Strategic Innovation Promotion Program (SIP)　Phase Two – Automated Driving
(Expansion of Systems and Services)

Research and development on the provision of SPaT information through methods other than vehicle-to-infrastructure communication via ITS roadside radio units and others

Progress Report for Fiscal Year 2019

March 2020

UTMS Society of Japan
Nippon Signal Co., Ltd.
Panasonic System Solutions Japan Co., Ltd.
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1. Purpose and outline of research and development

<Purpose>

In this research and development project, detailed functional and technical requirements will be prepared for four types of methods for providing SPaT information, namely three highly-applicable methods (a traffic control-based method, centralized method (1) and controller-based method) developed in the fiscal 2018 research plus a centralized method (2) that was newly included during this R&D project. Draft specifications will also be examined and developed for the installation of a model system scheduled for the fiscal 2020.

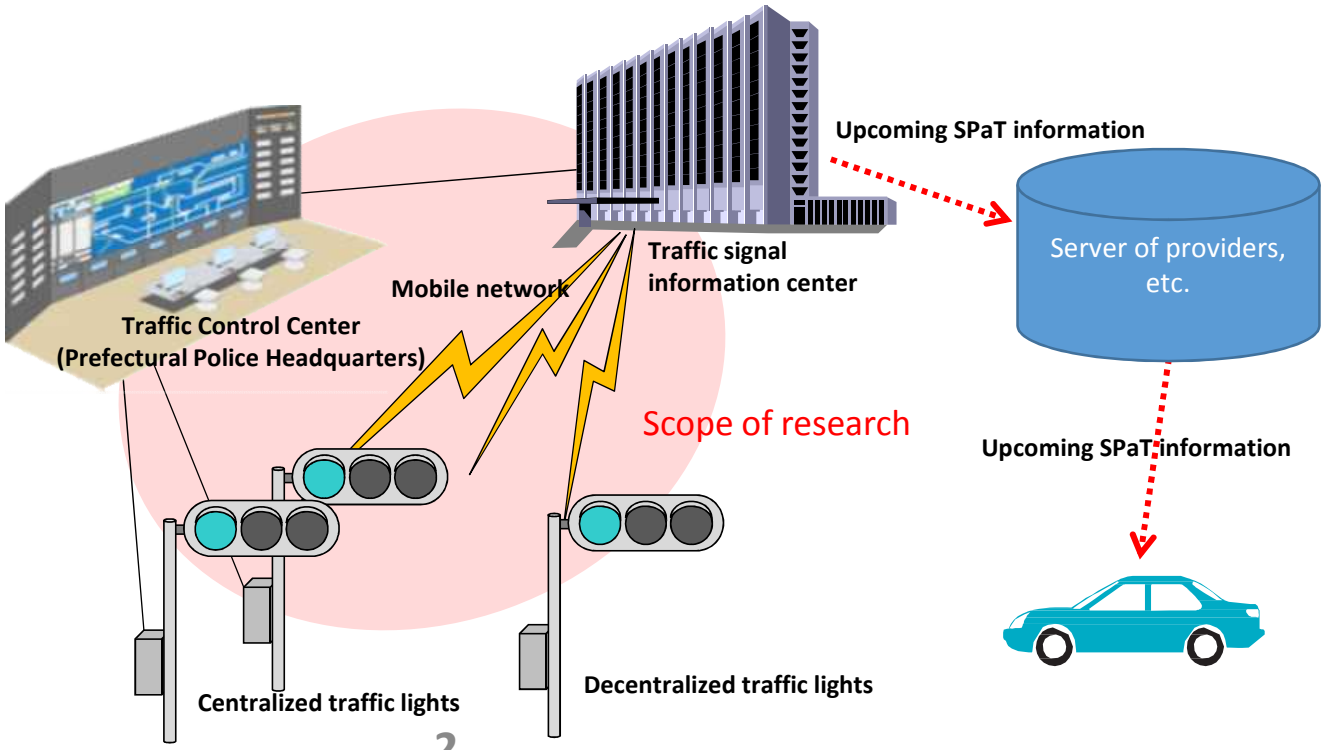
<Outline>

(1) Preparation of detailed functional and technical requirements for methods to provide SPaT information
(2) Verification of the four proposed methods to provide SPaT information using a simulated system
(3) Preparation of draft specifications for a model system to be built for the fiscal 2020 project.

<Participating members>

A committee was established, consisting of

- Automotive manufacturers
- Traffic signal infrastructure makers
- Communications carriers
- JAMA

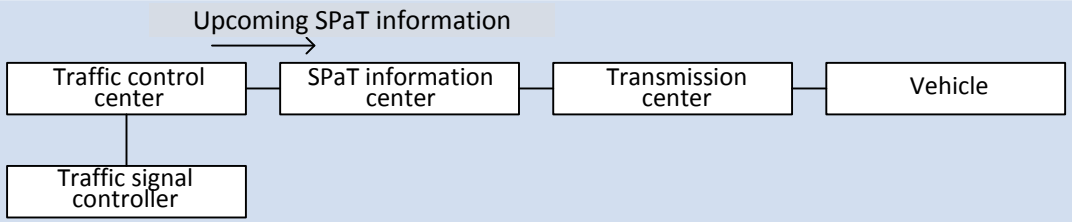
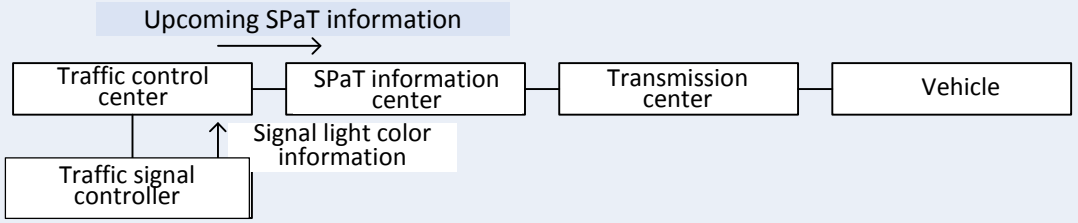
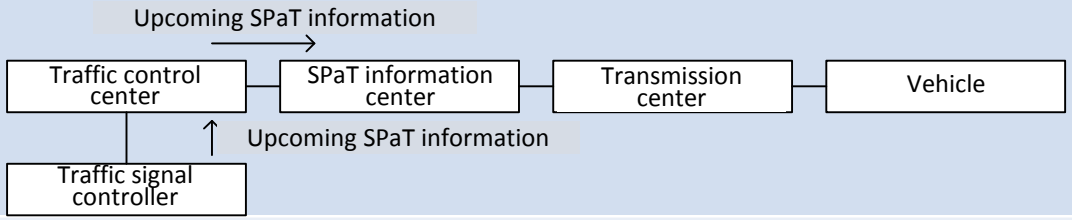
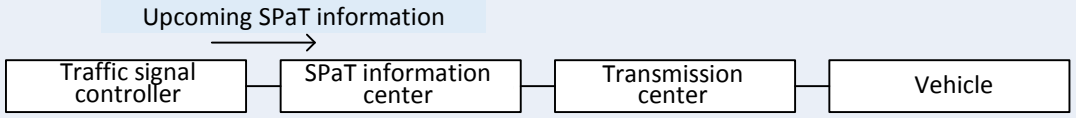


2. Positioning of the project

	Content of the project	Fiscal 2018	Fiscal 2019	Fiscal 2020	Fiscal 2021	Fiscal 2022
SIP Project	Research and survey on basic functions for providing SPaT information using methods other than V2I communication via ITS roadside radio units, etc.	➡				
	- Preparation of detailed functional and technical requirements for methods to provide SPaT information - Verification of the four proposed methods to provide SPaT information using a simulated system - Preparation of draft specifications for a model system to be built for the fiscal 2020 project		➡			
	Installation and verification of a model system for prefectural police headquarters Examination of specifications for the NPA's model system			➡		
	Preparation of the NPA's SPaT information integration model and the installation of its model system in three prefectures				➡	
	Verification of the effects of the NPA's SPaT information integration model and its model system for three prefectures					➡

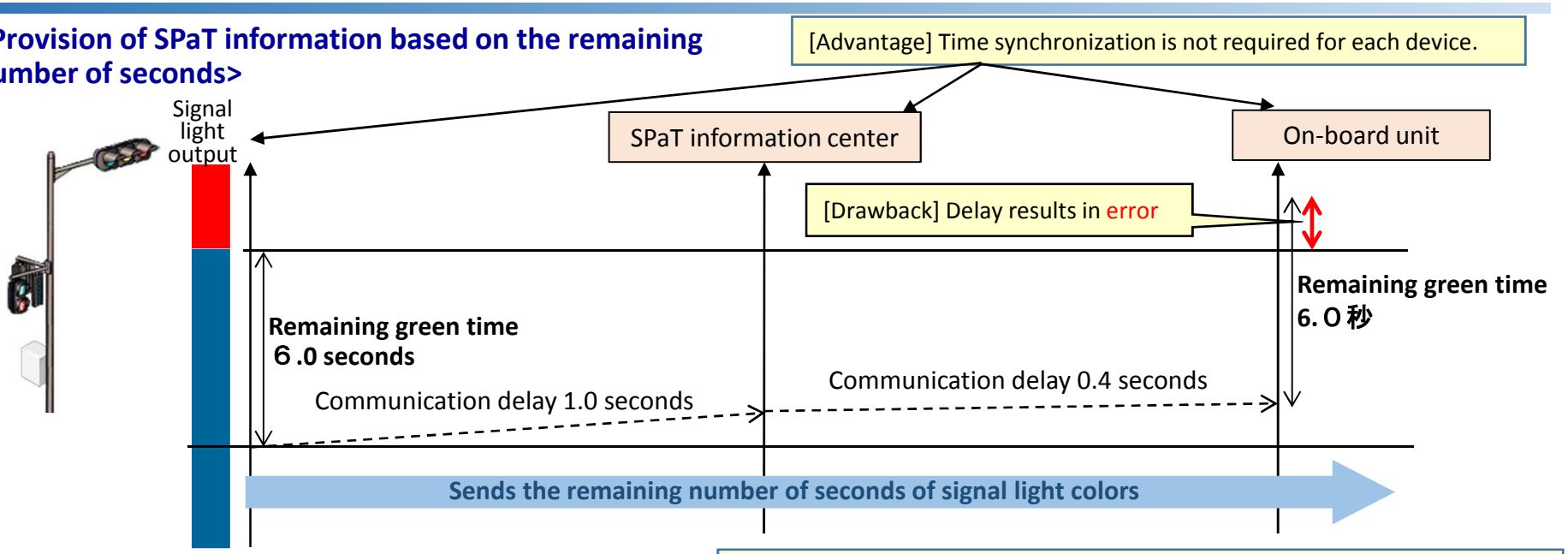
3. Methods for providing SPaT information

The four SPaT information provision methods that are the subject of evaluation are shown below.

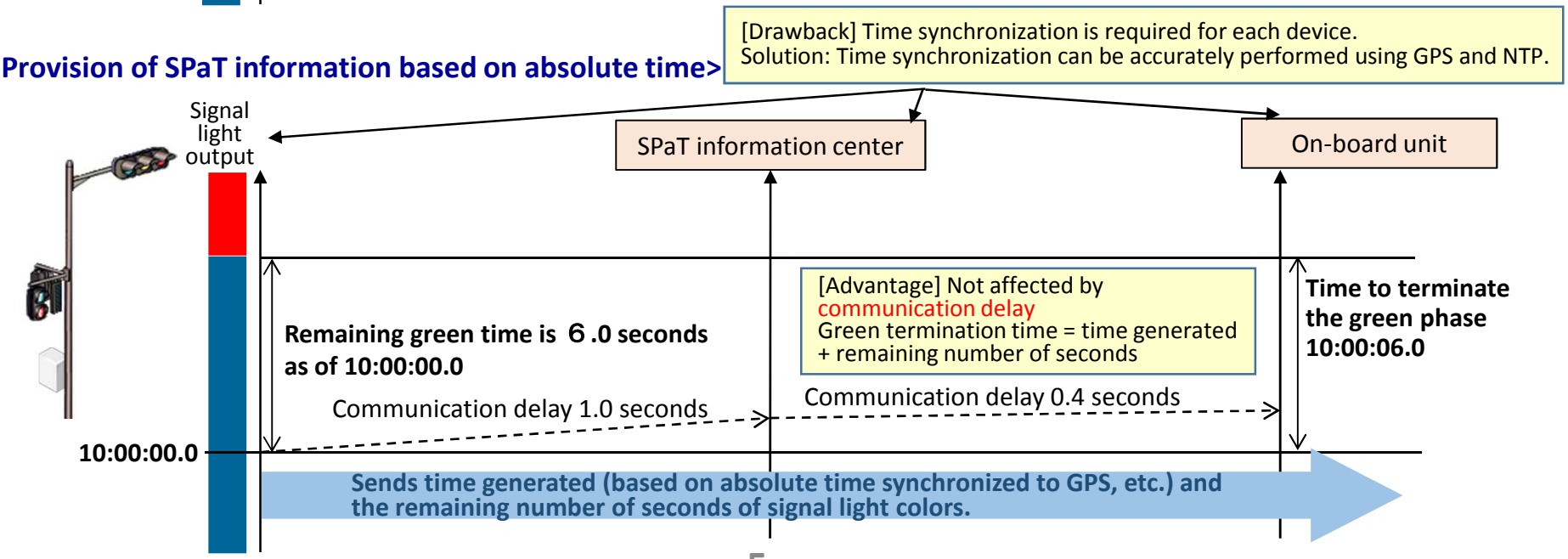
Method	SPaT information generator	Configuration
Traffic control-based method	Traffic control center	
Centralized method (1)	Traffic control center	
Centralized method (2)	Traffic signal controller	
Controller-based method	Traffic signal controller	

4. System built for evaluating the methods based on control of absolute time

<Provision of SPaT information based on the remaining number of seconds>



<Provision of SPaT information based on absolute time>



5. Main evaluation results (1)

An environment was created for each method using a simulated on-board unit, in which the process from the generation to the display of upcoming SPaT information was performed.

<Verification of communication delays>

Because each method uses a mobile network, there is a communication delay of up to 1.4 to 2.5 seconds. For upcoming SPaT information that uses a fixed number of seconds for signal steps, it is possible to correct differences in the signal color indication timing caused by delay based on absolute time; however, for upcoming SPaT information of traffic-actuated signal control, in which the number of seconds of signal steps varies, there are issues that need to be addressed, including reducing delays.

Example of communication delay measurement results (between SPaT information generator – on-board unit)

(Unit: millisecond)

	Traffic control-based method	Centralized method (1)	Centralized method (2)	Traffic controller-based method
Maximum value	1840	2220	2490	1343
Minimum value	460	590	0840	160
Average value	875	1150	1411	673
Standard deviation	394	400	0400	393

※ Because each method uses a different number of devices through which SPaT information passes, the measured delays also varied by method.

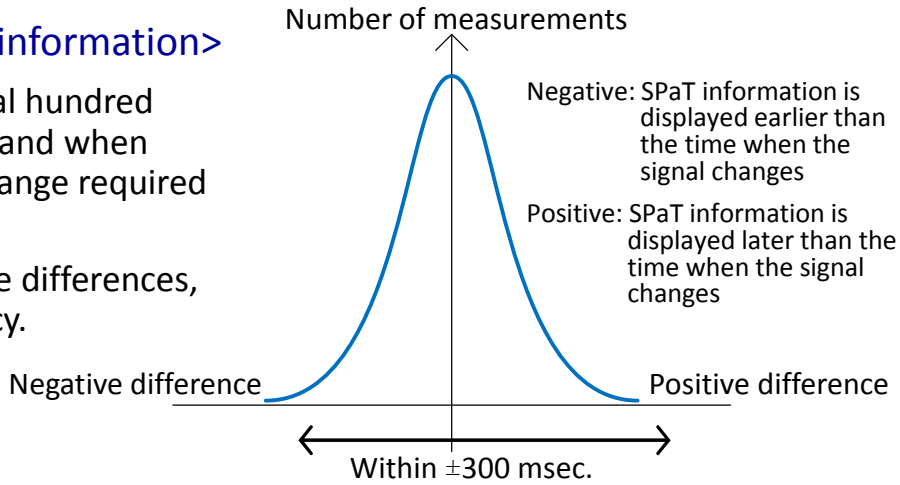
Traffic control-based method:	SPaT information transmission device (Control center) → Simulated SPaT information center → Simulated on-board unit
Centralized method (1):	Terminal control block (Control center) → SPaT information transmission device (Control center) → Simulated SPaT information center → Simulated on-board unit
Centralized method (2):	Traffic signal controller → Terminal control block (Control center) → SPaT information transmission device (Control center) → Simulated SPaT information center → Simulated on-board unit
Traffic controller-based method:	Traffic signal controller → Simulated SPaT information center → Simulated on-board unit

6. Main evaluation results (2)

<Verification of the accuracy of provision of SPaT information>

In each method, there was a difference of around several hundred milliseconds between the time when the signal changes and when SPaT information is displayed, which deviated from the range required by JAMA (±300 milliseconds).

In the future, it is necessary to investigate ways to reduce differences, such as increasing absolute time synchronization accuracy.



Example of difference measurement results (on one phase in one direction) (Unit: millisecond)

		Traffic control-based method	Centralized method (1)	Centralized method (2)	Traffic controller-based method
Start of green	Maximum value	200	1020	470	420
	Minimum value	※ -920	20	270	170
	Average value	-90	110	370	230
	Standard deviation	430	180	60	90
End of green	Maximum value	200	150	450	290
	Minimum value	※ -950	20	250	200
	Average value	-120	70	340	250
	Standard deviation	440	50	60	30

※ In the traffic control-based method, there are cases in which a negative difference of nearly 1 second occurs when a follow-up operation is performed by a terminal as a result of time correction carried out by the traffic signal controller; therefore, measures such as disabling the terminal's follow-up function need to be considered.

7. Main evaluation results (3)

<Examination of applicability to each function >

Function of signal controller	Traffic control-based method	Centralized method (1)	Centralized method (2)	Controller-based method	
				Centralized	Decentralized
Coordinated control function	△	○	○	○	△
Traffic-actuated control function	×	×	△	△	△
Gap responsive control function	×	○	○	○	○
(Other functions)	Except the traffic control-based method, the applicability was almost the same.				

1. The current traffic control-based method is not able to obtain real-time results of traffic-actuated control and other signal control operations.
2. For other methods, the applicability of these methods to each signal control function was almost the same.

<Others>

Criteria for selecting methods were determined by identifying and listing issues from various evaluation perspectives.

[Comparison items]
- Error detection ・・・・・・・・・・・・・・・・・・・・・・・・・ Detectability of errors in systems including traffic signal controllers
- Ease of introduction ・・・・・・・・・・・・・・・・・・・・・・ Impact of introducing the methods on the existing traffic signal control systems
- Operational restrictions ・・・・・・・・・・・・・・・・・・ Accuracy issues that may arise unless changes are made to the existing traffic signal systems
- Regulatory and institutional issues, etc. ・・ A need to change the existing traffic signal lighting specifications of National Police Agency

8. Points in selecting methods for a model system

Based on the evaluation, methods used for a model system were selected.

<Points for the selection>

Points for the selection based on the project's purposes

1. Selected methods are implemented to provide upcoming SPaT information at lower cost and over a wider area than methods that require the installation of ITS roadside radio units.
2. It is possible to change the operational method of the current traffic control in order to provide upcoming SPaT information.
3. Implementation of selected methods will be examined with priority given to areas with centralized traffic control where the necessity of SPaT information is considered high.

Points for the selection with an eye on future traffic control

4. It is possible to provide SPaT information even when using control methods (autonomous distributed control performed by control terminals) in which the number of seconds is determined by control terminals.

Based on the points described above, a comparison was made for each method.

9. Selection of methods for a model system

Methods were decided by the National Police Agency after a comprehensive judgment based on the verification results.

Item	Reasons for evaluation results	Traffic control-based	Centralized (1)	Centralized (2)	Controller-based
Cost	Cost to be incurred assuming that the provision of upcoming SPaT information is implemented at intersections across the country	◎	○	○	△
	Cost to be incurred assuming that the provision of upcoming SPaT information is implemented at intersections of special zones	◎	△	○	○
Delay error	Because experiment results alone did not show obvious difference between methods, delay errors will be verified again in a real environment in the next fiscal year.	—	—	—	—
Applicability to each function	Applicability to traffic-actuated control	× ※1	○	○	○
Others	Error detection	×	○	○	○
	Ease of introduction	◎	×	○	○
	Operational restrictions	△	○	○	○
	Regulatory and institutional issues	◎	△※2	△※3	○

※1 There are issues to be examined, such as changes to traffic signal control systems and the interface between the devices.
※2 It is necessary to remodel each of the devices that comprise the traffic control center and traffic signal controllers and to change specifications for the interface between the devices.
※3 It is necessary to formulate specifications for the interface used for the output of upcoming SPaT information from traffic signal controllers.

- A model system will be built and verified with focus on the **traffic control-based method**.
- To respond to cases where the traffic control-based method cannot be applied even after changing traffic signal control systems, the **centralized method (2)** and **controller-based method** will also be verified on a small scale.

10. Future issues (1)

<Issues>

1. Examination and demonstration of measures to provide upcoming SPaT information to automated driving vehicles a few seconds before early termination of signal phase in the cases of traffic control such as traffic-actuated control and recall control, where the signal color sequence and the number of seconds for each step vary due to the control performed by control terminals after a cycle starts.

(Proposed measures) Introduce control systems, which determine the number of seconds per actuation and the sequence of signal light colors before the time at which the signal light color changes.

2. Examination and demonstration of measures to improve the accuracy of delays in transmitting upcoming SPaT information and errors in displaying signal light colors

(Proposed measures) Revise the processing cycle of devices through which data is transferred.

11. Future issues (2)

<Other issues that need to be addressed>

Item	Description of issue
Communication lines	Although this research project used LTE communication lines for the communication between traffic signal controllers and a simulated SPaT information center in the traffic signal controller-based method, research and verification of communication lines taking account of “real time performance,” “security” and “robustness” can be considered.
Communication application standards	Specifications for the communication application standard used in this research project are not common to each method. In the future, it is necessary to verify standardization of specifications between the methods.
Verification of the failure notification function	It is necessary to examine functions to notify traffic signal maintenance and operations personnel of failure information.