戦略的イノベーション創造プログラム

“Strategic Innovation Promotion Program (SIP)
Phase Two / 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”

Progress Report for Fiscal Year 2020

Overview

UTMS Society of Japan
Nippon Signal Co., Ltd.
Omron Social Solutions Co., Ltd.
Panasonic System Solutions Japan Co., Ltd.

March 2021

History of this Research

Research name	Before FY 2018	FY 2018	FY 2019	FY 2020	In and after FY 2021
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 requirements for the SPaT Information Center** • **Examination of the linkage and integration with other information**
[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 October		• Continued efforts toward widespread use by promoting cost reduction

Assignment of Themes

Theme 1 “R&D on the provision of upcoming SPaT information using cloud and other technologies (Review of specifications for the prefectural police model system)”

[UTMS Society of Japan]

Theme 2 “R&D on the provision of upcoming SPaT information using cloud and other technologies (Formulation of a model system for the proposed “control-based” provision method)

[Nippon Signal Co., Ltd.]

Theme 3 “R&D on the provision of upcoming SPaT information using cloud and other technologies (Formulation of a model system for the proposed “centralized” provision method)

[Nippon Signal Co., Ltd.]

Theme 4 “R&D on the provision of upcoming SPaT information using cloud and other technologies (Formulation of a prefectural police model system for the proposed “controller-based” provision method)

[Omron Social Solutions Co., Ltd.]

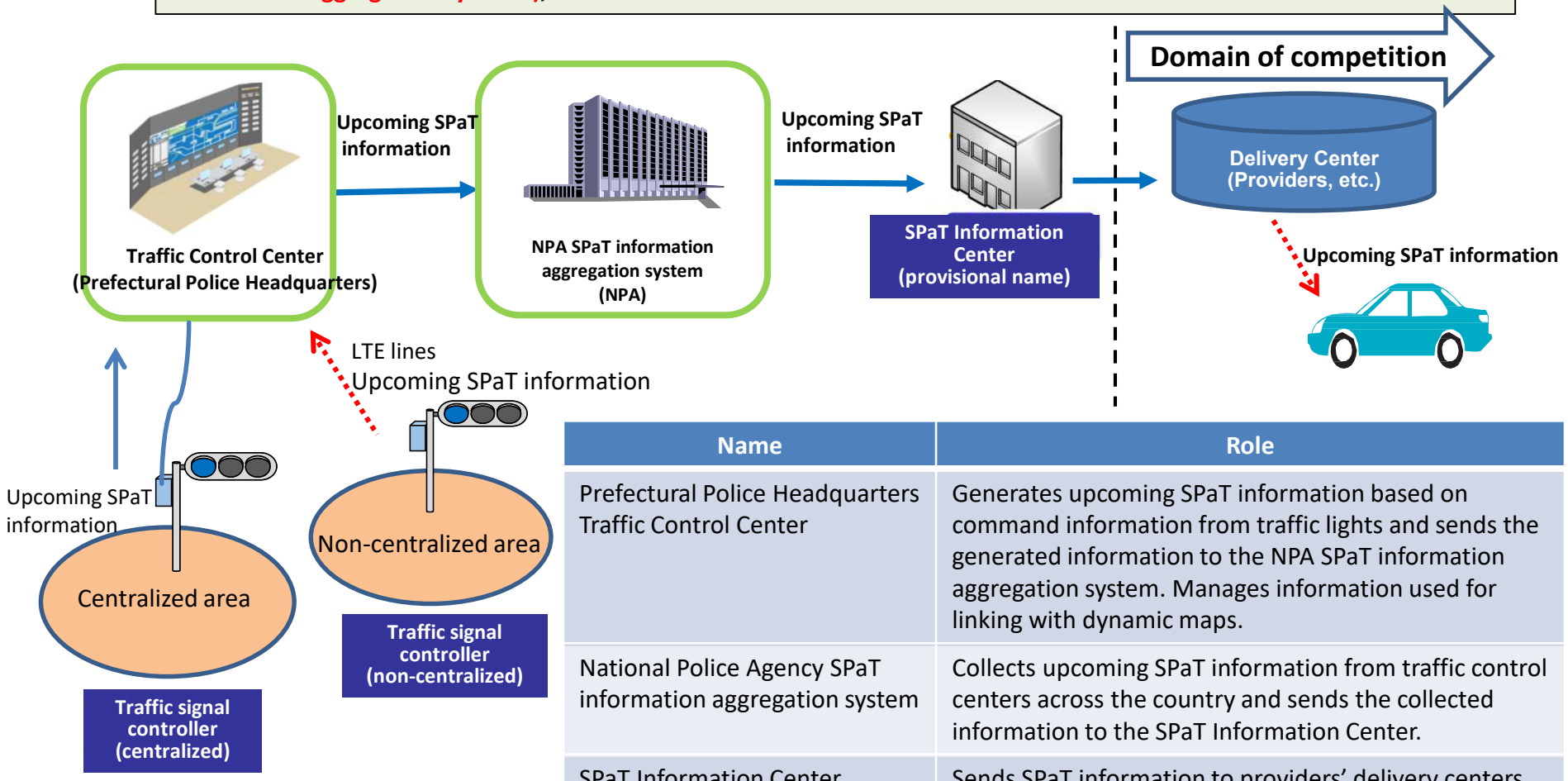
Theme 5 “R&D on the provision of upcoming SPaT information using cloud and other technologies (Specification of the NPA SPaT information aggregation system)

[Panasonic System Solutions Japan Co., Ltd.]

Overview of Research and Development

[Overview]

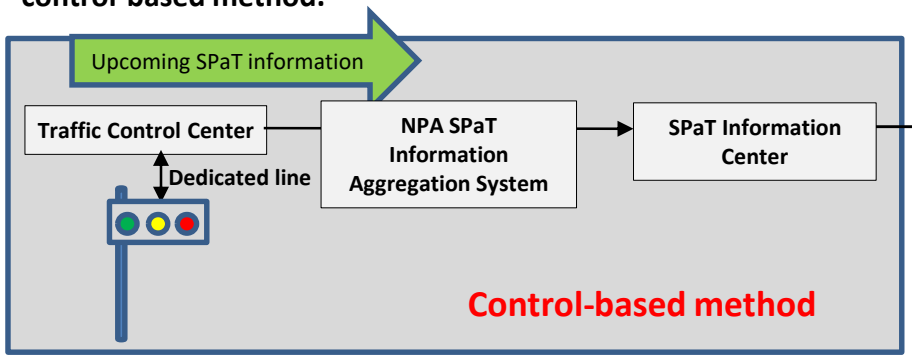
With the aim of contributing to the realization of the provision of SPaT information using cloud and other technologies, this R&D project will verify the provision of upcoming SPaT information for automated driving by building a model system for prefectural police headquarters (hereafter called "the prefectural police model system") based on the results of the examinations carried out in fiscal 2020. The project will also examine and formulate draft specifications for a system to aggregate upcoming SPaT information to the National Police Agency (hereafter called "the NPA SPaT information aggregation system"), which is scheduled to be built in and after fiscal 2021.

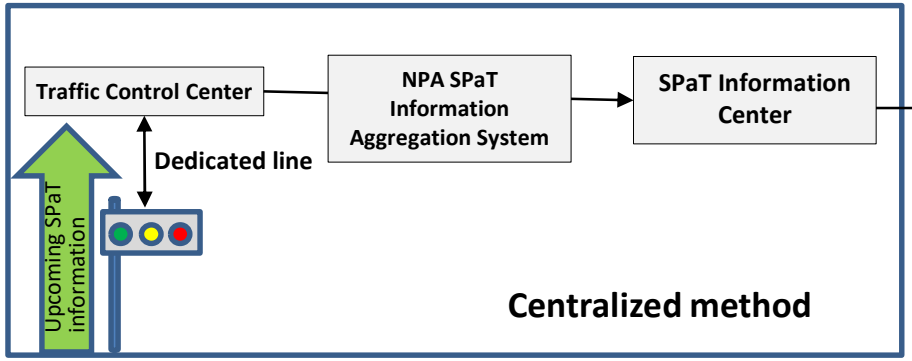


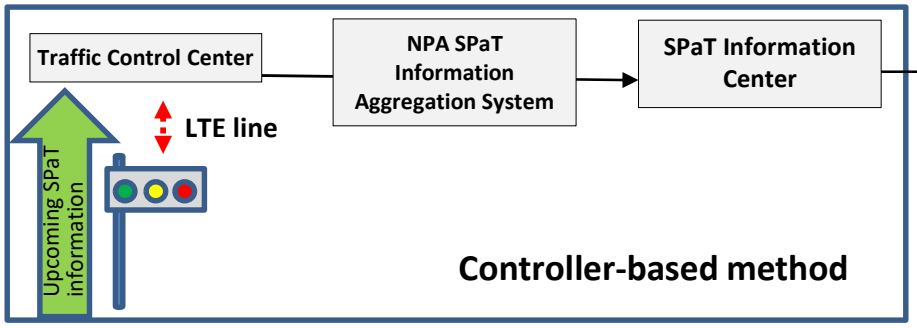
Name	Role
Prefectural Police Headquarters Traffic Control Center	Generates upcoming SPaT information based on command information from traffic lights and sends the generated information to the NPA SPaT information aggregation system. Manages information used for linking with dynamic maps.
National Police 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.

Upcoming 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.

Delivery Center (Servers of private sector providers, etc.)

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

Delivery Center

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

Delivery Center

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

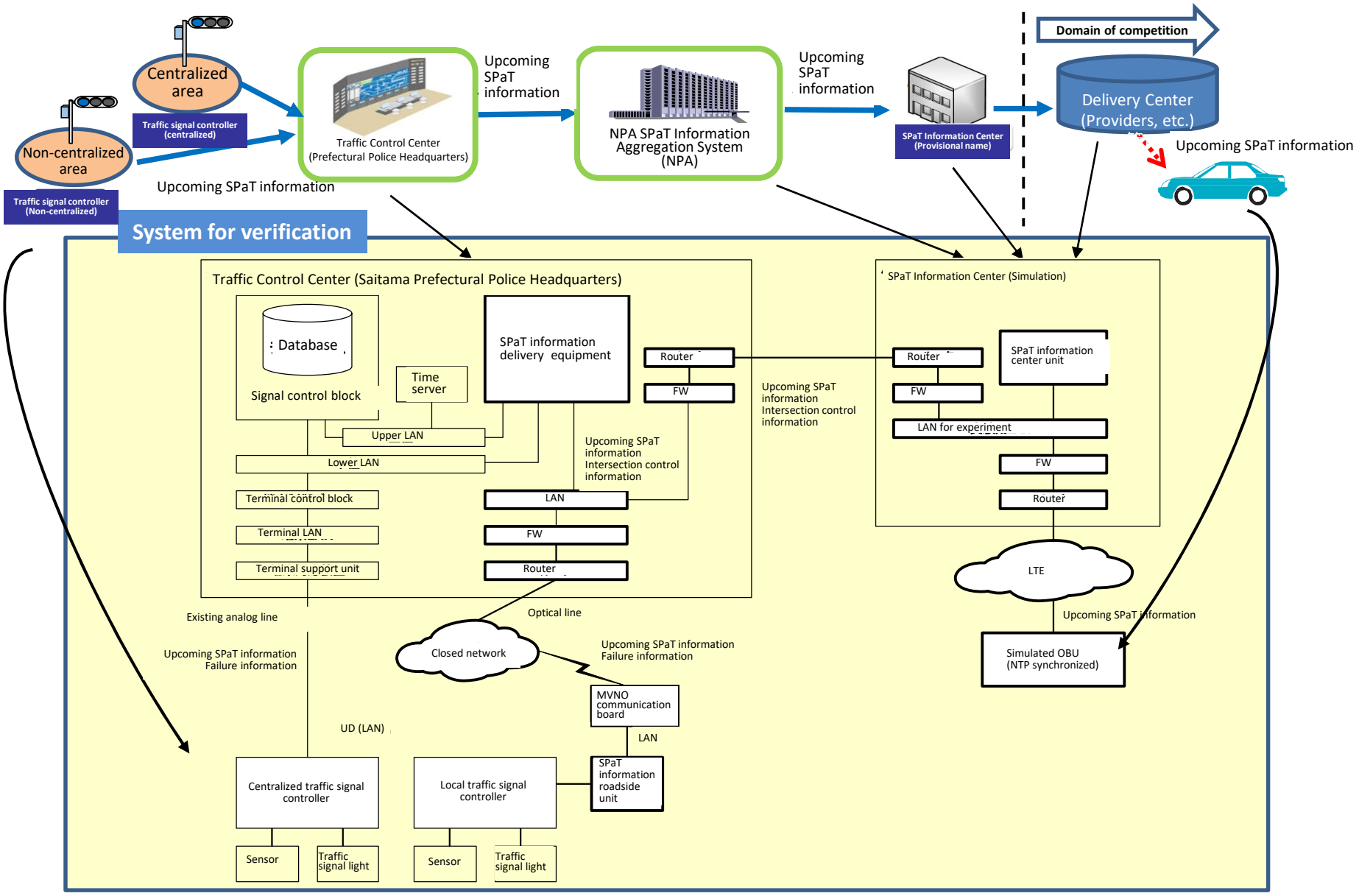
★ Applicable to independently operating traffic signal controllers

Schedule of Research and Development (Fiscal year 2020)

	Item	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Prefectural police model system	**Examination of the prefectural police model system** ● Specifications for the model system ● Upcoming SPaT information verification plan ● Traffic signal control method modification design documents									
	Verification using the prefectural police model system ● Production of the prefectural police model system ● Verification of upcoming SPaT information ● Verification of upcoming SPaT information by changing traffic signal control methods									
	Review of draft specifications for the prefectural police model system ● Specifications for the prefectural police model system									
	Preparation of draft guidelines for traffic signal control methods required for the provision of upcoming SPaT information ● Guidelines for traffic signal control methods									
SPaT information aggregation	**Survey and examination of technical requirements for the NPA SPaT information aggregation system** ● A written plan for the aggregation system's technical requirements survey									
	Examination of screens and forms **Examination of the system reliability**									
	Examination of draft specifications for the aggregation system ● Aggregation system specifications									
Committee	**Holding of the Model System Committee (about once a month)**			9/1	9/25	10/28	11/25	12/23	1/28	2/19
	NPA SPaT Information Aggregation System Committee (about four times)			8/28		11/6			1/22	2/17

I. Building of the Prefectural Police Model System

Configuration of the Prefectural Police Model System (for verification)



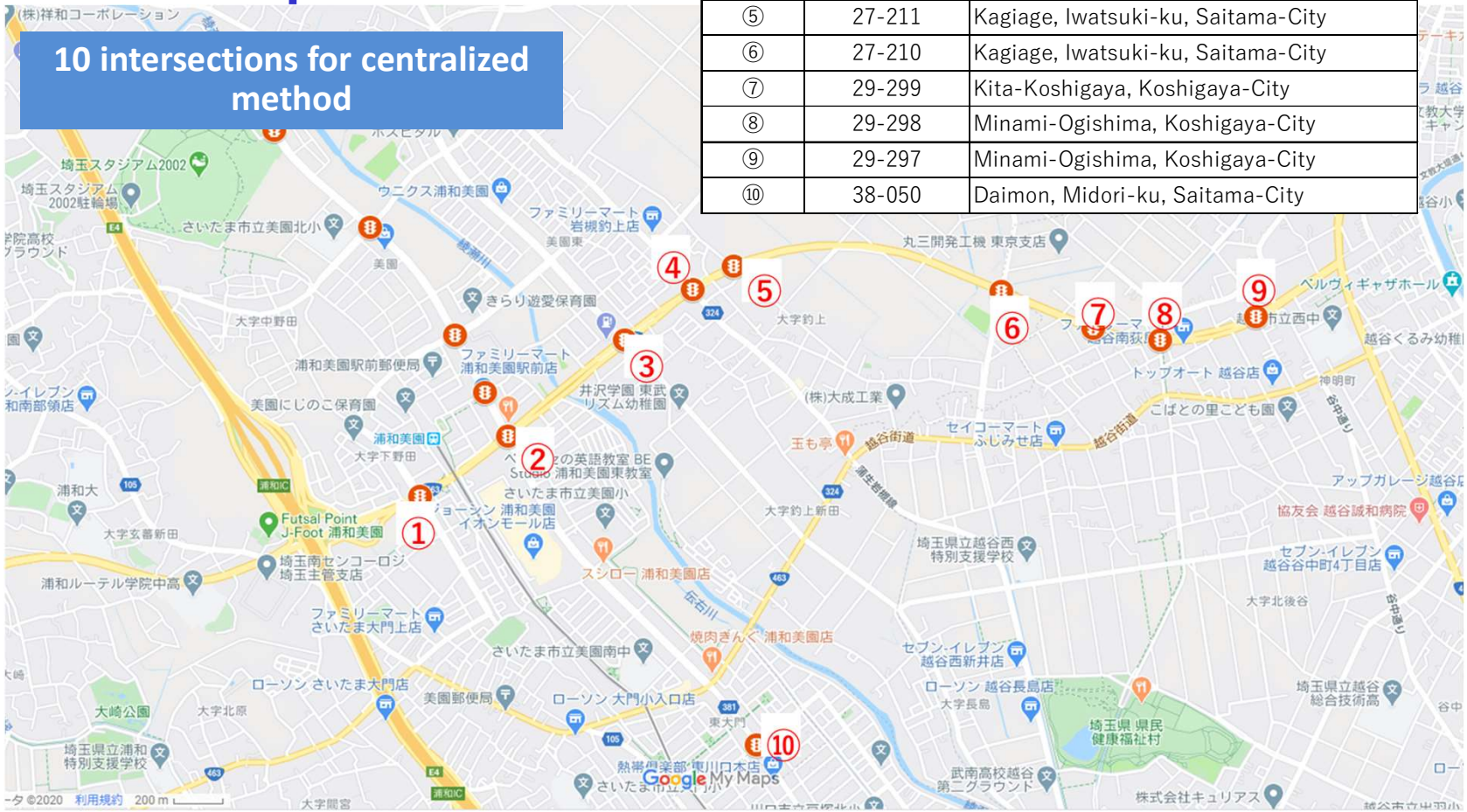
Intersections for the experiment of control-based and centralized methods

About 2700 intersections across Saitama Prefecture for traffic control-based method

+

10 intersections for centralized method

No.	Control No, (Prefectural police)	Location
①	38-108	Shimonoda, Midori-ku, Saitama-City
②	38-107	Daimon, Midori-ku, Saitama-City
③	27-213	Kagiage, Iwatsuki-ku, Saitama-City
④	27-212	Kagiage, Iwatsuki-ku, Saitama-City
⑤	27-211	Kagiage, Iwatsuki-ku, Saitama-City
⑥	27-210	Kagiage, Iwatsuki-ku, Saitama-City
⑦	29-299	Kita-Koshigaya, Koshigaya-City
⑧	29-298	Minami-Ogishima, Koshigaya-City
⑨	29-297	Minami-Ogishima, Koshigaya-City
⑩	38-050	Daimon, Midori-ku, Saitama-City



Map source: Google Map (https://www.google.co.jp/maps)

Theme 2, 3: Nippon Signal Co., Ltd.

Verification items for control-based and centralized methods

The following items will be verified through the prefectural police model system.

No	Verification item	Verification details
1	Common verification	Verifies basic performance, including time accuracy, errors and communication delays of upcoming SPaT information
2	Confirmation of response to traffic-actuated control	In order to prevent the occurrence of dilemma zones in traffic-actuated control, the signal control method is changed so that upcoming SPaT information can be determined before Δt seconds, and the results will be verified.
3	Confirmation of the provision of SPaT information during flashing operation * For the centralized method only	Verifies the accuracy of upcoming SPaT information provided during flashing (flashing signal in abnormal conditions, etc.) status.
4	Confirmation of system configuration	Confirms that upcoming SPaT information for automated driving created by the traffic signal controller can be provided to the simulated on-board unit even in a security-conscious system configuration.
5	Confirmation of switch of timed table	Verifies errors of upcoming SPaT information when the number of seconds of steps changes before and after the switch of the timed table.
6	Collection of time synchronization data	Compares the current time synchronized by communication sequence between the control center and the traffic signal controller with the time when synchronization is performed by GPS.
7	Confirmation of failure notification function	Verifies that failure information can be added and correctly notified in order to notify the maintenance and operation staff of the failure information for failure recovery.
8	Confirmation of continuous provision	Confirms that upcoming SPaT information for automated driving can be provided continuously and correctly at multiple intersections (routes).

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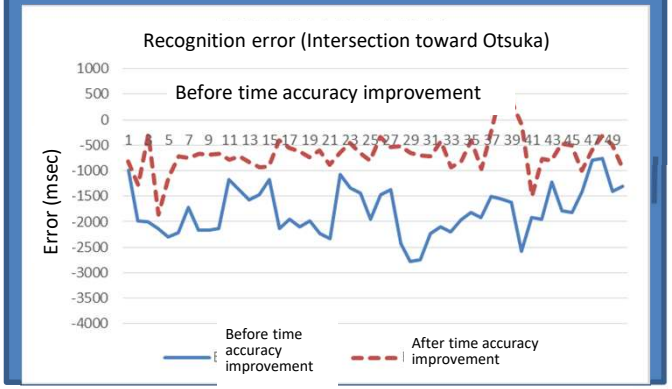
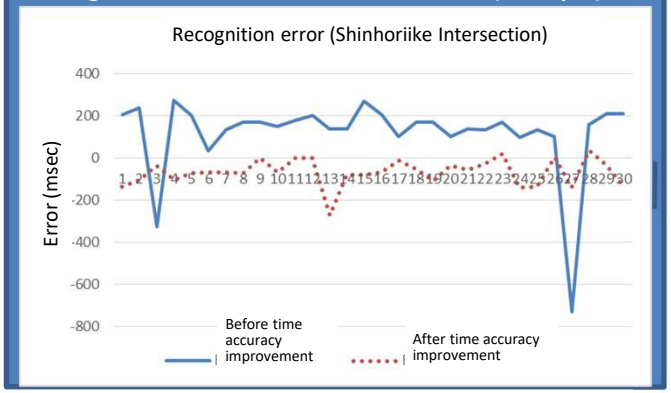
Verification results of control-based and centralized methods

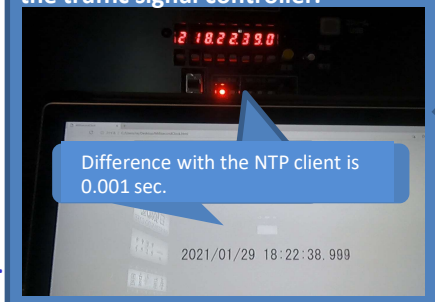
Recognition errors in control-based method (Example)



Recognition errors in centralized method (Example)

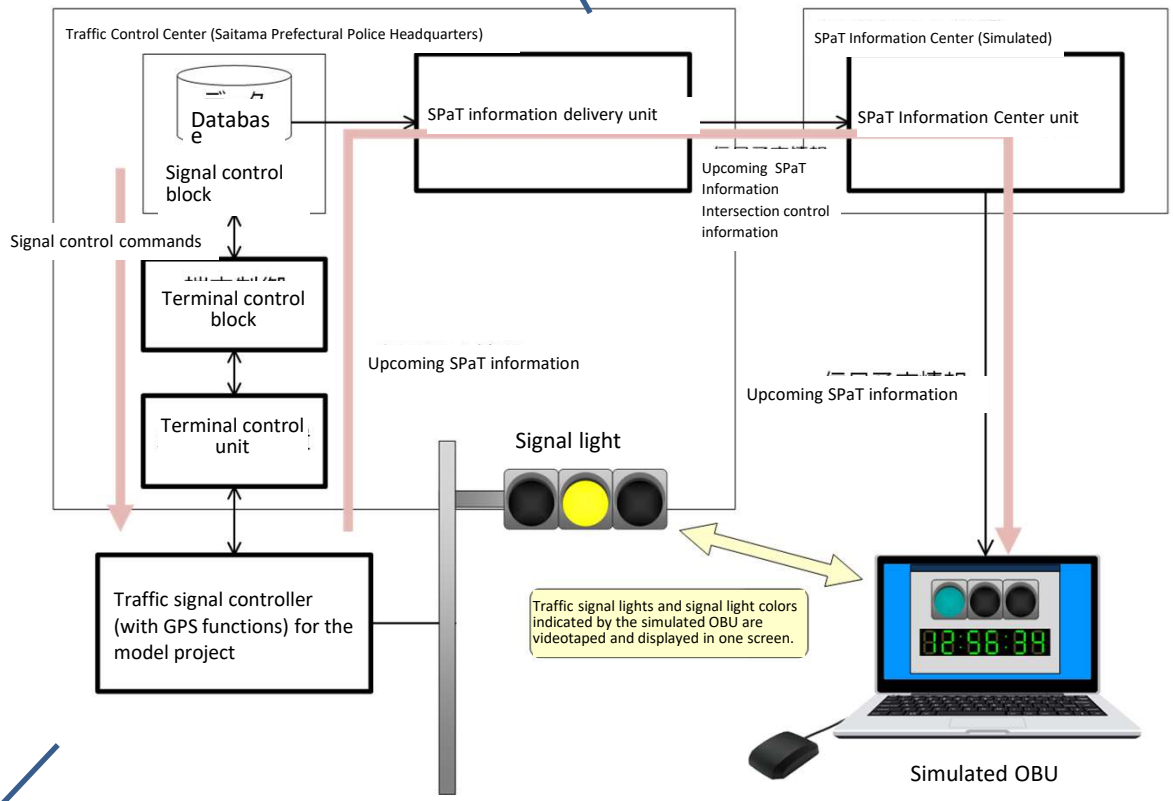


Improved time accuracy was confirmed after installing GPS to the traffic signal controller.



Communication delay from traffic signal controller (Example)

SPaT information delivery unit (msec.)	SPaT Information Center (msec.)	Simulated OBU (msec.)
1,990	2,050	2,340
2,350	2,440	2,550
1,950	2,010	2,100



Recognition error =
Time when the traffic light color changed – Time when the traffic light color indicated by OBU changed

- **In the control-based method, it was confirmed that the recognition error exceeds 1 sec. even after the time accuracy improvement made to the traffic signal controller.**
- **In the centralized method, it was confirmed that the recognition error within ±300 msec. can be achieved after the time accuracy improvement made to the traffic signal controller if there were no changes in the situation, such as the operation of traffic-actuated control.**
- **Delay time from the traffic signal controller to the SPaT information delivery unit was about 2 sec.**

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Summary of verification results for control-based and centralized methods

1. In the control-based method, recognition errors of about few seconds (difference between the signal light indication and the recognition by the OBU) occurred. The main reason for this is that the traffic signal controllers control in units of 100 msec., while the traffic control center processes in units of seconds.

2. In the centralized method, it was confirmed that the recognition error is within ±300 msec., except in the case of immediate change of control contents such as traffic-actuated control (including recall and flashing).

3. In the simulation, we reviewed the control method to determine the upcoming SPaT information before Δt seconds for intersections under traffic-actuated control, and confirmed that the control can be executed without problems and that the upcoming SPaT information can be provided.

   → However, when actually introducing the system, it is necessary to make a decision in consideration of the impact on traffic and other factors. In addition, the concept of Δt seconds needs to be re-examined in consideration of the delay time of the entire system, based on the results of the study conducted by the Aggregation System Committee and the measures taken by the Ministry of Internal Affairs and Communications.

4. As for the functional tests (system configuration check, failure notification function check, and continuous provision check), it was confirmed that the system operates without any problems.

In the case of the control-based method, the traffic control center is also expected to improve the recognition error by setting the unit of processing time to 100 msec. However, in order to satisfy the JAMA's request for performance within ±300msec, continued examination is needed, with a view to conducting further evaluation and verification, as well as review of requirement definition.

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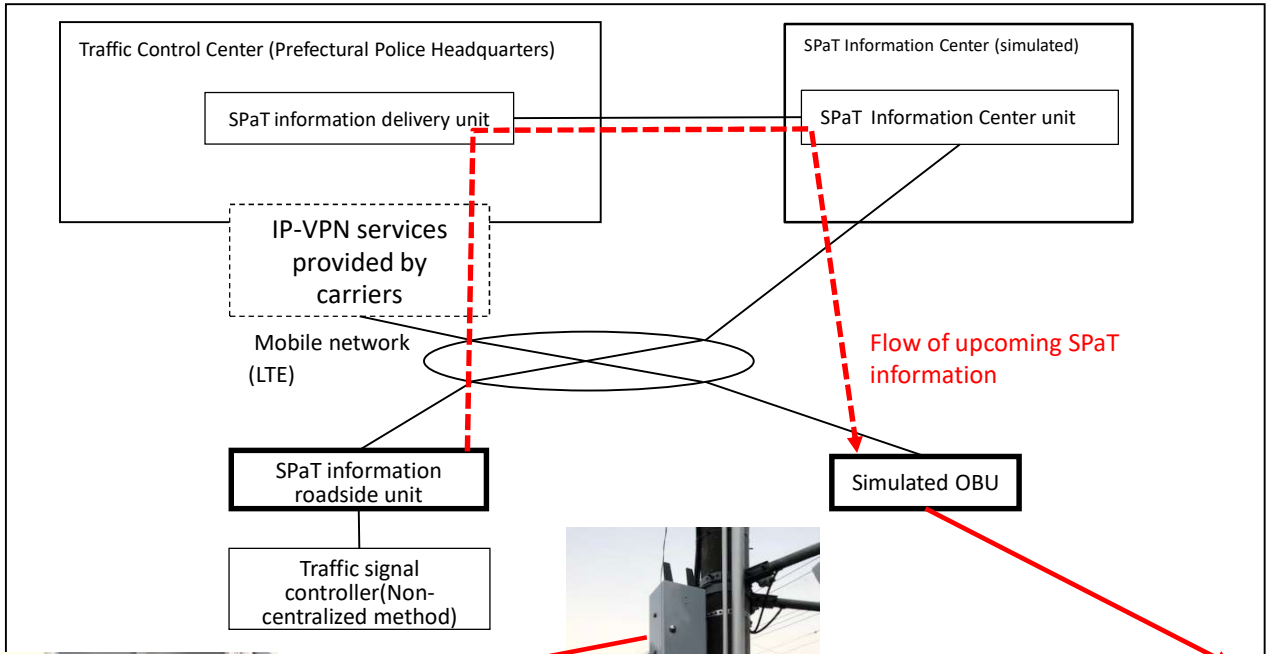
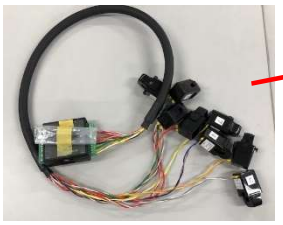
Model system for traffic signal controller-based method

The following shows the equipment prepared for the prefectural police model system and the screen on the simulated on-board unit.

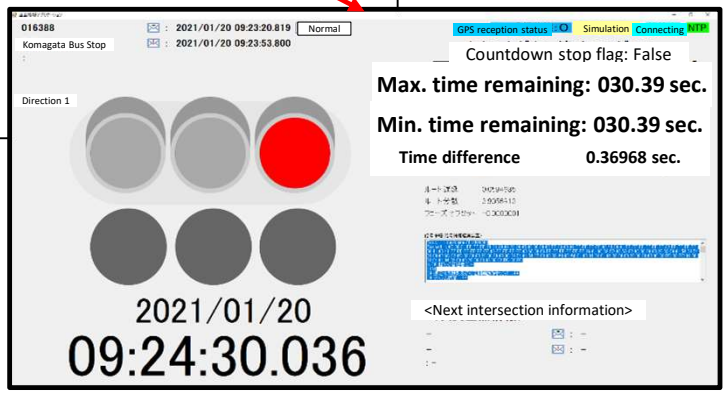


(a) Inside SPaT information roadside unit



(b) CT sensor

(c) Unit installation status



(d) Screen of simulated OBU

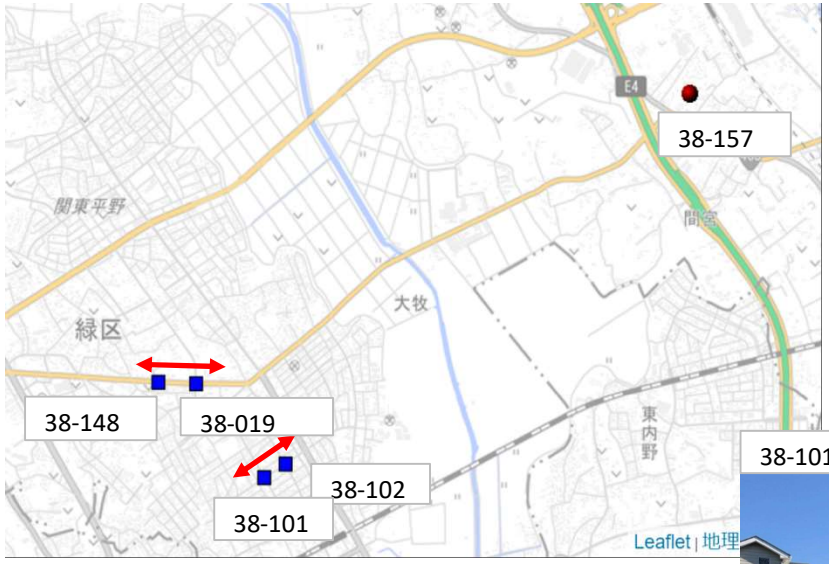
Intersections for verification experiment of the controller-based method

The following are the intersections for the verification experiment and the status of equipment installation.

Control N. (Prefectural police headquarters)	Location	Control classification
38-019	Higashi-Urawa, Midori-ku, Saitama-City	Coordinated
38-101	Higashi-Urawa, Midori-ku, Saitama City	Coordinated
38-102	Higashi-Urawa, Midori-ku, Saitama-City	Coordinated
38-148	Higashi-Urawa, Midori-ku, Saitama-City	Coordinated
38-157	Oaza-Daimon, Midori-ku, Saitama-City	Independent

38-148

38-019



Map source: Map issued by the Geographical Survey Institute is used from the following website.
http://ktgis.net/gcode/lonlatmapping.html

38-157

38-102

38-101

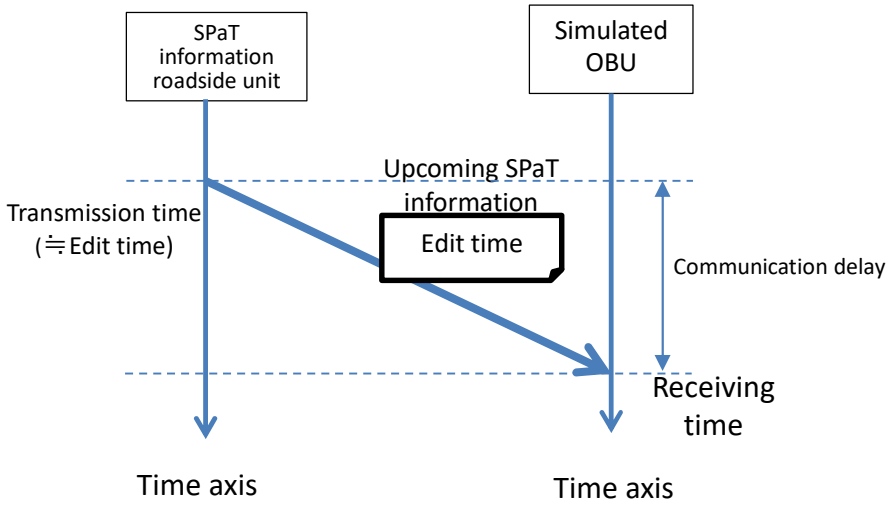
Results of verification of prefectural police model system for controller method

Each verification item was implemented as planned, and generally good results were obtained. There were some issues that became apparent during the verification using actual equipment, which need to be addressed in the future.

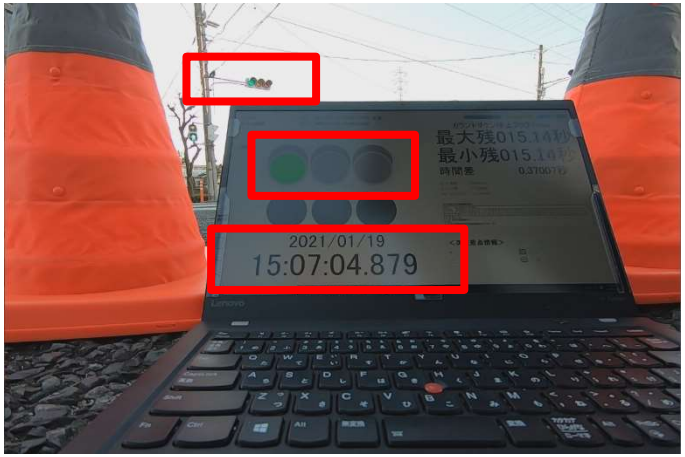
No.	Verification item	Details	Results	Explanation of results
1	Time accuracy	Verification of error of 50 msec. or less from absolute time	○	Confirmed that it is possible to achieve an error of 35msec or less. Confirmed that time synchronization can be done by communication (ntp) without using GPS. We believe that time synchronization by communication (ntp) is effective for cost reduction.
2	Communication delay	Understanding of the actual value of the communication delay to the onboard unit	○	The average communication delay at the five intersections is about 400 msec, which is better than the evaluation in fiscal year 2019. Since it depends on the system configuration, continuous verification will be necessary in the future.
3	Recognition error	Confirmation that the error is within ±300msec	○	Confirmed to be within ±300 msec by video recording.
4	System configuration confirmation	VPN, message encryption	○	Confirmed that there was no problem through verification using a system with security measures such as the construction of a virtual closed network using VPN and encryption of communication messages.
5	Timed table switch confirmation	Confirmation of recognition error within ±300 msec	△	When we checked the provision of scheduled signal information before and after a switch at intersections under coordinated control, we found that the recognition error sometimes exceeded ±1 second, so performance needs to be improved. For fixed-period intersections, there were places where upcoming SPaT information cannot be provided before and after a switch. Software improvements are needed to provide the information.
6	Failure notification function confirmation	Addition and confirmation of failure notification function	○	Failure notification messages were added, and it was confirmed that in addition to equipment faults, quasi-normal and abnormal conditions can be notified according to the degree of recognition error of upcoming SPaT information. Utilization of the system on the automated driving vehicles is being proposed, but has not yet been decided.
7	Continuous provision confirmation	Confirmation of reception in actual driving	○	Confirmed that vehicles can receive upcoming SPaT information without significant delay when approaching an intersection during continuous passage through intersections.

Prefectural police model system for controller-based method
Result details (Reference)

■Communication delay verification method

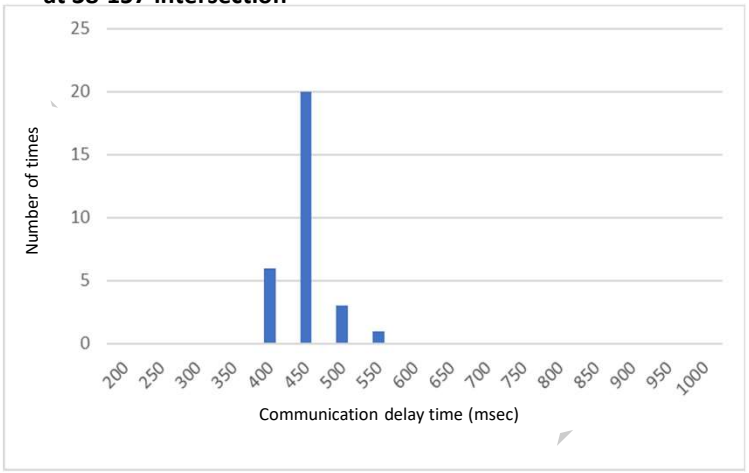


■Recognition error verification method

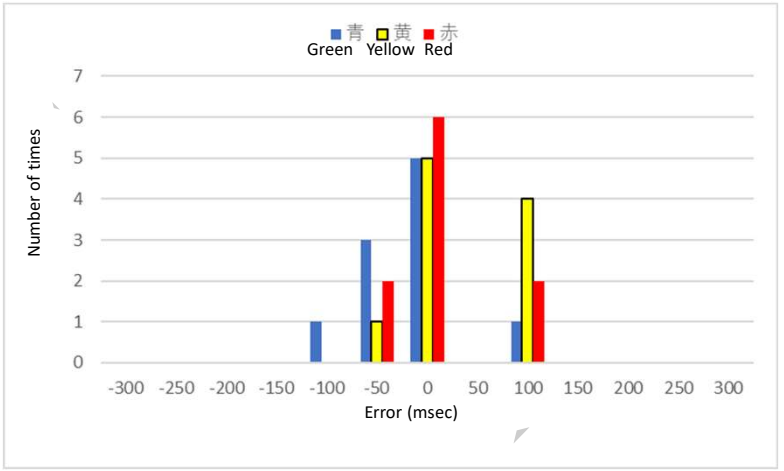


**Recognition error = Time when the traffic light color changed –
Time when the traffic light color indicated by OBU changed**

■Communication delay distribution example (Measured 30 times) at 38-157 intersection



■ Traffic signal recognition error distribution example (measured 30 times) at 38-102 Intersection: Coordinated control



Factory verification results of controller-based method

Verification of each item was completed as planned. The feasibility of providing upcoming SPaT information under special conditions is being confirmed. There are some issues regarding the method of editing and using upcoming SPaT information, and discussions are needed between system manufacturers and the user (Japan Automobile Manufacturers Association) of upcoming SPaT information.

No	Verification item	Details	Results	Explanation of results
1	SPaT information provision during recall control	SPaT information provision at intersections with push button signals	○	Confirmed that it is possible to provide upcoming SPaT information based on the determination of recall phases using three methods (flashing pedestrian lights, dummy lights, and confirmation indicator lights). Discussion is needed on how to edit and use some of the items in the upcoming SPaT information.
2	Upcoming SPaT information provision during traffic-actuated control	Provides upcoming SPaT information that can ensure Δt	○	Provision of upcoming SPaT information was performed. The upcoming SPaT information was determined after judging the end of the actuated control step using two methods (pedestrian flashing, fixed step time + dummy light lighting). It was confirmed that Δt can be secured. Discussion is needed on how to edit and use some of the items in the signal schedule information.
3	Upcoming SPaT information provision during traffic-actuated control	Impact of the addition of fixed steps on traffic flow	○	Verification by simulation was conducted. It was confirmed that adding fixed steps and continuing the traffic-actuated control had less impact on traffic flow than stopping the traffic-actuated control.
4	Provision of upcoming SPaT information during flashing	Verification of the provision of upcoming SPaT information including before and after flashing	△	It was confirmed that the flashing status can be detected, but it was found that there are issues in providing upcoming SPaT information, including after manual flashing. The examination will be continued.
5	Provision of upcoming SPaT information using LPWA	Feasibility confirmation	○	Evaluated using commercially available cellular LPWA communication devices. Although the communication delay is large, the recognition error is good at less than ±300msec. There is a possibility of contributing to the reduction of communication costs. However, it is necessary to clarify the required specifications for reliability and conduct a long-term evaluation.

Linking maps for automated driving with intersections to which upcoming SPaT information is provided

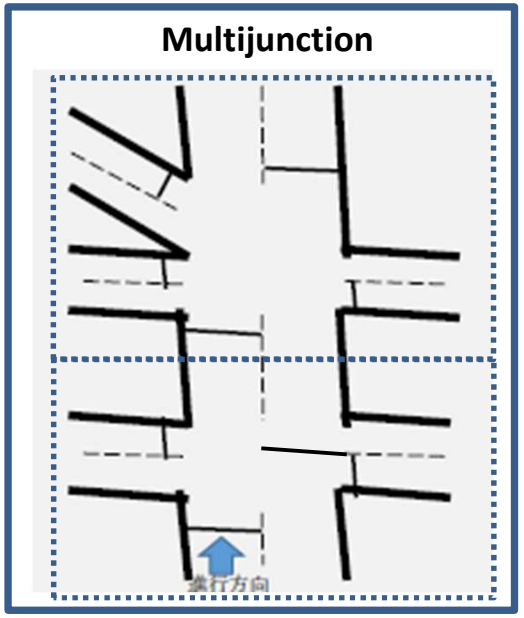
[Issue]
Defining the information necessary to link dynamic maps and intersections to which upcoming SPaT information is provided, and creating a system for operation

[Basic policy for realization]
- The definition information to be linked to dynamic maps should be shared with others as much as possible in terms of maintenance and cost.
- For the intersection location information, intersection shall only be linked to the maps.

[Other publicly available intersection information]
1. Intersection information in the SIP Phase II "the advancement of driving support by **utilizing traffic regulation information**"
   <Advantage>
   It is the definition information for automated driving.
   <Issue>
   There is no direction information.
2. Intersection information provided by (PIIF) Japan Traffic Management Technology Association
   <Advantage>
   It has a mechanism for providing paid services.
   <Issue>
   There are few applicable intersections.

[Issue]
The unit of intersections required for the provision of upcoming SPaT information do not necessarily match the unit of intersections managed by each prefectural police.

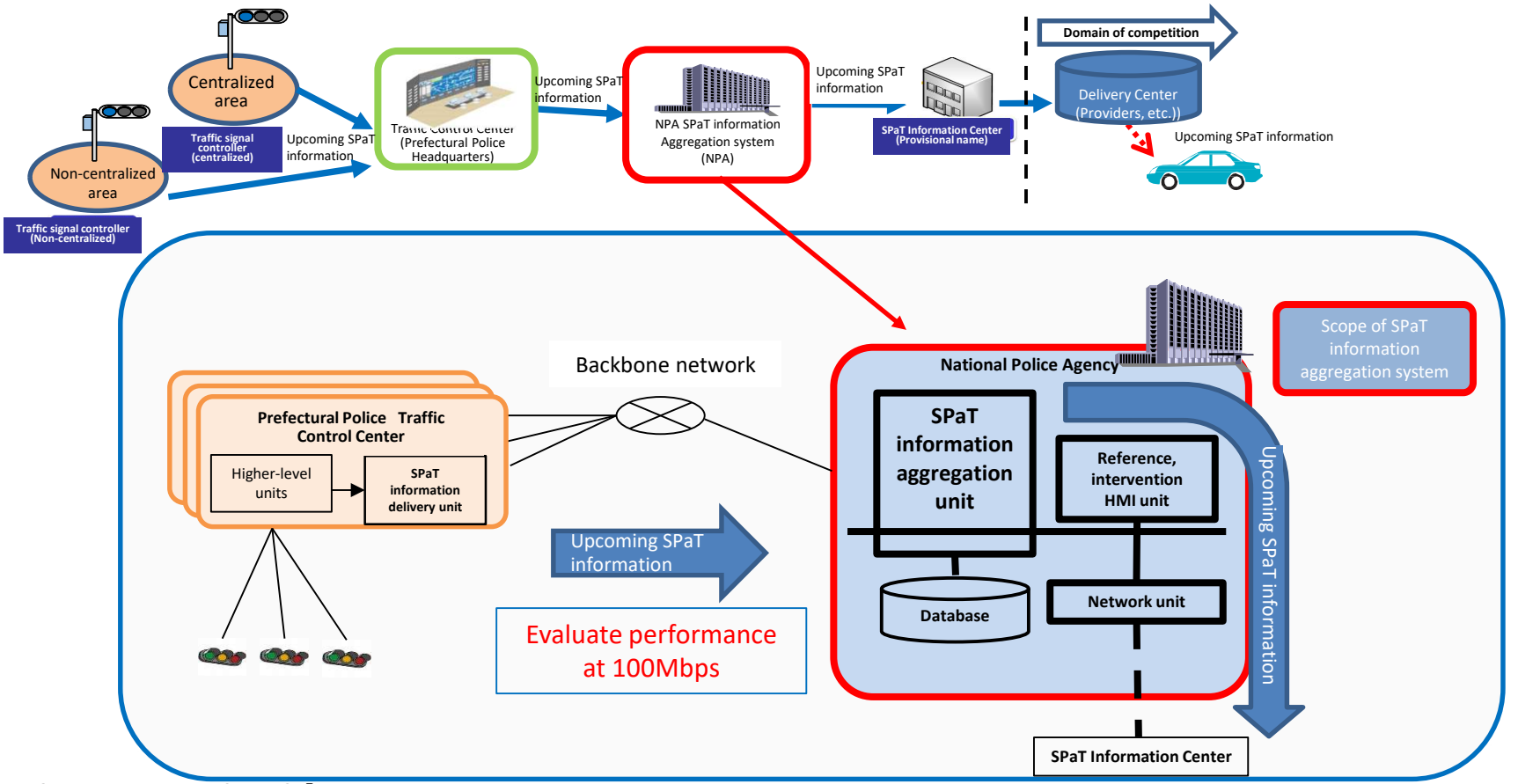
Opportunities for examination will be established to continue examination toward social implementation.



II. Examination of NPA SPaT Information Aggregation System

Overview of NPA SPaT Information Aggregation System

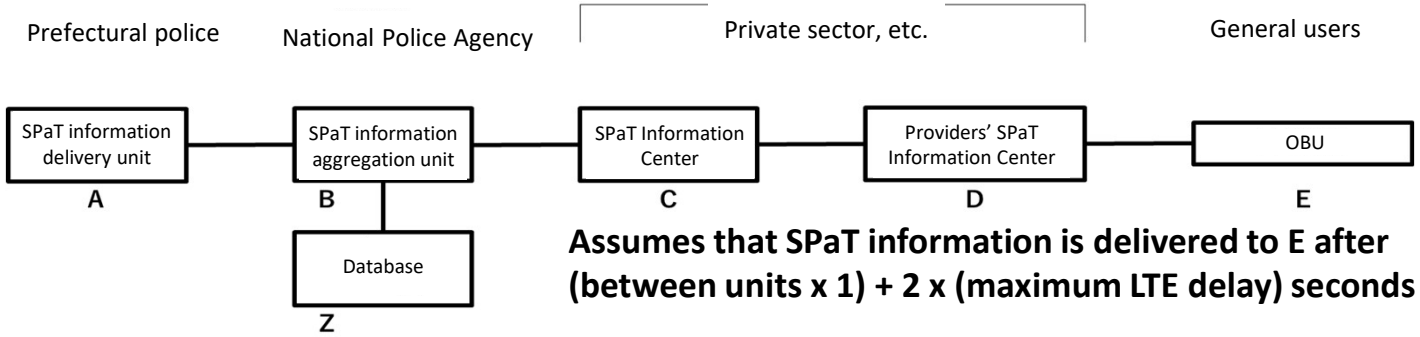
Develop system specifications for aggregating upcoming SPaT information from prefectural police traffic control centers and sending it to the Signal Information Center. (Evaluation in the in-house environment this fiscal year)



[Implementation details]

- **At 100Mbps(12.5Mbyte/s) Assumes a communication capacity of 7.2 Kbytes/msec with a NW efficiency of 60%**
- **Verifies that a data size of 2.4 Kbyte can be processed at 3 msec intervals, taking database performance evaluation into consideration. Verify is completed.**

SPaT information aggregation unit　Performance evaluation



Assumes that SPaT information is delivered to E after (between units x 1) + 2 x (maximum LTE delay) seconds

In order to evaluate the load on the aggregation unit, an MQTT environment and a database environment were constructed, and upcoming SPaT information was generated sequentially for intersections with cycle lengths of 60 seconds (24-hour continuous execution).
Measured the minimum, average, and maximum values of "communication time + database processing time" for A → B → A (virtual C).
Conducted performance measurement at 1000 intersections and 4000 intersections. (For B, format check and range check were performed.)
An overload test of the SPaT information aggregation system was conducted to obtain basic figures for future design.

Number of intersections	Data size (byte)	Minimum number of seconds (msec)	Average number of seconds (msec)	Maximum number of seconds (msec)	Notes
1000	1024	864	2066	6520	Standard numbers of traffic lights for vehicles and pedestrians (4) (Basic road sections, standard two-phase system, etc.)
1000	2048	917	2131	12855	Maximum numbers of traffic lights for vehicles and pedestrians (12)
4000	1024	3269	5422	15135	Standard numbers of traffic lights for vehicles and pedestrians (4) (Basic road sections, standard two-phase system, etc.)
4000	2048	3630	6925	13425	Maximum numbers of traffic lights for vehicles and pedestrians (12)

NPA SPaT information aggregation system Details of efforts

No	Requirements	Work details
1	Operational requirements	Clarify the system configuration, examine the scale of traffic signals to be aggregated from prefectural police across the country, the volume of data from each prefectural police, and the data transmission interval. Examine the scale of the number of intersections that can be accommodated in the SPaT information aggregation unit server and database, and completed clarify the workflow.
2	Functional requirements	Visualized and clarified the flow of data (information) to and from units related to this aggregation unit. In utilizing the database, examine registration, reference, statistics, and search functions. Consideration should also be given to confirming the reception interval of upcoming SPaT information, its distribution history, and the status of provision. In addition, the work also includes the identification of performance requirements for data transmission/reception and database storage.
3	Screens, forms-related	Organized screens for searching for and referring to intersections from which upcoming SPaT information is collected, and organize form-related tasks.
4	Non-functional requirements such as reliability of the system	From the viewpoint of the continuity of the upcoming SPaT information provision service, non-functional requirements including continuity and expandability as well as system reliability (availability) were to be examined, and information security requirements were to be examined by clarifying the scope of communication routes for security design. For example, security requirements suitable for each characteristic should be extracted for prevention functions and preventive measures against unauthorized access and computer virus infection from devices connected externally from the police agency's internal devices.
5	Specification-related	Summaries provided through the above work was compiled as a draft specification.