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

Research on the provision of traffic signal information through means other than vehicle-to-infrastructure communication via ITS roadside radio units and others

Progress Report for Fiscal Year 2018

March 2019

UTMS Society of Japan

1. Outline of Research

<Purpose>

With the goal of contributing to the realization of the provision of traffic signal information using methods other than vehicle-to-infrastructure communication, the research will conduct surveys on examples and technological trends of methods that allow the provision of traffic signal information and that do not use vehicle-to-infrastructure communication, and develop measures for addressing issues toward realizing methods that are highly feasible and highly applicable to automated driving vehicles based on views and needs of automotive manufacturers and other organizations.

<Outline>

(1) Surveys on examples of methods that allow the provision of traffic signal information other than the method of vehicle-to-infrastructure communication

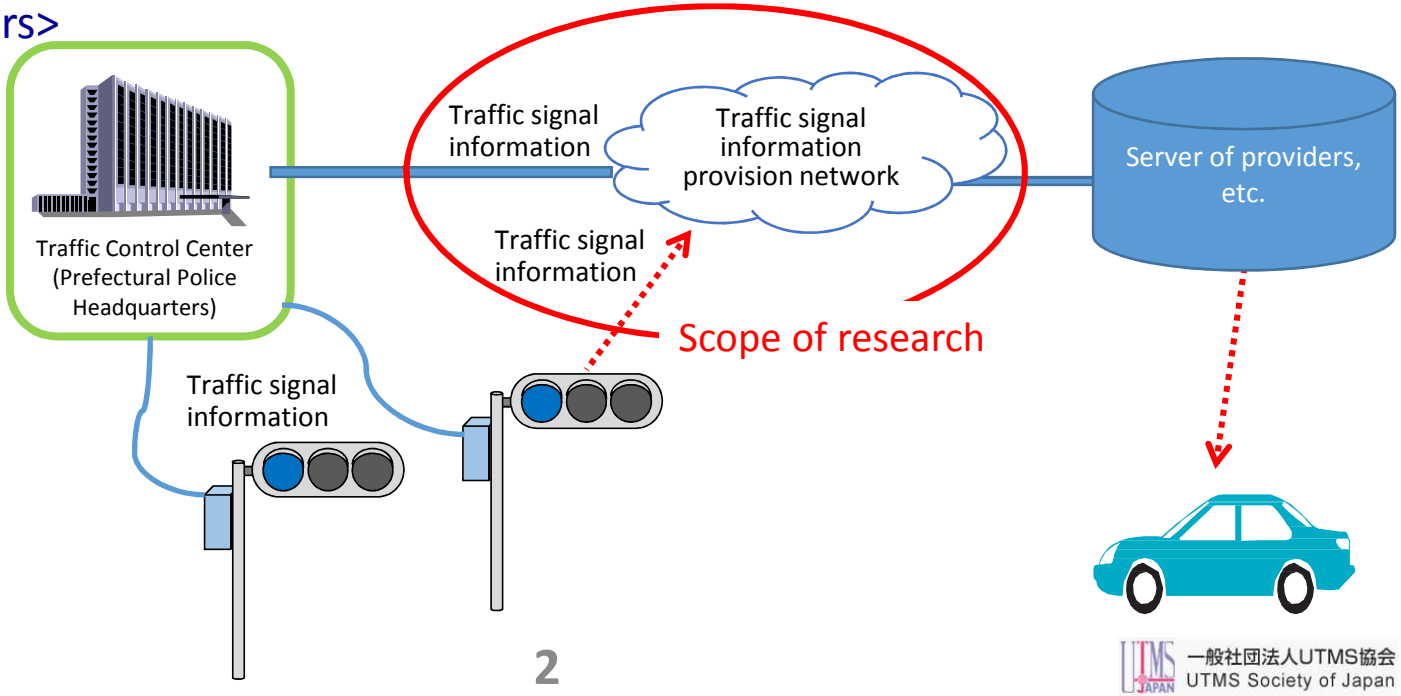
(2) Identification of methods that allow the provision of traffic signal information other than vehicle-to-infrastructure communication and the examination of feasibility of each method

(3) Examination of measures for addressing issues toward the realization of methods that are highly feasible.

<Participating members>

A committee was established, consisting of

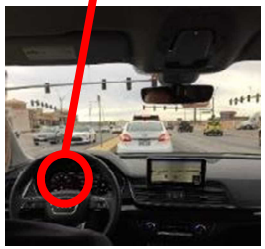
- Automotive manufacturers
- Traffic signal infrastructure makers
- Communications carriers
- JAMA



2. Survey of examples in Japan and abroad

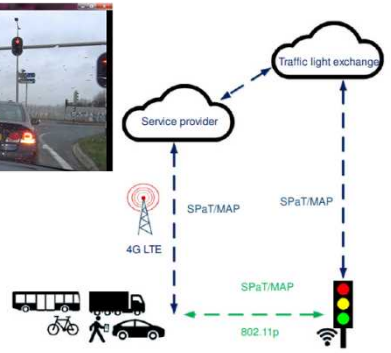
Las Vegas, the U.S. (TTS - Traffic Technology Services Inc.)

- Traffic signal information is provided to Audi vehicles via cellular network
- Information is provided at 20,000 intersections in cooperation with more than 90 traffic management authorities



North Holland Province, the Netherlands

- Traffic lights that are standardized for providing traffic signal information are managed by the government
- The government is responsible up to the point of sending traffic signal information. The rest falls under a competitive domain for the private sector.

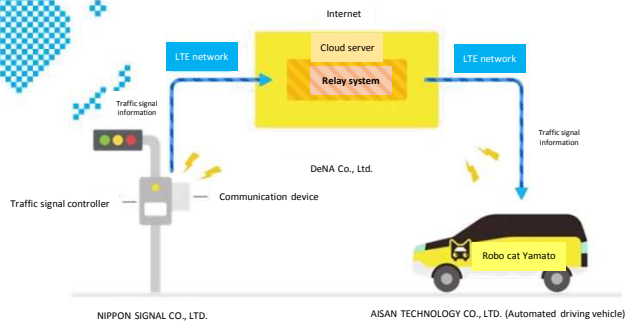


Wuxi City, China (Huawei)

- Roadside units are installed at 240 intersections, information is transmitted over LTE.
- Information provided includes traffic signal phases and traffic conditions

Fujisawa City, Kanagawa Pref. (DeNA, NIPPON SIGNAL CO., LTD.)

- Traffic signal information is sent to automated driving vehicles over LTE.
- The current and subsequent traffic signal colors and their numbers of seconds are transmitted till the next time the initially transmitted signal color is indicated.



3-1 Results of interviews with experts

○ Requirements for traffic signal information

Item	Expectation
Content of traffic signal information	・Current traffic signal color, upcoming timing for signal color indications ・Implementation status of traffic-actuated signal control (whether the upcoming timing for signal color indications dynamically change)
Timing information	・Timing of current and the following cycles (for two or more cycles) ・Timing of two or more times of red phases
Number of intersections to which traffic signal information is provided	・The intersections which the vehicle is to pass through first and next (two intersections)
Required accuracy (acceptable error)	・Within 300 ms (until the vehicle receives information)

○ Uses of traffic signal information

Classification	Uses
Information provision	・Information provision and alerting to support driving and prevent accidents ・Guiding an optimal route with consideration to traffic lights
Vehicle control	・Control of automated driving systems ・Control of driving support systems

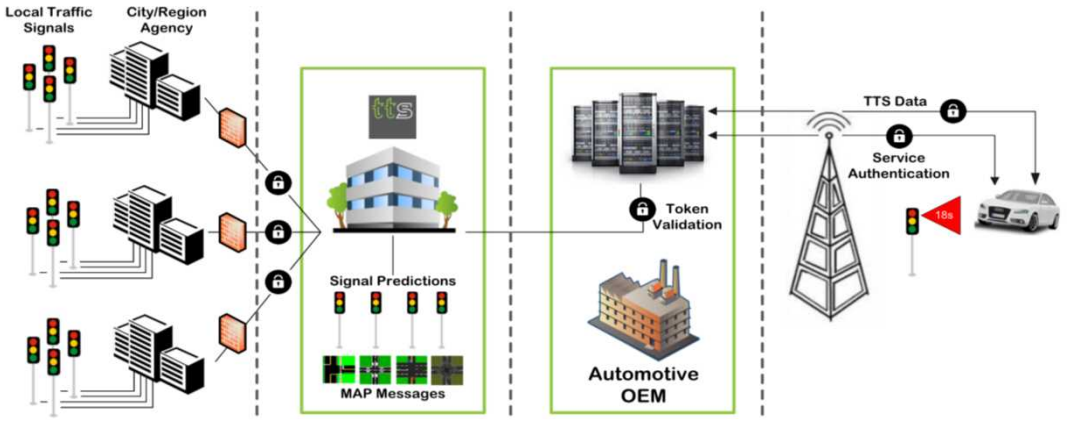
3-2 Examination of providing traffic signal information to automated driving vehicles

○ Method for minimizing errors

Item No.	Method	Error cause	Method outline
1	Set the start/end of signal color indications in clock time	Delay	Transmit the start/end of signal color indications in absolute clock time to minimize the effect of delay.
2	Compensate delays in clock time	Delay	Add the creation time to traffic signal information in clock time. The vehicle calculates communication delay based on the difference between the time the information was received and the creation time indicated in the traffic signal information received, and makes adjustments so that the communication delay is taken into account in the traffic signal information.
3	Reduce delay fluctuation range	Delay	The vehicle compensates delays with fixed values. Delays in devices through which the information is transmitted will be made constant so that delays become fixed values.
4	Reduce actual delays themselves	Delay	Reduce errors caused by delays by reducing actual delays themselves.
5	Control delays that occur when traffic signal information is created.	Accuracy	Reduce differences in clock times and discrepancies with signal color outputs that occur when traffic signal information is created in traffic signal controllers and others.

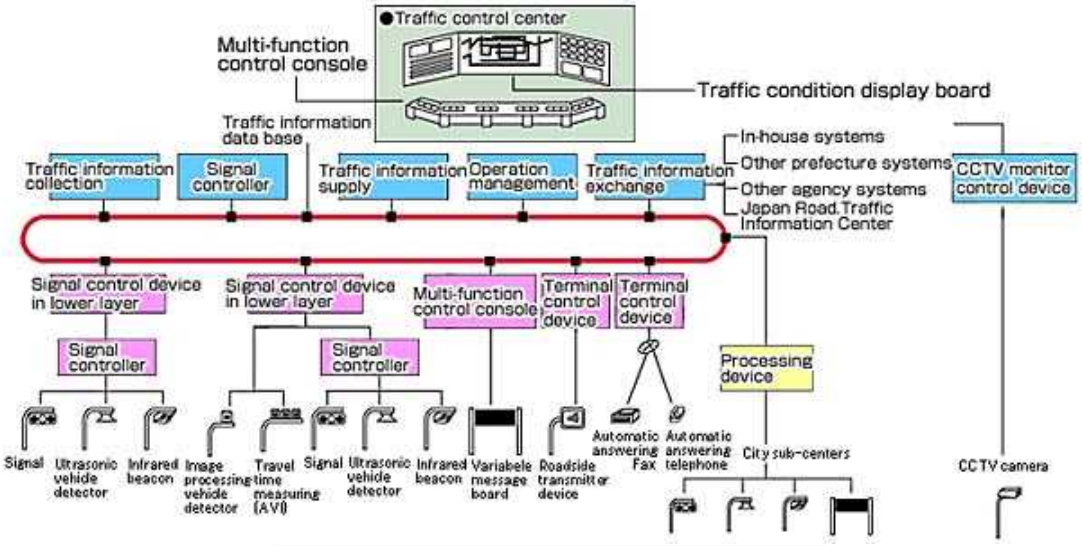
4 From the results of surveys of examples and interviews

The surveys of examples in Japan and abroad confirmed that there are examples providing traffic signal information via the cloud using the LTE network instead of through direct communication from intersections.



Example of Traffic Technology Services Inc. (TTS) , Las Vegas, the U.S.

In the interviews, experts pointed out that it is necessary to minimize errors in traffic signal information and provide upcoming signal timing information over the next two cycles.



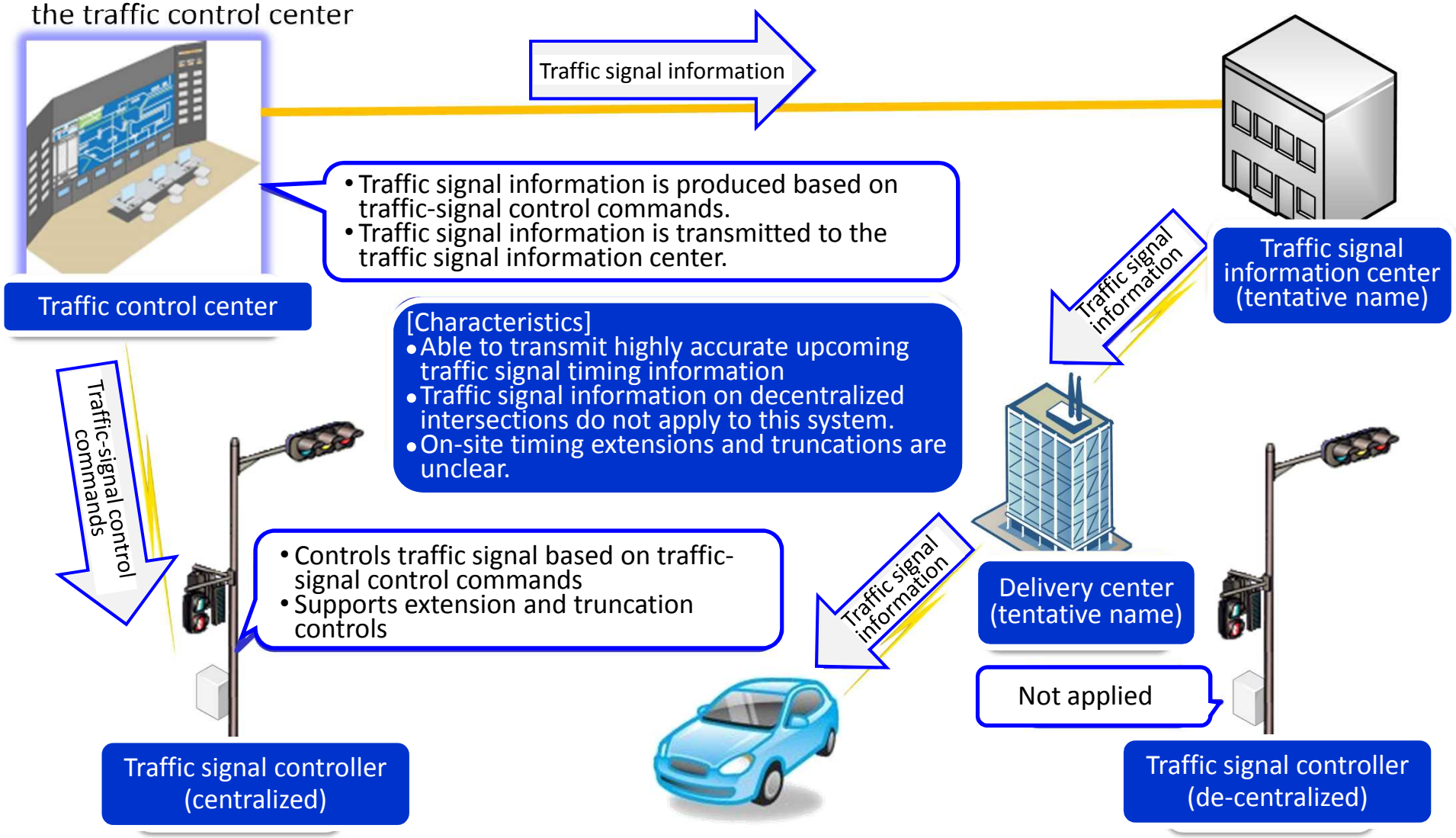
Current traffic control system

Based on the configuration of the current traffic control system, a traffic signal controller and traffic control center are considered to be prospective generators of traffic signal information.

System configuration plans for the traffic signal information provision system utilizing existing systems are shown in the following pages.

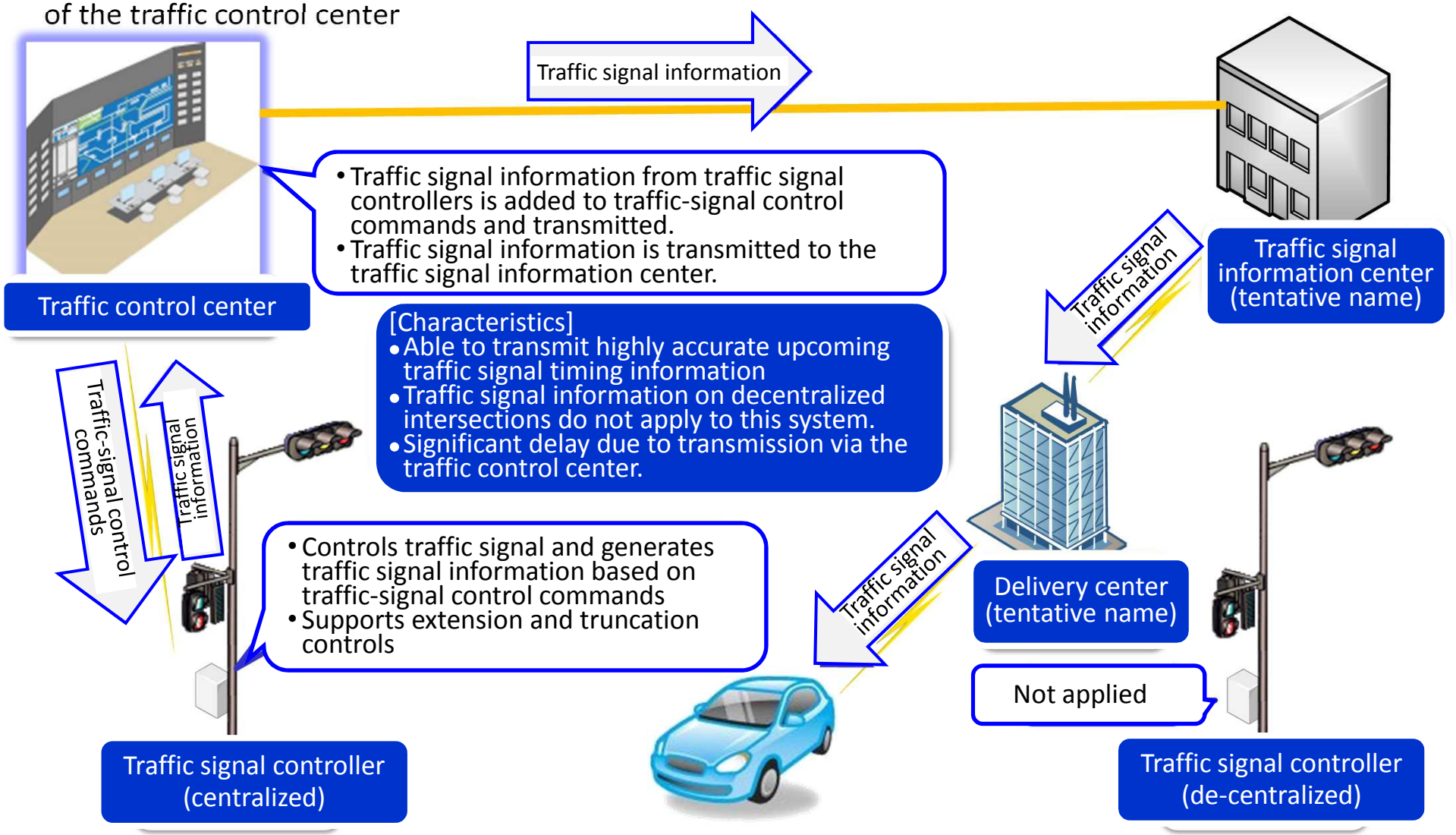
4-1 Methods and system configurations other than those of vehicle-to-infrastructure communication (a control-based system)

A system to deliver traffic signal information generated from traffic-signal control commands produced by the traffic control center



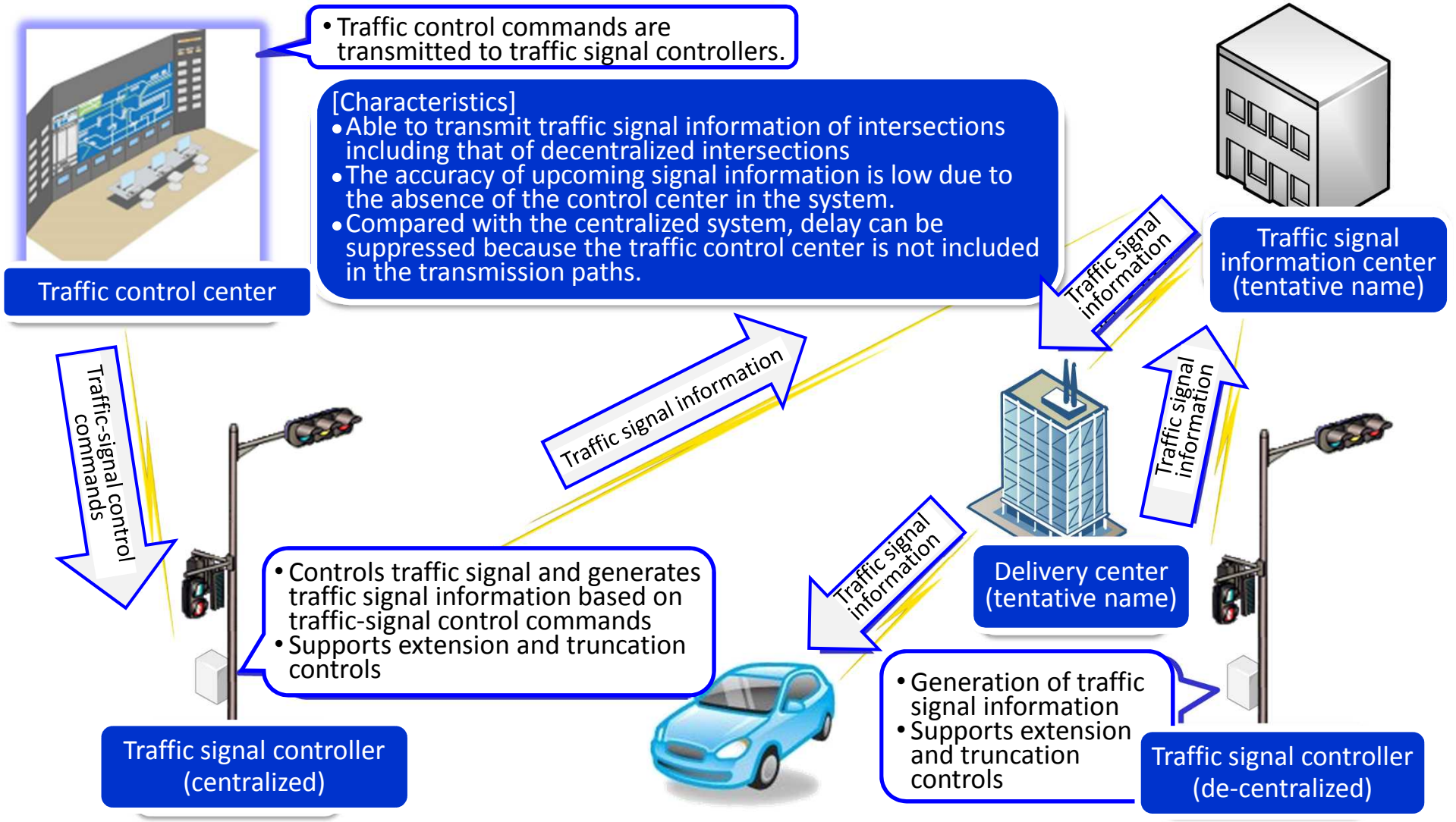
4-2 Methods and system configurations other than those of vehicle-to-infrastructure communication (a centralized system)

A system to deliver traffic signal information generated by traffic signal controllers (centralized) by way of the traffic control center



4-3 Methods and system configurations other than those of vehicle-to-infrastructure communication (a traffic signal controller-based system)

A system to generate and deliver traffic signal information using traffic signal controllers



5 Method to obtain traffic signal information at decentralized intersections

The following methods could be used to provide traffic signal information at decentralized intersections.

- Decentralized intersections are centralized so that traffic information is provided using the same systems as those used for centralized intersections.
- Traffic signal information is provided by using the traffic signal controller-based system only at decentralized intersections.
- The traffic control center or traffic signal information center generates and transmits traffic signal information after estimating the traffic control status of decentralized intersections based on parameters in traffic signal controllers.

Issues are considered to be as listed in the table below, and examination needs to be proceeded in view of dissemination, costs and others.

Issue	Draft measures to be examined
Determination of cycle start times (Unable to know when a cycle time started)	Incorporate cycle start times in the coordinated signal control system.
Clock synchronization (An error occurs when the clock time between traffic signal controllers and at the traffic control center differs.)	Provide traffic signal controllers with means to allow the correction of clock time (GPS and others)
Reliability of traffic signal information (Unable to identify the numbers of seconds during traffic-actuated control, the operation, abnormalities and operation performed over a period that is different from set numbers of seconds during recall control, etc.)	Install a device to determine online the operating state of traffic signal controllers.

6-1 Issues and examples of measures proposed (relating to the production of traffic signal information)

Item No.	Issue	Proposed measures
1	Synchronization of all clocks in the system	Clock synchronization using GPS and NTP is considered a possible measure. If synchronization cannot be obtained, steps shall be taken, including the suspension of the provision of traffic signal information and notification of the reduction in information accuracy.
3	Suppression of errors during the production of traffic signal information	・Traffic signal controllers generate information with errors of around 10 to 100 milliseconds. ・The accuracy of the information that can be handled by traffic signal controllers and the traffic control center is set in increments of 10 to 100 milliseconds.
4	Operation in the case where the timing of traffic signal information becomes indefinite (such as the cases of traffic-actuated control and others).	Measures will reflect the content being examined in the SIP research project, “the Enhancement of Technologies to Provide Traffic Signal Information toward the Realization of Automated Driving.” Examples are given below: ・Notification of the control status of traffic-actuated control and recall control ・Provision of traffic signal information during recall control and during control under FAST
5	Specification of delay requirements of each device and between devices	Allowable delay for the system is determined based on “how many seconds before the receipt of traffic signal information by the vehicle does the traffic signal information containing determined number of seconds need to be transmitted? ” and “what is the maximum number of seconds allowed from the detection of abnormalities until the receipt of abnormality notification by the vehicle,” and then allowable delay time for each device in the system is specified.
6	Consistency between traffic signal information and the lighting state of traffic signal	Consistency between signal color outputs by traffic signal controllers and traffic signal information is confirmed using traffic signal controllers, transmission devices and others.

6-2 Issues and examples of measures proposed (relating to traffic signal information centers and others)

Item No.	Issue	Proposed measures
1	Ensuring of security	Security requirements will be specified during the process of identifying functions and technical specifications. Examples of measures to ensure security are given below: ・Encryption of communication ・Periodic change of encryption keys ・Authentication of traffic signal information centers and its users ・Use of closed networks or virtual private networks (VPN) ・ Provision of firewalls ・Installation of latest security technologies ・Physical and logical isolation from existing systems (such as one-way communication)
2	Means of communication between the producer of traffic signal information and the traffic signal information center	Means of communication will be classified as follows: ・Wired and wireless (cellular telephone networks, peer-to-peer radio) ・Leased lines, virtual private networks, public lines Appropriate means will be examined taking into consideration required performance (delay and others), operational costs, security and others.
3	Unit of division based on which the number of traffic signal information centers is defined	Examination of the unit of division by which the number of traffic signal information centers to be installed is defined, which ranges from area-based (covering several intersections) to prefecture-based (covering several hundred intersections) The examination should consider factors such as the ease of installation at the time of construction, operational and maintenance costs, delay due to distance and processing delay caused by an increase in the number of terminals.

7 Future issues

The research conducted in the fiscal year 2018 identified methods to provide traffic signal information other than those that use vehicle-to-infrastructure communication and examined issues and measures to be taken in realizing these methods.
In the future, after verifying the results of the examination, systems to respond to the needs of the automated driving society have to be proposed while making the maximum use of existing facilities.

1. Examination of clock synchronization to eliminate the effects of errors and transmission delays.
2. Consistency between traffic signal information and the lighting state of traffic signal
3. Operation in the case where traffic signal information fluctuates, such as the cases of traffic-actuated control and others
4. Examination of cost-effectiveness in consideration of implementation and operational costs