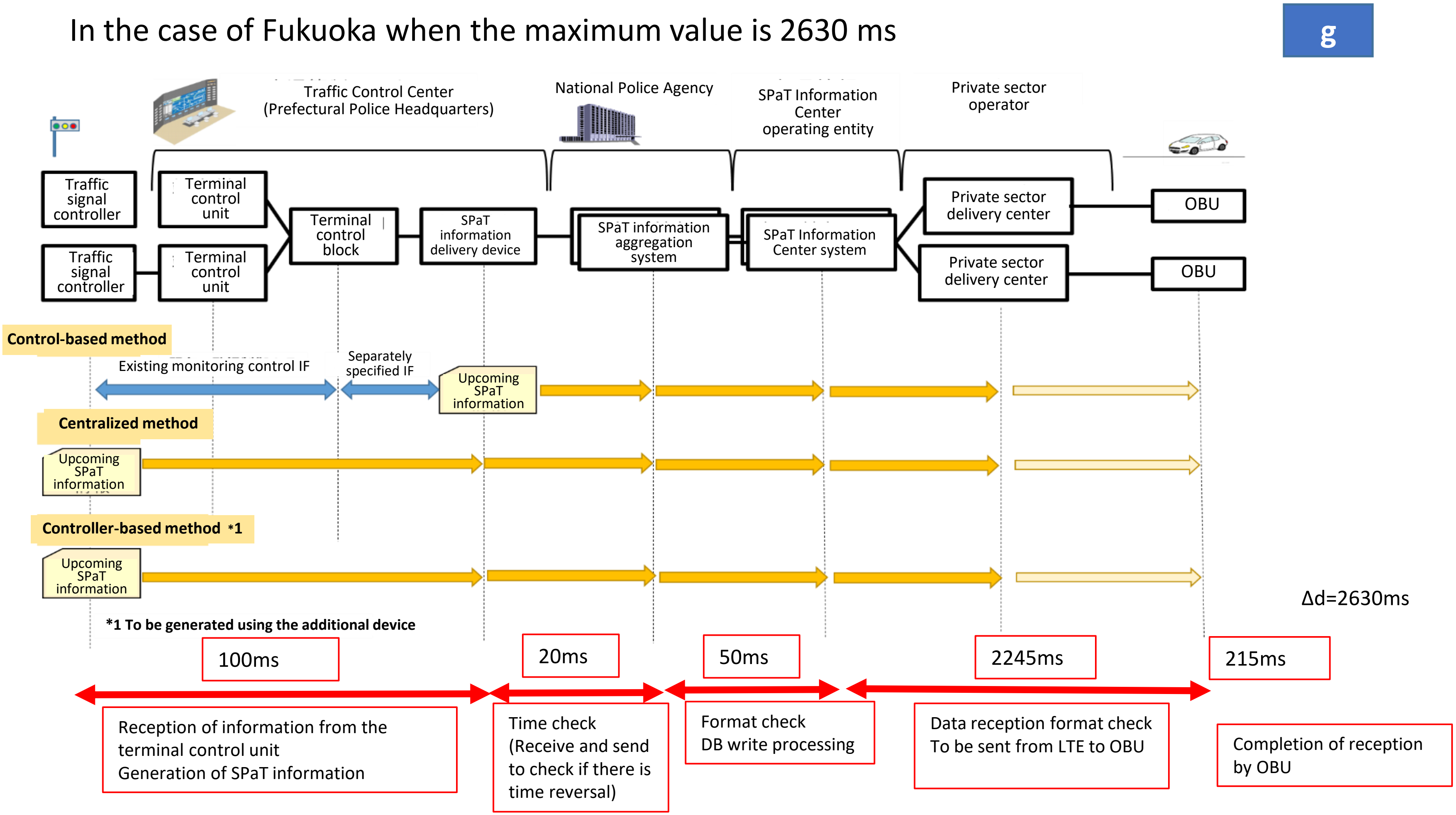
Communication between the Center and the OBU was lost twice during 24-hour continuous operation, disabling measurement. Restored after retries.

10. Investigation of Δt and Δd (processing + communication delay)

(Panasonic System Solutions Japan Co., Ltd.)

*Δd = Processing + communication delay

In the case of Fukuoka when the maximum value is 2630 ms



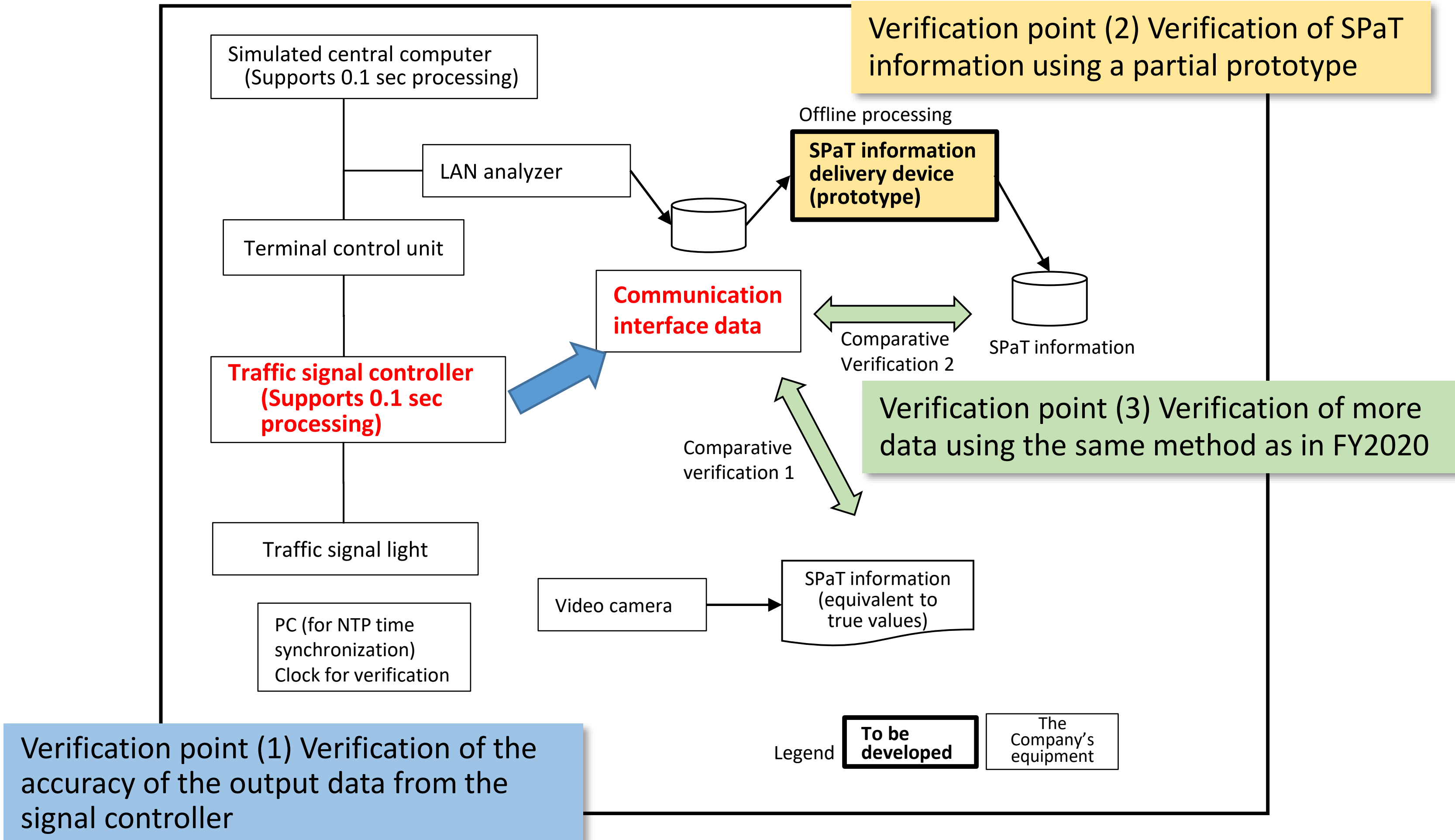
Time from the start of the cycle to the end of green > Time for the upcoming SPaT information to reach the OBU + ΔT was confirmed.

10. Verification of the improvement in accuracy of SPaT information (Control-based method)

f

(OMRON Social Solutions Co., Ltd.)

The verification confirms that the accuracy of the output data is the required accuracy in order to edit signal information based on the output data from the signal controller (0.1 second processing). To perform effective verification in a short period of time, a prototype of off-line processing was developed. To verify more data (with a longer period of time), video cameras were used and data-to-data comparisons were conducted.



11. Verification of the improvement in accuracy of SPaT information (Control-based method)

f

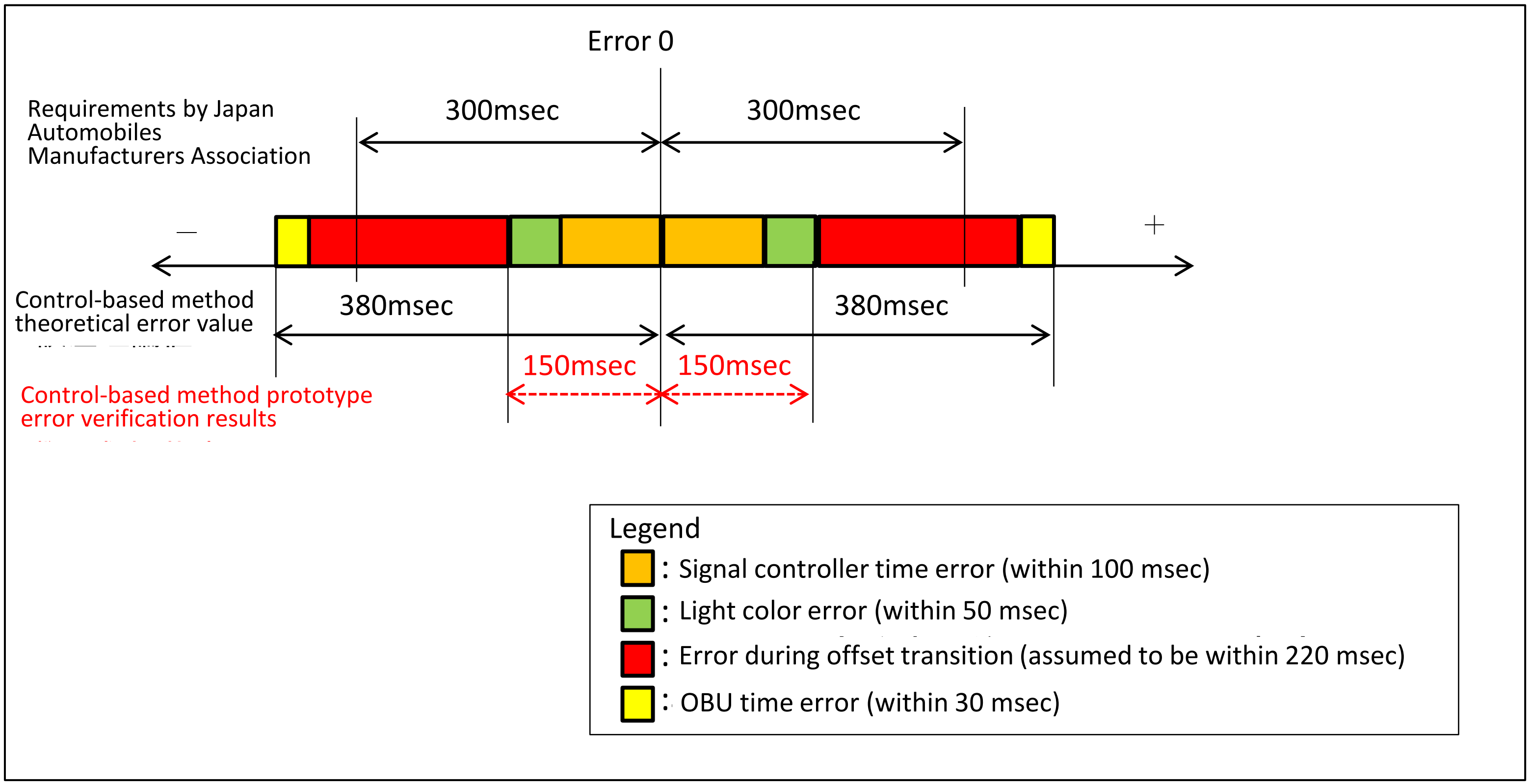
(OMRON Social Solutions Co., Ltd.)

Verification point	Verification results	Issues and prospects
Verification of the accuracy of the output data from traffic signal controllers	Confirmed the improvement of time accuracy by GPS (error of less than 100 msec).	No problem under normal conditions. Need to check GPS satellite supplementation status at intersections.
	Confirmed the improvement of the accuracy of signal control history (error of less than 150 msec).	Sufficient accuracy as source information for upcoming SPaT information. No issues.
	Confirmed the accuracy of recall request receipt information.	SPaT information provision at pushbutton activated intersections, which had been an issue to date, is now possible.
Verification of the accuracy of SPaT information using a partial prototype	Verified that JAMA requirements are met for the Company's signal controllers.	Signal controllers manufactured by other companies may not meet JAMA's requirements due to expected performance degradation during offset transition. This is due to the fact that detailed specifications for offset transition of signal controllers are not made available to public. The committee discussed several proposed measures, but no conclusion has been reached.
	Examined operation specifications during abnormal conditions based on actual data.	This issue will be discussed, including the relaxation of JAMA’s requirements. Confirmation is underway as to whether or not there are any issues, including the operation on the OBU side in the event of an abnormality.

Supplementary material: Error analysis model for the control-based method

f

In the case of signal controllers manufactured by other companies, up to **200 msec is added** as an error during offset transition, which may result in **a total signal error of 380 msec.**



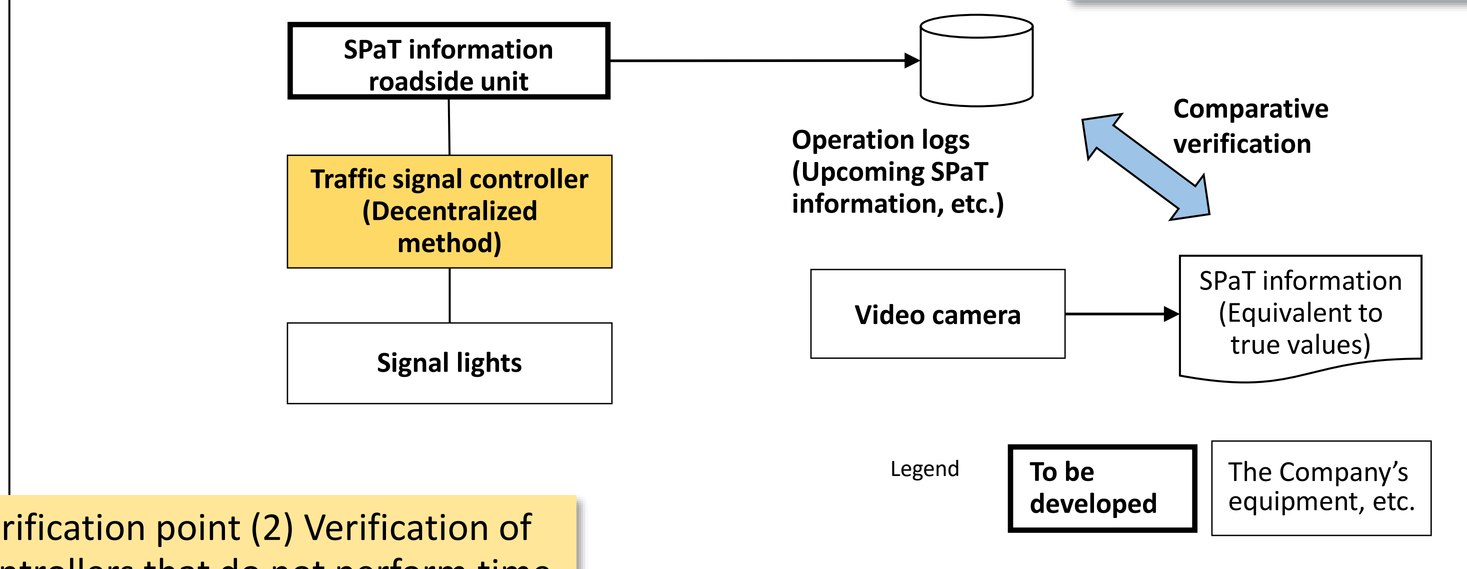
12. Verification of the improvement in accuracy of SPaT information (Controller-based method)

f

(OMRON Social Solutions Co., Ltd.)

Measures will be taken to address the accuracy decline during offset transition that was found in the FY2020 verification of the prefectural police model system, and the verification that the accuracy improves will be conducted. Also, the accuracy of controllers that do not perform time synchronization, which was not verified in FY2020, will also be verified.

Verification point (1) Accuracy improvement during offset transition



Verification point (2) Verification of controllers that do not perform time synchronization

Supplementary information: Other than "adding SPaT information roadside unit" to the signal controllers currently in operation, the controller-based method can also be implemented by upgrading current signal controllers to those that support the method.

29

12. Verification of the improvement in accuracy of SPaT information (Controller-based method)

f

(OMRON Social Solutions Co., Ltd.)

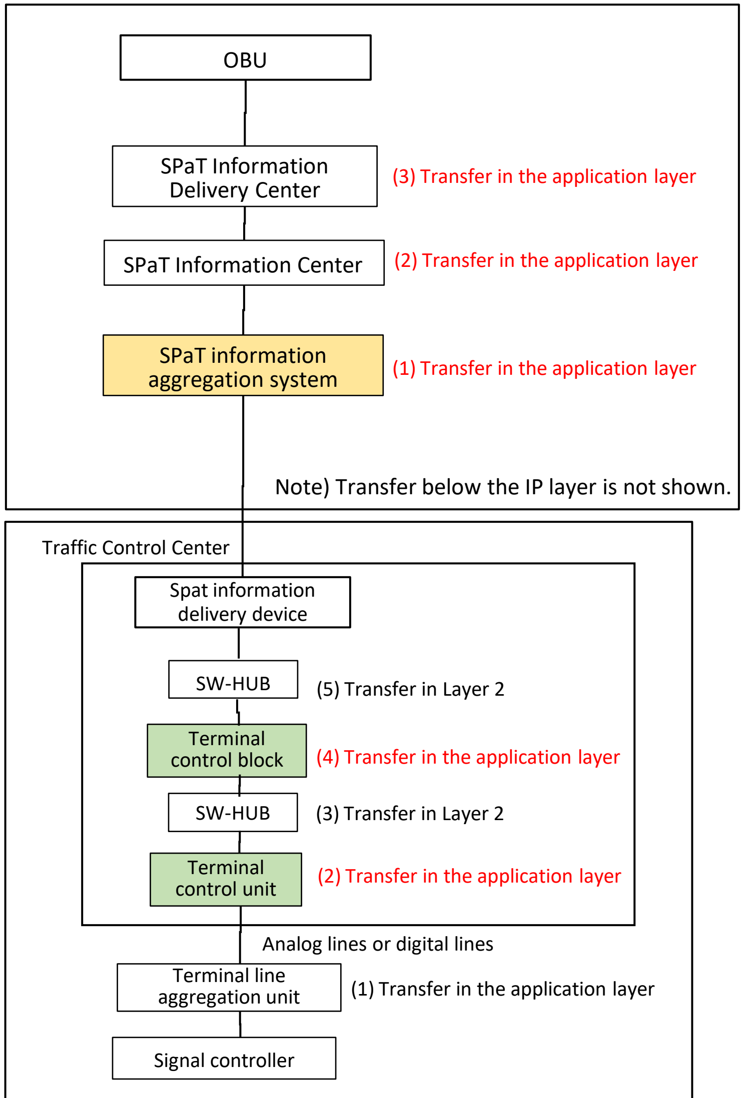
Verification point	Verification results	Issues and prospects
Accuracy improvement during offset transition	It was confirmed that during coordinated control, offset transition in 0.1 sec increments occurs depending on the manufacturer of the signal controller. It was confirmed that the JAMA requirements will be satisfied by learning offset transition in 0.1 sec increments.	It is necessary to verify the accuracy of SPaT information for signal controllers operated at intersections through long-term operation. It is desirable to verify the operation using signal controllers from manufacturers that performs offset transition in 0.1 sec increments.
Verification of SPaT information when traffic signal controllers are not time-synchronized	It was verified that, even when signal controllers are not time-synchronized, upcoming SPaT information is correctly generated by time estimation performed by the signal controllers.	It is necessary to verify the accuracy of SPaT information for signal controllers operated at intersections through long-term operation.

12. Reducing communication delays

g

(OMRON Social Solutions Co., Ltd.)

Assuming that the transfer time in the application layer is the cause of communication delay, the delay time for each device will be measured and measures to improve performance will be examined.



Verification point (1) The cause of the communication delay is assumed to be the transfer in the application layer.

With minimum required transfer functions, processing delays are small and there are no issues.

Verification point (2) For center-to-center communication, delays are measured by implementing transfer processing with MQTT using a prototype, and overall communication delay times are estimated.

Delay time increases by several percent when the number of traffic signals or the number of simultaneous generations of upcoming SPaT information increases.

Response to delays that are characteristic of communications are being examined

Verification point (3) Investigate transfer time of existing interfaces and examine measures to improve performance.

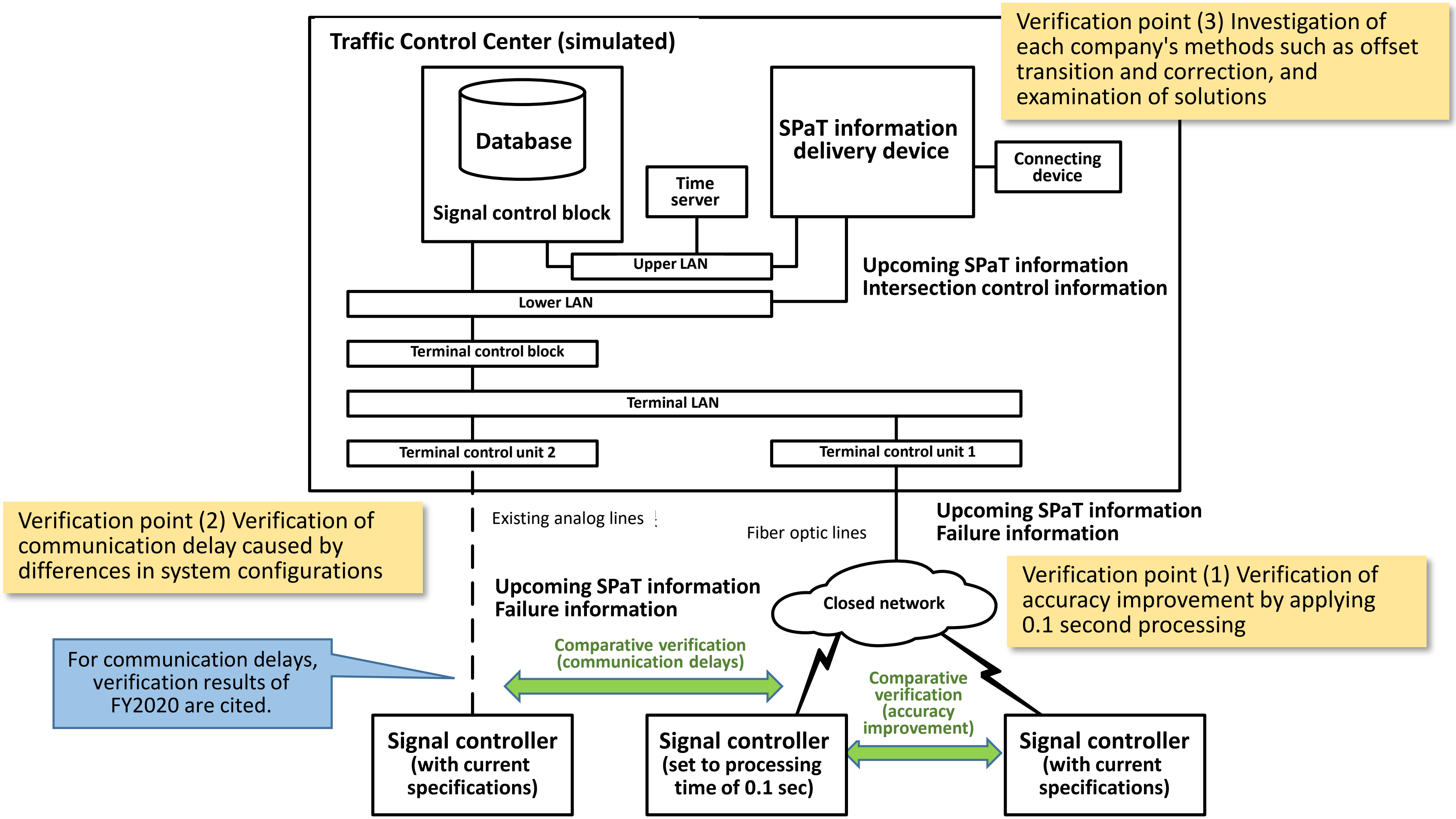
Confirmed the occurrence of a delay time of about 1.4 sec in the specifications. Timing will be designed as a precondition in the future.

13. Verification of the improvement in accuracy of SPaT information
(in the control-based method, centralized method)/communication delay reduction

f, g

(NIPPON SIGNAL CO., LTD.)

A simulated traffic control center environment was created, and comparative verification was conducted between signal control (0.1 second processing) and that of the current specification (1 second processing). The verification was conducted while effectively utilizing data from the actual field experiment in FY2020, and the effects of introducing the system to the actual field was estimated.



13. Verification of the improvement in accuracy of SPaT information (with control-based method, centralized method)/communication delay reduction

f, g

(NIPPON SIGNAL CO., LTD.)

Verification point (1) Verification of accuracy improvement by applying a 0.1 second processing cycle

The intersection demonstrated in Saitama in FY2020 was simulated within the network, verified the accuracy of SPaT information with both the control-based and centralized systems, and compared the results with those of FY2020 (results of the experiment with the former specifications).

Comparison with the FY2020 experiment results (control-based method)

Unit (ms)

Fiscal year	Version of traffic signal controller	Number of measurements	Maximum value	Minimum value	Average value	Standard deviation
FY2020	Version 4	84	-3,073	-43	-2,066	645
	Version 4 (with GPS correction)	84	-2,191	-244	-1,366	631
FY2021	Version 5	114	267	-117	170	46

Compared to FY2020 (Version 4), deviations in FY2021 (Version 5) were significantly reduced, indicating an improvement in accuracy.

Comparison with the FY2020 experiment results (centralized method)

Unit (ms)

Fiscal year	Version of traffic signal controller	Number of measurements	Maximum value	Minimum value	Average value	Standard deviation
FY2020	Version 4	170	1,312	7	476	481
	Version 4 (with GPS correction)	181	274	0	-12	75
FY2021	Version 5	236	-167	0	-71	34

Compared to FY2020 (Version 4 with GPS correction), deviations in FY2021 (Version 5) were slightly reduced, indicating a modest improvement in accuracy.

13. Verification of the improvement in accuracy of SPaT information (with control-based method, centralized method)/communication delay reduction

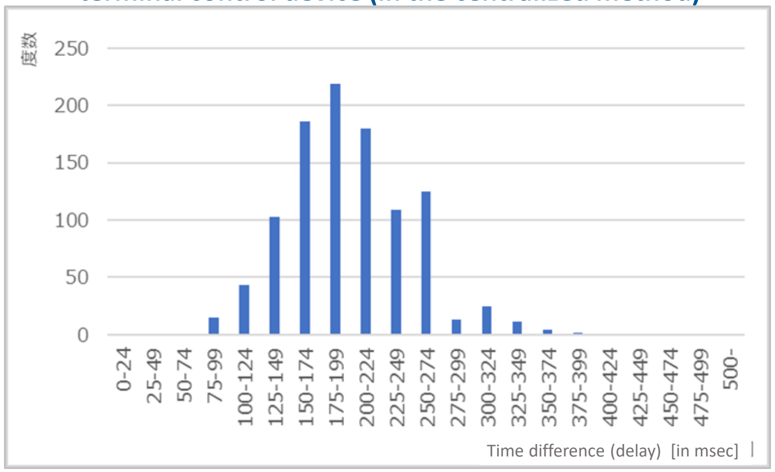
(NIPPON SIGNAL CO., LTD.)

f, g

Verification point (2) Verification of communication delay caused by differences in system configurations

The time difference between the data creation time in the traffic signal controller and the data reception time in the terminal control device and the simulated OBU was measured as communication delay and was compared with the FY2020 results (the results of an experiment using an analog line in the field).

Communication delays between traffic signal controller and terminal control device (in the centralized method)



- **The difference in time from data generation in the traffic signal controllers to data reception in the terminal control devices (≒ the delay that occurred in the MVNO line section) was from 90 to 390 milliseconds.**
- **In other FOTs that have been conducted to date, the actual results in the MVNO line section have averaged 100 to 200 milliseconds, which are equivalent to the results of the experiment this time.**

Comparison with the FY2020 experiment results (between the traffic signal controllers and simulated SPaT Information Center with the centralized method)

Unit (ms)

Fiscal year	Version of traffic signal controller	Communication line to terminal	Number of measurements	Maximum value	Minimum value	Average value	Standard deviation
FY2020	Version 4 (with GPS correction)	Analog	105	4720	1350	2307	855
FY2021	Version 5	MVNO	1035	1430	550	960	148

Although the delay in FY2021 (MVNO lines) is significantly lower than in FY2020 (analog lines), this is believed to be due partly to the impact of the decrease in the number of devices to be routed as a result of the change of the terminal control unit from II to I.

13. Verification of the improvement in accuracy of SPaT information
(control-based method, centralized method)/communication delay reduction

f, g

(NIPPON SIGNAL CO., LTD.)

Verification point (3) Investigation of each company's methods such as offset transition and correction, and examination of solutions

[Background]

In the control-based method, change in the number of seconds of signal caused by offset transition needs to be added when SPaT information is generated in the traffic control center; however, detailed differences are assumed to be exist in each manufacturer's calculation methods, such as in methods of allocating the amount of offset transition to each split, and this may result in discrepancies between the calculation results of the traffic control center and the outputs of signal lights.

[Implementation of questionnaire survey]

Implementation period: From December 23, 2021 to January 7, 2022
Survey respondents: Five traffic signal controller manufacturers
Content: Method of determining and calculating the amount of offset transition and solution to this issue

[Results]

The results of the questionnaire survey found that there are differences between the companies in methods of determining and calculating the amount of offset transition. When assuming the implementation using traffic signal controllers with new specifications, recognition error during offset transition may be up to around 500msec.
Continued examination needs to be conducted to determine how to address this issue in conjunction with the resolution of other issues.

<Reference> Offset: A phase difference between traffic signals (difference in switchover timing)
Offset transition: When the cycle length and offset change due to traffic conditions, time of day, etc., values are changed gradually to meet the target values, taking into account the impact on traffic and safety.

13. Summary on the verification of the improvement in accuracy of SPaT information

d, e

(NIPPON SIGNAL CO., LTD.)

It was confirmed that the increase of recognition errors in the control-based method, which was the issue for FY2020, is improved by the new specification for traffic signal controllers and the central computer of the traffic control center. Improvement was also confirmed, although modest in degree, in the centralized method.

Item	Content	Control-based method	Centralized method	Controller-based method (information generated by roadside unit)	Controller-based method (information generated by controller)	Police A
SPaT information generation accuracy	Normal operation Note 1	○	○	○	○	○
	During offset transition	× Note 2	○	○	○	○
	Traffic-actuated control by terminals	—	○	○	○	○
Fail-safe	Detection of abnormal conditions (consistency with signal light colors)	×	○	○	○	○
Operation	Centralized control	○	○	—	—	○
	Non-centralized control	—	—	○	○	—

— : Not appliable

Note 1) A state in which the traffic signal controller operates at timings in seconds determined by the control center.

Note 2) Recognition errors of up to around 500 msec may occur. (JAMA target ±300 msec)

The recognition error of ±300 is believed to be satisfied by combining the control-based method and centralized method for intersections with centralized control and by applying the controller-based method for intersections with non-centralized control. However, issues of communication delays exist in the fail-safe system of the control-based method and in both methods in the V2N environment, and continued examination is necessary to address notification delays in the event of abnormalities and when the number of seconds of signal steps changes due to traffic-actuated control by terminals.

14. Examination of the integrated delivery of information other than SPaT information (traffic regulation information, etc.)/Examination of linking SPaT information and high-precision three-dimensional maps

d, e

(NIPPON SIGNAL CO., LTD.

In addition to examination of the feasibility with experts toward realization, simulations (desk-top verification) were conducted based on several examples.

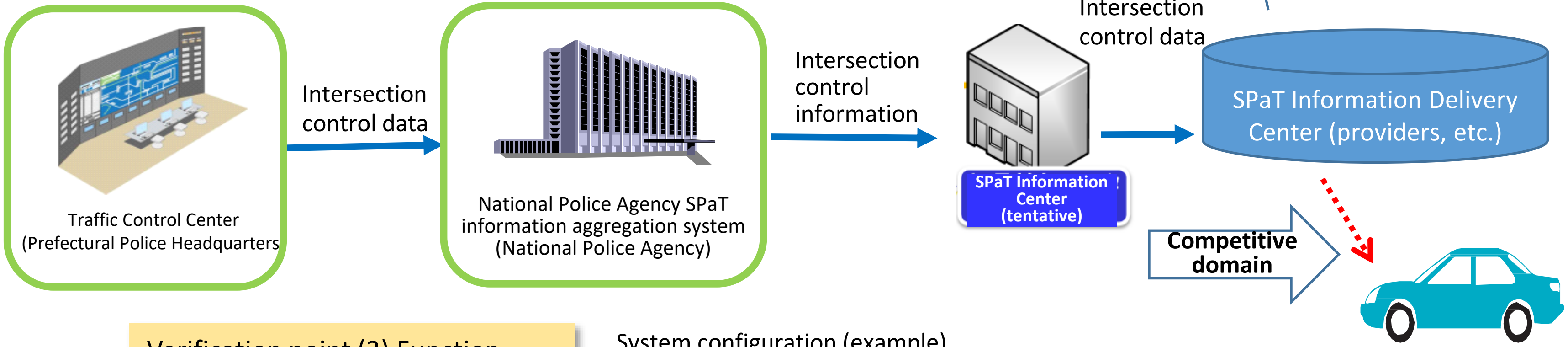
Configuration DF/DE	Representation form	Code	Remarks
DF_Provision point control number			
DE_Prefecture code	bin(8)	E-2	
DE_Provision point type code	bin(1)	E-4	
DE_Intersection ID/basic road ID	bin(15)	C-2	
Preliminary DE_Multiple intersecting road flags	bin(8)		Most significant bit If 1, it indicates multiple intersecting roads
Preliminary DE_Intersection name	bin(16*32)		32 characters with 2-byte representation characters
DF_Intersection ID Defines center position (Sized to the preliminary of intersection identification information)			
Version information	bin(8)		Version number of constant information
DF_Central latitude			
DE_Latitude (degrees)	bin(8)	B-1	
DE_Latitude (minutes)	bin(8)	B-2	
DE_Latitude (seconds)	bin(16)	B-3	1/100 sec.
DF_Central longitude			
DE_Longitude (degrees)	bin(9)	B-4	
DE_Longitude (minutes)	bin(7)	B-5	
DE_Longitude (seconds)	bin(16)	B-6	1/100 sec.
DF_Intersection information (each path information, etc.)			
Operation mode	bin(1)		0: test 1: operation
DE_Number of paths (I)	bin(7)		Number of paths
DF_Path angle information: 1			
Angle information by path	bin(8)		Represents absolute azimuth (in 1.5 degree increments: 0 to 239) with true north at 0 degrees
. .			
DF_Path angle information: I			

Intersection control data (example)

Verification point (1) Whether information can be integrated with traffic regulation information

Linking

Verification point (2) Information required for linking to maps and rules for assigning IDs, etc.



Verification point (3) Function placement and maintenance and management methods

System configuration (example)

14 Examination of the integrated delivery of information other than SPaT information (traffic regulation information, etc.)/Examination of linking SPaT information and high-precision three-dimensional maps

d, e

(NIPPON SIGNAL CO., LTD.)

Integration with traffic regulation information (Examination point (1))

It was decided that, among the items of intersection control information to be defined by each prefectural police for linking them with high-precision three dimensional maps, intersection IDs and central longitude and latitude information will be aligned with traffic regulation information that had already been made available as open data.

Large category	Format item	Attribute	Byte count	Notes
Prefecture information				
	Prefecture code	Code	2	[Common code] Refer to prefecture codes
	Police station code	Code	4	[Defined by prefectural police
	Related police station code 1	Code	4	[Defined by prefectural police
	Related police station code 2	Code	4	[Defined by prefectural police
	Related police station code 3	Code	4	[Defined by prefectural police
	Related police station code 4	Code	4	[Defined by prefectural police
	Related police station code 5	Code	4	[Defined by prefectural police
	Related police station code 6	Code	4	[Defined by prefectural police
	Related police station code 7	Code	4	[Defined by prefectural police
	Related police station code 8	Code	4	[Defined by prefectural police
Information by regulation type				
	Code by common regulation type	Code	6	[Common code] Refer to codes by common regulation type
	Point, line and area code	Code	2	[Common code] Refer to point, line and area codes
	Name by regulation type by prefecture	Characters	100	
Date management				
	Regulation decision date	Date	10	YYYY/MM/DD
Regulation number management				
	Unique key by prefecture	Numerical value	12	Unique key by prefecture
	Regulation number	Numerical value	8	
	Number	Numerical value	8	
Regulation information Location				
	Longitude and latitude of regulation location	Coordinate	No limit	World Geodetic System (WGS84) Fractional degree values with variable length Up to 16 bytes (16 characters) including decimal points of each longitude and latitude "Longitude (X1) Latitude (Y1)" "Longitude (X2) Latitude (Y2)" ….. "Longitude (Xn) Latitude (Yn)" Example: "135.22490 35.31567" "135.22411 35.31572" …"135.24131 35.72572"
	Regulation location start point	Characters	200	
Regulation information Route name				
	1 – Route 1	Characters	60	
	1 – Route 2	Characters	60	
	1 – Route 3	Characters	60	
	1 – Route 4	Characters	60	
Regulation information Direction				
Regulation information Targets and exemptions Time				
Regulation information Items by regulation type				
	Reason for update	Characters	200	
	Remarks	Characters	600	

From instructions of Traffic Regulation Information (103 kinds) on JARTIC Website

[Issue] Data creation and management methods

Traffic control information prepared by each prefectural police

Configuration DF/DE	Representation form	Remarks
DF_Provision point management No.		
DE_Prefecture code	bin(8)	
DE_Provision point type code	bin(1)	
DE_Intersection ID/Basic road ID	bin(47)	
Preliminary DE_Multiple intersecting road flag	bin(8)	If most significant bit is 1, it indicates multiple intersecting roads.
Preliminary DE_Intersection name	bin(16*32)	32 characters with 2-byte representation characters.
DF_Intersection information		
Version information	bin(8)	Represents the generation of traffic control information (1 -). This information prevents inconsistencies between the static information recognized by the vehicle side and SPaT information caused by changes of intersection locations and the number of paths due to road improvement works, etc.
DF_Central longitude and latitude		
DE_Longitude	bin(32)	Location longitude information. The geodesic is WGS84 (or its equivalent.) Positive values indicate east longitude, negative values indicate west longitude. If indefinite, set to -2147483648 (0x80000000). Unit is 0.0000001 degrees, range is -180 to 180.
DE_Latitude	bin(32)	Location latitude information. The geodesic is WGS84 or its equivalent. Positive values indicate north latitude, negative values indicate south longitude. If indefinite, set to -2147483648 (0x80000000). Unit is 0.0000001 degrees, range is -90 to 90.
Operation mode	bin(1)	0: Test 1: Operation
DE_Number of paths (I)	bin(7)	Number of paths (up to 8)
DF_Path angle information: I		
DF_Angle information by path	bin(8)	Represents absolute azimuth (in 1.5 degree increments: 0 to 239) with true north at 0 degrees.
. .		
DF_Path angle information: I		

14. Examination of the integrated delivery of information other than SPaT information (traffic regulation information, etc.)/Examination of linking SPaT information and high-precision three-dimensional maps

d, e

(NIPPON SIGNAL CO., LTD.

1. Summary of investigation results of the linking of high-precision three-dimensional maps (Examination point (2))

In the Tokyo Waterfront area FOTs, the linking of signal lights on the high-precision three-dimensional maps with SPaT information was realized by creating the association table (hereafter SPaT information association table) to link the maps with SPaT information. Therefore, the realization of the provision of SPaT information using high-precision three-dimensional maps is believed to be feasible by providing **intersection ID (including location identification) and paths**, which are defined by the SPaT information association table.

2. Proposed function placement (Examination point (3))

In the Tokyo Waterfront FOTs, the SPaT information association table was managed by the simulated OBU; however, when looking at social implementation, it is believed that, rather than the information managed by each service provider, this is the information that needs to be managed by the cooperative domain as is the case with dynamic maps.

<Proposed function placement>

Prefectural police (including National Police Agency)	Cooperative domain for SPaT information provision (SPaT Information Center, map vendors, etc.)	**Competitive domain (Vehicle manufacturers, automated driving operators, etc.)**
Provision of the following information • Intersection IDs to identify information and location information to identify locations on maps • Information to identify route IDs and locations on maps	• Management of the SPaT information association table to link SPaT information (intersection IDs, paths) with high-precision three dimensional maps (stop lines (routes), signal lights) • Linking of high-precision three dimensional maps and SPaT information	Provision of SPaT information to vehicles

FY2022 Field Operational Tests in Nara Prefecture

1. Overall picture of research and development for FY2022

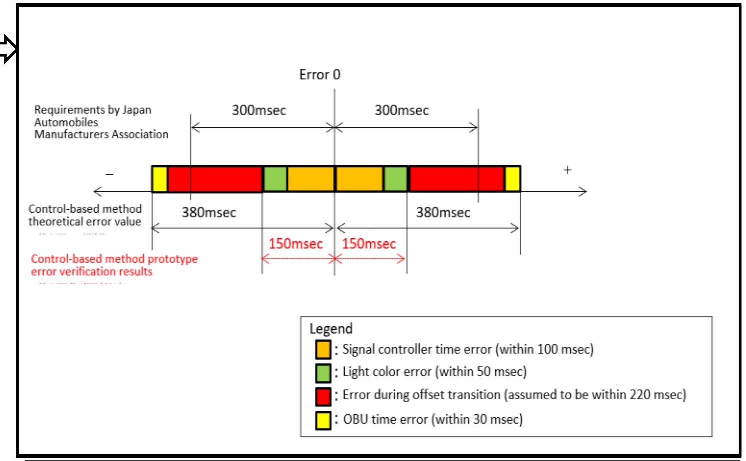
- Establishment of SPaT information provision environment for the practical application of automated driving
  - SPaT information generation environment
    - V2I method
      - Cleared JAMA requirements
      - Demonstrate that SPaT information at diverse types of intersections can be provided accurately and with a system that further reduces costs by using equipment in operation.
    - V2N method
      - Cleared JAMA requirements + reduced installation cost
      - Control-based method
        - Verification that the method can be established as a cost-advantageous method
        - Remaining issue: Examination for improvement of accuracy during offset transition
      - Centralized method
        - FOTs that the method can be established as a highly feasible method for intersections including those with special controls
      - Controller-based method
        - FOTs that the method can be established as a method to be introduced at intersections without centralized control
  - Demonstrate that the targeted performance can be achieved under MQTT, multi-center configuration, and under systems using LTE lines.
  - SPaT information delivery environment
    - SPaT information delivery unit
      - FOTs that the design of the SPaT information generation and delivery functions is valid
    - SPaT information aggregation system
      - FOTs that the design of the SPaT information aggregation and delivery functions is valid
    - SPaT Information Center
      - FOTs that the design is valid for basic functions such as receiving SPaT information and transmitting it to the delivery center.
    - SPaT Information Delivery Center
      - FOTs that the design of the overall system configuration for the provision of SPaT information, including this center, is valid
    - Communication line
      - Confirmation of methods for selecting lines that satisfy performance requirements and reduce costs

○: Goal achievement confirmed

2. Main technical goals

SPaT information generation

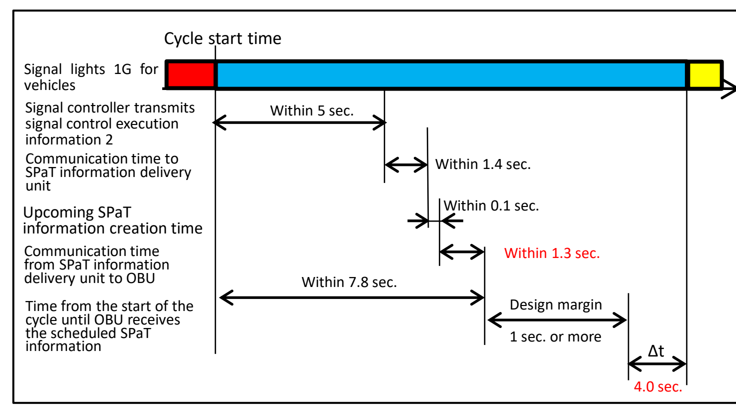
- SPaT information error within ±300 ms ○
  (1) Differences between signal light colors and SPaT information are within the specifications.
- Fail-safe functions: Failure detection ○
  (2) Functions such as light color signal monitoring and failure information monitoring are implemented.
- Eliminate the time periods when the provision is not possible. ○
  (3) There is no omission in the provision of SPaT information for a long period of time.
- Provision of pedestrian SPaT information ○
  (4) Information in provided correctly.
- Information linked to dynamic maps ○
  (5) Correct intersection management information is provided



Error analysis model for the control-based method

SPaT information delivery

- Delivery before Δt seconds for “gradual deceleration” ○
  (6) Ability to deliver information within 1.3 seconds (tentative target)
- Number of intersections whose SPaT information is provided ○
  (7) Functions and performance should be exhibited at 512 (the maximum number in one prefecture for the time being) x 3.
- Required equipment performance ○
  (8) Hardware specifications of the equipment must be valid.
- Communication line requirements ○
  (9) Ability to select line speeds that meet performance
  The target time for center-to-center communication (including internal processing) is 20 to 30 ms



Time chart of the centralized method

▭ indicates requested items from the Automobile Manufacturers Association.

3. Verification in the system at prefectural police (Theme 8)

(Organization in charge : OMRON Social Solutions Co., Ltd.)

3.1 Summary of verification results

Verification item	Verification results summary	Higher-level goals
Confirmation of time accuracy of traffic signal controllers	High time accuracy is a prerequisite for SPaT information. Verified to be in accordance with specifications.	(1) SPaT information error within ±300 ms
Confirmation of SPaT information accuracy after performance improvement	Confirmed that the goal has been achieved from video images and accumulated data	(2) Fail-safe function: Failure detection
Intersections with recall control	Confirmed that the goal has been achieved from accumulated data.	(3) Eliminate the time periods when the provision is not possible.
Confirmation of behavior during abnormal conditions	Implemented in the factory. Communication error and single operation occurred at the site.	(3) Eliminate the time periods when the provision is not possible.
Communication delay time measurement (confirmation of time chart)	Verified that the communication delay time is as designed. Confirmed the occurrence status of UD communication retransmission delay (+5 sec.).	(6) Delivery before Δt seconds for "gradual deceleration"
Relevance of standardizing communication interfaces	Operation has been confirmed with OBUs from three companies. Some differences between manufacturers were confirmed in the interpretation of standards.	
Confirmation of the accuracy of intersection definition information	Examined traffic regulation information (open data) across the country. Issues have been identified. Operation verification has been conducted with in-vehicle equipment.	(5) Information to be linked to dynamic maps
Confirmation of connection with SPaT information aggregation system	Confirmation completed. Using MQTT, the connection was easily verified and small delays were also identified.	(6) Delivery before Δt seconds for "gradual deceleration"
Operation confirmation for long-term operation of SPaT information provision	SPaT information provision was implemented at 111 intersections, including 17 intersections placed by the SIP. Confirmed operation for about 2 months.	(3) Eliminate the time periods when the provision is not possible.

3-2 Verification environment (Prefectural police model system)

Traffic signal controller **(Ver. 5)**(newly installed)
- Centralized control
- Control-based method

Characteristics of traffic signal controller (ver. 5)

- Accurate time synchronization by GPS (error less than 0.1 second)
- Improvement of information resolution (1 sec ⇒ 0.1 sec)
- Notification of recall requests (push-button-actuated, etc.) to the control center

Traffic signal controller (**Ver. 5** Centralized method) (newly installed)
- Centralized control
- Centralized method

SPaT information delivery unit (newly installed)

Characteristics of SPaT information delivery unit
- Generates upcoming SPaT information with the control-based method
- Accumulates, delivers and monitors SPaT information generated with the three methods

In the NPA
- Aggregation system (newly installed)
- Simulated SPaT Information Center (newly installed)
- Simulated SPaT Information Delivery Center (newly installed)
- Carrier network LTE router (newly installed

Simulated OBU (newly installed)
- LTE connection
- GNSS

Traffic signal controller (Already existing)

Local control

SPaT information roadside unit (newly installed)
- Controller-based method
- LTE connection

Characteristics of SPaT information roadside unit

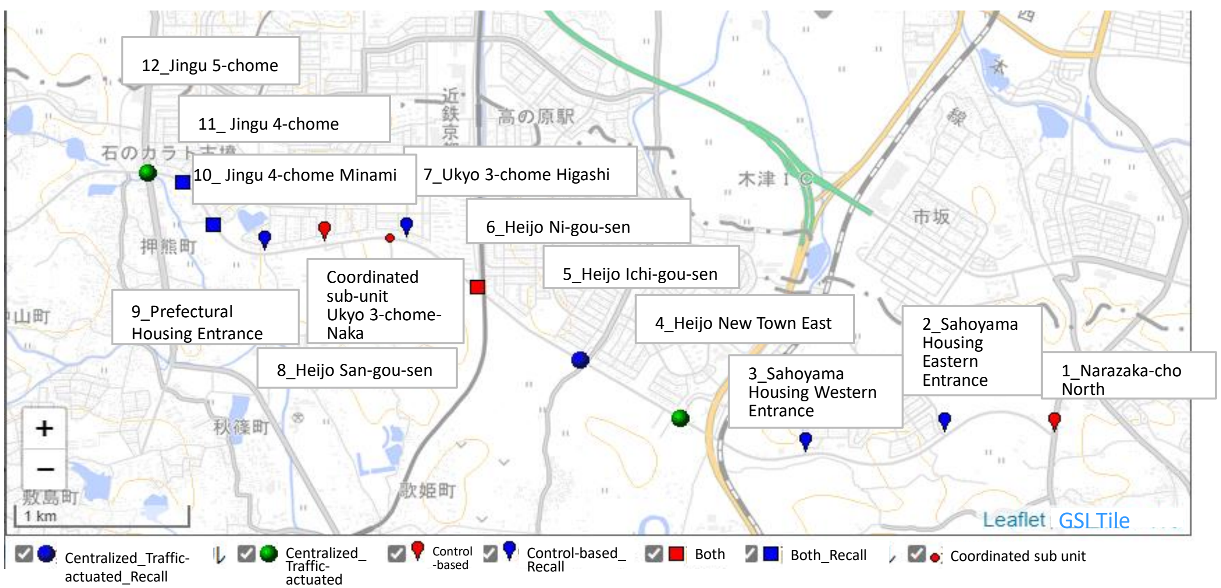
- Can be connected to signal controllers of all manufacturers
- Connected by light color signal and CT sensor

3-3 Verification environment (intersections for verification)

- Centralized intersections are in a 6 km section of Narayama Main Street near Nara University.
- Verification during recall control, right-turn actuated control, and nighttime flashing was conducted for the first time in the actual field as V2N. Verification of the accuracy during offset transition, which is an issue, was conducted for all methods.
- For intersection locations, open data traffic regulation information was used to the extent possible.

	Number of intersections	Recall control (push-button-actuated, etc.)	Right-turn actuated control	Coordinated control (Offset)	Nighttime flashing	Location information available in traffic regulation information
Control-based method	9 Note)	6	0	9	0	6
Centralized method	6 Note)	3	3	6	0	4
Controller-based method	5	1	0	4	4	0

Note) Both the control-based method and centralized method were implemented at the three intersections.



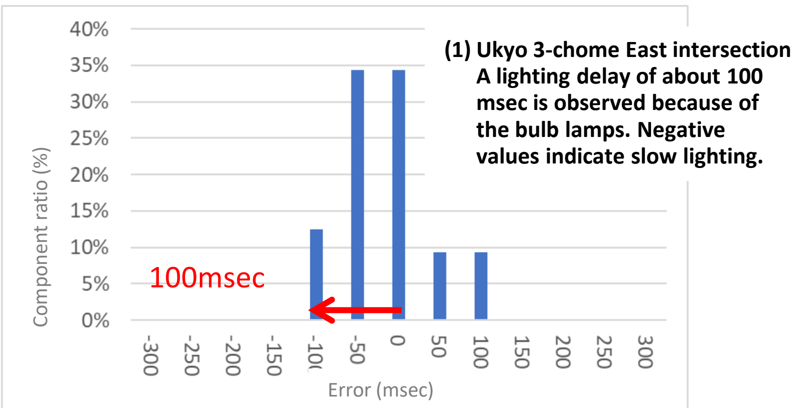
Source: The website of Saitama University (Map from the Geospatial Information Authority of Japan is used). Non-centralized intersections (with the controller-based method) are not shown.

3-4 Verification results on the control-based method (1)

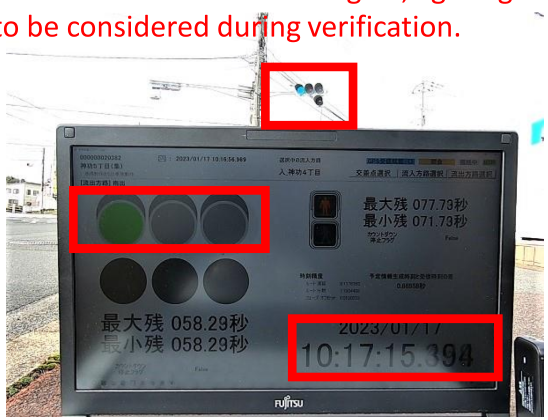
(1) SPaT information error within ±300 ms

(1) Confirmed that errors in **the data accumulated (in 0.1 second increments) in the traffic signal controller (ver. 5) in the control center and errors of signal light colors** are within the specification.
(2) Compared **the SPaT information of the simulated on-board unit with signal light colors**. Confirmed that errors are within the specification.

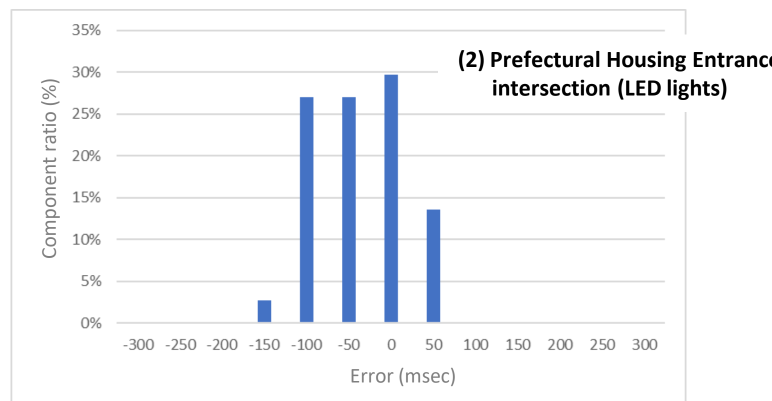
Verification item	Results	Description
(1) Time accuracy of traffic signal controller	○	Error: -100 to +200 msec (Confirmation by video) Will be reconfirmed by the clock in the controller because there are measurement errors.
(2) SPaT information accuracy	○	Error: -150 to +100 msec (Confirmation by video)



At intersections with bulb lights, lighting delays need to be considered during verification.



Videotaping scene

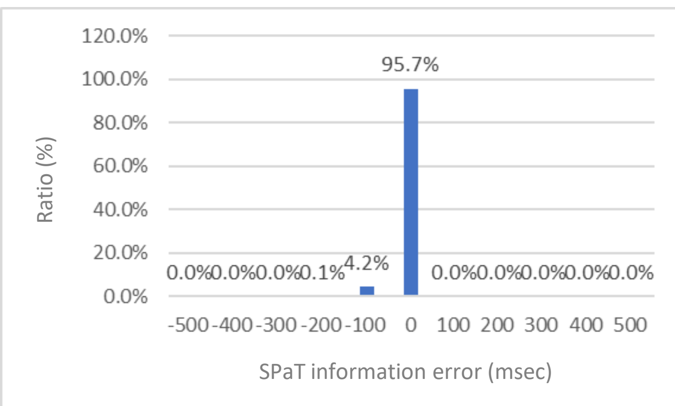


3-5 Verification results on the control-based method (2)

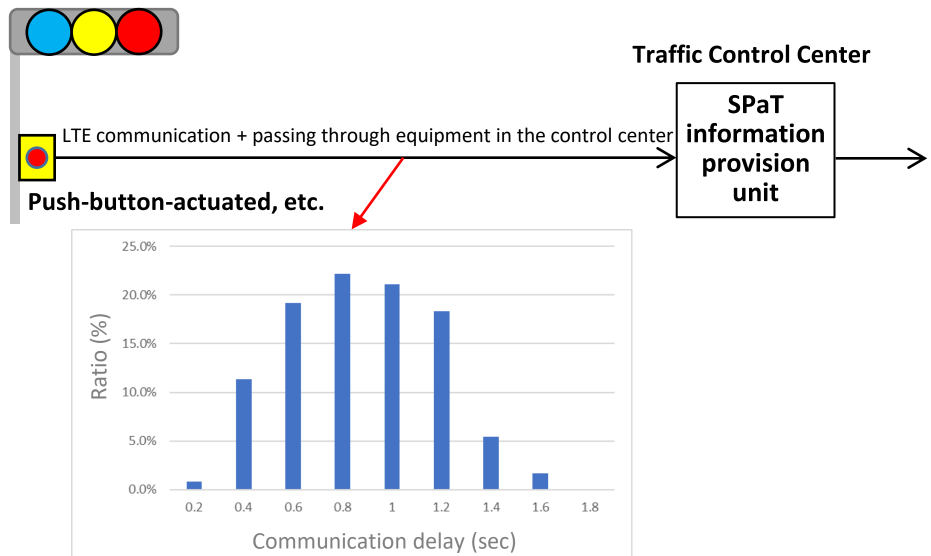
(1) SPaT information error within ±300 ms

(3) Eliminate the time periods when the provision is not possible.

Verification item	Results	Description
(1) SPaT information accuracy (Verified: 6 intersections)	○	Error: -200 to +200 msec (Confirmed by accumulated data)
(2) Provision of SPaT information of intersection with recall control (Verified: 1 intersection)	○	Confirmed by presence/absence of recall request in all timings Provision within 1.6 sec after recall request (push-button, etc.)
(3) Measurement of communication delay time	○	Signal controller to SPaT information delivery unit 0.2 sec to 1.6 sec (Average 0.82 sec) – As designed However, the result was 6.3 sec during re-transmission.



(1) Signal error distribution at Narazaka-cho North intersection on January 25.
The + direction indicates that the SPaT information changes slower than it actually does



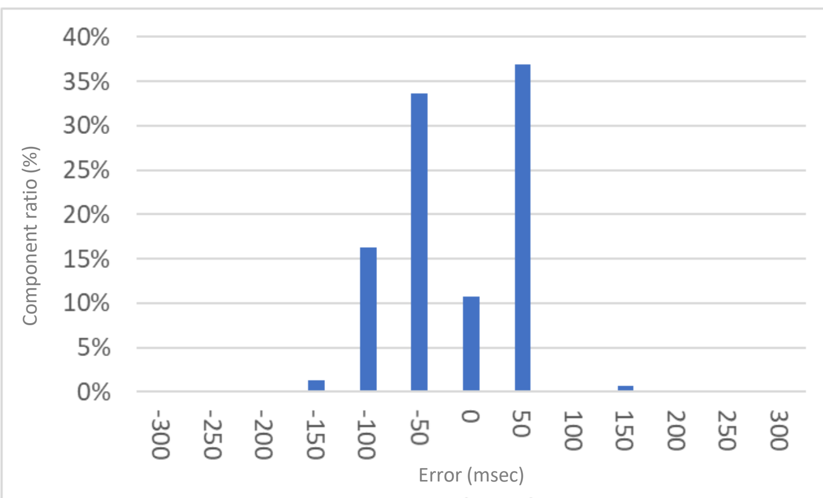
(3) Communication delay measurement result
(At Sahoyama Residence Eastern Entrance intersection on January 13)

3-6 Verification results on the controller-based method

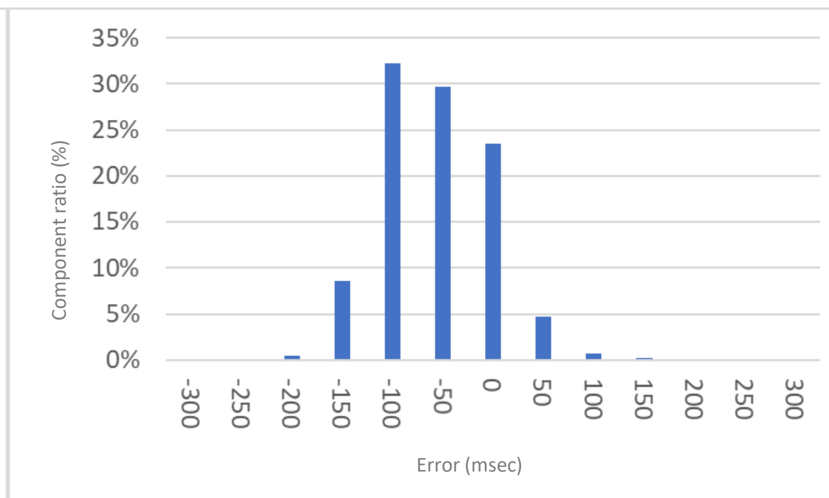
(1) SPaT information error within ±300 ms

- Confirmed that the communication standards are met and that errors are within specifications.

Verification item	Results	Description
(1) SPaT information accuracy	○	Error: -200 to +200 msec (Confirmed by accumulated data)
(2) Provision of pedestrian SPaT information	○	Confirmed the provision with the simulated OBU.



(1) Jingu 4-chome East intersection (pre-timed control)
5:00 - 24:00



(1) Ukyo 3-chome East intersection (Coordinated control)
6:00 - 22:00

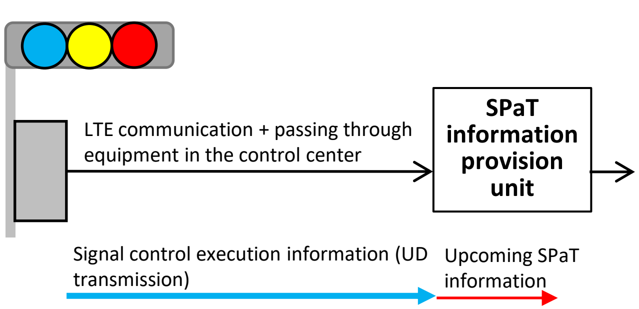
3-7 Verification of the time chart up to signal information generation

(6) Delivery before Δt seconds for "gradual deceleration"

- Confirmed that **the time chart is as designed.**
- **Communication delay (+5 seconds) at the time of communication retransmission** in the UD communication section is difficult to avoid and **needs to be considered in the overall anomaly system design**.

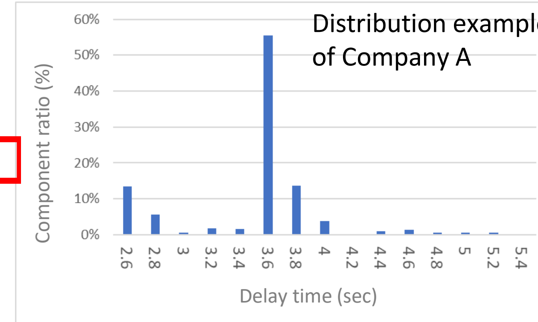
Control-based method

Traffic Control Center

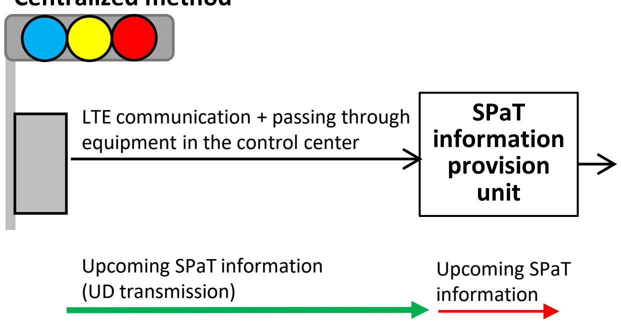


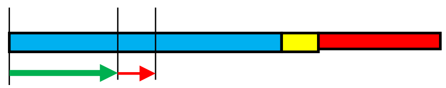
Company A: Ave. of 3.6 sec, max. of 5.6 sec.
Company B: Ave. of 1.0 sec, max. of 6.7 sec.

Information creation delay for signal controllers is allowed up to 5 seconds and is in accordance with specifications.



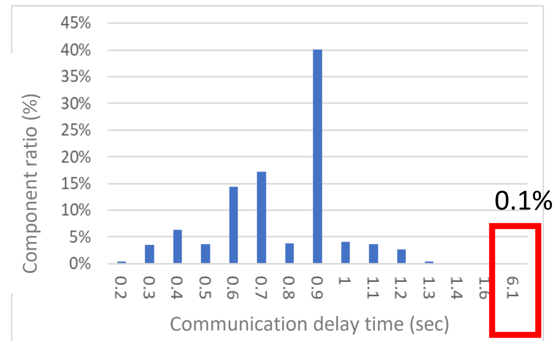
Centralized method



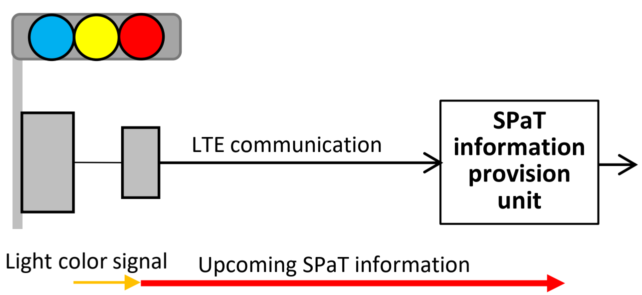


Company B: Ave. of 1.0 sec, max. of 6.7 sec.

It is around 1 sec and as designed.
Retransmission of communication about once a day causes a +5 sec delay.

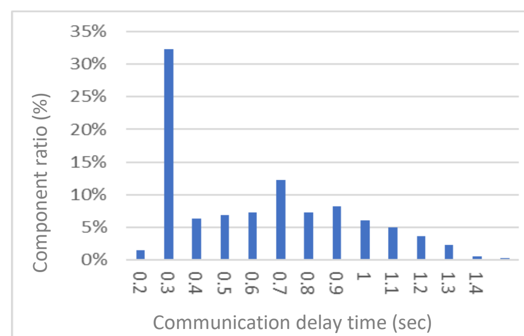


Controller-based method



Company A: Ave. 0.6 sec, max. of 1.6 sec.

Estimated to be the actual performance value of general LTE communication. Bias in some time periods is due to communication timing.



→ Processing time for the thin line section is less than 10 msec.

→ Processing time for the thin line section is less than 200 msec.

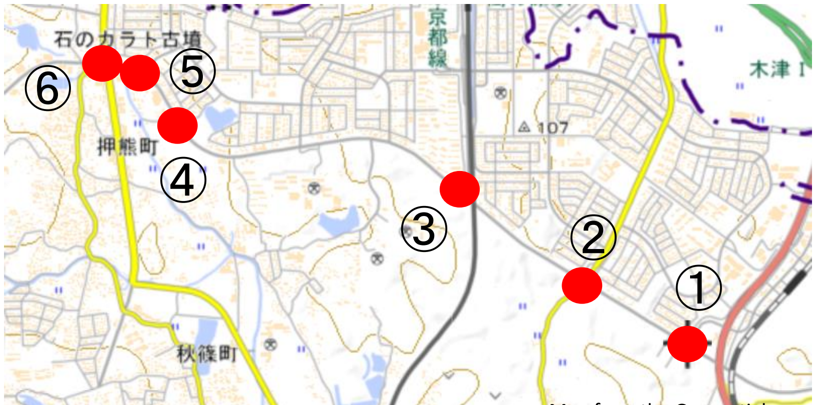
4. Verification in the system at prefectural police (Theme 7)

(Organization in charge: NIPPON SIGNAL CO., LTD.)

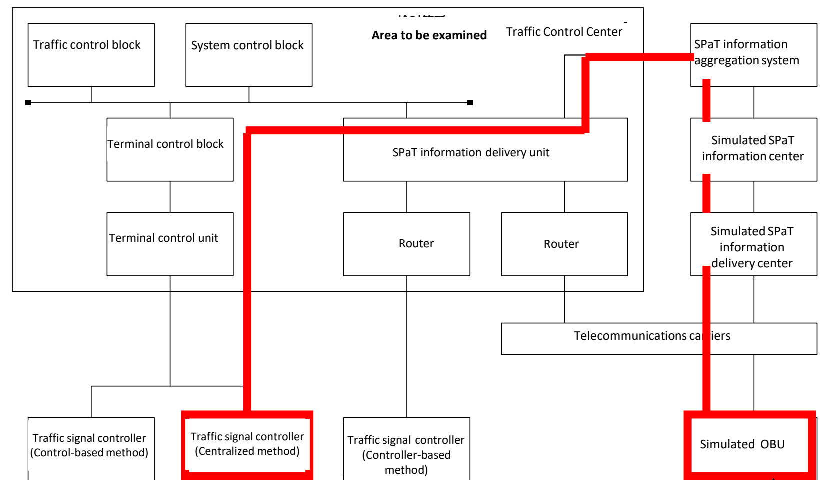
4-1 Summary of verification results

Verification item	Verification results summary	Higher-level goals
Confirmation of time accuracy the centralized method	Confirmed by video image that the goal has been achieved. Confirmation being continued.	(1) SPaT information error within ±300 ms
Confirmation of transmission delay of the centralized system	Analyzed and verified the accumulated data of the simulated OBU and confirmed that the goal has been achieved.	(6) Delivery before Δt seconds for "gradual deceleration"
Confirmation of intersections that use the centralized method and provide recall control	The goal is expected to be achieved after confirming the accuracy of SPaT information and transmission delay of the centralized system.	(6) Delivery before Δt seconds for "gradual deceleration"
Confirmation of SPaT information common message standard	It has been confirmed that information can be transmitted using a common standard for the control-based system, centralized system, and controller-based system, and can be received by the individual simulated on-board units of the three companies. The draft standard is under review due to some differences in interpretation.	

4-2 Intersections where the centralized method were implemented and the installation of equipment



Map from the Geospatial Information Authority of Japan



1) Completed installation of controllers at each intersection.
2) Confirmed the provision of SPaT information from the controller. Confirmed the reception of SPaT information by the simulated OBU.

No.	ID	Intersection name	Additional function	Installation work	SPaT information delivery using simulated OBU
①	20297	Heijo New Town East	Gap responsive	Completed	Completed
②	20298	Heijo Ichi-gou-sen	Recall 1, Gap responsive	Completed	Completed
③	20299	Heijo Ni-gou-sen		Completed	Completed
④	300384	Jingu 4-chome Minami	Recall 1	Completed	Completed
⑤	300375	Jingu 4-chome	Recall 1	Completed	Completed
⑥	20382	Jingu 5-chome	Gap responsive, coordinating base unit	Completed	Completed

4-3 Evaluation method for the intersections where the centralized method was implemented

Item	Evaluation item
Error	Difference between the lighting status of signal lights and the lighting status recognized by a car
Transmission delay	Time difference from when signal information is generated to when it is received by a car

(1) SPaT information error within ±300 ms

(6) Delivery before Δt seconds for "gradual deceleration"

<Measurement of errors>

Comparison

A video is taken in such a way that the vehicle lights and the simulated on-board unit's screen are placed in the same angle of view.
The time difference of signal switching between the simulated OBU and the vehicle signal lights is measured at the timing of signal change.

<Measurement of transmission delay>

/signal/29/20297,2023/01/10 18:04:08.039,301,1D 00 00 00 00 4F 49 00 00 01 01 00 00 01 CB 20 23 01
10 18 04 06 90 01 04 03 02 03 03 01 80 40 00 7B 00 7B 00 7B 00 EF 01 0E FF FF 02 80 FF 00 A6 00 A6 00
A6 01 0E FF FF 01 0E 03 80 FF 00 4A 00 4A 00 4A FF FF 00 EF 01 0E 18 01 00 01 F3 01 F3 02 00 00 1E 00 1E
03 00 00 94 00 94 03 40 01 CB 01 CB 01 00 00 B4 09 60 02 00 00 0A 00 50 03 00 00 32 05 28 03 40 00 8C
09 60 27 03 40 02 A5 02 A5 01 00 01 8F 01 8F 02 40 00 1E 00 1E 03 40 01 0E 09 60 01 00 00 78 08 C0 02
40 00 0A 00 50 03 40 00 0A 00 50 3C 01 00 01 F3 01 F3 02 10 00 1E 00 1E 03 10 00 1E 00 1E 03 14 00 26
00 26 02 00 00 1E 00 1E 03 00 01 FD 01 FD 01 00 00 B4 09 60 02 10 00 0A 00 50 03 10 00 0A 00 50 03 14
00 14 04 38 02 00 00 0A 00 50 03 00 00 96 09 60 16 01 01 8E 01 8E 02 00 3C 00 3C 03 02 A6 02 A6 01 00
A0 08 70 02 00 0A 00 50 03 00 D2 09 60 26 03 02 A5 02 A5 01 00 F0 00 F0 02 00 3C 00 3C 03 01 8F 09 60
01 00 64 04 38 02 00 0A 00 50

Log data of the simulated OBU

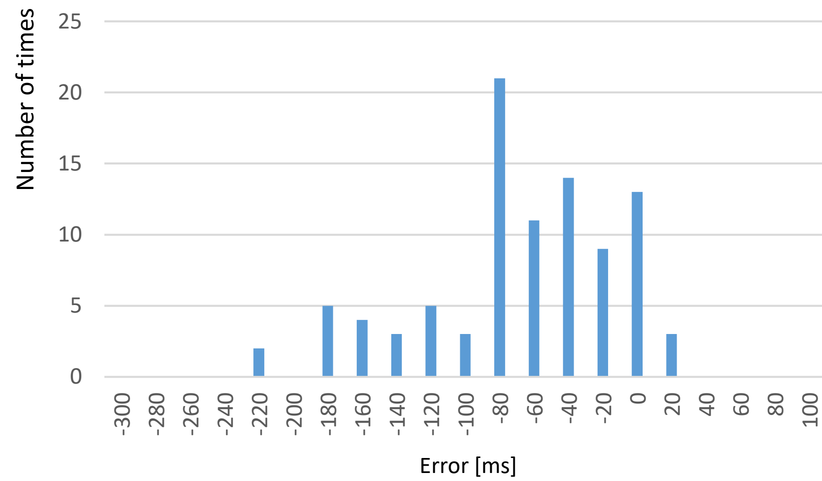
The log data of the simulated OBU is analyzed and calculated.
The difference between the information creation time in the SPaT information and the time received by the simulated OBU is calculated.

4-4 Measurement results at intersections where the centralized method was implemented

(1) SPaT information error within ±300 ms

<Measurement of errors>

Item	Measurement results
Average value	-77 ms
Minimum value (with absolute value evaluation)	0 ms
Maximum value (with absolute value evaluation)	-233 ms
Standard deviation	58 ms



Results were obtained that were within the target value of ±300 ms.

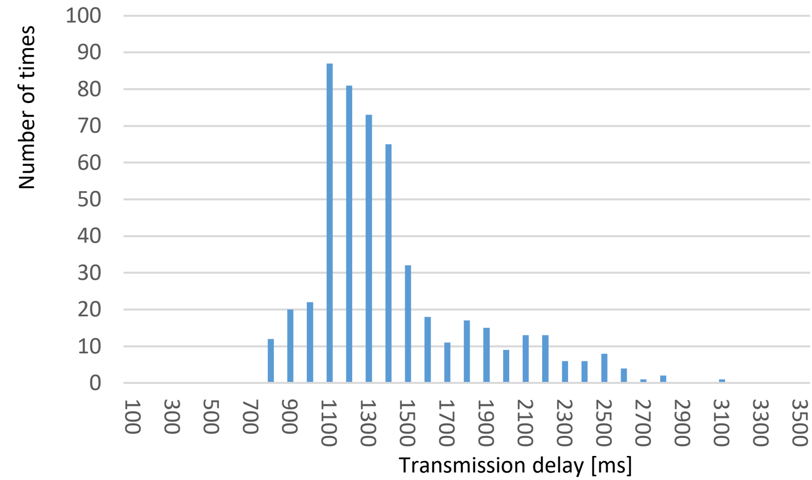
1) Calculation formula
Error = (Light color change time of the simulated OBU) – (Signal light color change time)
If the vehicle's light color changes faster, the value will be on the negative side.
2) As previously described, the color change of the simulated OBU and the signal lights were videotaped together, and the time difference between each change was measured.
3) The signal lights evaluated are of the bulb type and require time to light up.
This caused a delay of about 100 ms observed in the video confirmation.
As a result, the time of light color change became slower (larger in numerical value) and was biased toward the minus side.
Considering the lighting delay of the signal lights, the target value of ±300 ms is satisfied even if the overall time is shifted to the positive side by about 100 ms.

4-5 Measurement results at intersections where the centralized method was implemented

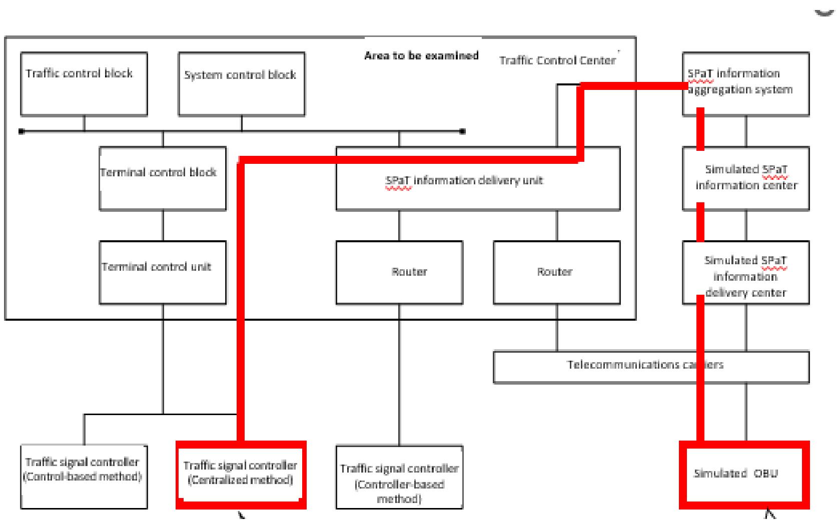
(6) Delivery before Δt seconds for "gradual deceleration"

<Measurement of transmission delay>

Item	Measurement results
Average value	1357 ms
Minimum value	710 ms
Maximum value	3042 ms
Standard deviation	406 ms



Transmission delay = (Reception time by the simulated OBU) – (SPaT information creation time)



Based on the results with an average value of 1357 ms and a standard deviation of 406 ms, the information by and large reached the vehicle with a transmission delay of within 2 seconds.

The results are equivalent to those of the on-premises tests conducted in FY 2021. This means that, as in the on-premises test, the effect of using PTSDS (Police Traffic Safety Device Specifications) No. 1012 Ver. 5 and adopting MVNO for the line was also obtained in the actual field.

<Reference (results of the on-premise tests for FY2021)

Average value	:	1765 ms
Minimum value	:	780 ms
Maximum value	:	3020 ms
Standard deviation	:	522 ms

5. Verification after connecting the prefectural system to the National Police Agency's SPaT Information Aggregation System (Theme 6)

5-1 Summary of verification results

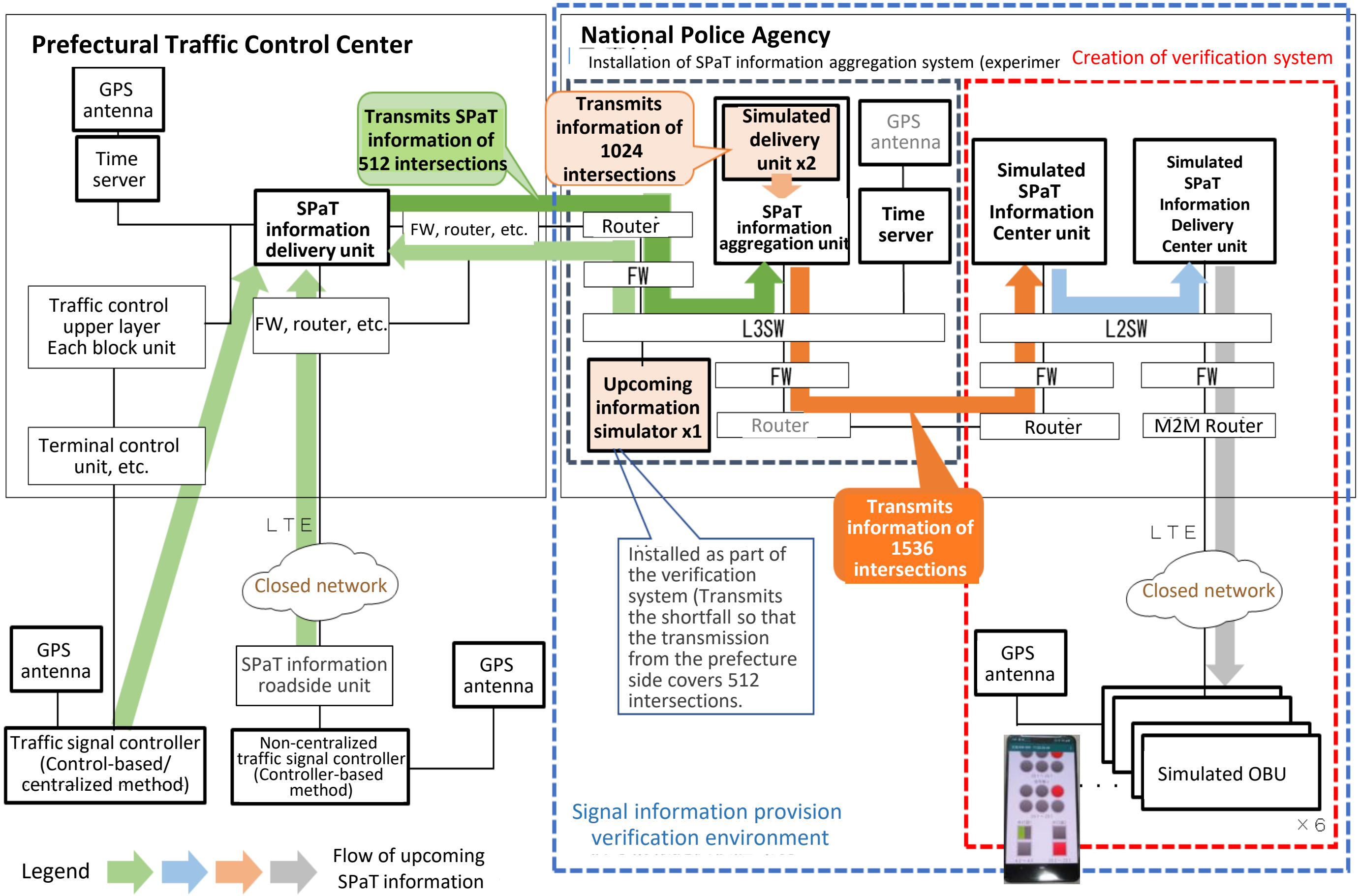
（Organization in charge : Panasonic Connect Co., Ltd.）

Verification item	Verification details and results	Applicable items
Time synchronization operation	Confirmed time accuracy of signal information aggregation equipment and verification-related equipment	System configuration verification
Security operation verification	Implemented server and client authentication over the MQTTS protocol and confirmed transfer and delivery of upcoming SPaT information. TLS1.2 and TLS1.3 interconnection was also confirmed.	
Basic function verification	Completed verification of the validity of the hardware environment and software functions prepared for the system verification	Load verification (7) Number of intersections providing information (8) Required equipment performance
Verification of delay time	Implemented measurement and verification of the transfer delay between each equipment, i.e., the signal information aggregation unit ⇒ units of each center to be verified ⇒ simulated OBU and confirmed the targeted performance (delay time within 1.3 seconds).	(6) Delivery before Δ t seconds for "gradual deceleration"
Verification of conformance to standards	For the degree of conformance to the interface standards for upcoming SPaT information (dynamic), data collection has been completed for the inspection of conformance to data specification standards and for the number of violations (to be continued to improve the accuracy).	Positioning of "(2) Fail-safe functions: Failure detection" in a broad sense
Availability rate of upcoming SPaT information	Completed measurement of simulated OBU available time (time during which the upcoming SPaT information was valid (hereinafter referred to as "upcoming information available time")	(3) Verification of the time periods when the provision is not possible.
Network bandwidth verification	Between the aggregation unit and the centers to be verified: Completed the verification of bandwidths 1Mbps, 2Mbps, and 10Mbps for shaping. Identified a conclusion that the network bandwidth under maximum load is 2 Mbps.	(9) Communication line requirements
Verification of operation under abnormal conditions	Will confirm the behavior of the entire system in the event of a failure that is assumed to occur as a system. In particular, will confirm the behavior of the system to notify abnormality information by center-to-center failure information and promptly invalidate the signal schedule information. (Verification to be continued)	Load verification (7) Number of intersections providing information (8) Required equipment performance Positioning of "(2) Fail-safe functions: Failure detection" in a broad sense

5-2

Summary of the verification results from (6) to (9)

Results of the verification system



Aggregation unit specification

- Up to 512 intersections in 1 prefecture
- Up to 3 prefectures supported the specification
- Verification conducted at 1536 intersections

Prefecture <–> National Police Agency: 20Mbps
Within National Police Agency: 20Mbps to 100Mbps
LTE: 10Mbps (at best effort)

[Results]

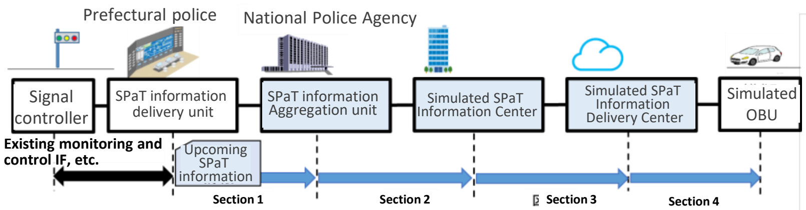
- **Completed the creation of a system that collectively manages and delivers SPaT information from all over the country, using equipment installed on the prefectural side and on the National Police Agency side, and equipment of the simulated centers onthe verifying side.**
- **Completed the confirmation of performance, such as delay time, during normal operation and maximum scale operation (the system was operated with no significant difference)**
- **Completed system specification determination (NW bandwidth, CPU utilization, and DB capacity) through the verification**
- **Completed various types of verification for practical application**

5-3 Cumulative delay and frequency

(6) Delivery before Δt seconds for “gradual deceleration”

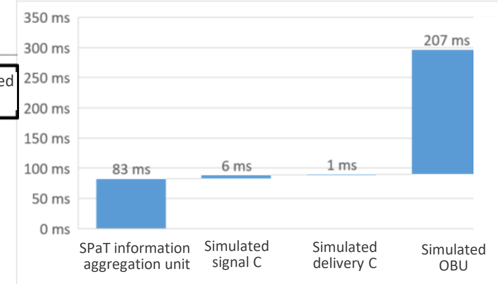
• The cumulative delay to the simulated OBU was **generally within 1400 ms,** which was the expected delay second.

Control-based method (for 8 days)

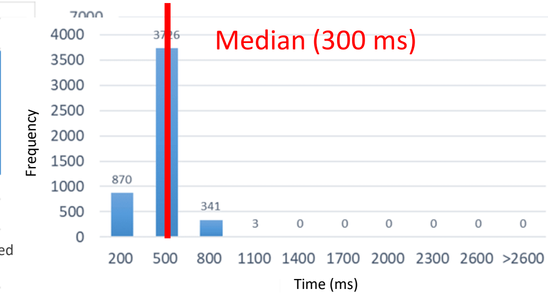


Communication delay to OBU Median: 300 ms
Delay is mainly in the LTE section from the centers to OBU.
Delay variation is small.

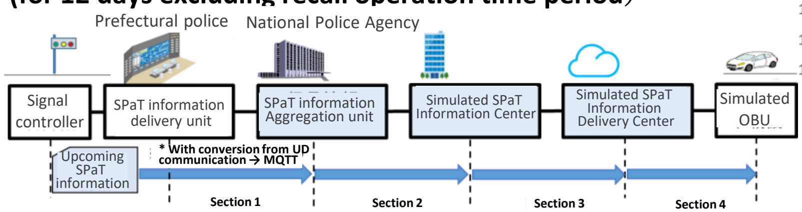
Sectional distribution of delay time



Cumulative delay distribution



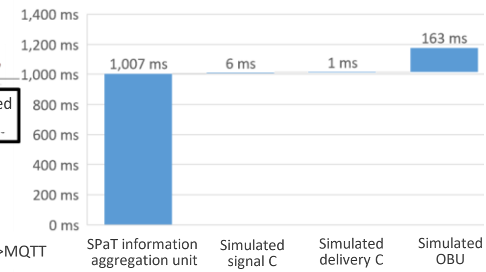
Centralized method (for 12 days excluding recall operation time period)



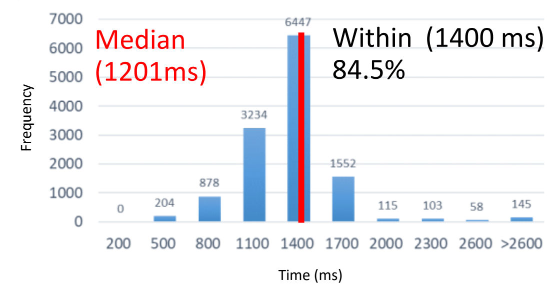
Communication delay to OBU Median: 1201ms
Delay is in the LTE section on the way to the prefecture.
Accounts for the variability of the overall delay.

*UD communication =>MQTT

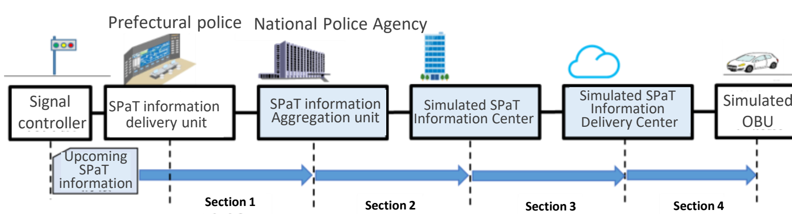
Sectional distribution of delay time



Cumulative delay distribution

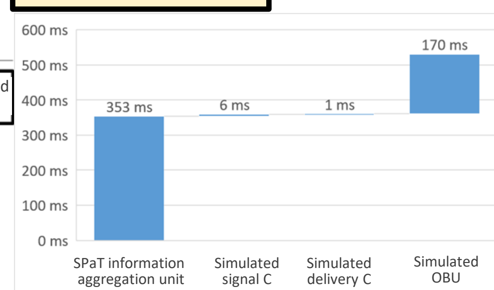


Controller-based method (for 3 days)



Communication delay to OBE Median: 1039 ms
Delay is in the LTE section on the way to the prefecture.

Reference results



* There may be a large amount of data of small packet size with invalid system state because tuning is in progress.

Control-based method	3 intersections	For a total of 8 days	Upcoming SPaT information: Acquired 7489 data (No responsive, no recall)
Centralized method	4 intersections	For a total of 12 days	Upcoming SPaT information: Acquired 12736 (excluding recall operation time periods from 22:00 to 06:00)
Controller-based method	1 intersection	For a total of 3 days	Upcoming SPaT information: Acquired 4398 samples (excluding the OBU section)

5-4 [CPU utilization and database usage]

Load verification
(7) Number of intersections providing information
(8) Required equipment performance

■CPU utilization (70% or less at maximum load (in the previous report))

Unit name	CPU	Remarks
SPaT information aggregation unit	Intel® Xeon® E-2388G Processor 3.2 GHz 8 cores	The unit consists of two units with a data base server unit in addition to the main unit that handles data transfer.
Simulated SPaT Information Center Simulated SPaT Information Delivery Center	Intel Xeon® Silver 4208 Processor 2.1 GHz 8 cores Storage: HDD 1.2TB 16 GB memory	

[Preliminary values] During operation at 52 intersections (5-day average as of January)

	Average utilization	Maximum utilization
SPaT information aggregation unit	0.56(%)	46.49(%)
Simulated SPaT Information Center	0.61(%)	2.61(%)
Simulated SPaT Information Delivery Center	0.62(%)	3.18(%)

[Preliminary values] Under load conditions (As of December)

	Average utilization	Maximum utilization
SPaT information aggregation unit	0.76(%)	40.15(%)
Simulated SPaT Information Center	1.60(%)	9.00(%)
Simulated SPaT Information Delivery Center	1.47(%)	7.81(%)

⇨ Even considering the maximum scale, operation is possible if a CPU with the listed specifications is implemented.

■DB usage (50% or less at maximum load (in the previous report))

[Preliminary values] During operation at 52 intersections (5-day average as of January)

	Load for 3 hours increase	Load for 1 day increase
SPaT information aggregation unit	6,300 (KB)	50,398 (KB)
Simulated SPaT Information Center	3,240 (KB)	26,033 (KB)

[Preliminary values] Under load conditions (As of December)

	Load for 3 hours increase	Load for 1 day increase
SPaT information aggregation unit	800,611 (KB)	6,404,884 (KB)
Simulated SPaT Information Center	517,268 (KB)	4,138,140 (KB)

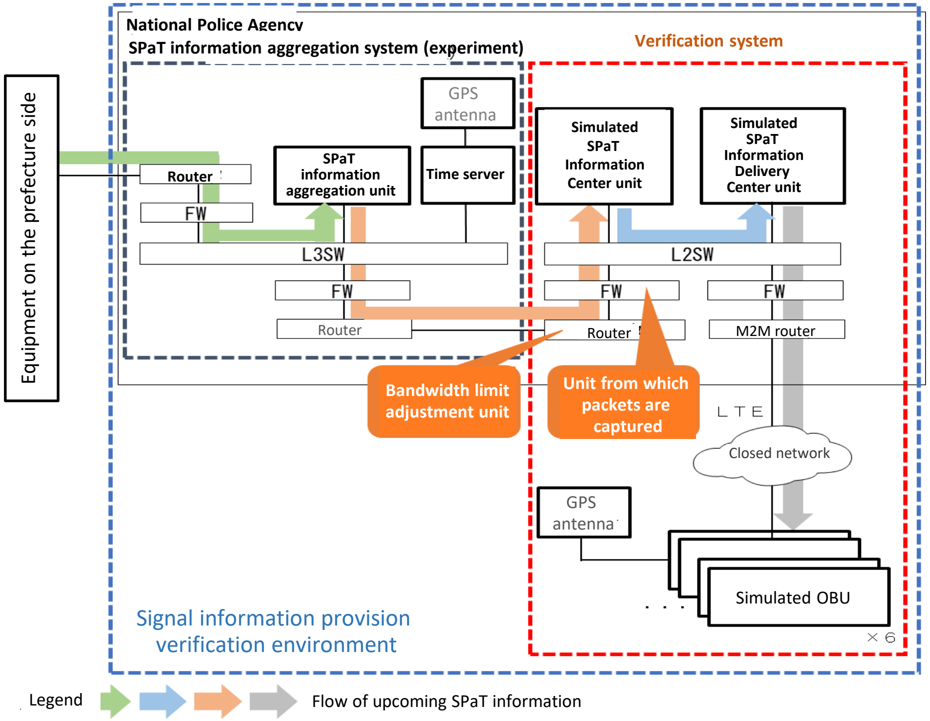
⇨ Given the large discrepancy between the required scale and the maximum scale, it is preferable to determine the scale of implementation in line with information provision plans of intersections.

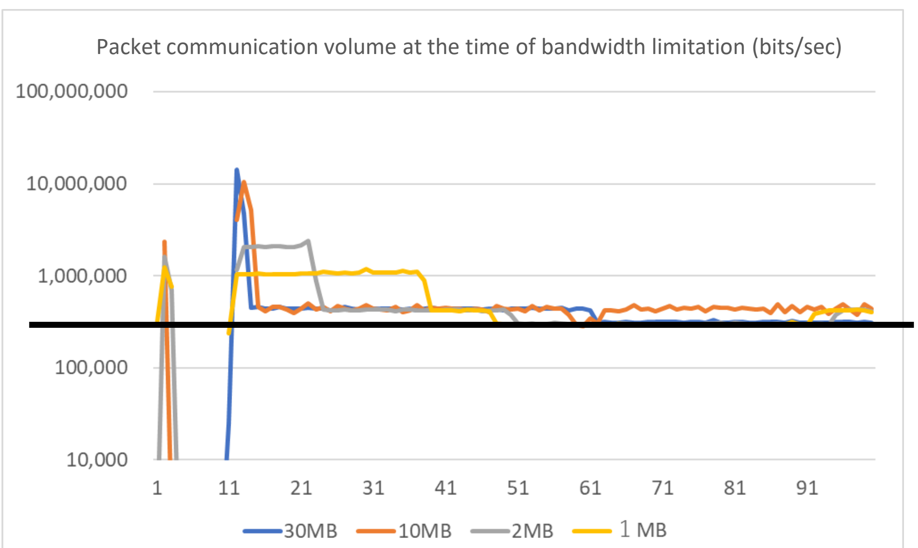
Estimated values for SPaT information aggregation unit (10-day accumulation)
Normal times: Requires 0.55 GB Maximum times (for 1536 intersections) : Requires 70.4 GB

Estimated values for SPaT Information Center (31-day accumulation)
Normal times: Requires 0.33GB Maximum times (for 1536 intersections) : Requires 134.0 GB
(365 day accumulation)
Normal times: Requires 10.98 GB Maximum times (for 1536 intersections) : Requires 1.54 TB

5-5 Verification of network bandwidth throttling

(9) Communication line requirements





Bandwidth of router	Remarks
30Mbps	
10Mbps	Setting at the time of verification
2Mbps	Communication capacity about 4 times that during operation under load
1Mbps	Communication capacity is about 4 times that during operation under load Communication capacity is about twice as that during operation under load

Measurement conditions **1424 intersections Data size 1429byte (Maximum)**
52 intersections are from prefectural data (300 to 400 byte)
In steady state 500kbps

Obtaining information at the time of reconnection when bandwidth limitation is applied to upcoming SPaT information.
Delay of the first upcoming SPaT information is shown on the left.
0.5 sec delay in the case of 10 Mbps
7.6 sec delay in the case of 2 Mbps
20.5 sec delay in the case of 1 Mbps

Considering operation, it is desirable to provide an allowable range for connection and reconnection between centers.

In this verification, approximately 2 Mbps or more seems to be required, taking into account large delays at the time of connection.

5-6 Availability rate (Control-based method)

(3) Eliminate the time periods when the provision is not possible.

- **Control-based method availability rate per intersection**

Key indicators	Provision method	Control-based method	Control-based method	Control-based method
	Control type	Recall: No Responsive: No	Recall: No Responsive: No	Recall: No Responsive: No
	Intersection name	Heijo Ni-gou-sen	Narazakacho Kita	Jingu 4-chome
	ID	400379	20302	400375
	Implementation period	01/20 10:16 ～ 01/23 10:36 * Excluding Jan. 21	01/23 11:30 ～ 01/26 11:47	01/31 12:01 ～ 02/03 12:07 * Excluding each maintenance period
	Scheduled provision period	175,019 sec	260,259 sec	237,679 sec
	Non-provision period	5,658 sec	494 sec	3,311 sec
	Number of information transmissions	2,434 times	2,361 times	2,541 times
	Availability rate	**96.767 %**	**99.810 %**	**98.607 %**
	Average provision period (≒MTBF)	24,194 sec	129,883 sec	18,301 sec
	Average non-provision period (≒MTTR)	943 sec	494 sec	256 sec

- **Control-based method 98.59%**
  - **In the case of non-provision due to invalid system state, the duration of non-provision takes about 5-15 minutes:**
    Heijo Ni-gou-sen: 6 times, Narazakacho Kita: 1 time, Jingu 4-chome: 4 times, accounting 99.8% or more of the overall non-provision periods.
  - **Cases where the information provision period is simply lost occurred 9 times at Jingu 4-chome for a total of 23 seconds, accounting for 0.2% or more of the total.**

    ⇒There is a possibility of reducing the number of non-provision periods by changing the invalidity judgment logic in the SPaT information delivery unit, etc.

5-6 Availability rate (Centralized method)

(3) Eliminate the time periods when the provision is not possible.

- **Centralized method availability rate per intersection**

Key indicators	Provision method	Centralized method	Centralized method	Centralized method	Centralized method
	Control type	Recall: No Responsive: No	Recall: No Responsive: **Yes**	Recall: No Responsive: **Yes**	Recall: No Responsive: No
	Intersection name	Heijo Ni-gou-sen	Heijo Ichi-gou-sen	Jingu 5-chome	Jingu 4-chome
	ID	20299	20298	20382	300375
	Implementation period	01/20 10:16 ～ 01/23 10:36	01/23 11:30 ～ 01/26 11:46 * Excluding recall time periods	01/27 11:10 ～ 01/30 12:01	01/26 12:01 ～ 01/30 12:01
	Scheduled provision period	260,368 sec	173,984 sec	264,066 sec	345,651 sec
	Non-provision period	0 sec	0 sec	0 sec	739 sec
	Number of information transmissions	2,434 times	3,028 times	4,392 times	2,879 times
	Availability rate	**100.000 %**	**100.000 %**	**100.000 %**	**99.786 %**
	Average provision period (≒MTBF)	260,368 sec	43,496 sec	262,274 sec	114,952 sec
	Average non-provision period (≒MTTR)	0 sec	0 sec	0 sec	370 sec

- **Centralized method Availability rate 99.9%**

Excluded due to issues regarding the method of providing information during the recall time period.

3 intersections: Availability rate: 100%.

Total period of provision: 289 hours 18 minutes

6 . Summary of results and issues related to this research and development

6-1 Summary of Results

(1) Technology for signal Information Generation

Although there are still issues to be addressed with each of the three methods (control center method, centralized method and controller-based method) under consideration, we have achieved a certain degree of success in our initial goal of satisfying the requirements (accuracy error of scheduled signal information within ±300 msec, ability to provide scheduled signal information by the time it is safe to stop, and a function to check the consistency between signal light colors and delivered information) of the Japan Automobile Manufacturers Association (JAMA) for signal information provision.

(2) Technology for distributing signal information

Among the delivery routes to the automatic vehicle (in-vehicle equipment), we studied the system up to the signal information center, which is a non-competitive area.

The performance verification of the entire system from the signal controller to the in-vehicle equipment was conducted in a simulated environment.

【System configuration】

The system configuration was verified to be capable of distributing information on traffic signals in Nara Prefecture to Tokyo.

【Functional Assignment】

Verified that the expected functional allocation between the signal information aggregation system and the distribution center can be implemented.

6-2 Challenges

To date, the following issues have been identified

- Standardization of specifications, standards and technical knowledge and know-how created in the SIP project
- How to apply the three V2N methods and the V2I method according to use cases
- Specify specifications according to the level required for social implementation, taking into account the fact that V2N is inferior to V2I in terms of fail-safe functions, etc.
- Establishment of a mechanism to periodically verify the correctness of signal information to be distributed, and clarification of the boundary of responsibility among prefectural police, National Police Agency, signal information centers, and distribution centers.
- Organize the concept of generating scheduled signal information, which differs among signal manufacturers (guidelines for preparation are needed).

6-3 Future Outlook

✓ In the future, the Working Group on Automated Driving Infrastructure established within the UTMS Association will continue to study these issues. The results of the study within the working group will be returned to the committee members of this project.

✓ In addition, we would like to promote comprehensive studies including the in-vehicle equipment side, which is an area of competition, in cooperation with the Japan Automobile Manufacturers Association and other external organizations.

Reference materials
(prepared by each company)

Supplementary materials

(Organization in charge: Panasonic Connect Co., Ltd.)

[1]Margin Number of seconds for the first signal phase

Material that calculated the number of seconds of leeway for the first signal phase to achieve the goal of before Δt seconds for “gradual deceleration”

[2]Detail of conformance verification

Material that compiled the data showing the number of items to be checked in the data structure of the upcoming SPaT information at the Signal Information Center and the cumulative number of items that have been checked.

[3] Packet retransmission rate verification

Material outlining the policy on data retransmission

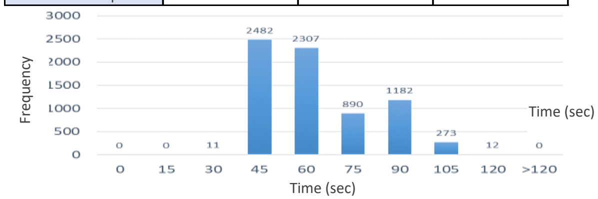
[1] Margin number of seconds for the first signal phase Excluding recall operation

(6) Delivery before Δt seconds for “gradual deceleration”

■Number of seconds remaining during the first phase in the control-based method

Jan. 20 to Feb. 3 (a total of 187h)
ID:400379, 20302, 400375

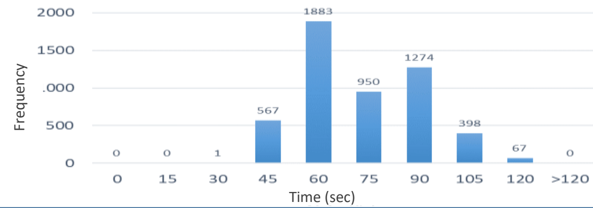
	Vehicle light 1		
	Simulated SPaT Information Center	Simulated SPaT Information Delivery Center	Simulated OBU
Median value	**49.02 s**	**49.02 s**	**48.90 s**
Maximum value	108.24 s	108.24 s	107.83 s
Minimum value	28.07 s	28.07 s	27.92 s
Average value	55.58 s	55.57 s	55.34 s
Standard deviation	18.47 s	18.47 s	18.47 s
Number of samples	7157	7157	7157



■Number of seconds remaining during the first phase in the centralized method

Jan. 20 to Jan. 30 (total of 290h)
ID:20299, 20298, 20382, 300375
*** Excluding recall operation time period (22:00 to 06:00)**

	Vehicle light 1		
	Simulated SPaT Information Center	Simulated SPaT Information Delivery Center	Simulated OBU
Median value	**61.86 s**	**61.86 s**	**61.63 s**
Maximum value	114.08 s	114.07 s	113.96 s
Minimum value	27.00 s	27.00 s	26.69 s
Average value	65.18 s	65.18 s	64.98 s
Standard deviation	17.27 s	17.27 s	17.27 s
Number of samples	5140	5140	5140



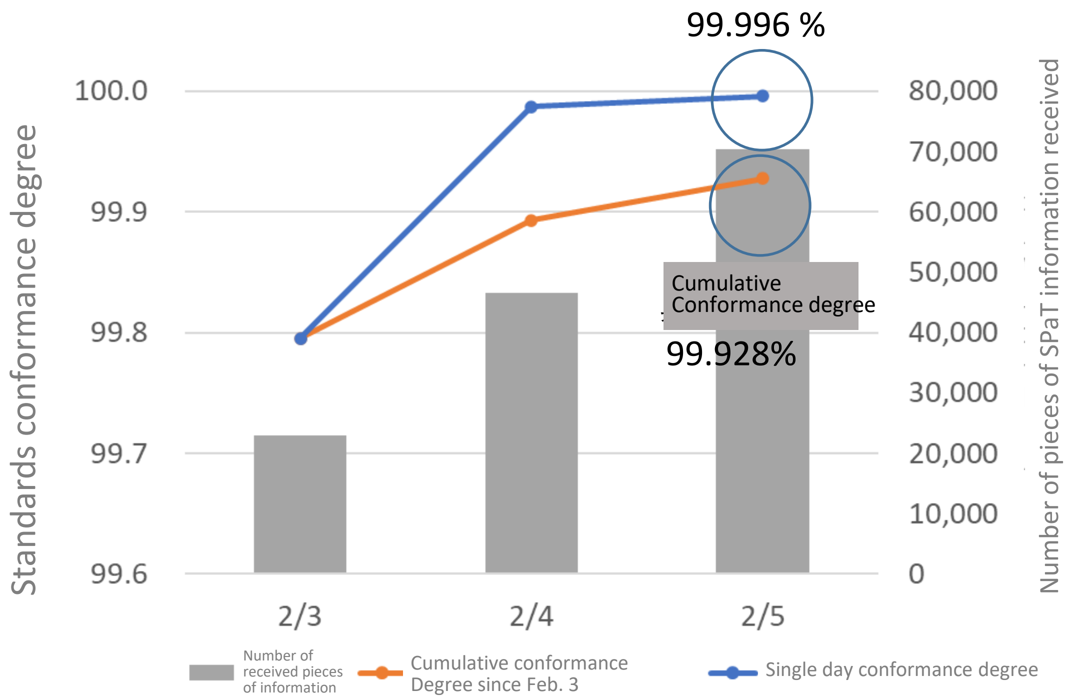
Heijo Ni-gou-sen Intersection results in different methods

Control-based method	Vehicle light 1		
	Simulated SPaT Information Center	Simulated SPaT Information Delivery Center	Simulated OBU
Median value	59.99 s	59.99 s	59.75 s
Maximum value	108.24 s	108.24 s	107.83 s
Minimum value	36.62 s	36.62 s	36.48 s
Average value	64.67 s	64.67 s	64.45 s
Standard deviation	16.80 s	16.80 s	16.81 s
Number of samples	2308	2308	2308

Centralized method	Vehicle light 1		
	Simulated SPaT Information Center	Simulated SPaT Information Delivery Center	Simulated OBU
Median value	59.91 s	59.91 s	59.76 s
Maximum value	108.24 s	108.24 s	108.12 s
Minimum value	37.47 s	37.47 s	37.10 s
Average value	65.26 s	65.25 s	65.08 s
Standard deviation	16.94 s	16.94 s	16.94 s
Number of samples	2435	2435	2435

[3] Standards conformance verification

Positioning of “(2) Fail-safe functions: Failure detection” in a broad sense



Information item	Range of standards
System state	Shall be 0 or 1
Creation date: Year	Shall be in BCD format and 0000 to 9999, or 0xFFFF
Creation date: Month	Shall be in BCD format and 01 to 12, or 0xFFFF
Creation date: Day	Shall be in BCD format and 01 to 31, or 0xFF
Creation date: Time (Time of day)	Shall be in BCD format and 00 to 23, or 0xFF
Creation date: Time (Minute)	Shall be in BCD format and 00 to 59, or 0xFF
Creation date: Time (Second)	Shall be in BCD format and 00 to 59, or 0xFF
Creation date: Time (millisecond)	Shall be in BCD format and 00 to 99, or 0xFF
Number of vehicle lights	Shall be 0 to 12
Number of pedestrian lights	Shall be 0 to 4
Number paths connected	Shall be 1 to 8
Number of service routes	Shall be 0 to 8
Route ID	Shall be 1 to 8
Vehicle light information pointer	Shall be 0 to 4000 or 0xFFFF
Pedestrian light information pointer	Shall be 0 to 4000 or 0xFFFF
Vehicle light ID	Shall be 1 to 12
Number of light output changes (K)/(L)	Shall be 1 to 12
Round signal light color indication	Shall be 0 to 6
Countdown stop flag	Shall be 0 or 1
Minimum number of sec remaining (0.1 sec.)	Shall be 0 to 2400, or 0x7FFF
Maximum number of sec remaining (0.1 sec.)	Shall be 0 to 2400, or 0x7FFF
Pedestrian light ID	Shall be 1 to 4

- **Over 70,000 pieces of upcoming SPaT information were received for conformance verification.**
- **The total conformance rate from Feb. 3 was 99.928%.**
  The conformance rate for the most recent single day was 99.996%, an extremely high conformance rate, which cleared the goal of 99% conformance.
- **The conformance reached 100%, excluding intersections where the frequency of the control system undergoing adjustment was high.**
  Further improvement in conformance to the standard can be expected once the adjustment is completed.

Simulated SPaT Information Center

- **Threshold checks listed above**
- **Mismatch in the number of actual data stored**
- **Date conformity**

After the standard conformity check process, data validity/invalidity judgment is made, and the data is sent to the simulated SPaT Information Delivery Center.

[4] Packet retransmission rate

(3) Verification of the time periods when the provision is not possible.

Period	Intersections verified
From Jan. 20 10:16 to Jan. 23 10:33	20299 centralized intersections

Carefully examined count values of upcoming SPaT information. Verified the data received by the simulated OBU from the SPaT information aggregation unit for 2435 messages and found that the 2435 messages were received successfully without omission.

Confirmed that MQTTS QoS=2 communication did not leave out any data.

As for the carrier network, a line failure occurred from 13:05 to 23:10 on February 3, 2023 during the verification period from December 2 to February 28, resulting in a communication delay from the base station (a delay time difference of about 1 sec occurred.

The LAN port that caused the failure was identified in the network equipment within the carrier service infrastructure, therefore, the port was blocked to reroute the communication, and it was confirmed that the communication delay event has been resolved.