Strategic Innovation Promotion Program (SIP) Automated Driving Systems/Large-scale Field Operational Test/Dynamic Map/Utilization of Vehicle Probe Information

Final Report – summary

PIONEER CORPORATION

February 28, 2019

Purpose of this activity

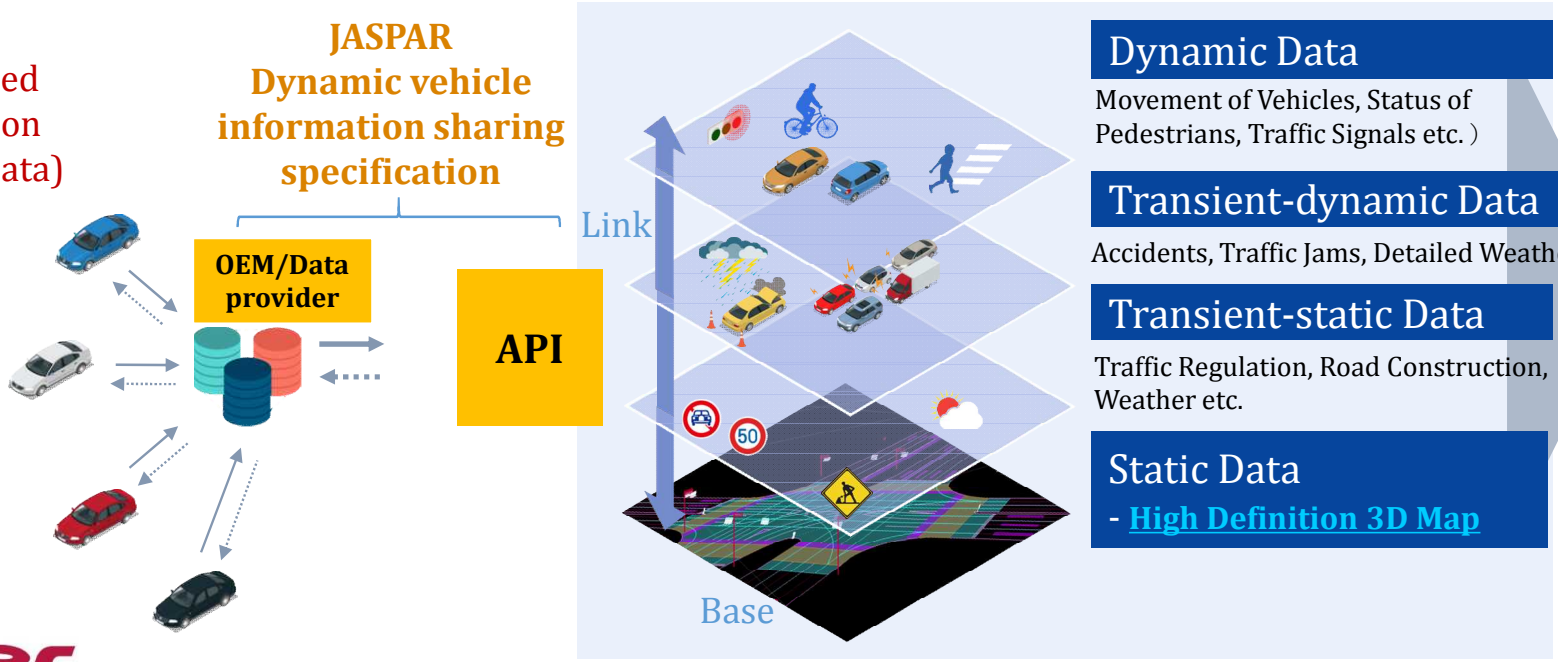
Background:

It is expected that the vehicle probe information will be shared among industries to realize a more efficient and safer society especially when automated vehicles become a reality.

Purpose:

Evaluate subjects in order to share probe information through the Field Operational Test.
Evaluate data set format and API that need for sharing probe data.
Implement “JASPAR Dynamic vehicle information sharing specification” for evaluation of probe data sharing.
Evaluate processing delay of “traffic flow” information generation

In this activity, we used traffic flow information (transient dynamic data)

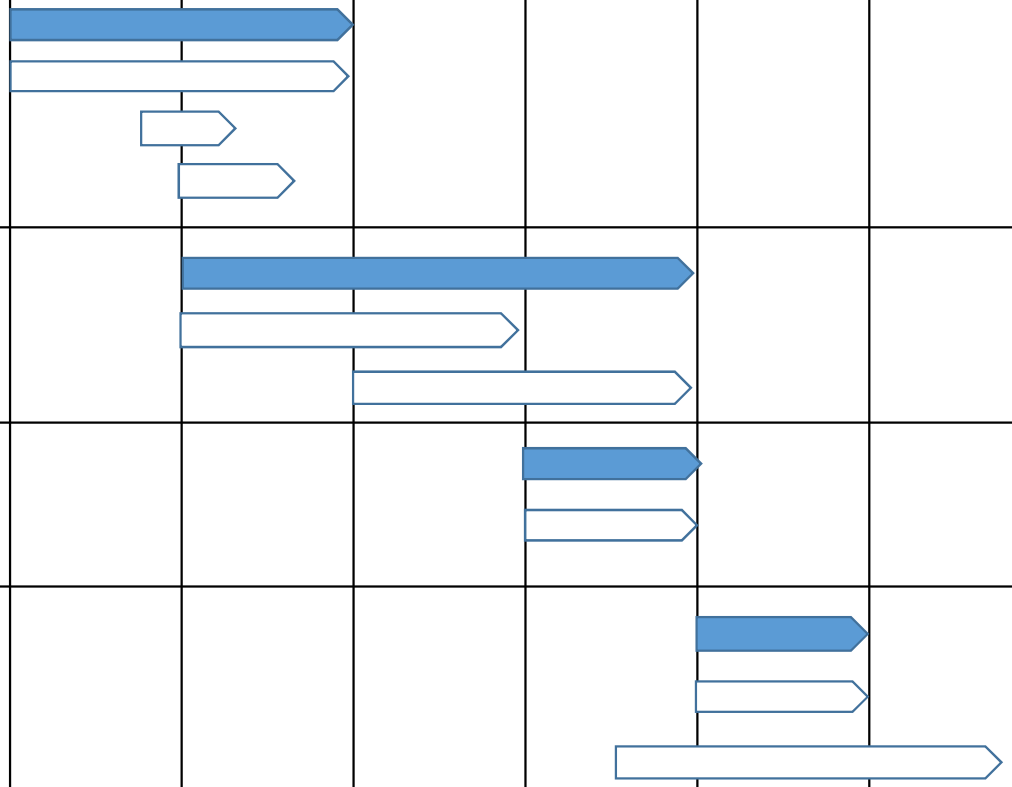


Note: JASPAR (Japan Automotive Software Platform and Architecture）

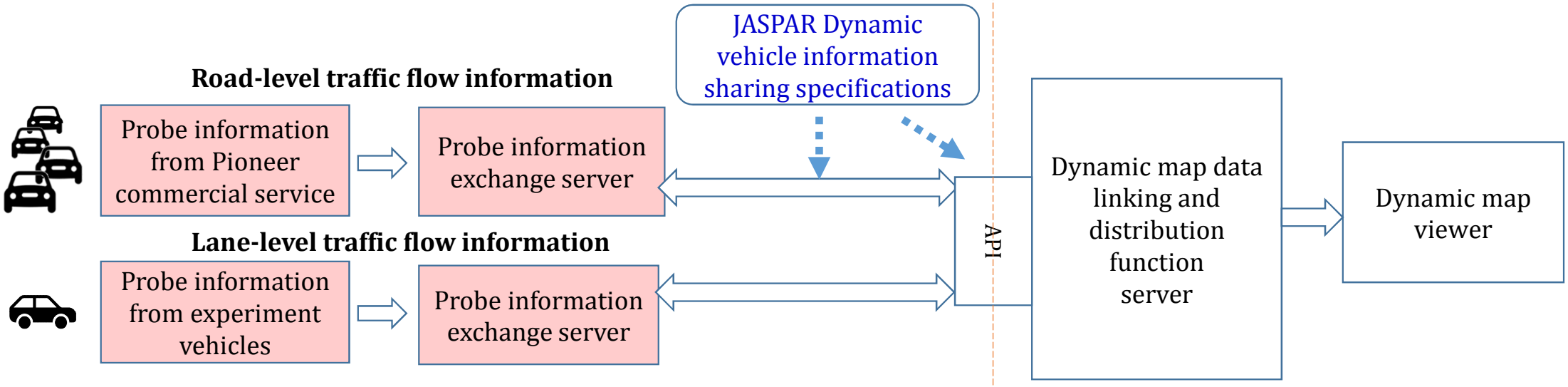
*reference: SIP document

Overview of working items

Working Item	2017-2018		2018-2019			
	10-12	1-3	4-6	7-9	10-12	1-3
Study probe information to utilize A) Prepare the probe data B) Check compatibility with JASPAR dynamic vehicle information sharing specification C) Visualization of probe information						
Preparation of probe information exchange server A) Implement basic functions B) Implement JASPAR specification						
Cooperation with Dynamic map large-scale FOT consortium A) Connection test, and operational test of functions						
Field Operational Test A) Co-experiment with SIP Dynamic map FOT consortium B) Evaluation						



Scheme of the field operational test



Operated by this project

Operated by Dynamic map large-scale Field Operational Test consortium (Another NEDO project)

- Implement the Dynamic vehicle information sharing draft specifications issued in early 2018
- Evaluate the “traffic flow” content specified in the above specification
- Feedback evaluation result for the specification

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Study probe information to utilize

◆ The following table shows probe information that we choose to utilize.

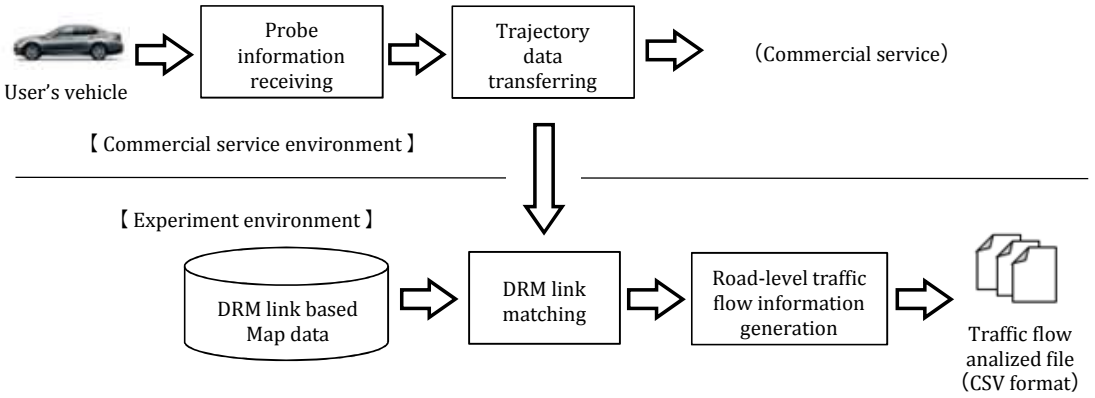
probe information	use-cases	description
Road-level traffic flow	Planning an appropriate route to avoid a road where a congestion occurs	Traffic flow information that is generated based on aggregated probe information derived from car navigation system equipped vehicles on the road.
Lane-level traffic flow	Planning a path to avoid a lane that is congested	Traffic flow information that is generated based on probe information derived from experiment vehicles equipped with customized car navigation system. An experiment vehicle drives predetermined lane and its prove information is used to generate traffic flow of that lane.

Study probe information to utilize

A) Prepare probe data

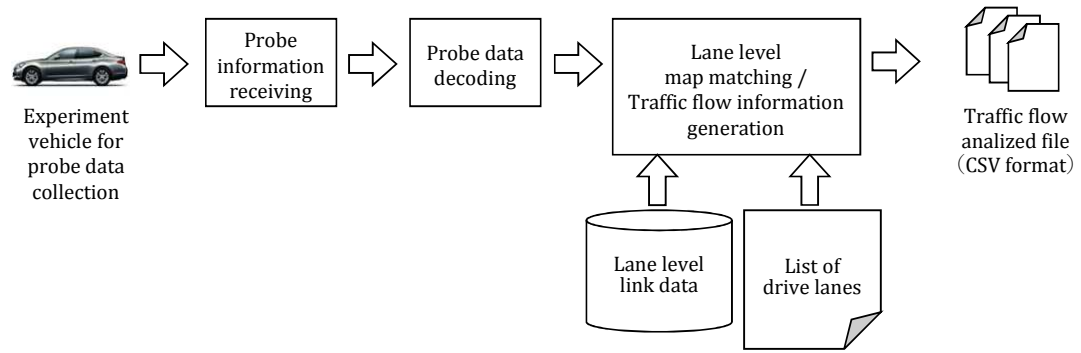
◆ **Road-level traffic flow:**
prepare road-level traffic flow information based on the commercial service

- utilize vehicle trajectory information from commercial service
- utilize DRM road link for map matching and traffic flow analysis
- confirm traffic flow data file by using SIP dynamic map viewer



◆ **Lane-level traffic flow:**
Prepare lane-level traffic flow information based on experiment vehicles

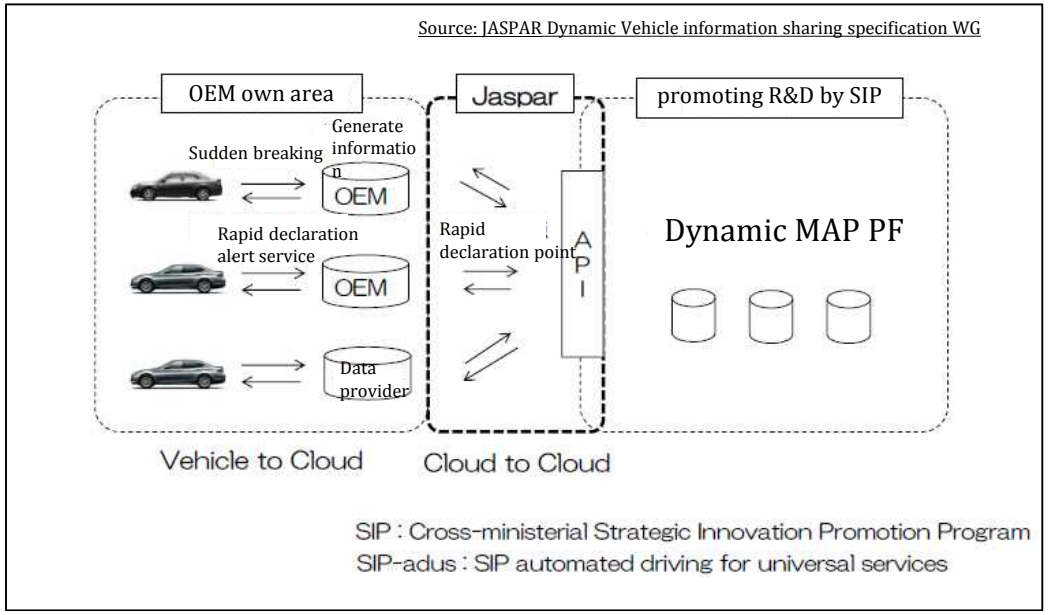
- Customize car navigation system to collect data for this specific purpose.
- Utilize SIP dynamic map lane link for map matching and traffic flow analysis
- confirm traffic flow data file by using SIP dynamic map viewer



Study probe information to utilize

B) Check compatibility with JASPAR dynamic vehicle information sharing specification

- Confirm compatibility with JASPAR specification
  - confirm whether JASPAR dynamic vehicle information sharing data set specification can be applied to probe information that we prepared.
  - confirm whether JASPAR dynamic vehicle information sharing API specification provides sufficient functions for the field operational test.
  - consider creating implementation specification if necessary



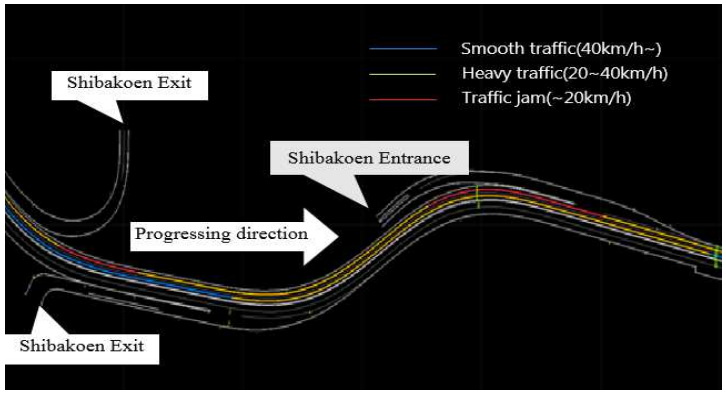
- Concept Specification
- Dataset Specification
- API Specification

JASPAR Dynamic vehicle information sharing specification

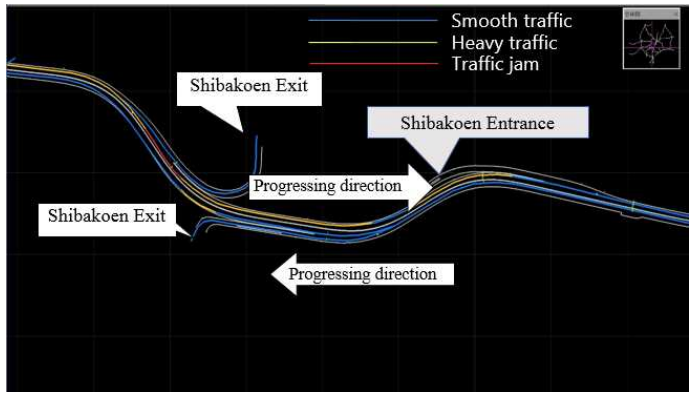
Study probe information to utilize

C) Visualization of probe information

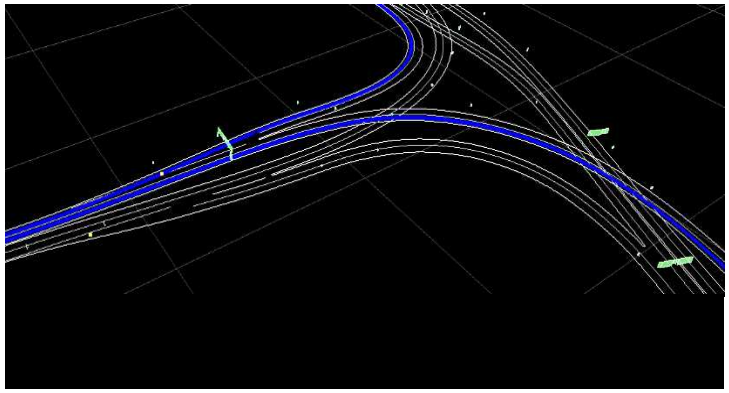
- We confirmed that the generated traffic flow is displayed on SIP dynamic map viewer correctly.
  - A traffic flow data that is based on a location of conventional navigation map can be represented almost correctly on SIP high-definition map.
  - We confirmed that traffic flow data can correctly be identified when road has a layered structure if altitude information is attached.



A lane-level traffic flow example on SIP Dynamic map Viewer



A road-level traffic flow example on SIP Dynamic map Viewer



Confirmation of a traffic flow with altitude data

Preparation of probe information exchange server

◆ We prepared probe information exchange server for road-level traffic flow and lane-level traffic flow respectively. The functions of each server are described as follows:

Road-level traffic flow:

- Generate road-level traffic flow information based on DRM road link with commercial service probe data.
- Convert traffic flow information to a specific data format that is defined by JASPAR specification
- Send traffic information to Dynamic map data linking and distribution function server by using JASPAR API specification.

Lane-level traffic flow:

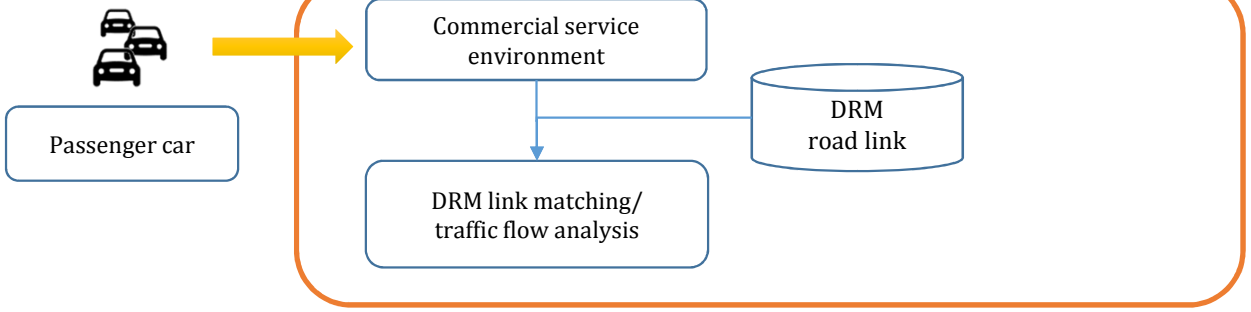
- Receive and decode probe data sent from experiment vehicle with customized car navigation system
- Generate lane-level traffic flow information based on SIP dynamic map lane link.
- Convert traffic flow information to a specific data format that is defined by JASPAR specification
- Send traffic information to Dynamic map data linking and distribution function server by using JASPAR API specification.

Preparation of probe information exchange server

A) Implement basic functions

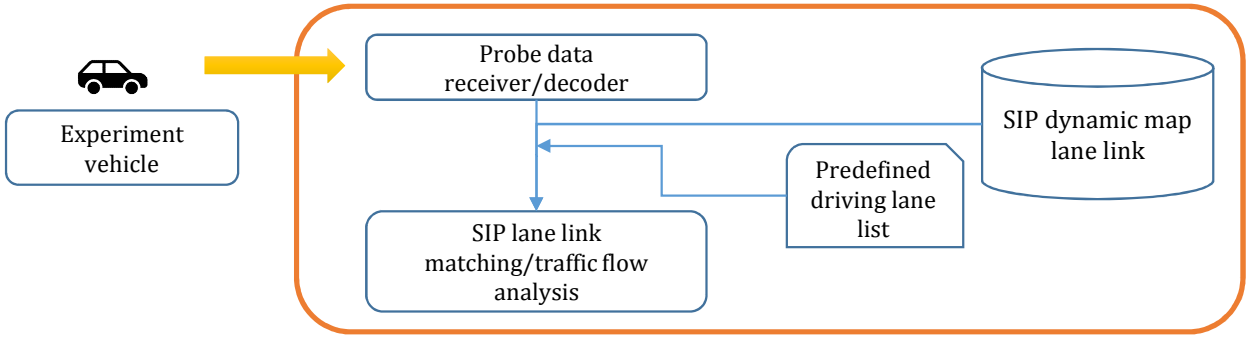
- We implemented basic functionality of probe information exchange server to generate traffic flow information from vehicle probe data.
  - We separated a road-level traffic flow generation server and lane-level traffic flow generation server due to a difference of data generation process.

Road-level traffic flow information
(commercial service)



Probe information exchange server for road-level traffic flow

Lane-level traffic flow information
(experiment vehicle)

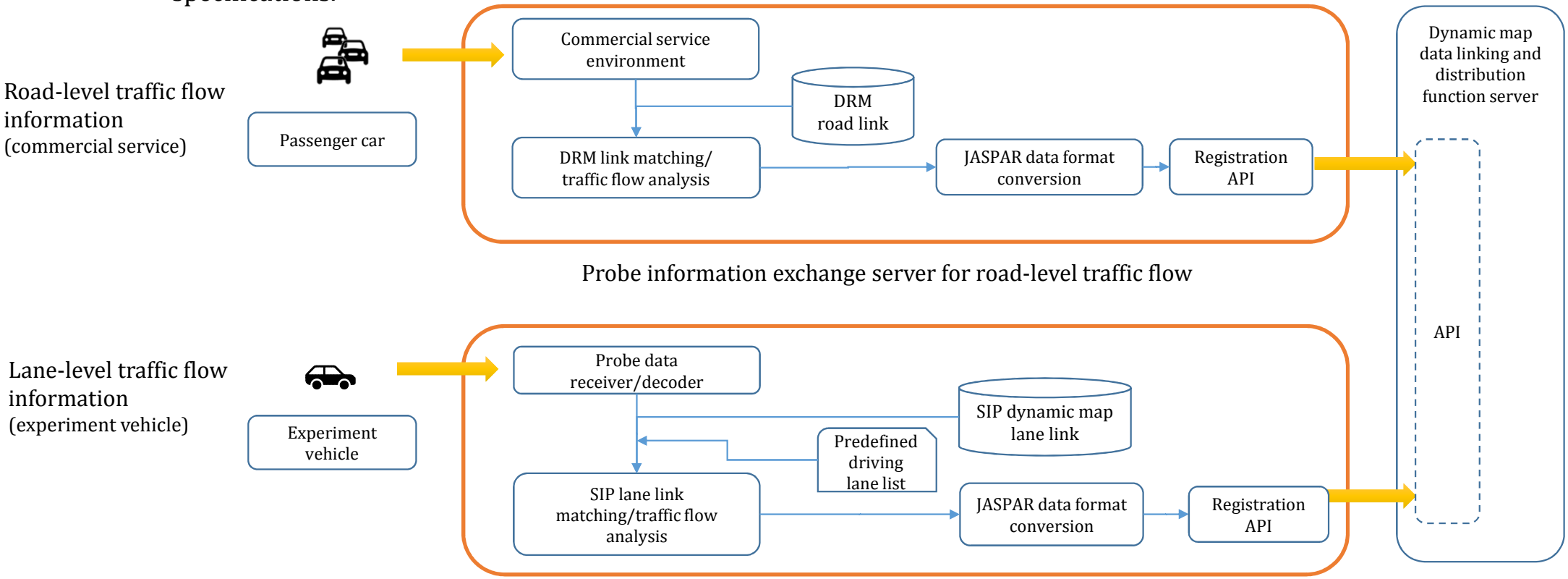


Probe information exchange server for lane-level traffic flow

Preparation of probe information exchange server

B) Implement JASPAR specification

- We implemented functions to convert traffic information to specific data format defined by JASPAR data set specification and to transfer it to Dynamic map data linking and distribution function server by API specification.
  - We have cooperated with Dynamic map large-scale field operational test consortium to implement JASPAR specifications.



Cooperation with Dynamic map large-scale FOT consortium

- Traffic flow information generated by this project will be sent to Dynamic map data linking and distribution function server that is operated under the Dynamic map large-scale field operational test consortium.

- To confirm that the traffic flow information is correctly communicated in comply with JASPAR specifications, and to confirm the traffic flow information is correctly displayed on SIP dynamic map viewer, and to confirm that the server will operate correctly even if system load becomes high, we both collaborated and performed logical connection test and system-level connection test between the probe information exchange server and the Dynamic map data linking and distribution function server.

- For lane-level traffic flow, we needed to drive real road environment. We prepared some experiment vehicles and tested whether the lane-level traffic flow information is correctly generated and transferred to the Dynamic map data linking and distribution function server.

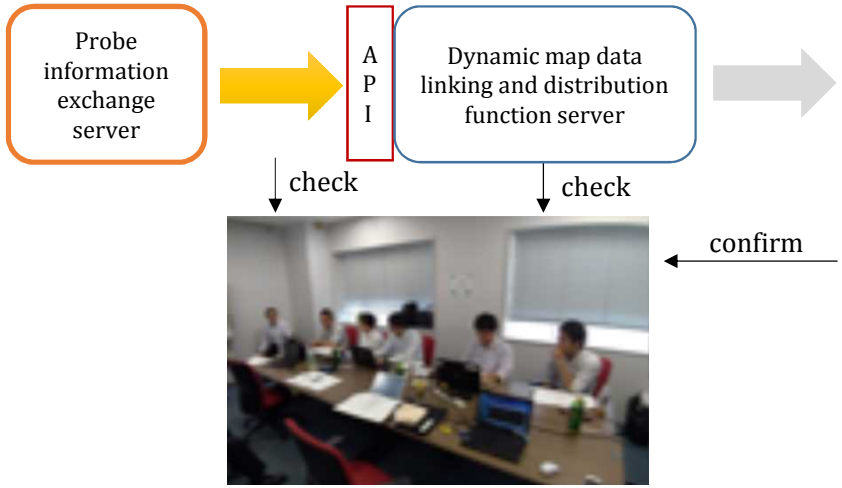
Cooperation with Dynamic map large-scale FOT consortium

A) Connection test, and operational test of functions (1)

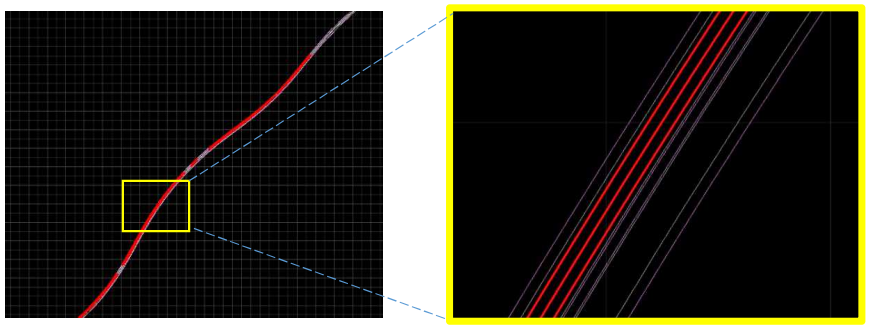
- We performed logical connection test and system-level connection test with Dynamic map large-scale field operational test consortium face to face.

Items of the connection test

- We created test items for format compliance check, data check, performance check
- Based on the above test items, we have checked one by one.
- 48 hours continuous operation test was also performed.



Connection test at Pioneer Kawagoe facility



Confirmation of transferred data on SIP dynamic map viewer
(Tomei expressway: vicinity of Atsugi)

Cooperation with Dynamic map large-scale FOT consortium

A) Connection test, and operational test of functions (2)

- We checked consistency of transferred data (JSON format) and its log data.


```
{
  "administration" : {
    "version"  : "01.1",
    "timeZone" : "+09.00",
    "datum"    : "JGD2011",
    "author"   : "PIONEER_TEST"
  },
  "basic" : {
    "time" : {
      "start" : "2018-10-09 09:00:000",
      "limit" : "2018-10-09 09:10:000"
    },
    "section" : {
      "begin" : {
        "latitude"  : 35.5872219,
        "longitude" : 139.5694656,
        "altitude"  : 4260
      },
      "end" : {
        "latitude"  : 35.5876550,
        "longitude" : 139.5701525,
        "altitude"  : 4050
      }
    }
  },
  "contents" : {
    "traffic" : {
      "seq"      : 1,
      "speed"    : 9,
      "accuracy" : 5
    }
  }
}
```


A traffic flow data (JSON file) that was sent from probe information exchange server (201810090900_533934_00042_01562_00001.json)


```
10/09 08:55:09 http_send[5092]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009085509659"}}}
10/09 08:55:09 http_send[5092]  Transfer : /var/pioneer/jaspar_1/201810090855/201810090855_533967_01126_00206_00019.json
10/09 08:55:09 http_send[5092]  [HTTP Send OK] 201 201
10/09 08:55:09 http_send[5092]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009085509686"}}}
10/09 08:55:09 http_send[5092]  http_exec OK
10/09 08:55:09 http_send[5092]  EXIT: Succsess
10/09 09:00:09 http_send[5361]  EXEC: /usr/local/pioneer/vics/bin/http_send.pl
10/09 09:00:09 http_send[5361]  Transfer : /var/pioneer/jaspar_1/201810090900/201810090900_533934_00042_01562_00001.json
10/09 09:00:09 http_send[5361]  [HTTP Send OK] 201 201
10/09 09:00:09 http_send[5361]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090009463"}}}
10/09 09:00:09 http_send[5361]  Transfer : /var/pioneer/jaspar_1/201810090900/201810090900_533934_01306_01309_00001.json
10/09 09:00:09 http_send[5361]  [HTTP Send OK] 201 201
10/09 09:00:09 http_send[5361]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090009491"}}}
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10/09 09:00:09 http_send[5361]  [HTTP Send OK] 201 201
10/09 09:00:09 http_send[5361]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090009519"}}}
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10/09 09:00:09 http_send[5361]  [HTTP Send OK] 201 201
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10/09 09:00:09 http_send[5361]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090009575"}}}
10/09 09:00:09 http_send[5361]  Transfer : /var/pioneer/jaspar_1/201810090900/201810090900_533936_02491_03805_00003.json
10/09 09:00:09 http_send[5361]  [HTTP Send OK] 201 201
10/09 09:00:09 http_send[5361]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090009602"}}}
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10/09 09:00:09 http_send[5361]  http_exec OK
10/09 09:00:09 http_send[5361]  EXIT: Succsess
10/09 09:05:10 http_send[5637]  EXEC: /usr/local/pioneer/vics/bin/http_send.pl
10/09 09:05:10 http_send[5637]  Transfer : /var/pioneer/jaspar_1/201810090905/201810090905_533934_01306_01309_00001.json
10/09 09:05:10 http_send[5637]  [HTTP Send OK] 201 201
10/09 09:05:10 http_send[5637]  RESPONCE : {"result":{"traffic":{"seq":1,"status":"201 Created","record-id":"20181009090510402"}}}
10/09 09:05:10 http_send[5637]  Transfer : /var/pioneer/jaspar_1/201810090905/201810090905_533934_01309_02146_00001.json
```


JSON file transfer log

response data

communication log of data transfer

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Cooperation with Dynamic map large-scale FOT consortium

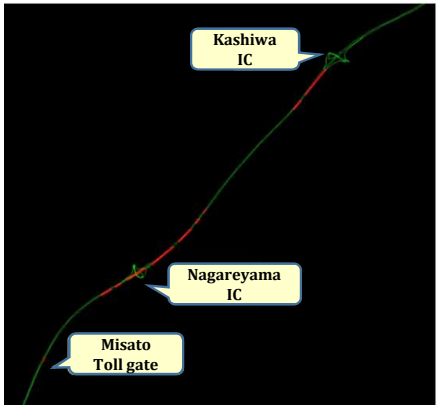
A) Connection test, and operational test of functions (3)

◆ Test item：

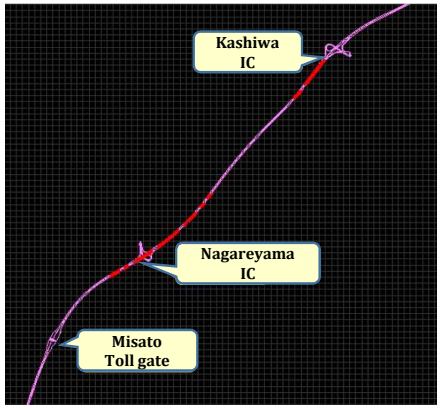
- traffic flow data transfer test in real environment
- check consistency between transferred data and received data by using SIP dynamic map viewer

Joban expressway

September 19, 2018 17:15



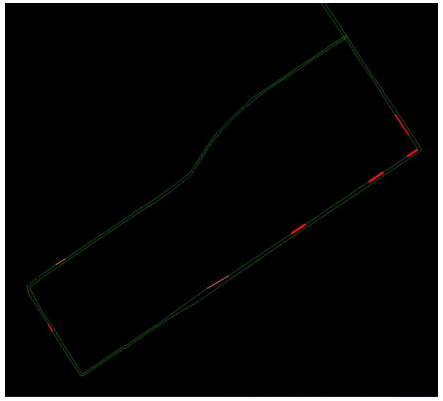
Transferred data（Red portion）



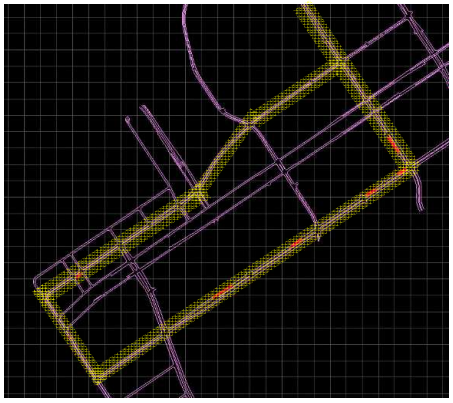
Received data

local road (Odaiba area)

September 7, 2018 15:40



Transferred data（Red portion）



Received data
(Yellow road section is subject to deliver)

Field Operational Test

- As a part of Dynamic map large-scale field operational test, we delivered road-level traffic flow information to Dynamic map data linking and distribution function server during the period of October 1, 2018 through December 27, 2018 except November 26, 2018 through November 30, 2018.
  The delivery of traffic flow data starts 9:00 AM and ends 6:00 PM on weekday.
  The area to be delivered is a part of Tomei expressway, Joban expressway and local road at Odaiba area where the SIP dynamic map data provided.

- For lane-level traffic flow information, we delivered it during the period of November 26, 2018 through November 30, 2018. The area to be delivered is in between Tanimachi junction and Hamazaki-bashi junction of the metropolitan expressway of Tokyo a.k.a. Shutoko C1 (Inner Circular Route).
  We used 10 experiment vehicles to produce lane-level traffic flow data. A road of the driving route consists of two lanes and an experiment vehicle departed our base every 15 minutes for each lane.

- The acquired log data during the field operational test is also utilized to analyze delay time of the traffic flow information processing.

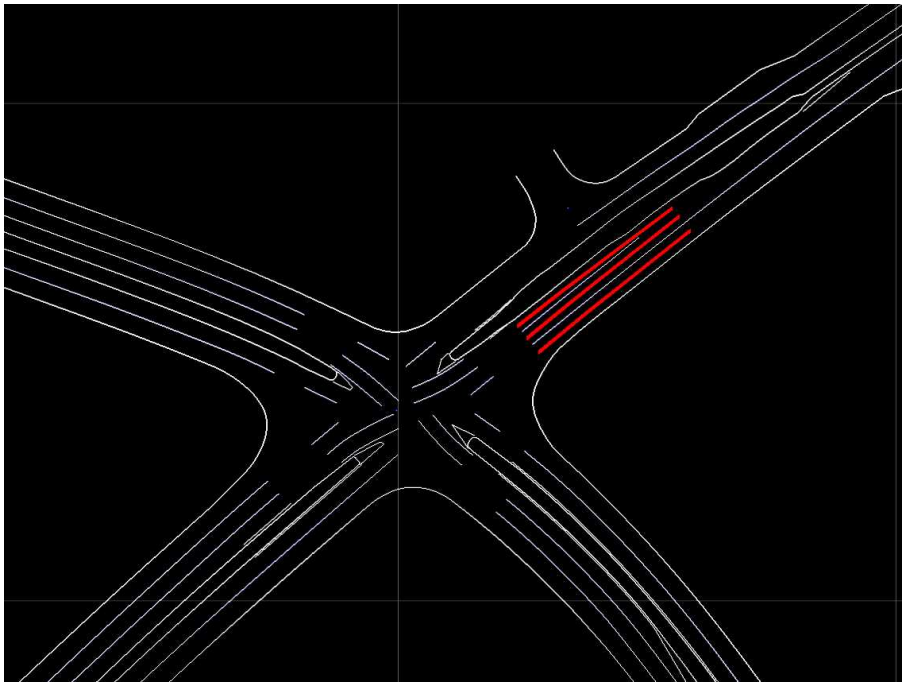
Field Operational Test

A) Co-experiment with SIP Dynamic map FOT consortium (1)

- **Road-level traffic flow generation and delivery**

We delivered road-level traffic flow information to Dynamic map data linking and distribution function server during the period of October 1, 2018 through December 27, 2018. The following figure shows the area where the road-level traffic flow information delivered.

Delivered area of Road-level traffic flow （green area）



e.g., Visualization of road-level traffic flow in Odaiba area
(congestion is represented as red line)

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Field Operational Test

A) Co-experiment with SIP Dynamic map FOT consortium (2)

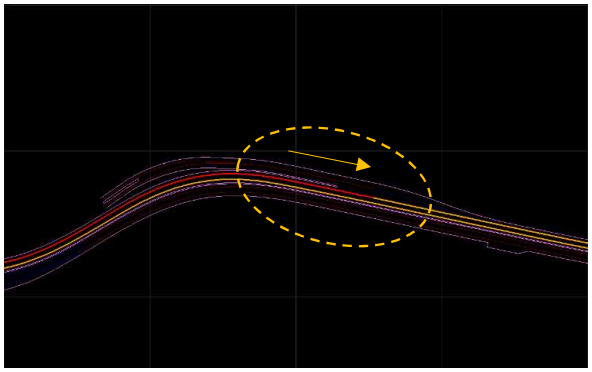
- **Lane-level traffic flow generation and delivery**

We delivered lane-level traffic flow information to the Dynamic map data linking and distribution function server during the period of November 26, 2018 through November 30, 2018.

Experiment vehicles drove each lane approx. every 15 minutes to produce lane-level traffic flow information.

Delivered road section of
lane-level traffic flow

The base of experiment vehicles
(courtesy of Tokyo Prince Hotel)



An example of lane-level traffic flow
displayed on SIP dynamic map viewer

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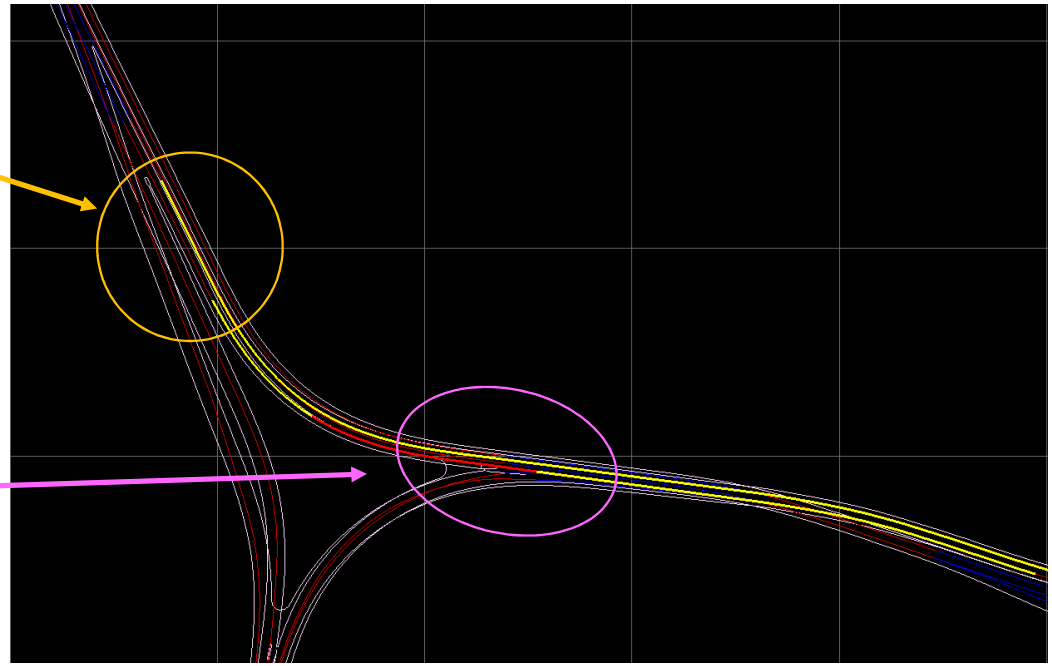
Field Operational Test

A) Co-experiment with SIP Dynamic map FOT consortium (3)

Comparison between real road situation and distributed traffic flow information



e.g., Vicinity of Ichinohashi junctoin (November 26, 2018 16:45)

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B) Evaluation

◆ Processing delay of traffic flow information (1)

We measured processing delay time of first three functional blocks in the Probe information exchange server.
It takes approx. 1.2 second to process vehicle probe information from the vehicle information receiver to vehicle speed calculation functional block. The lane-level map matching process was relatively time consuming process than the others.

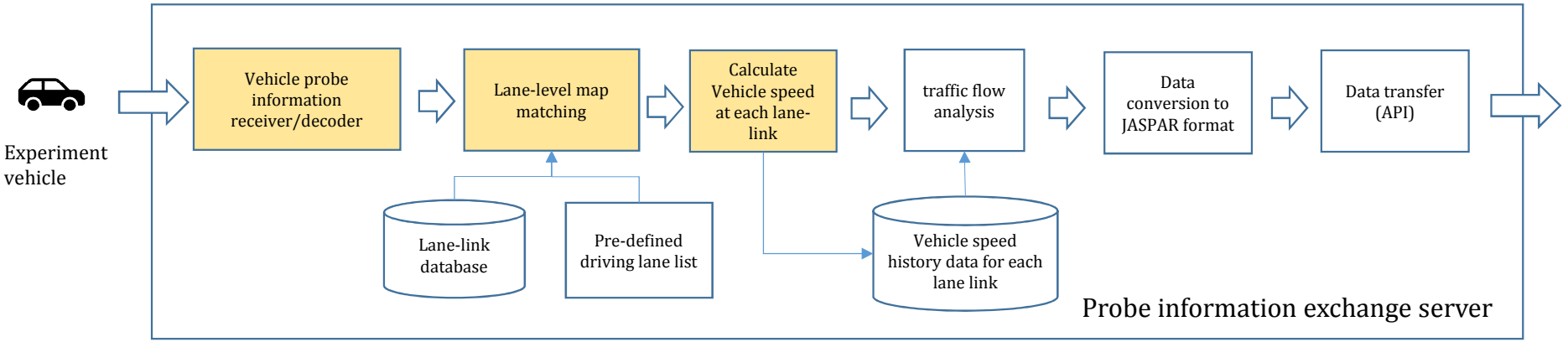


Fig. Functional blocks of Probe information exchange server

Table. Processing time at each functional block

Function	Average [msec]	Max. [msec]	Min. [msec]
Probe information decoder	96	253	44
Lane-level map matching	670	2043	273
Calculation of vehicle speed at lane-link	462	804	391
Total	1228	3100	708

Field Operational Test

B) Evaluation

◆ Processing delay of traffic flow information (2)

Next, we measured processing delay time of last part of functional blocks in Probe information exchange server.
Most time consuming process was a Data transfer function block.

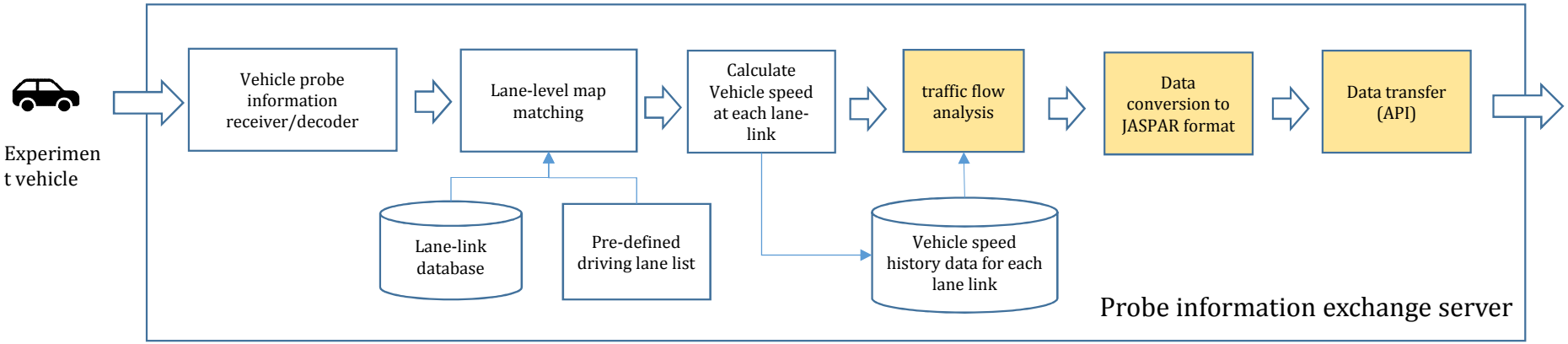


Fig. Functional blocks of Probe information exchange server

Table. Processing time at each functional block

Function	Average [msec]	Max. [msec]	Min. [msec]
Traffic flow analysis	5.1	11.2	3.2
Data conversion to JASPAR format	46.8	148.8	1.0
Data transfer	1217.8	2410.9	6.9
Total	1269.7	2570.9	11.1

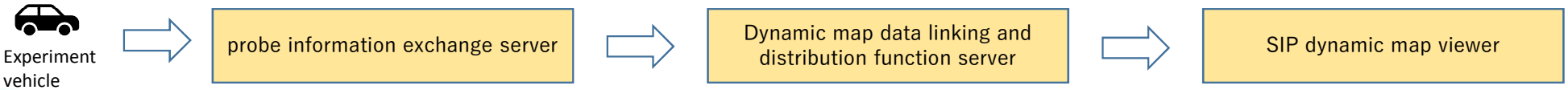
Field Operational Test

B) Evaluation

◆ Processing delay of traffic flow information (3)

Finally, we measured overall delay time through vehicle, probe information exchange server, the Dynamic map data linking and distribution function server, and SIP dynamic map viewer.
A delay time as a whole was approx. 12 minutes max. from vehicle to viewer.
As a result, the most time consuming process is waiting time for a batch process rather than actual traffic flow calculation.
To shorten the delay time, it is necessary to upload probe data more frequently from a vehicle. It is also necessary to reduce communication overhead.

Entity	Function	Processing time max. [sec]
Experiment vehicle (on-board car navigation device)	Sensor data collection and buffering	300
Batch process of vehicle speed calculation at a lane-link	Waiting time for batch process	10
	Probe information decoding	0.253
	Lane-level map matching	2.043
	Vehicle speed calculation at each lane-link	0.804
Batch process of Traffic flow calculation	Waiting time for batch process	300
	Calculation of traffic flow information	0.011
	Convert data to JASPAR format	0.149
	Data transfer	2.411
Process of Dynamic map data linking and distribution function server		90.1
Total		705.969



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Consideration (1)

◆ Optimization of traffic flow content data format

JASPAR dynamic vehicle information sharing specification defines that only one message can be transferred by register API function (HTTP request). If there are many congestion sections on the road/lane, a traffic flow content of each section shall be transferred one by one to the Dynamic map data linking and distribution function server. The HTTP request overhead becomes large impact for system performance. So we tested modified data format of JASPAR message to optimize number of HTTP requests. As a result, significant reduction of data transfer was fulfilled.
→ The result was feedback to JASPAR for specification improvement.

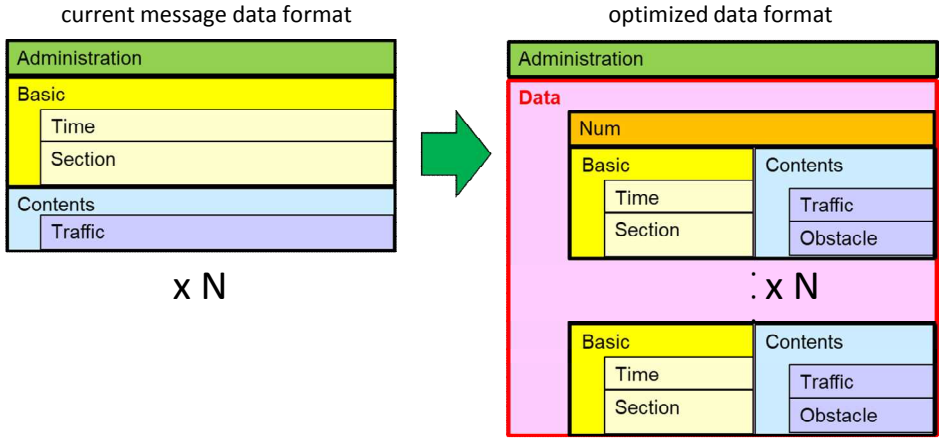


Fig – example of optimized message data format to reduce HTTP request overhead
(contents for plural sections can be transferred at once)

The number of transferred data	Transfer time in sec (current format)	Transfer time in sec (optimized format)
5000	30.03850889	1.199960279
10000	61.37561851	2.3039114
20000	122.7597192	4.355835772
40000	242.1740829	8.688527441
70000	418.9842041	14.99618721

Fig- Comparison result between current message format and optimized message format
(optimized message format can reduce HTTP request overhead)

Consideration (2)

◆ Location reference of traffic flow information

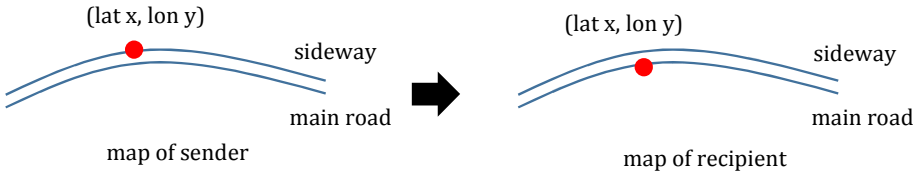
We makes use of absolute location reference to indicate a road/lane section of traffic flow content. We assumed that the location like followings would have a map matching problem in the future.

- **parallel section of main road and its sideway, merging section of a road**
- **complex shaped road like highway ramp, junction**

An inconsistency of location reference occurs between data sender and its recipient even if location is accurate.

For example,

- **Different maps are used by both sides**



If sender and recipient are using different map, then the indicated location on each map may not be the same even if absolute location is same.

To solve this kind of inconsistency, an appropriate location reference method should be used. For example,

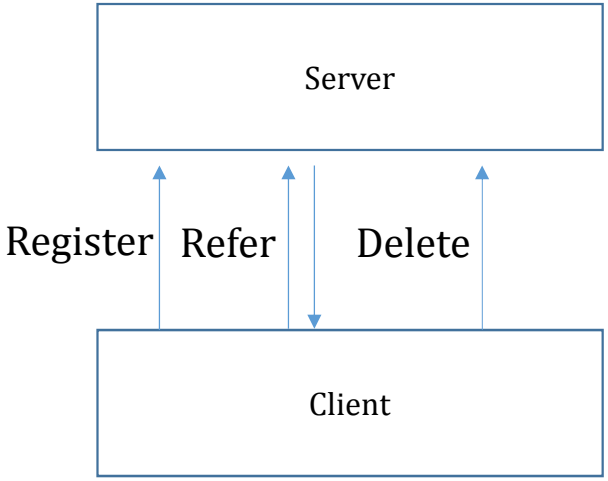
- **pre-coded type of location referencing method (both sender and recipient refer same link information)**

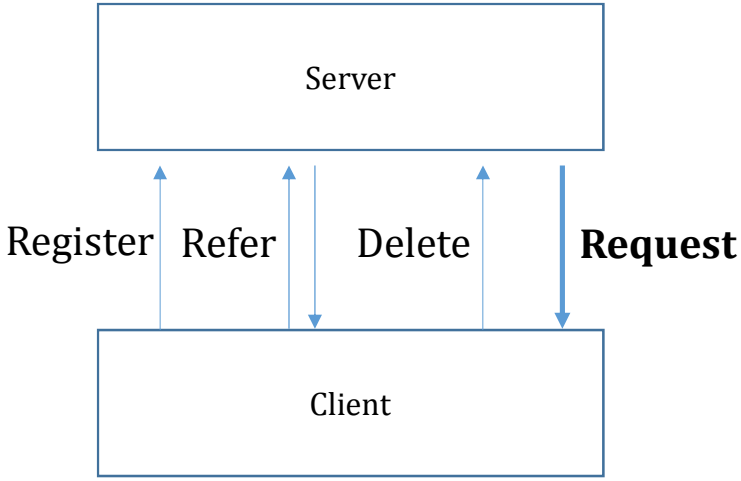
and so on.

Consideration (3)

◆ Means of data request for server side

JASPAR dynamic vehicle information sharing specification assumes server-client model. A client send/delete/refer their data to/from server.
On the other hand, a server does not have a means to request something for client (e.g., request a region of traffic flow to be transmitted).
This kind of function may be useful for some kind of application/use-cases.

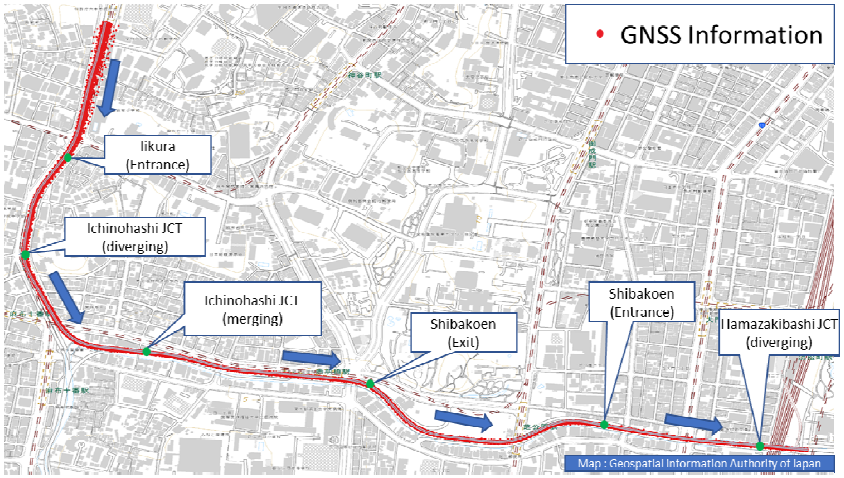




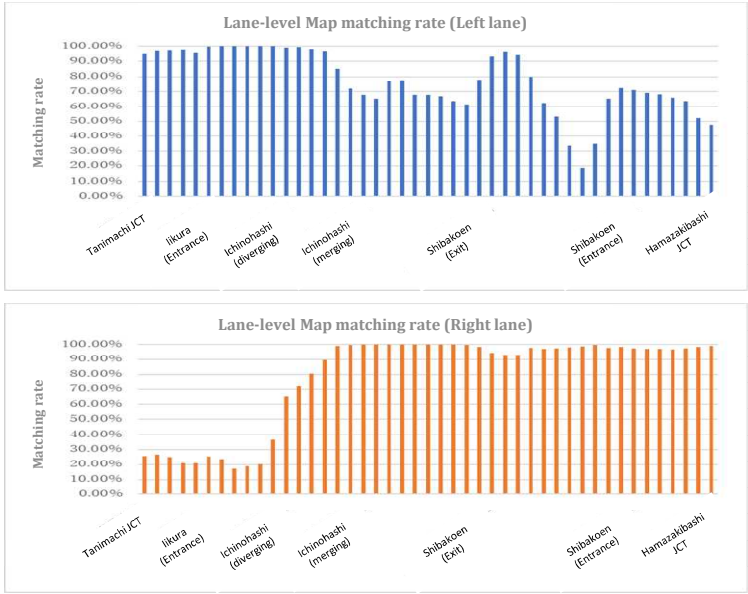
Consideration (4)

◆ Possibility of lane-level traffic flow data generation by GNSS data

It is expected that the lane-level traffic flow information can be generated from vehicle probe data. To understand the possibility of lane-level position estimation, we evaluated the GNSS data that is acquired during the course of field operational test. Basically, accuracy of GNSS depends on several factors such as satellites location, signal multi-path/blockage, atmospheric conditions, and so on.
As we anticipated, the result depends on the location. But it would be possible to improve the location quality if we combine GNSS information with gyro and acceleration sensor that are utilized for dead reckoning in car navigation system. In the future, when LiDAR sensor will be equipped for vehicle, more accurate lane-level location estimation will be possible in conjunction with high definition map data.



lane-level Map matching



Summary

◆ All scheduled work items for 2017 and 2018 are completed.

- **Summary**
  - We evaluated the JASPAR Dynamic vehicle information sharing specifications in real field operational test environment and proved that the specification is practical.
  - However, we found some issues on the specification. We feedback these items to JASPAR and we expect to contribute that the quality/usability of specification will be improved.
  - The field operational test was performed between different party and that there were many implementation-specific items to be decided for data exchange. This information will be useful as implementation guideline in the future.
  - We measured delay time of traffic flow information as a whole during field operational test with Dynamic map large-scale field operational test consortium. We got some feedback from participant of field operational test for example, delivery frequency of traffic flow information and a length of road/lane section that traffic flow calculation performed.

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