SIP
戦略的イノベーション創造プログラム

# "Strategic Innovation Promotion Program (SIP) Phase 2 / Automated Driving (Expansion of Systems and Services) / Research and Development Related to Collection, Integration, and Distribution of Narrow Area / Medium Area Information"

## Achievement report for 2020

## Overview version

NTT DOCOMO, Inc.
Oki Electric Industry Co., Ltd.
Sumitomo Electric Industries, Ltd.
Panasonic Corporation

April 2021

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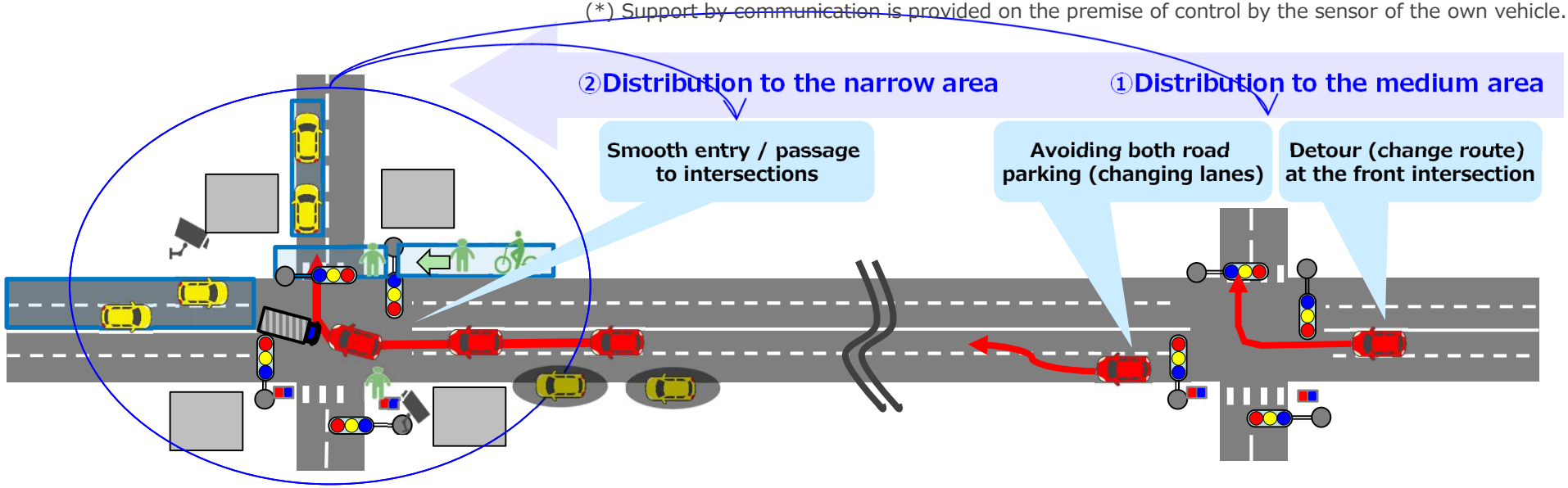
# 1．Overview of this research and development

**Assumed issues**
**In a complicated environment such as an intersection, the blind spot of the sensor of the own vehicle increases, and the automated vehicle will stop / slow down until the safety inside the intersection can be confirmed in front of the intersection, which affects the traffic flow.**

**Aim and purpose of this research and development**

- **Collecting and integrating target information, etc. that may be out of sight for each vehicle from multiple sources, distribute to automated vehicles (distribute only the necessary range of information in a format that can be shared with the information on the vehicle side)**
- **Distribution will be carried out in stages from the medium area to the narrow area, and support (*) assuming the following UC will be provided for each.**

(*) Support by communication is provided on the premise of control by the sensor of the own vehicle.




**In order to implement the above support, we will formulate a communication method / common interface for collecting information from multiple sources, a draft index for integrating the collected information, and an information distribution method for distribution to automated vehicles.**

**Output ■ Common interface for collection and distribution**
**■ Integrated indicators and guidelines for distribution methods**

# 1. Overview of this research and development (① Expected effects of the medium area network)

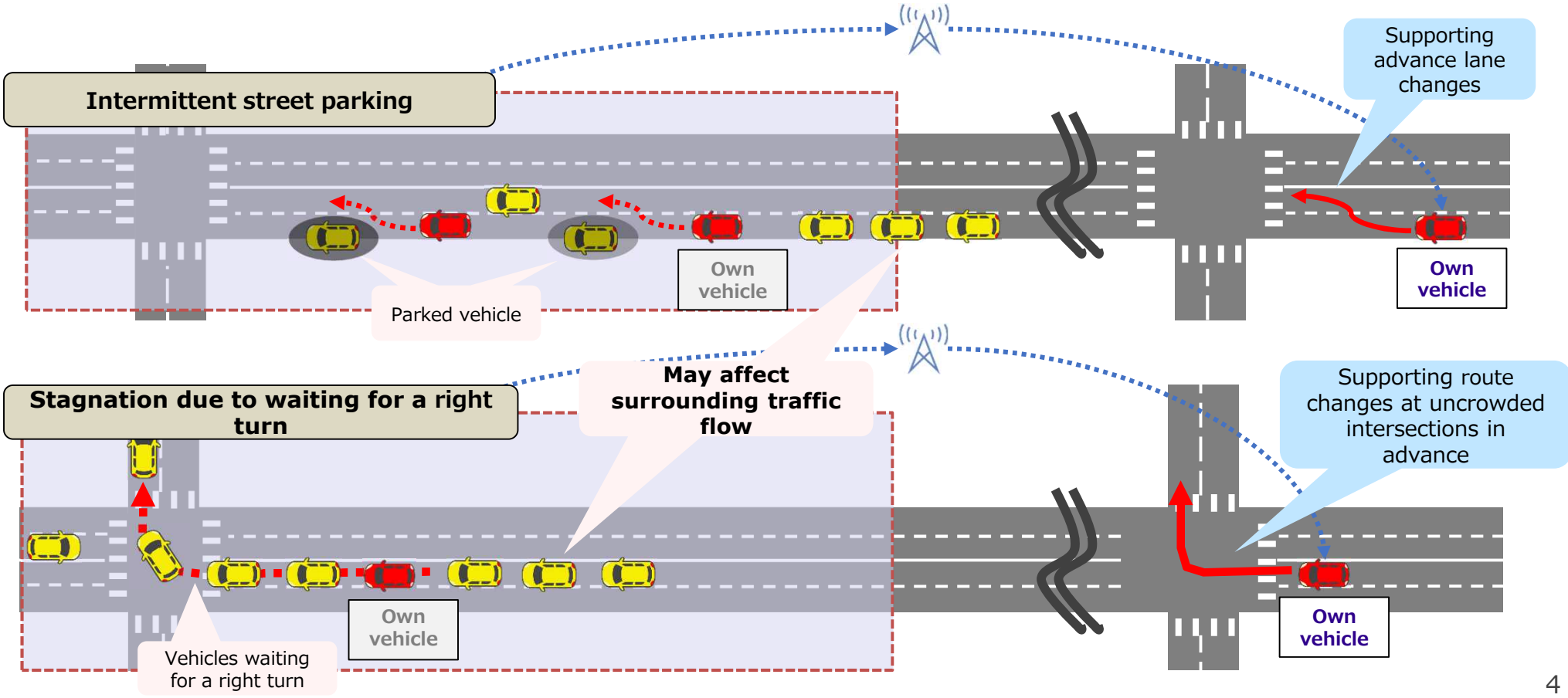
- **As information to support automated vehicles to change lanes or routes in advance, the situation in front of the vehicle (information for multiple intersections starting from the vehicle position) is continuously distributed.**

**Before**

There is a possibility that traffic flow in the surrounding area may be obstructed due to lane changes to avoid parked vehicles, etc., or stagnation of vehicles in crowded intersections.

**After**

By continuously distributing **the situation in front of the vehicle**, it supports lane changes and route changes in advance and realizes smooth traffic flow.



# 1. Overview of this research and development (② Expected effects of the narrow network)

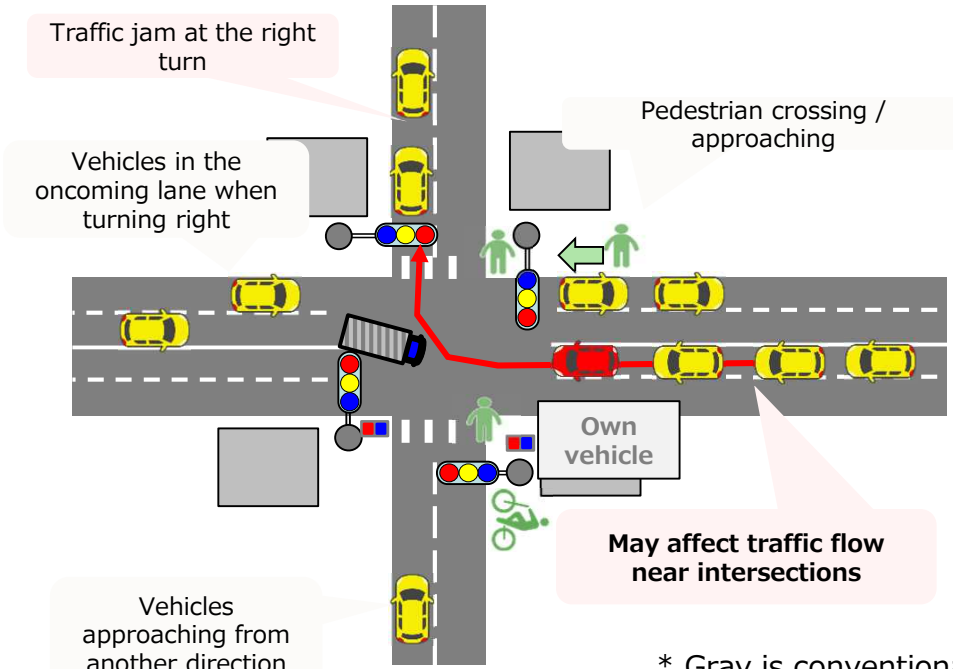
- **In order to support smooth entry and passage into intersections with complicated traffic environments, we will grasp the traffic conditions inside and near the intersection and distribute it to automated vehicles.**

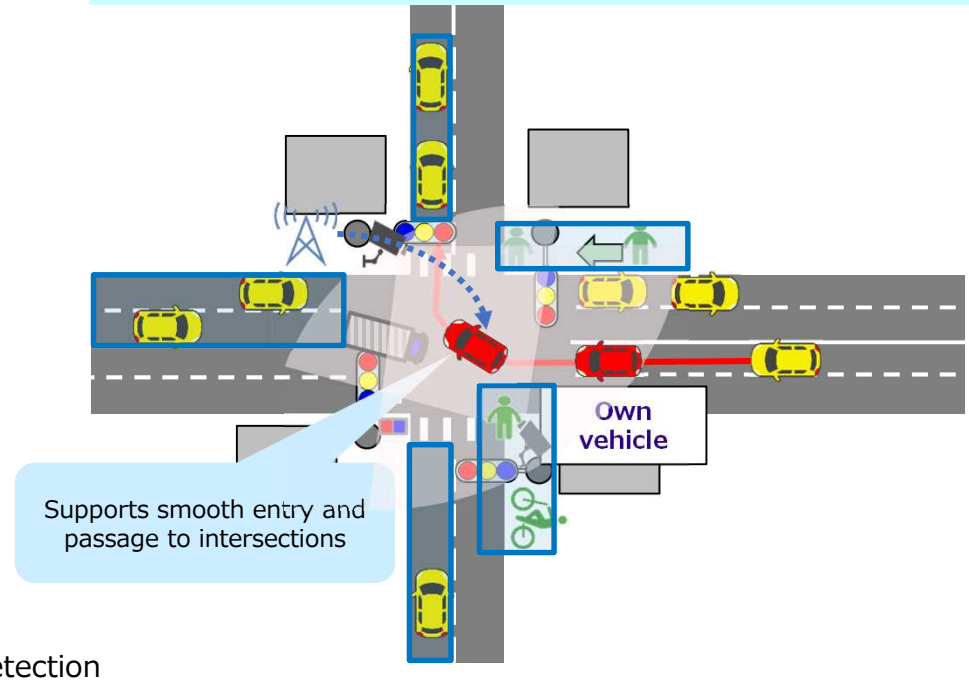
**Before**

Obstructions such as surrounding buildings and vehicles cause out-of-sight from automated vehicles
→Traffic flow may be affected by stopping in front of the intersection when entering the intersection or stagnating in the intersection when passing through the intersection.

**After**

In addition to information on vehicles traveling around the intersection, non-line-of-sight targets and pedestrians are collected and integrated from information sources such as existing roadside infrastructure and pedestrian terminals installed near the intersection, and distributed to vehicles before entering the intersection. By doing so, in addition to the conventional detection, it supports smooth entry / passage to intersections in situations such as traffic jams at the right turn and crossing / approaching pedestrians / bicycles, and realizes smooth traffic flow.

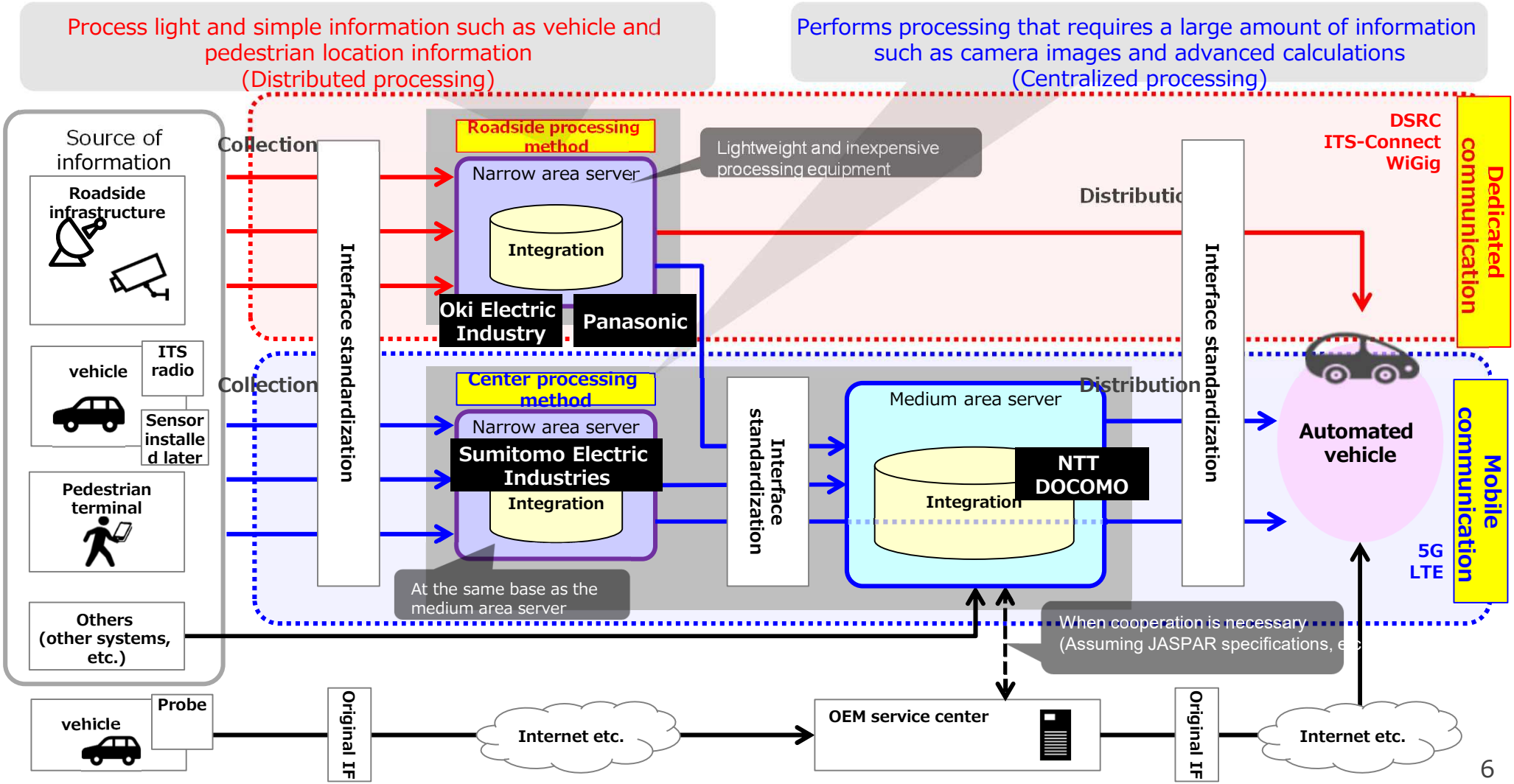



* Gray is conventional detection

# 2. Implementation details and implementation system

- For narrow areas, we evaluated two methods, "installed on the roadside for dedicated communication" and "installed on the center for mobile communication".
- The medium area is "configured to be installed in the mobile communication network", and communication delays and communication traffic are evaluated.
- Oki Electric Industry / Panasonic / Sumitomo Electric Industries are in charge of the narrow area, and NTT DOCOMO is in charge of the medium area.



# 3. Assumed use case

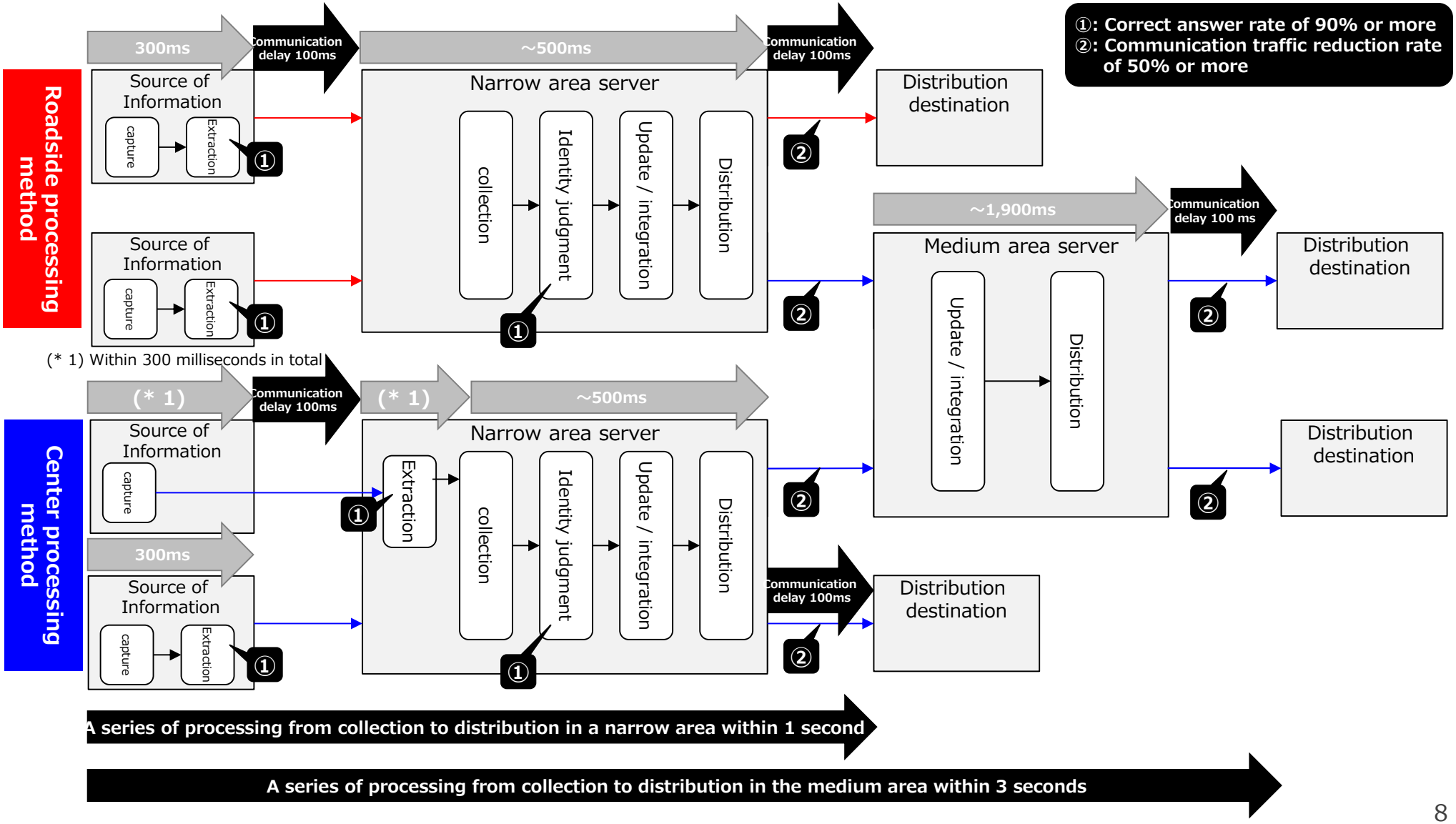
- Reconfirmed the consistency with UC examined in the Cooperative Automated Driving Communication Method TF
- Each UC is detailed and prioritized. (Required or optional)

| SIP Cooperative Automated Driving UC | Detection target | | UC # | Use case details | Medium Area | Narrow Area | | | [Reference] Correspondence with existing system |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Center | Roadside | | |
| | | | | | DOCOMO | SEI | Panasonic | OKI | |
| d-5 | (Information collected from narrow area network etc.) | | M1 | Provides information such as stagnating status due to waiting for a right turn at the front intersection (→ Support for route change) | ○ | – | – | – | – |
| d-1 | (Information collected from narrow area network etc.) | | M2 | Provides information such as intermittent road parking ahead (→ Supports lane change) | ○ | – | – | – | – |
| c-2-2 | Oncoming lane straight-ahead vehicle | Straight vehicle | N1 | Provides information on oncoming straight-ahead vehicles that cannot be detected by the own vehicle sensor | – | ○ | – | ○ | DSSS |
| c-2-2 (*1) | Right turn road congestion | Right turn situation | N2 | Provides information on the status of the right turn (empty space, etc.) | – | ○ | ○ | ○ | – |
| | Pedestrian | Approaching | N3-1 | Provides information on the approach of pedestrians and bicycles to the pedestrian crossing | – | ○ | ○ | ○ | – |
| | | Waiting for crossing | N3-2 | Provides detailed attribute information for pedestrians stopped near the pedestrian crossing | – | △ | – | – | – |
| | | Crossing | N3-3 | Provides information on pedestrians and bicycles on pedestrian crossings | – | ○ | ○ | ○ | DSSS |
| d-5 | Obstacle | Around the vehicle | N4-1 | Providing vehicle sensing information (can be used for UC other than right turn support) | – | ○ | – | – | – |

(* 1) Added "Right turn road congestion" and "Pedestrian" as part of the verification variation of c-2-2 "Driving support based on intersection information (V2I)"

# 4. Achievement Goal (KPI)

- The definition of R & D KPIs is clarified based on the following contents described in the specifications (explained in the previous WG).
- In the process of refining the UC scenario for verification, the KPI is also refined for each UC.



# 4．Achievement goal (KPI) [Detailed (1/2)]

| Research items | Achievement goal (KPI) | | | Definition | KPI determination method and validity for each use case | Points and ingenuity in research and development |
|---|---|---|---|---|---|---|
| | Index | Assumed target values and rationale | | | | |
| Extraction | Correct answer rate of information extracted from information sources | 90% or more | Equivalent to the correct answer rate of general sensors [Reference conditions] | Percentage of correctly detecting the presence (type, position) of vehicles, bicycles, and pedestrians | ① Define the allowable range of position error for each UC based on the road and sidewalk width, etc.<br>② Set the ratio (correct answer rate) of the extraction result within the allowable range of position error to the true value as the target value. | Examination of extraction algorithm and sensor installation conditions for each sensor |
| Collection | Communication delay from information source to narrow area server | Within 100ms | Equivalent to communication delay in existing vehicle-to-vehicle communication standards | Time required to collect information by communication | ① Within 100ms between the information source and the narrow area server<br>Add a time stamp with the application of the sending device (PC, etc.) and calculate the difference between the reception time and the time stamp with the application of the receiving device (narrow area edge). | Verification of delay in large-capacity data collection by 5G communication |
| Integration | Correct answer rate of information integrated in narrow area server | 90% or more | There is no deterioration in accuracy due to integration with respect to the accuracy rate of extraction. | Percentage of information extracted from multiple sources that could be integrated without excess or deficiency | ① Set the ratio (correct answer rate) of the integration result within the allowable range of position error to the true value as the target value. | Examination of the same judgment method as the condition arrangement of time deviation and position deviation |
| | Communication traffic reduction rate from narrow area server etc. to medium area server | 50% or more | Uniform target value to secure a margin for the number of users that can be accommodated (number of narrow areas, etc.) | Communication traffic reduction rate compared to the case where the technology is not applied | ① Limit the collected information only to the direction of travel of the vehicle | |
| Distribution | Communication delay from narrow area server to distribution destination | Within 100ms | Equivalent to communication delay in existing vehicle-to-vehicle communication standards | Time required for information distribution by communication | ①Within 100ms between the narrow area server and the distribution vehicle<br>Add a time stamp with the application of the sending device (narrow area server) and calculate the difference between the receiving time and the time stamp with the application of the receiving device (PC, etc.) | Examination of communication specifications / control when distributing multiple vehicles by DSRC |
| | Communication traffic reduction rate | 50% or more | A uniform target value to secure a margin for the number of users (distribution destinations) that can be accommodated | Communication traffic reduction rate compared to the case where the technology is not applied | ① Limit the collected information only to the traveling direction of the vehicle, and distribute the information as well. | Reduction of duplicate targets by integrated processing, examination and simulation of distribution control algorithm |

# 4. Achievement goal (KPI) [Detailed (2/2)]

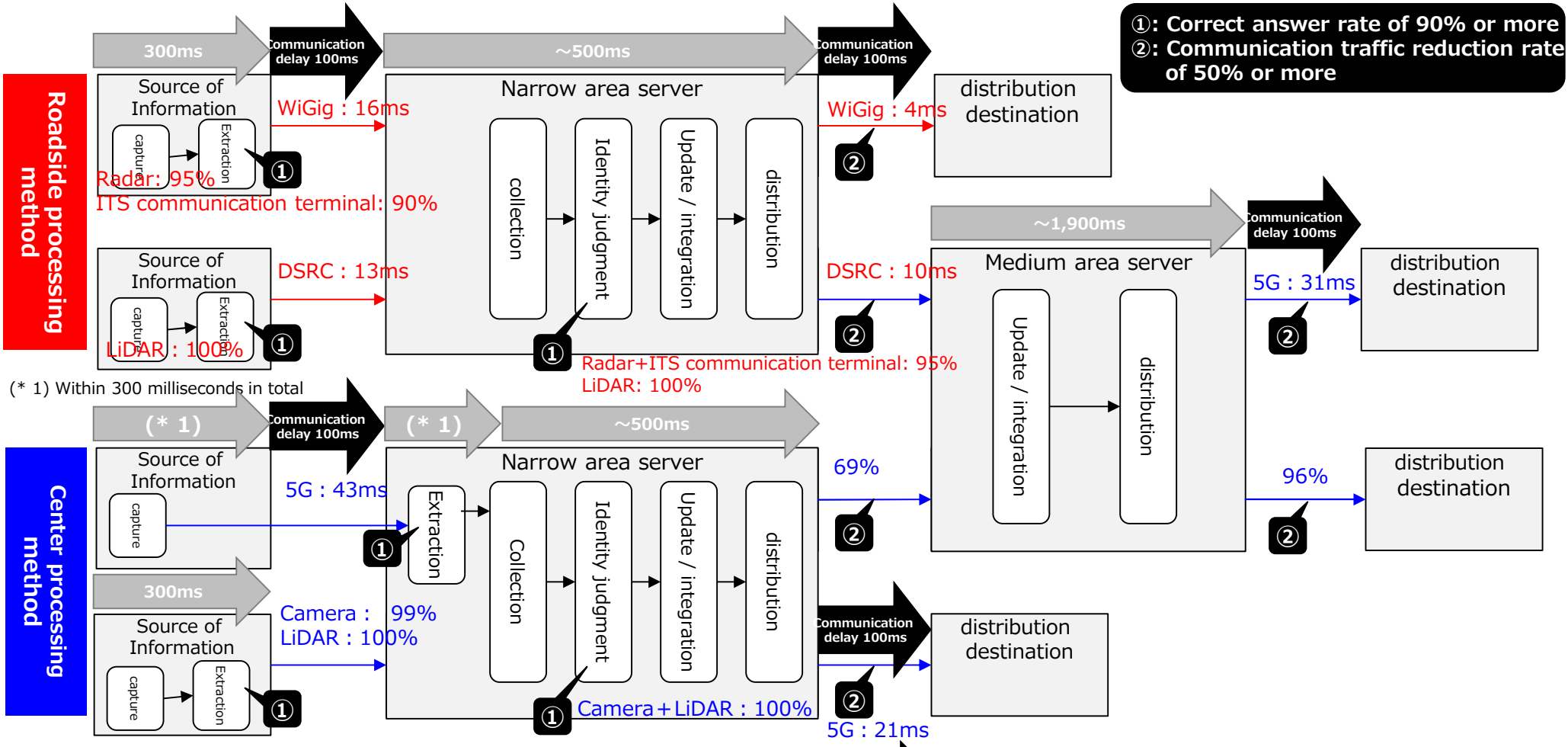
| Research items | Achievement goal (KPI) | | | Definition | KPI determination method and validity for each use case | Points and ingenuity in research and development |
|---|---|---|---|---|---|---|
| | Index | Assumed target values and rationale | | | | |
| Distribution (continued) | Communication delay from medium area server to distribution destination | Within 100ms | Equivalent to communication delay in existing vehicle-to-vehicle communication standards | Time required for information distribution by communication | Communication delay within 100ms from the medium area server to the distribution destination vehicle. The target is communication between connection IFs (server processing performance is not considered). Calculate the difference between the time stamps of the medium area server and the in-vehicle terminal<br>* For time stamps, compare and confirm the differences in advance. The wireless section is evaluated based on the measured values. | Reduction of unnecessary information by integrating sensor information, reduction of distribution frequency / target according to the driving status of the distribution destination vehicle, examination of a mechanism to collect driving status by communication |
| | Communication traffic reduction rate | 50% or more | A uniform target value to secure a margin for the number of users (distribution destinations) that can be accommodated | Communication traffic reduction rate by reducing the distribution range according to the situation of the distribution destination vehicle, etc. | Calculate the traffic reduction rate depending on the presence or absence of distribution control Implemented distribution control according to the running speed of the vehicle<br>* Minimum area (200m) when traveling 60km or 30km. Based on the traffic flow simulation data, the amount of traffic data when the distribution range is variable is examined on the desk and the reduction rate is calculated. | |
| Overall | A series of processing time from collection to distribution (narrow area) | Within 1s | Equivalent to the definition of "dynamic information" (≤1s) in the dynamic map | Total time required for extraction processing by information source or narrow area server, collection by communication (information source to narrow area server), integrated processing by narrow area server, and distribution by communication | ① Not changed for each UC to realize smooth running of automated vehicles | Determining the limit when the target number increases (verified for each processing unit) |
| | A series of processing time from collection to distribution (medium area)) | Within 3s | Set the shortest case (information distribution of the previous intersection) among the UCs assumed by the medium area server | Total time required for extraction processing at the information source or narrow area server, collection by communication (information source-narrow area server, narrow area server-medium area server), integrated processing at the medium area server, and distribution by communication | Distribution time from the narrow area server to the in-vehicle terminal is within 3 seconds. Calculate the processing time from the time stamps of the narrow area server and the in-vehicle terminal<br>* For time stamps, compare and confirm the differences in advance. A series of required time is calculated by extracting the time required to connect the target section from the time stamp and adding them together. The target sections are ① information source to narrow area server, ② narrow area server to medium area server, and ③ medium area server to distribution target vehicle. A series of processing time is calculated by adding up the times of ① , ②, and ③ above. | Standardization of interfaces (message format, etc.) for data collection / integration / distribution processing time reduction, etc. |

# 5. R & D evaluation / verification (Summary: KPI achievement status)

- **In the case of UC1 (* 1) in the medium area and UC3 (* 2) in the narrow area (communication delay and processing time are average values)**

(* 1) UC M1-1: Route change
(* 2) UC N 3-1: When turning right at an intersection

**①: Correct answer rate of 90% or more**
**②: Communication traffic reduction rate of 50% or more**



# (1)Narrow area network: Roadside processing method 1 [Oki Electric Industry]

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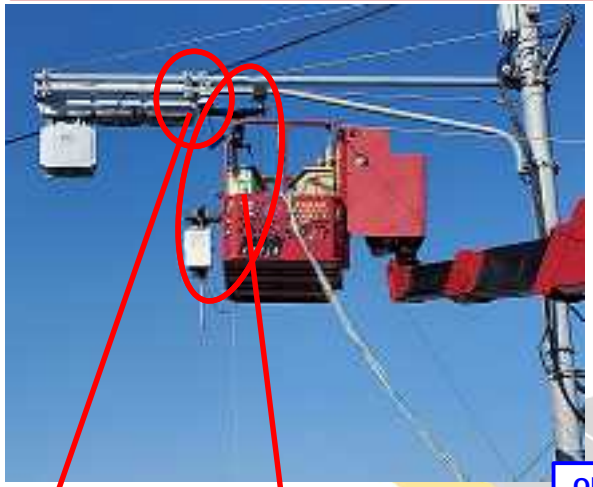
In the JARI Tsukuba test course, the following test environment was constructed, and device connection confirmation and KPI evaluation were carried out.



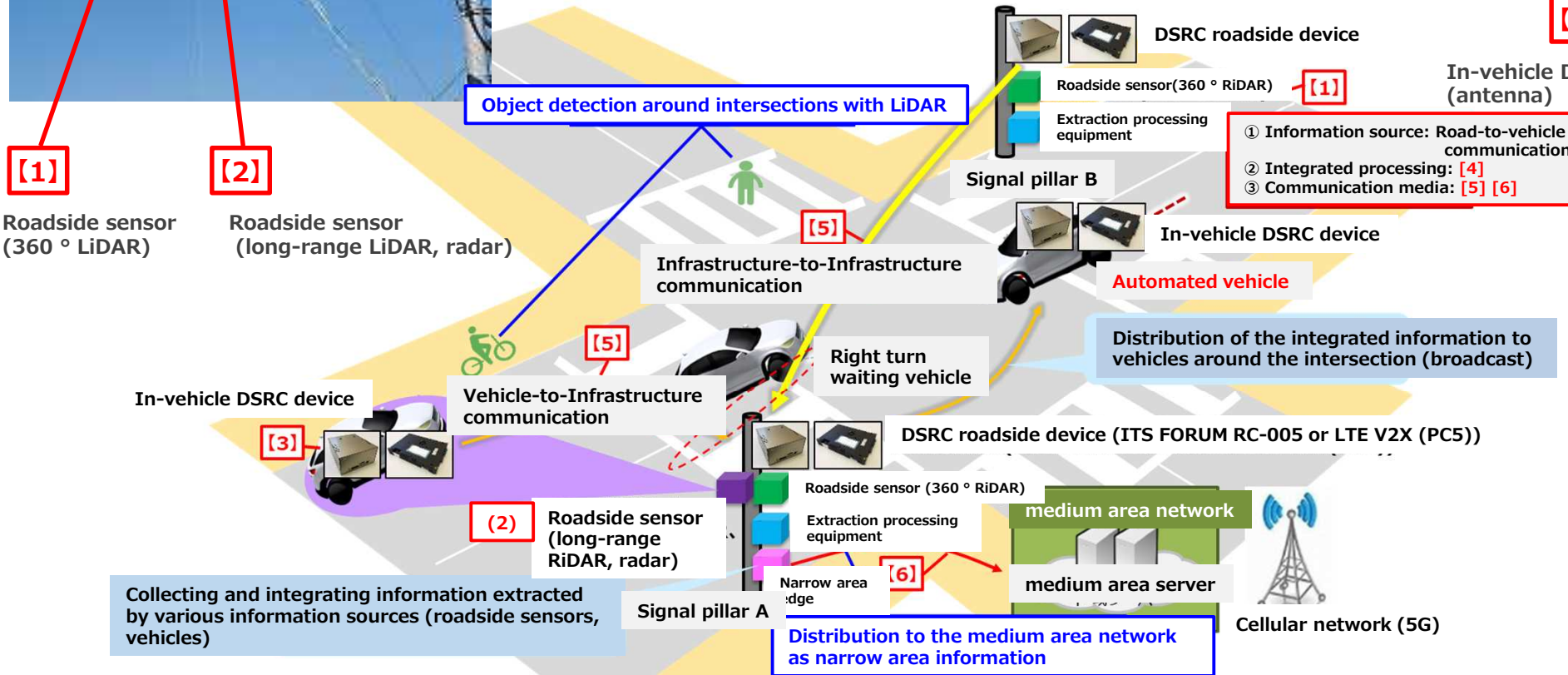
【1】 Roadside sensor (360 ° LiDAR)

【2】 Roadside sensor (long-range LiDAR, radar)

GNSS Receiver (RTK)

GNSS receiver (quasi-zenith compatible)

【3】 In-vehicle DSRC unit (antenna)



# (1) Narrow area network: Roadside processing method 1 [Oki Electric Industry] Distribution control method

- **When an automated vehicle collects vehicle information acquired by an independent sensor as target information, it improves the packet arrival rate / increases the number of vehicles that can be collected by controlling the transmission timing of collection and distribution.**
- **Separate the transmission timing of the in-vehicle device according to the distance from the lane and the intersection**
- **Confirmed that the packet arrival rate increases compared to the conventional method by applying collection / distribution control.**

## ■Action item

**Examination and simulation evaluation of collection / distribution control that "time-divides the transmission timing of the roadside unit and the in-vehicle unit" and "time-divides the transmission timing of the in-vehicle unit for each area"**

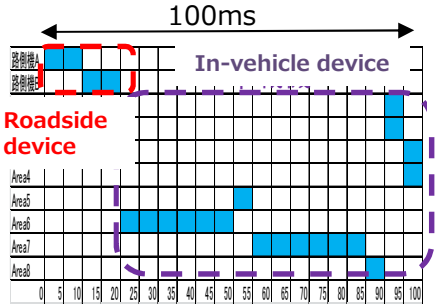
**(1) Issues**

・Packet collisions are increasing because the communication status of other radios cannot be grasped due to the shielding of radio waves by buildings at intersection corners and large vehicles.

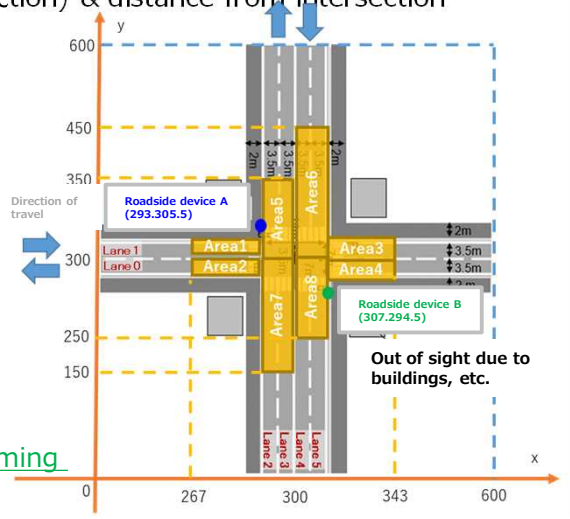
**(2) Countermeasures**

・Time division between roadside unit and in-vehicle unit: See ARIB STD-T109

・Time division between in-vehicle devices: Separation by communication area based on driving lane (direction) & distance from intersection




Time division of transmission timing (example))

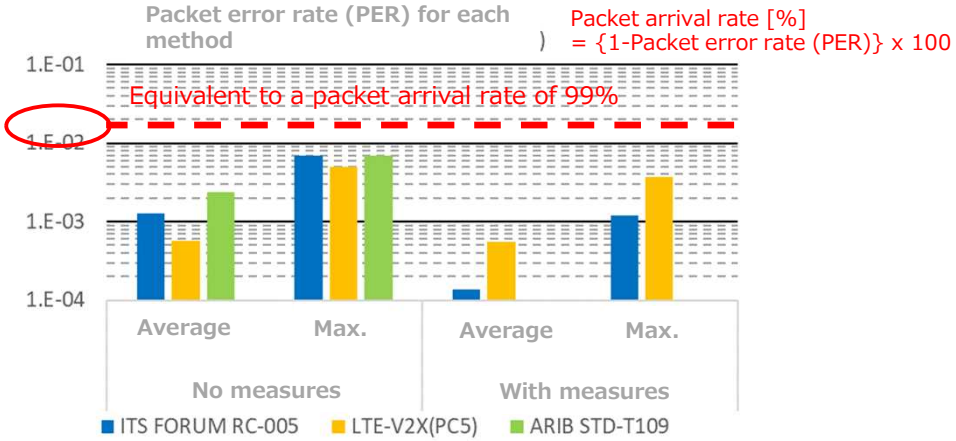



Time-division area of transmission timing of in-vehicle device (example))

## Simulation conditions (example)

- Number of vehicles: 57 (assumed at peak times)
- Message size (sent only required, no overhead assumed)
  Vehicle / roadside unit transmission: 55 bytes / 2,000 bytes
- Transmission cycle: 100ms (Number of continuous transmissions: 2 times) * Conventional method ARIB STD-T109 does not continuously transmit
- Radio wave propagation model: Path loss, NLOS (intersection angle): ITU-R P.1411 model, Shielding loss due to large vehicles: 10 dB, fading: 3GPP model

## ■ Evaluation result (example): Packet error rate of in-vehicle device transmission (collection)




## ■ Consideration

- **Confirmed that PER decreases (packet arrival rate increases) due to application of countermeasure technology**
- **The improvement effect of PC5 is small because of packet collision when switching the transmission timing at the center of the intersection (random selection from empty slots).**
- **Performance improvement confirmed by changing the division area (without switching at the center)**

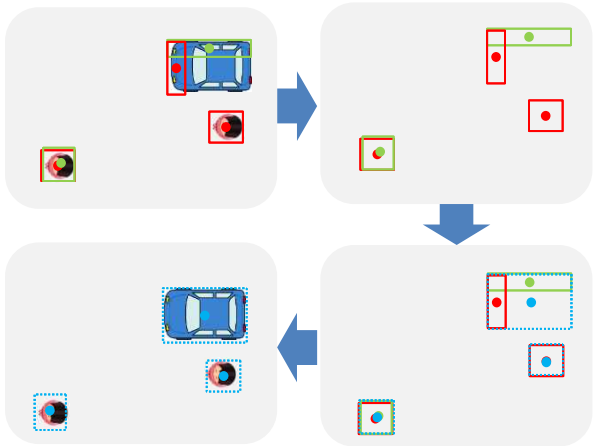
# (1) Narrow area network: Roadside processing method 1 [Oki Electric Industry] Integrated method

➢ **Integrate multiple sensor extraction information ⇒ Combine sensor areas in a wide range and provide detailed attributes**

## (1) Issues

**Identification process of multiple sensor information for the same object**


## (2) Countermeasures

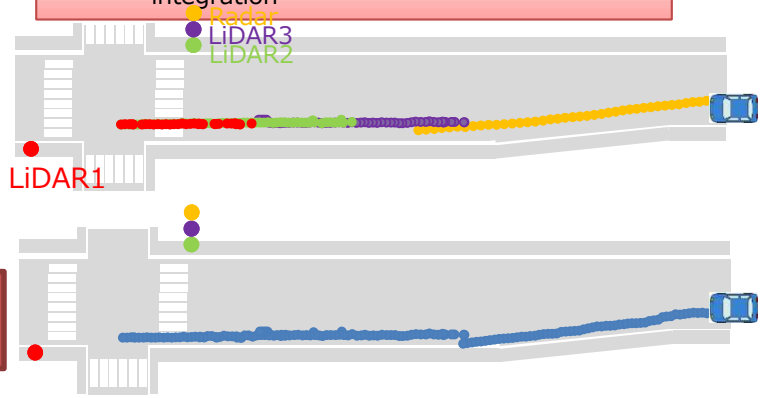


**(Processing in countermeasures)**
- **Integrated processing is carried out at regular intervals**
- **Select the extraction result received within a certain time from the integrated processing start time.**
- **From the position and size information of the selected extraction results, calculate the smallest rectangular area and midpoint that include the overlapping extraction results and use it as the integration result.**

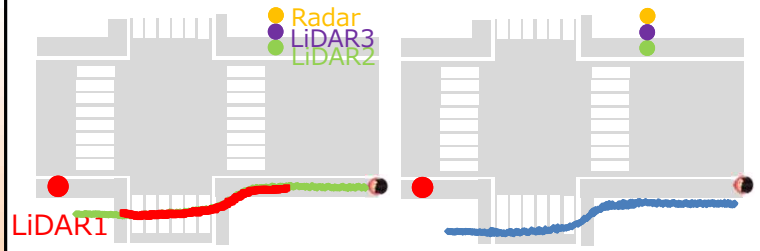
## ■ Evaluation results

UC1-1 Integrated correct answer rate: 100%
UC3 Integrated correct answer rate: 100%

<UC1> Example of vehicle driving trajectory integration




<UC3> Example of pedestrian crossing trajectory integration




## ■ Consideration

- **High-precision positioning over a wide range is possible using multiple sensors.**
- **A wide range and reliability can be improved by adding more sensors.**

[Reference]
Average error: UC1 (single unit) 0.3m ⇒ (integrated) 0.2m
UC3 (single unit) 0.4m ⇒ (integrated) 0.3m

# (1) Narrow area network: Roadside processing method 1 [Oki Electric Industry]

- **KPI verification (target: communication delay within 100ms, series processing time within 1 s, extraction / integration correct answer rate 90% or more)**

About the progress of KPI verification results
- Data acquisition and organization by field verification and simulation (emulation) were almost completed
  (Simulation results of limit test are being organized)

Task
①:When the number of vehicles is large, such as during peak hours, to collect vehicle information, secure communication performance (packet arrival rate, communication delay) by applying countermeasure technology to narrow-area communication.
⇒ It is necessary to verify the countermeasure technology using the actual machine (this time only simulation evaluation)

Typical UC scenarios were selected and described

| Verification type | UC scenario | Common test | Correct answer rate (position) | | | | Communication delay / processing time | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extraction | Pass / Fail | Integration | Pass / Fail | ① Information source ⇒ Narrow area server | Pass / Fail * 1 | ② Extraction | ③ Integration | ④ Narrow area server ⇒ Distribution destination | Pass / Fail * 1 | Total (①～④) | Pass / Fail * 2 | |
| Field verification | UC1-1-1 | | ① : 100%<br>② : 100%<br>③ : 100% | ○ | 100 % | ○ | ① : 13ms<br>② : 28ms<br>③ : 32ms | 99. % or more | ① : 50ms<br>② : 59ms<br>③ : 69ms | ① : 46ms<br>② : 95ms<br>③ : 100ms | ① : 10ms<br>② : 23ms<br>③ : 28ms | 99. % Or more | ① : 119ms<br>② : 205ms<br>③ : 229ms | 99. % or more | ・Sensors: ①2, ②, ③1<br>・Extracted targets: 1<br>・Distributed vehicles: 1 |
| | UC2-1-1 | ○ | ① : 99% | ○ | 100 % | — | ↑ | ↑ | ① : 51ms<br>② : 60ms<br>③ : 68ms | ① : 51ms<br>② : 96ms<br>③ : 100ms | ↑ | ↑ | ① : 125ms<br>② : 207ms<br>③ : 228ms | 99. % or more | ・Sensors: :①2<br>・Extracted targets: 1<br>・Distributed vehicles: 1 |
| | UC3-1-0 | ○ | ① : 100% | ○ | 100 % | ○ | ↑ | ↑ | ① : 49ms<br>② : 54ms<br>③ : 60ms | ① : 49ms<br>② : 96ms<br>③ : 101ms | ↑ | ↑ | ① : 121ms<br>② : 201ms<br>③ : 221ms | 99. % or more | ・Sensors: ①2<br>・Extracted targets: 1<br>・Distributed vehicles:1 |
| | UC4-1-1 | | | | | | | | | | | | | | Not subject to evaluation |
| Peak assumption | Limited area ② (UC2 ~ 3) | ○ | — | — | — | — | ① : 53ms<br>② : 57ms<br>③ : 57ms | 99% aor more | — | ① : 56ms<br>② : 101ms<br>③ : 106ms | ① : 53ms<br>② : 57ms<br>③ : 57ms | 99% or more | ① : 162ms<br>② : 215ms<br>③ : 220ms | 99% or more | ・Sensors: 3(assumed)<br>・Extracted targets: 32<br>・Distributed vehicles: 57 |
| Limit test | Limitation of collection / distribution (UC1 ~ 4) | | — | — | — | — | — | — | — | ① : 73ms<br>② : 118ms<br>③ : 123ms | — | — | — | — | ・Sensors: 3(assumed)<br>・Extracted targets: 150<br>・Distributed vehicles:143 |

Simulation (emulation) evaluation result

Sensor type: ① LiDAR, ② long-range LiDAR, ③ radar

Communication delay / processing time: (①average, ②CDF95%, ③CDF99%

* 1: Describe the CDF value that is 100ms or less
* 2: Describe the CDF value that is 1s or less.

# (2) Narrow area network: Roadside processing method 2 [Panasonic]

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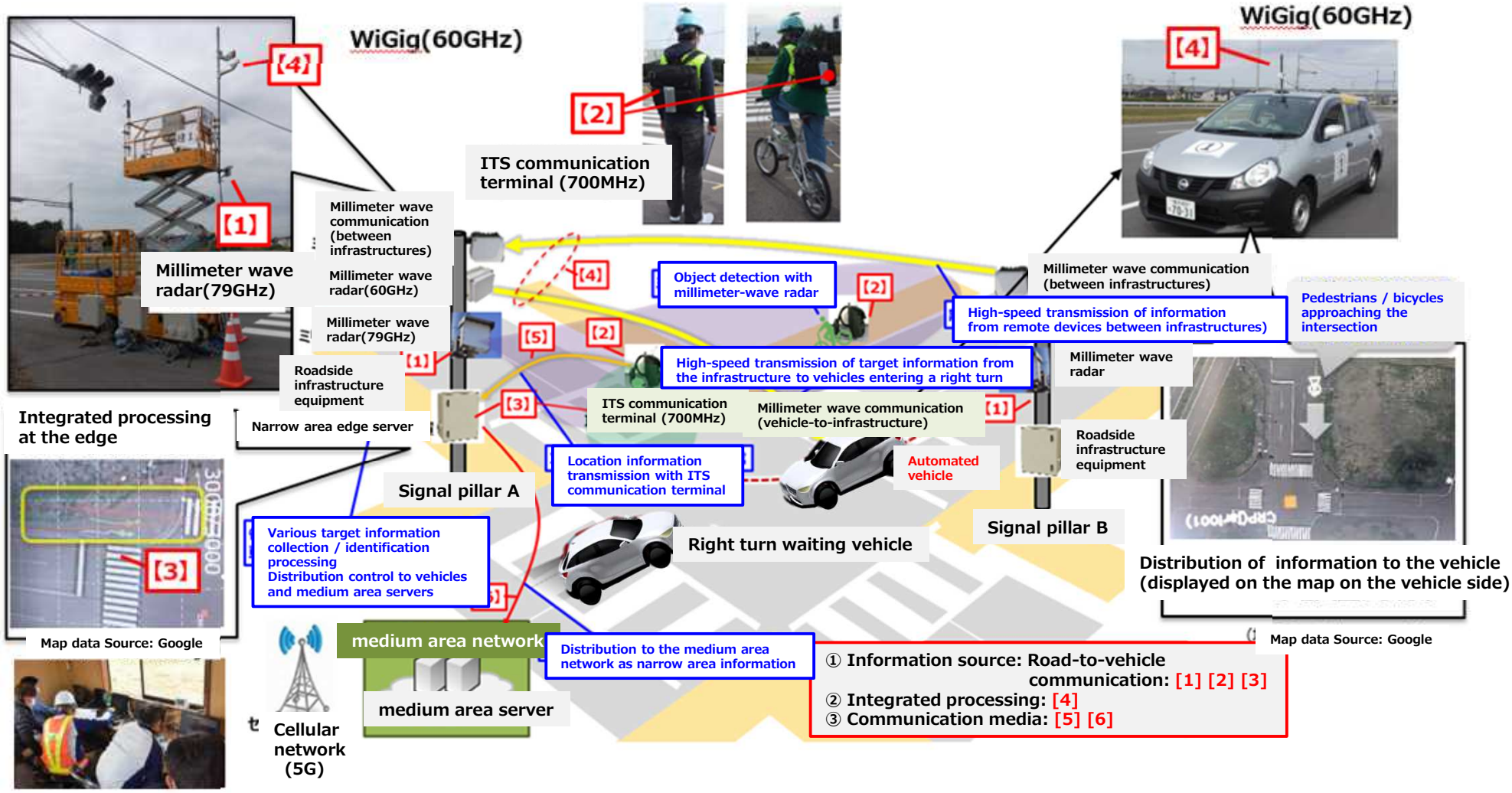
**In the JARI Tsukuba test course, the following test environment was constructed, and device connection confirmation and KPI evaluation were carried out.**

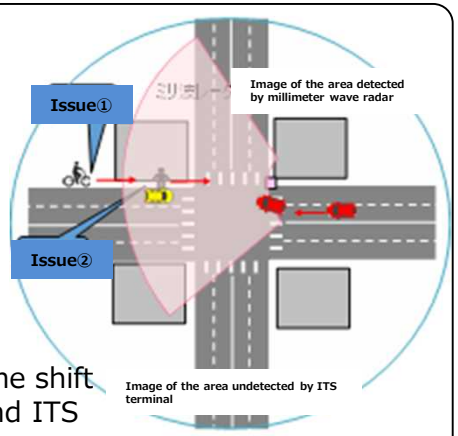


# (2) Narrow area network: Roadside processing method 2 [Panasonic] Integrated processing details

- Identifies roadside radar detection information and pedestrian position information of ITS terminals and distributes them to vehicles as one target information
- Take measures against time shift and position shift issues, and confirm that the correct answer rate KPI for integrated processing has been achieved.

## Action item

In the case where a pedestrian / bicycle holding an ITS terminal approaches or crosses an intersection from outside the line of sight, the sensing result of the roadside radar detection area and the ITS terminal are identified and distributed to the vehicle as one target information.




**Task:**

The following issues arise due to the time shift and position shift of the radar sensor and ITS terminal, which are the information sources.

Issue①: Seamless detection across sensor detection areas

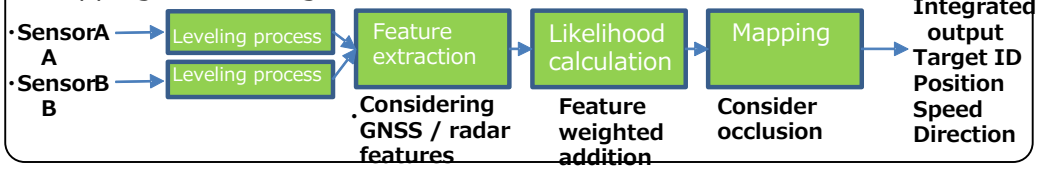
Issue②: Same judgment of target information detected by different sensors

**Time shift measures:**

An NTP server synchronized with the time pulse of the GNSS receiver was constructed for each roadside infrastructure device, and a highly accurate time synchronization system was adopted.

**Measures against misalignment:**

COS similarity (direction similarity) is converted to features, weighted addition and likelihood are calculated in consideration of position and trajectory. Uses an identification method that enables flexible mapping considering radar occlusion.




## Evaluation results

・Integrated position correct answer rate, identification correct answer rate

| Test ID | | UC-3-1-0/ UC-3-3-0 | UC-3-1-1/ UC3-3-1 | UC-3-1-2/UC3-3-2 | |
|---|---|---|---|---|---|
| Contents of test | | Pedestrian | Bicycle | Pedestrian | Bicycle |
| Correct answer rate | Integrated position | 100% | 100% | 100% | 100% |
| | Identification judgement | 98% | 94% | 97% | 96% |

*** Integrated position correct answer rate, identification correct answer rate.**

*** Extraction position error of 2 m or more and undetected data are excluded from aggregation.**

*** Position correct answer rate: judged as correct answer if the position error is within 2 m.**

*** Integrated correct answer rate: The rate at which the position error of data for which the same judgment is successful is within 2 m.**

*** Identification correct answer rate: The rate at which the expected ITS terminal ID and radar ID are determined to be the same.**

## Consideration

- When the extraction position error is within 2 m, the integrated position accuracy rate is 100%, confirming the achievement of KPI.
- The same judgment correct answer rate is 90% or more, and it is confirmed that the amount of distributed data is reduced by integrating as one target information.
- In the roadside radar detection area, the position accuracy of the target is improved by utilizing the position information of the radar and integrating it with the ITS terminal information.

Supplement)

Even if the position accuracy rate of extraction by the ITS terminal deteriorates due to the influence of the time-varying satellite arrangement (about 71%), the position accuracy rate improves by the integrated processing (about 80%).

# (2) Narrow area network: Roadside processing method 2 [Panasonic] Distribution control details

- **By the integrated processing, the target information that is duplicated by multiple sensors is integrated into one (as described above).**
- **Distributing only necessary information in consideration of the position and direction of travel of the support vehicle**

**→ Achieved the reduction rate target (50% or more) by distribution control**

## Action item

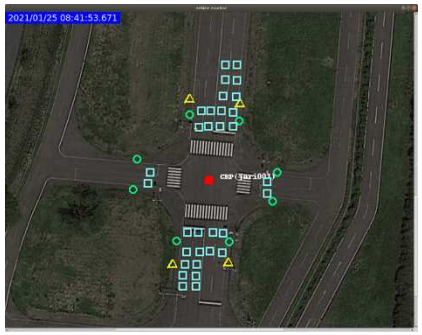
**Distribution control of information necessary to vehicles**

**(1) Method**

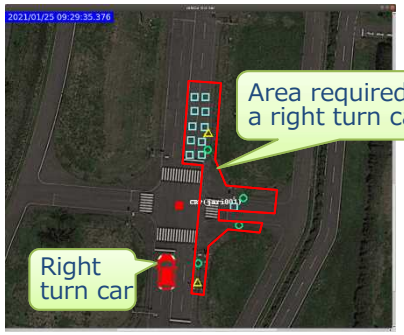
Only the targets on the area inside the intersection required for the distribution destination vehicle will be distributed (the figure is limited to the area required for turning right)

**(2) Distribution conditions**

Simulate the virtual placement of targets that will be the peak traffic volume, and measure the reduction rate of the amount of data distributed.



**No integration / no distribution control**




**With integration / distribution control**

(Optimal distribution for vehicles entering the intersection from below

(Target symbol □: Vehicle, ○: Pedestrian, △ Bicycle)

**Detailed conditions**

・Assuming that the processing target of integration is pedestrian / bicycle

・Targets in the intersection
32 vehicles, 8 pedestrians (ITS), 4 bicycles (ITS)
Targets before integration 32 + 8x2 + 4x2 = 56
Targets after integration 32 + 8 + 4 = 44
Targets after distribution control (turn right) 11 + 4 + 2 = 17

## Evaluation results

Communication traffic can be significantly reduced by distributing information according to the position and direction of travel of the vehicle, achieving a reduction of 50% or more of the target.

| Evaluation / Pattern Item | No integration | | With integration | |
|---|---|---|---|---|
| | No distribution control | With distribution control | No distribution control | With distribution control |
| Average amount of communication data per distribution (bytes) | 6,218.0 | - | 4,947.0 | **2,069.0** |
| **Reduction rate(%)** | | | | |

Distribute **all** information detected at the Intersection

Distribute only necessary information depending on **the position and direction of travel of the vehicle**

# (2) Narrow area network: Roadside processing method 2 [Panasonic] Result summary

**KPI verification (targeting a correct answer rate of 90% or more for extraction / integration and a processing delay of 1 second or less from collection to distribution)**

- **Confirmation of target value achievement under specific conditions by field verification**
- **Confirm communication / processing time and integration limit value performance under peak conditions on a general-purpose small PC with one narrow-area server**
- **Checking the limit performance when load balancing processing a narrow area server with multiple general-purpose small PCs**

Typical UC scenarios were selected and described

* Includes waiting time for periodic processing (250ms) of identification processing

| Verification type | UC scenario | Common test | Correct answer rate (position) | | | | Communication delay / processing time*3 | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extraction | Pass / Fail | Integration | Pass / Fail | (1) Information source ⇒ Narrow area server | Pass / Fail * 1 | (2)Extraction | (3)Integration * Excluding distribution control, etc. | (4) Narrow area server ⇒ distribution destination | Pass / Fail * 1 | Total (Information source ⇒ distribution destination) | Pass / Fail | |
| Field verification | UC1-1-1 | | | | | | | | | | | | | | Not subject to evaluation |
| | UC2-1-2 | ○ | ①:95% or more | ○ | Not subject to integration | ○ | ① : 14ms<br>② : 19ms<br>③ : 24ms | 99% or more | - | ① : 39ms<br>② : 58ms<br>③ : 73ms | ① : 4ms<br>② : 5ms<br>③ : 6ms | 99% or more | ① : 218ms<br>② : 302ms<br>③ : 330ms | 99% or more | ・Sensors:①1<br>・Extracted targets:1<br>・Distributed vehicles:1 |
| | UC3-1-0 | ○ | ①:95% or more<br>②:90% or more | ○ | 95% or more | ○ | ① : 15ms<br>② : 20ms<br>③ : 26ms | 99% or more | - | ① : 48ms<br>② : 75ms<br>③ : 89ms | ① : 4ms<br>② : 5ms<br>③ : 5ms | 99% or more | ① : 269ms<br>② : 454ms<br>③ : 504ms | 99% or more | ・Sensors:①1, ②1<br>・Extracted targets:1<br>・Distributed vehicles:1 |
| | UC4-1-1 | | | | | | | | | | | | | | Not subject to evaluation |
| Peak | Peak scenario | ○ | | | | | ① : 51ms | | | ① : 173ms<br>② : 209ms<br>③ : 229ms | ①7ms | 99% or more | ① : 518ms | | Simulation implementation<br>・Extracted targets:44<br>・Integrated targets:12<br>・Distributed vehicles:57 |
| Distribution limit | Peak scenario | | | | | | | | | Integration + distribution processing + distribution time<br>① 499ms | | | | | Distribution destination vehicles:73<br>Integration condition is peak scenario |
| Integration limit | Integration scenario | | | | | | | | | ① : 242ms<br>② : 270ms<br>③ : 302ms | | | | | Simulation implementation・Integrated targets: 40・Distributed vehicles: 1 |

Sensor type in extraction: ①Radar, ②ITS communication terminal

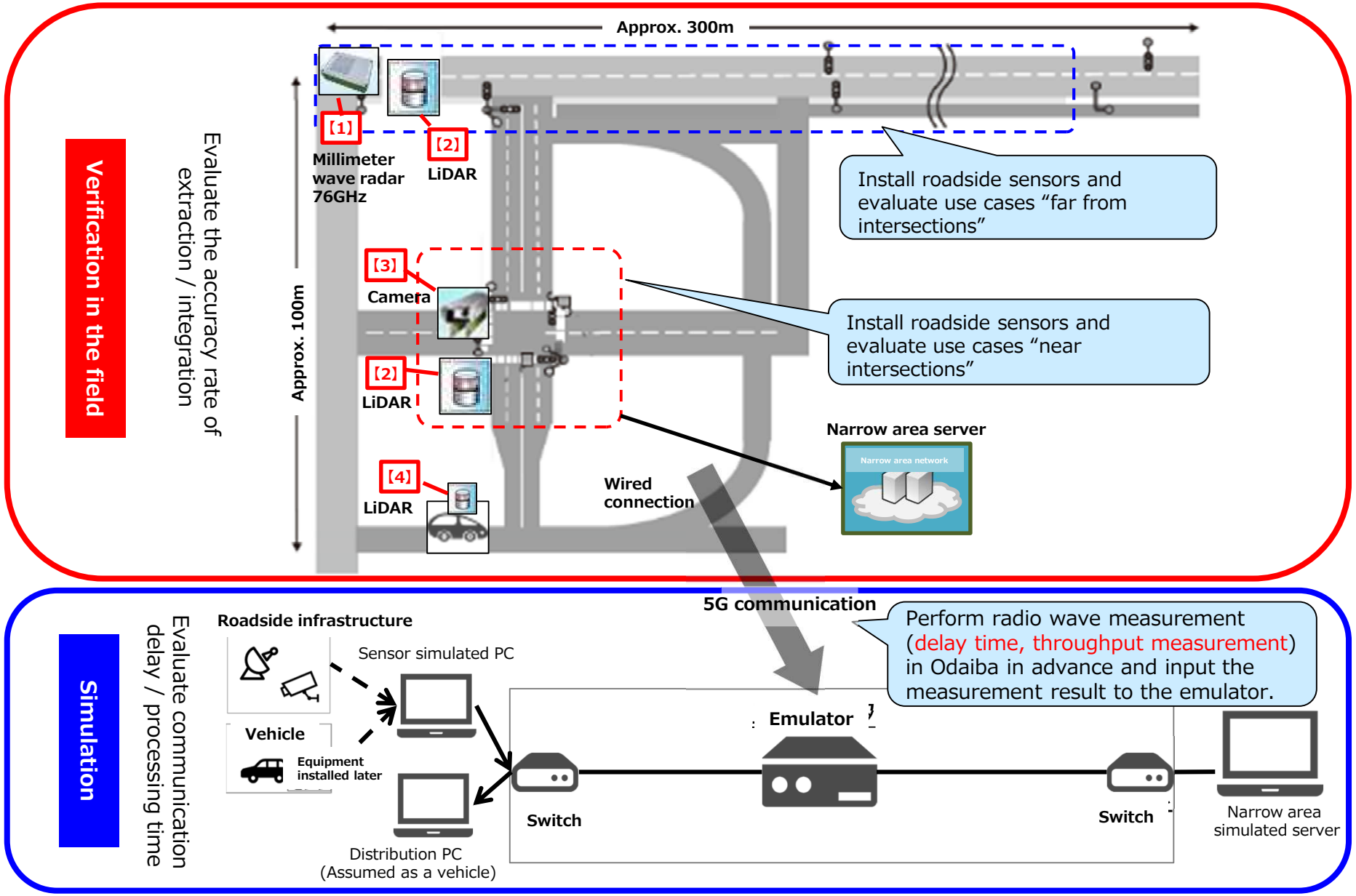
Communication delay / processing time: ①average, ② CDF95%, ③CDF99%

* 1: Describe the CDF value that is 100ms or less.
* 2: The one with the larger delay, the radar side is listed.
* 3: Reprocessing result based on actual measurement log.

# (3) Narrow area network: Center processing method [Sumitomo Electric Industries]

# (3) Narrow area network: Center processing method [Sumitomo Electric Industries]

**In our test course, we built the following test environment and carried out device connection confirmation, simulation, and KPI evaluation.**



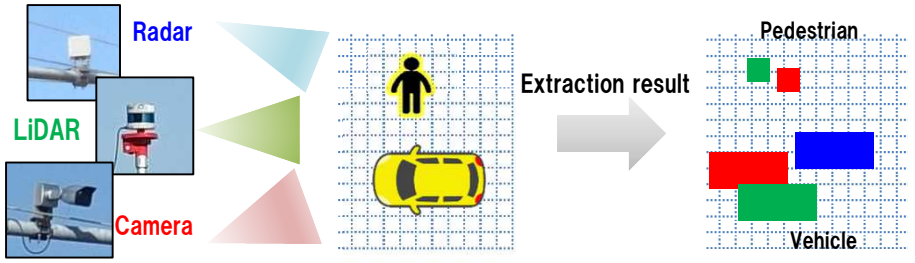
# (3) Narrow area network: Center processing method [Sumitomo Electric Industries]

- **Integrate multiple sensor extraction information ⇒ Combine sensor areas in a wide range and provide detailed attributes**
- **Confirmed KPI achievement of correct answer rate of integrated processing**

## Action item

**Identification process of multiple sensor information for the same object**

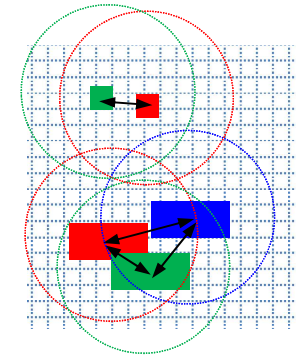
**(1) Task**




Multiple sensors extract the same object

Deviation from the actual situation
- Increase in data volume
⇒ Need for identification / integration

**(2) Countermeasure**




**(Processing)**

Compare the sensor detection time of the extraction result and judge whether the time difference is within the allowable range

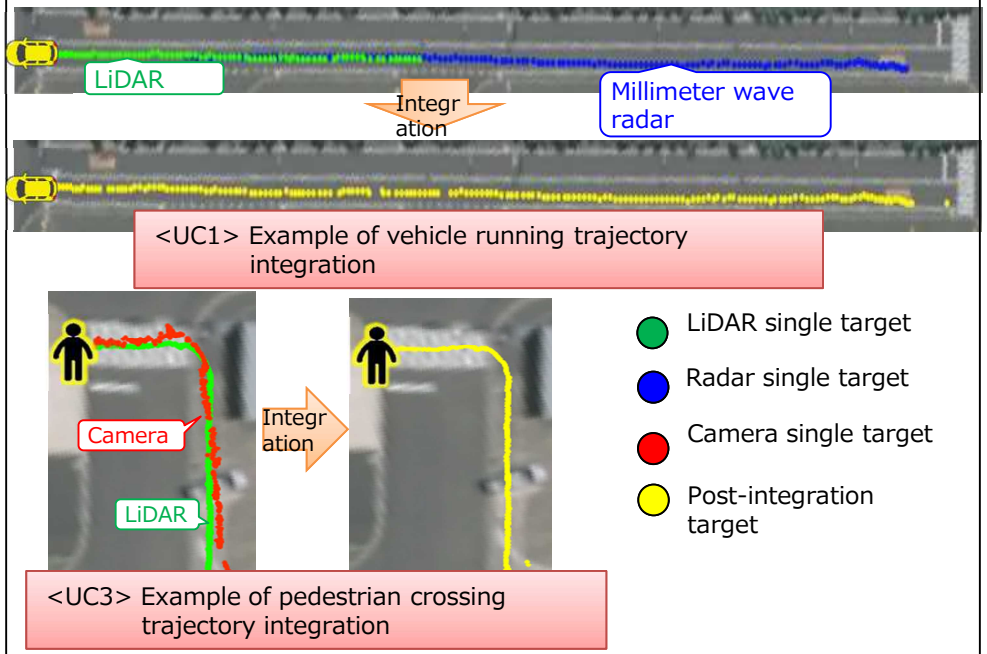
Identify the same object by Euclidean distance

Select highly accurate extraction results for each sensor

Example)
- Object type: Camera
- Object position: LiDAR
- Pedestrian orientation: Camera

## Evaluation results

| | Integrated correct answer rate |
|---|---|
| UC1-1 | 100% |
| UC3 | 100% |




## Consideration

- **In UC1, both sensor areas are seamlessly connected and the sensor area is successfully expanded.**
- **In UC3, the pedestrian attribute of the camera and the detection position of LiDAR are fused to improve the information accuracy.**

[Reference]
Average position error (single unit ⇒ integrated)
UC1-1 : 0.94m ⇒ 0.65m　UC3 : 0.69m ⇒ 0.10m

# (3) Narrow area network: Center processing method [Sumitomo Electric Industries'] Distribution control method

- **Distributing only the information required for the direction of travel of the support vehicle**
- **Confirmed achievement of KPI of traffic reduction rate by distribution control**

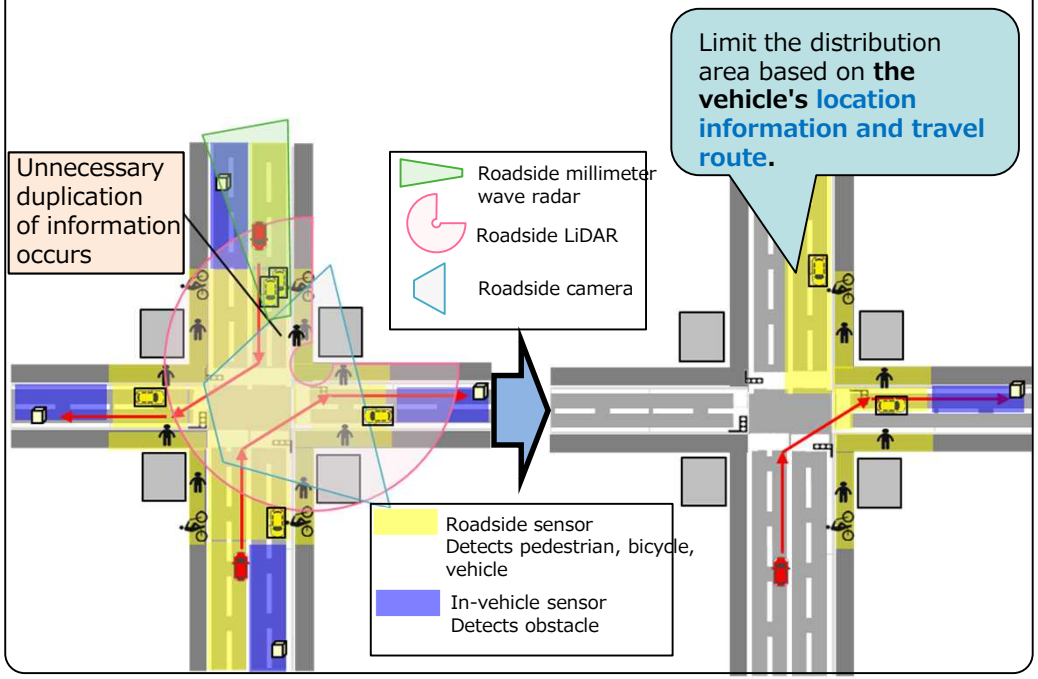
## Action item

**Distribution control to vehicles limited to necessary information**

**(1) Task**

When all traffic information is distributed, unnecessary information is included depending on the vehicle, which imposes an unnecessary load on the network and processing on the vehicle side.

**(2) Countermeasure (Method / algorithm, etc.)**




## Evaluation results

**(1) Average traffic**

| Evaluation pattern | No integration | | With integration | |
|---|---|---|---|---|
| | No distribution control | With distribution control | No distribution control | With distribution control |
| Average traffic per distribution vehicle (bytes) | 9,901.0 | 1,933.3 | 7,933.0 | **1,441.3** |

**(2) Average traffic reduction rate**

| Item \ Evaluation pattern | No integration | | With integration | |
|---|---|---|---|---|
| | No distribution control | With distribution control | No distribution control | With distribution control |
| Average traffic reduction rate (%) | 0.00 | -80.47 | -19.88 | **-85.44** |

Distribute **all** information detected at the intersection

Distribute only necessary information depending on **the position and direction of travel of the vehicle**

## Consideration

By distributing information according to the position and direction of travel of the vehicle, traffic can be significantly reduced, achieving a target reduction of 50% or more.

# (3) Narrow area network: Center processing method [Sumitomo Electric Industries]

**KPI verification (target: communication delay within 100ms, series processing time within 1 s, extraction / integration correct answer rate 90% or more)**

- **Confirmation of KPI achievement of correct answer rate of extraction / integration by field verification**
- **Confirmation of KPI achievement of communication delay and series of processing time by field verification and simulation conditions assuming peak time**
- **Confirmation of communication delay KPI achievement under simulation conditions of limit test**

<Collection data size>
① Radar Approximately 0.5Kbyte / 100ms
② LiDAR Approximately 180Kbyte / 100ms
③ Camera Approximately 230Kbyte / 100ms

<Distribution data size>
① Header about 53 bytes / 100ms
② Approximately 112 bytes / 100ms per target
⇒⇒ (① + (② * Number of target)) * Number of distributions

Typical UC scenarios were selected and described

| Verification type | Verification No .(UC scenario) | Common test | Correct answer rate (position) | | | | Communication delay / processing time | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extraction | Pass/Fail | Integration | Pass/Fail | ① Information source ⇒ Narrow area server | Pass/Fail*1 | ② Extraction | ③ Integration | ④ Narrow area server ⇒ Distribution destination | Pass/Fail*1 | Total (Information source ⇒ Distribution destination) | Pass/Fail *2 | |
| Field validation | 2-1 (UC1-1-1) | | ① : 99%<br>②100% | ○ | 100 % | ○ | ① : 38ms<br>② : 54ms<br>③ : 60ms | 99. % or more | ① : 30ms<br>② : 40ms<br>③ : 43ms | ① : 4ms<br>② : 6ms<br>③ : 7ms | ① : 22ms<br>② : 28ms<br>③ : 29ms | 99. % or more | ① : 98ms<br>② : 134ms<br>③ : 145ms | 99. % or more | ・Sensor: ①1, ②1<br>・Extracted target: 1<br>・Distributed vehicle: 1 |
| | 2-2-1 (UC2-1-1) | ○ | ②100% | ○ | — | — | ① : 40ms<br>② : 55ms<br>③ : 61ms | 99. % or more | ① : 29ms<br>② : 38ms<br>③ : 42ms | ① : 1ms<br>② : 2ms<br>③ : 2ms | ① : 21ms<br>② : 26ms<br>③ : 28ms | 99. % or more | ① : 95ms<br>② : 128ms<br>③ : 140ms | 99. % or more | ・Sensor: ②1<br>・Extracted target: 1個<br>・Distributed vehicle: 1 |
| | 2-3 (UC3-1-0) | ○ | ②100%<br>③ : 99% | ○ | 100 % | ○ | ① : 43ms<br>② : 64ms<br>③ : 72ms | 99. % or more | ① : 70ms<br>② : 81ms<br>③ : 85ms | ① : 5ms<br>② : 8ms<br>③ : 9ms | ① : 21ms<br>② : 26ms<br>③ : 26ms | 99. % or more | ① : 143ms<br>② : 186ms<br>③ : 200ms | 99. % or more | ・Sensor: ②1, ③1<br>・Extracted target: 1<br>・Distributed vehicle: 1 |
| | 2-4-1 (UC4-1-1) | | ② : 97% | ○ | — | — | ① : 43ms<br>② : 63ms<br>③ : 71ms | 99. % or more | ① : 36ms<br>② : 49ms<br>③ : 55ms | ① : 211ms<br>② : 221ms<br>③ : 226ms | ① : 21ms<br>② : 27ms<br>③ : 28ms | 99. % or more | ① : 316ms<br>② : 368ms<br>③ : 389ms | 99. % or more | ・Sensor: ②1<br>・Extracted target: 1<br>・Distributed vehicle: 1 |
| Peak assumption | 3-8 (UC2~3) | ○ | — | — | — | — | ① : 44ms<br>② : 67ms<br>③ : 77ms | 99. % or more | (① : 70ms<br>② : 81ms<br>③ : 85ms) | ① : 89ms<br>② : 141ms<br>③ : 163ms | ① : 21ms<br>② : 27ms<br>③ : 30ms | 99. % or more | ① : 233ms<br>② : 319ms<br>③ : 349ms | 99. % or more | ・Sensor: ②2, ③2<br>・Extracted target: 32<br>・Distributed vehicle: 57 |
| Limit test | 4-5 (UC1~4) | | — | — | — | — | ① : 43ms<br>② : 66ms<br>③ : 75ms | 99. % or more | — | — | ① : 33ms<br>② : 51ms<br>③ : 58ms | 99. % or more | — | — | ・Sensor: ①2, ②3, ③3<br>・Extracted target: 96<br>・Distributed vehicle: 143 |

Simulation evaluation result

Sensor type: ① Radar, ② LiDAR, ③ Camera

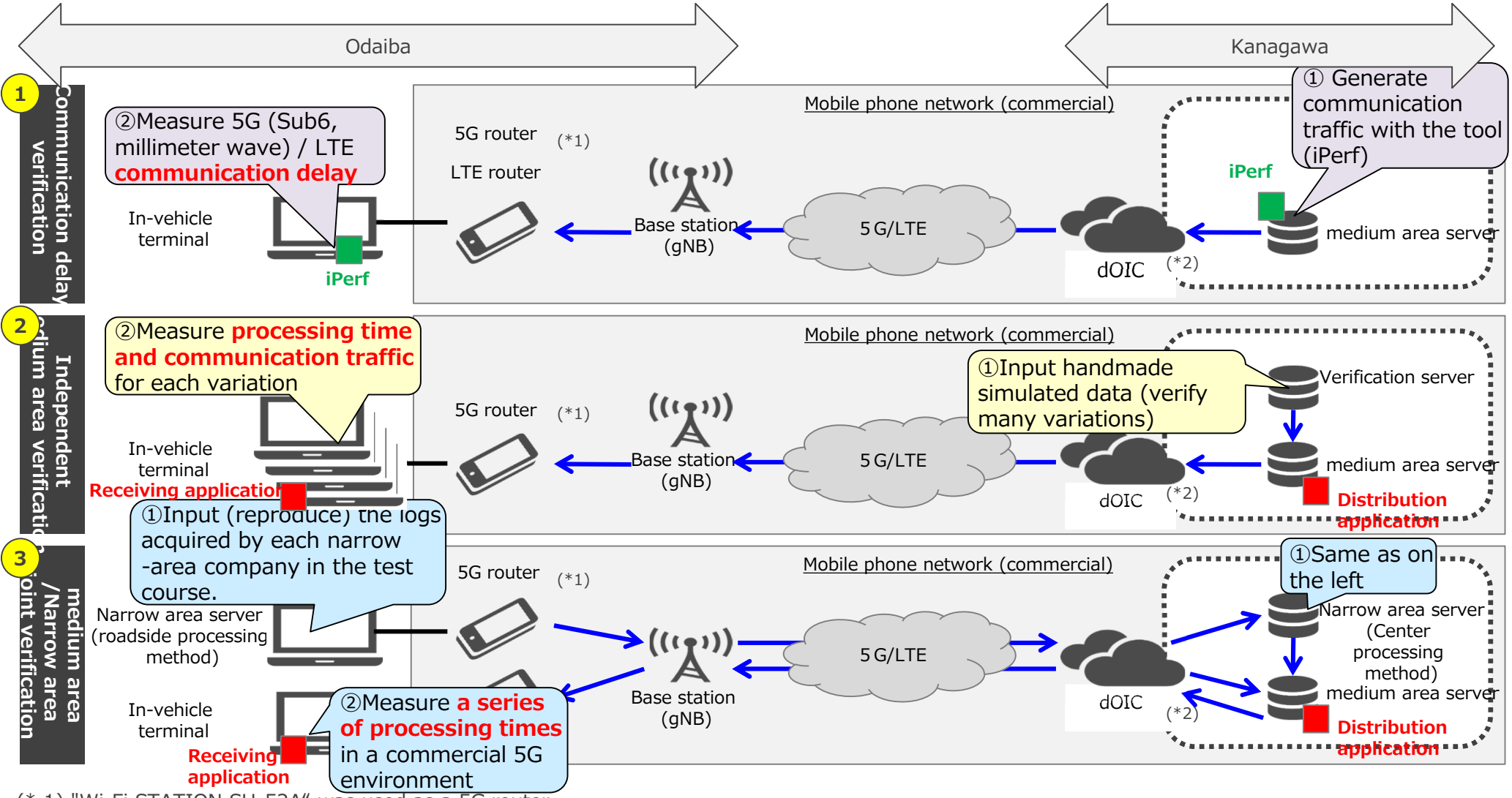
Communication delay / processing time: ①average, ② CDF95%, ③CDF99%
* Reflect the latest measurement results after emulator verification

* 1: Describe the CDF value that is 100ms or less.
* 2: Describe the CDF value that is 1s or less.

# (4) Medium area network [NTTDOCOMO]

# (4) medium area network [NTT DOCOMO]

- In Odaiba and Kanagawa, we built the following test environment and carried out three-stage verification
- A commercial network was used as a mobile phone network, and communication delays were evaluated as 5G (Sub6, millimeter wave) and LTE, respectively.

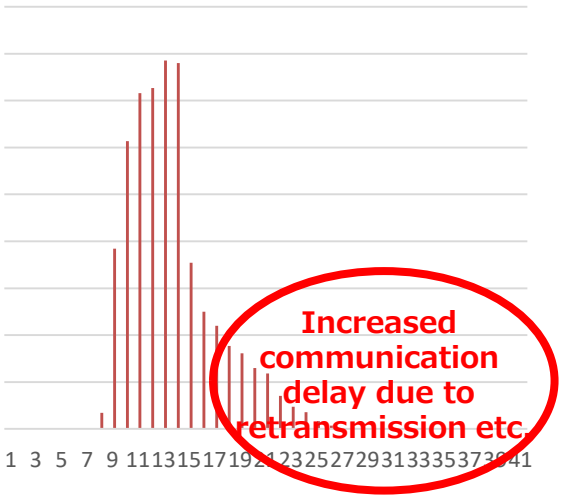



(* 1) "Wi-Fi STATION SH-52A" was used as a 5G router.
(* 2) docomo Open Innovation Cloud: A cloud platform with MEC's characteristics of achieving low latency and high security by installing it in a mobile phone network.

# (4) medium area network [NTT DOCOMO]
## ① Communication delay verification

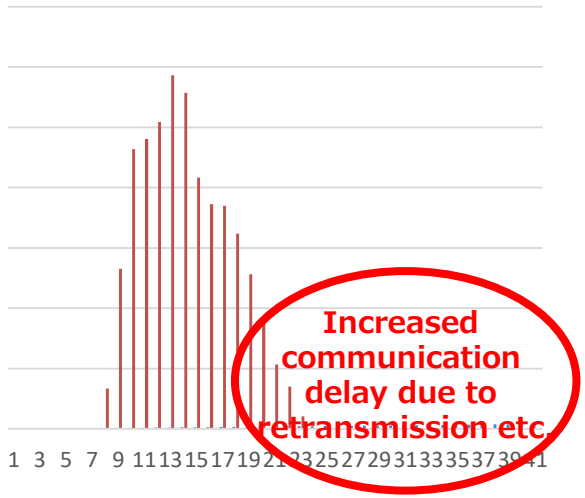
- KPI verification (communication delay: 100ms or less) ⇒ [achieved]
- Regarding the communication delay at 5G (mmW, Sub6), the average value, median value, CDF [95% or 99% tile value], etc. are within the range of several tens of ms, and it can be judged that the KPI has been achieved.
- Consideration on the influence of communication traffic by general users is described on the next page.

**Down link (5G: mmW)**



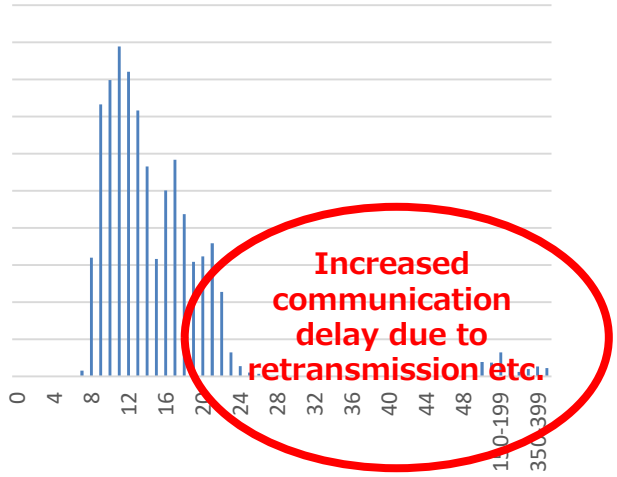

| | | |
|---|---|---|
| Average value | 12.5 | [ms] |
| Standard deviation | 3.4 | [ms] |
| Maximum value | 27.5 | [ms] |
| Median | 11.9 | [ms] |
| Minimum value | 6.4 | [ms] |
| CDF(95%) | 18.1 | [ms] |
| CDF(99%) | 20.4 | [ms] |

**Down link (5G : Sub6)**




| | | |
|---|---|---|
| Average value | 13.2 | [ms] |
| Standard deviation | 3.4 | [ms] |
| Maximum value | 31.3 | [ms] |
| Median | 12.8 | [ms] |
| Minimum value | 5.6 | [ms] |
| CDF(95%) | 18.8 | [ms] |
| CDF(99%) | 21.1 | [ms] |

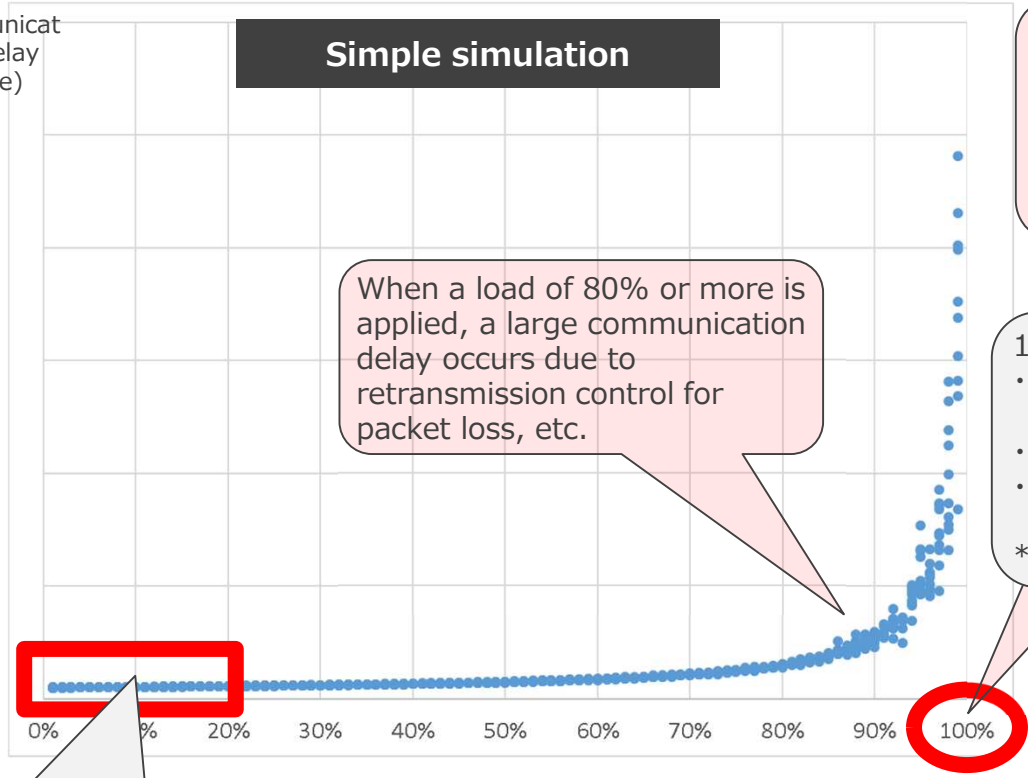
**Down link (LTE) *Reference**




| | | |
|---|---|---|
| Average value | 20.3 | [ms] |
| Standard deviation | 40.6 | [ms] |
| Maximum value | 451.5 | [ms] |
| Median | 13.3 | [ms] |
| Minimum value | 6.8 | [ms] |
| CDF(95%) | 87.0 | [ms] |
| CDF(99%) | 114.6 | [ms] |

# (4) medium area network [NTT DOCOMO]
## ① Communication delay verification (supplementary explanation)

- **As shown in the simple simulation below, the communication delay of the cellular system remains flat up to about 50% of the maximum capacity of the load (cell throughput) on the base station, and increases linearly up to about 80%.**
- **Since the load on the base station by the medium area network examined this time is sufficiently small with respect to the maximum capacity, it can be considered that the communication delay is not affected by the communication traffic within the range of the assumed UC.**




The horizontal axis represents the percentage of data sent and simulated with respect to the amount of data that can be sent per unit time.
(For example, if a maximum of 100 packets can be transmitted in 100 unit times, 80% means that an attempt was made to transmit 80 packets of data.)

When a load of 80% or more is applied, a large communication delay occurs due to retransmission control for packet loss, etc.

100% = Effective speed is set for maximum capacity
- LTE → NTT DOCOMO website nationwide total: 237 Mbps (median)
- 5G (Sub6) → Odaiba actual measurement: 400Mbps (mode)
- 5G (mmW) → Odaiba actual measurement: 800Mbps (mode)

* Refer to the report text for the above setting basis.

Load range from the medium area network (**5.1Mbps to 37.1Mbps (reference value)**)
* Refer to the report text for the above setting basis.

**Since the load on the base station by the medium area network is sufficiently small, the communication delay can be considered to be unaffected by the communication traffic.**

# (4) medium area network [NTT DOCOMO]
## ② Independent medium area verification

- **KPI verification (communication delay from medium area server to distribution destination: within 100ms) ⇒ [Achieved]**
- **As the amount of distributed data increases, MQTT packets are divided and transmitted, but the delay of the wireless communication part is confirmed to reach the target within 100ms(*1).**
- **Even when the number of distribution destinations increased, it was confirmed that the delay of the wireless communication part achieved the target within 100ms, but the processing time of the medium area server will increase, so consideration must be given to the design.**

| Category | Verification variation | (1) Integration / Distribution in medium area server [Processing time] | (2) medium area server⇒MQTT broker [Processing time] | (3) Processing in MQTT broker [Processing time] | (4) MQTT broker ⇒ dOIC transmission [Processing time] | (5) Wireless communication time [Processing time] | (6) In-vehicle unit split packet reception [Processing time] | Total ((1)-(6)) |
|---|---|---|---|---|---|---|---|---|
| Distribution range (data volume) | 200m x 200m (3 targets) | ① 99.8ms<br>②201.7ms<br>③243.9ms | ① 17.6ms<br>② 88.7ms<br>③118.2ms | ① 1.0ms<br>② 2.1ms<br>③ 2.6ms | ① 1.0ms<br>② 1.7ms<br>③ 2.0ms | ① 8.8ms<br>② 19.7ms<br>③ 24.2ms | | ①128.2ms<br>②314.0ms<br>③390.9ms |
| | 500m x 500m (16 targets) | ① 92.1ms<br>②146.8ms<br>③169.5ms | ① 23.2ms<br>②132.2ms<br>③177.4ms | ① 3.0ms<br>② 7.2ms<br>③ 8.9ms | ① 1.7ms<br>② 3.5ms<br>③ 4.2ms | ① 17.5ms<br>② 81.9ms<br>③108.5ms | ① 9.5ms<br>② 81.2ms<br>(* 1) ③110.9ms | ①146.8ms<br>②452.7ms<br>③579.5ms |
| | 1km x 1km (64 targets) | ① 99.8ms<br>②201.7ms<br>③243.9ms | ① 41.9ms<br>②261.8ms<br>③353.0ms | ① 11.1ms<br>② 12.2ms<br>③ 39.5ms | ① 4.3ms<br>② 11.4ms<br>③ 14.3ms | ① 38.1ms<br>② 68.0ms<br>③ 80.4ms | ① 54.2ms<br>②201.3ms<br>③262.2ms | ①249.3ms<br>②775.4ms<br>③993.4ms |
| Number of distribution destinations | 1 vehicle | ① 99.8ms<br>②201.7ms<br>③243.9ms | ① 17.6ms<br>② 88.7ms<br>③118.2ms | ① 1.0ms<br>② 2.1ms<br>③ 2.6ms | ① 1.0ms<br>② 1.7ms<br>③ 2.0ms | ① 8.8ms<br>② 19.7ms<br>③ 24.2ms | | ①128.2ms<br>②314.0ms<br>③390.9ms |
| | 22 vehicles (Reference value) | | ① 87.9ms<br>②338.0ms<br>③441.6ms | ①116.1ms<br>②456.1ms<br>③597.0ms | ① 53.5ms<br>②216.0ms<br>③283.3ms | ① 30.1ms<br>② 42.7ms<br>③ 47.9ms | | |
| | 44 vehicles (Maximum number of vehicles that one base station can accommodate) | ①270.6ms<br>②842.7ms<br>③1079.8ms | ① 4519.1ms<br>②11380.0ms<br>③14222.6ms | ① 453.7ms<br>②1124.4ms<br>③1402.2ms | ①212.4ms<br>②581.1ms<br>③725.8ms | ① 32.0ms<br>② 52.6ms<br>③ 61.2ms | | ① 5507.1ms<br>②13980.7ms<br>③17491.6ms |

【Usage Guide】
① Average value
② CDF 95%
③ CDF 99%

(* 1) Since communication in dOIC is a best effort service, it is possible that the processing time will be 100ms or more.

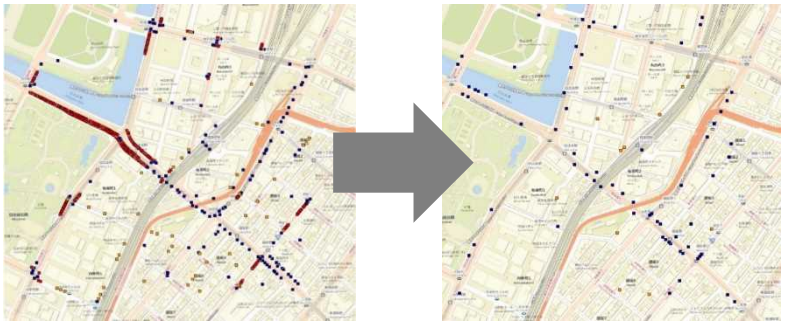
# (4) medium area network [NTT DoCoMo]
## ② Independent medium area verification

- **KPI verification (communication traffic reduction rate: 50% or more) ⇒ [Achieved]**
- **①For the "Narrow area server → Medium area server" section, implement a "collection control function" that limits the target information collected from the narrow area server to only the information used for the assumed UC, and confirm the effect.**
- **②For the "medium area server → Distribution destination vehicle" section, implement a "distribution control function" that narrows down the distribution range (distribution target information) according to the traveling speed of the distribution destination vehicle, and confirm the effect.**

[Measurement conditions (assumed environment)]

・Narrow area server: 4 units per 1km ^ 2 ・Target information: 52 targets per 1 narrow area server, 16 of which are stagnant targets

| Category | Evaluation item | BEFORE | AFTER |
|---|---|---|---|
| | | No collection control function (example: 60km / h) | With collection control function (example: 60km / h) |
| ① | Number of targets to be distributed (data volume) | 208 Target (approx. 54.3 kbyte) | 64 Target (approx. 13.6 kbyte) |
| | Communication traffic reduction rate | Standard value | 69.2 % |
| | Operation check | – | ○ |



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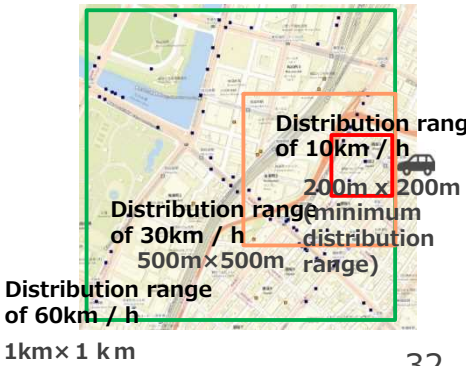
| Category | Evaluation item | BEFORE | AFTER | | |
|---|---|---|---|---|---|
| | | Per Municipality (27km ^ 2 * 1) | 60km / h (1km ^ 2) | 30km / h (500m x 500m) | Minimum area (200m x 200m) |
| ② | Number of targets to be distributed (data volume) | 5616 Target (approx. 1.43 Mbyte) | 208 Target (approx. 54.3 kbyte) | 52 Target (approx. 13.6 kbyte) | 9 Target (approx. 2.4 kbyte) |
| | Communication traffic reduction rate | Standard value | 96.30 % | 99.07 % | 99.84 % |
| | Operation check | – | ○ | ○ | ○ |



# (4) medium area network [NTT DOCOMO]
## ③ medium area/Narrow area joint verification

- **KPI verification (a series of processing time in the medium area: within 3 seconds) ⇒ [Achieved]**
- **The data is under limited conditions (* 1), but the processing is completed within a few hundred milliseconds.**
- **If the amount of distribution data or the number of distribution destinations is increased, the processing time of the medium area server will increase as shown on the previous page, so design consideration is required.**

| Category | UC scenario | (1) Extraction from information sources **[Processing time]** | (2) Information source ⇒ Narrow area server **[Communication delay]** | (3) Integration in narrow area server **[Processing time]** | (4) Narrow area server ⇒ Medium area server **[Communication delay]** | (5) Integration / distribution in medium area server **[Processing time]** | (6) Medium area server ⇒ Distribution destination **[Processing time]**(*2) | Total ( (1)-(6)) |
|---|---|---|---|---|---|---|---|---|
| Oki | UC M1-1-1 (No stagnation) | ①50.4ms<br>②56.0ms<br>③61.0ms | ①11.1ms<br>②29.0ms<br>③31.0ms | ①48.9ms<br>②89.0ms<br>③99.0ms | ①33.2ms<br>②62.2ms<br>③74.2ms | ①28.0ms<br>②86.6ms<br>③110.9ms | ①15.8ms<br>②24.9ms<br>③28.6ms | ①187.4ms<br>②347.7ms<br>③404.7ms |
| | UC M1-1-2 ～1-1-3 (Route change) (*3) | ①50.2ms<br>②55.0ms<br>③60.0ms | ①11.1ms<br>②28.0ms<br>③31.0ms | ①57.2ms<br>②94.0ms<br>③100.0ms | ①26.2ms<br>②44.5ms<br>③52.1ms | ①21.6ms<br>②57.5ms<br>③72.3ms | ①10.3ms<br>②17.2ms<br>③16.3ms | ①176.6ms<br>②296.2ms<br>③331.7ms |
| Panasonic | UC M1-1-1 (No stagnation) | ①14.0ms<br>②21.0ms<br>③27.0ms | ①20.2ms<br>②33.5ms<br>③41.0ms | ①37.4ms<br>②49.0ms<br>③51.0ms | ①29.5ms<br>②39.8ms<br>③44.1ms | ①24.1ms<br>②119.3ms<br>③158.7ms | ①16.4ms<br>②15.8ms<br>③19.9ms | ①141.6ms<br>②278.4ms<br>③341.7ms |
| | UC M1-1-3 (Route change) | ①12.9ms<br>②18.0ms<br>③20.0ms | ①20.5ms<br>②33.5ms<br>③49.0ms | ①33.4ms<br>②47.0ms<br>③53.0ms | ①27.8ms<br>②38.4ms<br>③42.7ms | ①17.7ms<br>②93.4ms<br>③124.8ms | ①17.2ms<br>②27.9ms<br>③32.3ms | ①129.5ms<br>②258.2ms<br>③321.8ms |
| | UC M2-3 (Departure of vehicle parked in the street) | ①13.0ms<br>②19.0ms<br>③20.0ms | ①20.2ms<br>②33.5ms<br>③41.0ms | ①32.4ms<br>②46.0ms<br>③48.0ms | ①26.3ms<br>②35.2ms<br>③38.9ms | ①21.0ms<br>②124.0ms<br>③166.7ms | ①19.7ms<br>②25.2ms<br>③27.9ms | ①132.6ms<br>②282.9ms<br>③342.5ms |

(* 1) In the JARI test course, the log of the case where one target information was distributed to one distribution destination vehicle is played back in the 5G environment of Odaiba.
(* 2) Including communication delay (→ Refer to "Verification result 1" for evaluation of communication delay itself), and time until all received messages are received at the distribution destination
(* 3) Since the stopped target is not detected, it is carried out without integrated processing.

【Usage Guide】
① Average value
② CDF 95%
③ CDF 99%

# (5) Comprehensive confirmation

- For the target vehicle, we conducted verification assuming a series of UC scenarios, such as supporting route changes in the medium area and supporting right turns at intersections in the narrow area.
- In the process of UC scenario, measure the series of processing time (KPI is within 3 seconds) of collection ⇒ integration ⇒ distribution
- Validate the entire system architecture examined and constructed and carry out KPI evaluation

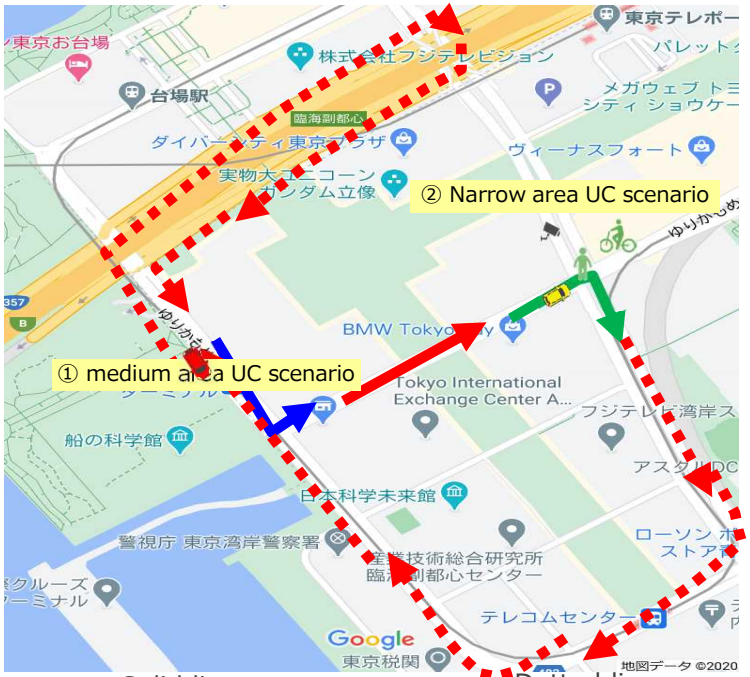
**Driving route in Odaiba**

① medium area scenario

・Distribute information on the stagnation of narrow-area extraction vehicles via 5G
・Receive target information (stagnation information) with a medium area support vehicle

② Narrow area scenario

After receiving ① above, turn left at the intersection and continue straight ahead.) Receive information on narrow areas at the Aomi 1-chome intersection
(The information captured by the narrow area sensor installed on the roadside is received by the medium area support vehicle)



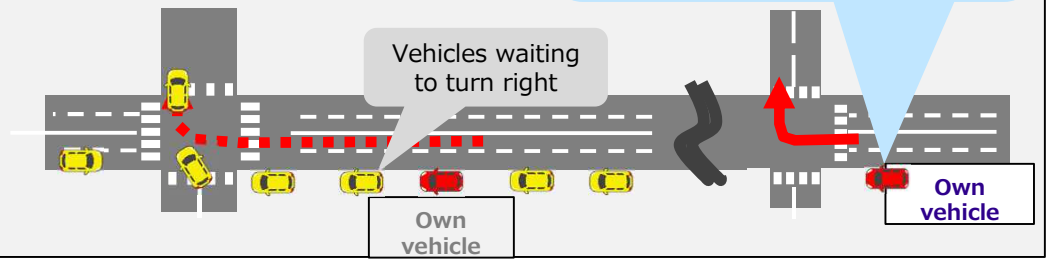

Solid line: Test implementation

Dotted line: Circumferential circuit

**① medium area UC scenario**

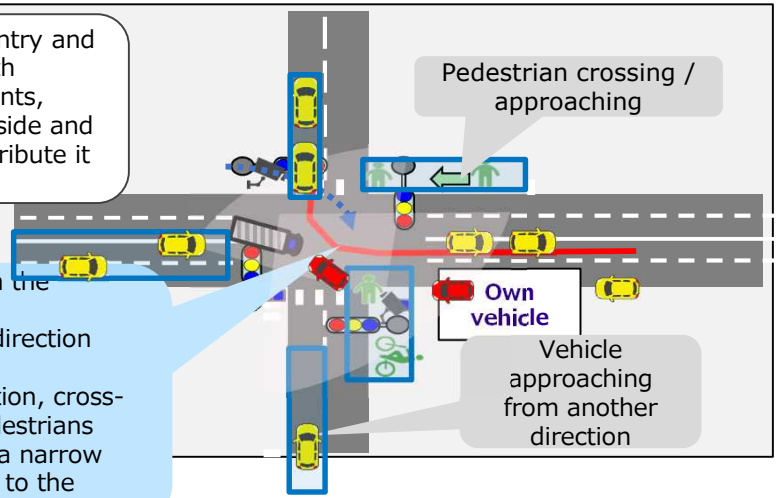
By continuously distributing the situation in front of the vehicle, it supports lane changes and route changes in advance and realizes smooth traffic flow.

Supporting route changes at uncrowded intersections in advance.
* The Odaiba demonstration was conducted on the assumption that the route was changed from going straight to turning left.




**② Narrow area UC scenario**

In order to support smooth entry and passage into intersections with complicated traffic environments, grasp the traffic conditions inside and near the intersection and distribute it to automated vehicles.




Detects vehicles traveling in the oncoming lane and vehicles approaching from another direction when turning right.
* In the Odaiba demonstration, cross-sectional information of pedestrians and bicycles is detected by a narrow area sensor and distributed to the vehicle.

# (5) Comprehensive confirmation ① Medium area use case scenario

- **KPI verification (a series of processing time in the medium area: within 3 seconds) ⇒ [Achieved]**
- **Processing is completed within a few hundred milliseconds, although it is under the condition of one intersection and one distribution destination in Odaiba.**
- **Similar to the above-mentioned medium area verification, if the amount of distribution data (including the number of intersections) and the number of distribution destinations are increased, the processing time (5) and (6) of the medium area server will increase by up to 1 second, but it will be within 3 seconds.**
- **In addition, it is expected that transmission interruption of about 400ms will occur when switching base stations (* 1), but even if this is taken into consideration, it will be within 3 seconds.**

| Category | UC scenario | (1) Extraction from information sources **[Processing time]** | (2) Information source ⇒ Narrow area server **[Communication delay]** | (3) Integration in Narrow area server **[Processing time]** | (4) Narrow area server ⇒ Medium area server **[Communication delay]** | (5) Integration / distribution in medium area server **[Processing time]** | (6) medium area server ⇒ Distribution destination **[Processing time]** (* 4) | Total ((1)-(6)) |
|---|---|---|---|---|---|---|---|---|
| Oki (* 2) | UC M1-1-1 (No stagnation) | ①37.4ms<br>②46.0ms<br>③53.0ms | ①0.6ms<br>②1.0ms<br>③2.0ms | ①49.7ms<br>②99.0ms<br>③101.0ms | ①28.9ms<br>②80.9ms<br>③102.4ms | ①20.1ms<br>②62.7ms<br>③80.5ms | ①80.0ms<br>②43.9ms<br>③49.2ms | ①216.7ms<br>②333.5ms<br>③388.1ms |
| Panasonic (* 3) | UC M1-1-1 (No stagnation) | ITS<br>①1.4ms<br>②2.0ms<br>③2.0ms<br><br>Radar<br>①13.4ms<br>②20.0ms<br>③23.0ms | ITS<br>①3.0ms<br>②4.0ms<br>③5.0ms<br><br>Radar<br>①2.1ms<br>②3.0ms<br>③4.0ms | ①48.0ms<br>②72.0ms<br>③78.0ms | ①48.0ms<br>②71.7ms<br>③81.5ms | ①32.9ms<br>②71.6ms<br>③94.0ms | ①8.7ms<br>②43.9ms<br>③58.4ms | ITS<br>①142.0ms<br>②265.2ms<br>③318.9ms<br><br>Radar<br>①153.1ms<br>②282.2ms<br>③338.9ms |

【Usage Guide】
① Average value
② CDF 95%
③ CDF 99%

(* 1) In the case of LTE base station switching (handover), which is an anchor band.
Regarding switching between 5G and LTE, LTE communication will continue, so transmission interruption will not occur.
(* 2) Medium area UC ⇒ Narrow area UC scenario.
(* 3) Narrow area pedestrian detection scenario.
(* 4) Including communication delay (→ Refer to "Verification result 1" for evaluation of communication delay itself), and time until all received messages are received at the distribution destination.

# (5) Comprehensive confirmation ② Narrow area use case scenario

- **KPI verification (a series of processing time in a narrow area: within 1 second) ⇒ [Achieved]**
- **In collaboration with each company, measure narrow-range distribution (medium area distribution is also carried out at the same time) in the test environment of Odaiba.**
  - **Confirmed that the communication quality in the communication area is 99% or more of the packet arrival rate [Oki Electric Industry]**
  - **Improve the software processing time and time synchronization method from the time of JARI and confirm the improvement [Panasonic]**

| Category | UC scenario | (1) Extraction from information sources **[Processing time]** | (2) Information source ⇒ Narrow area server **[Processing time]** | (3) Integration in narrow area server **[Processing time]** | (4) Narrow area server ⇒ Distribution destination **[Processing time]** | Total ((1)-(4)) |
|---|---|---|---|---|---|---|
| Oki | UC N3-1-0 ～3-1-3 (Crossing the intersection) | ①37.4ms<br>②46.0ms<br>③53.0ms | ①0.6ms<br>②1.0ms<br>③2.0ms<br>(*1) | ①49.7ms<br>②99.0ms<br>③101.0ms | ①10.0ms<br>②22.0ms<br>③28.0ms | ①97.7ms<br>②168.0ms<br>③184.0ms |
| Panasonic | UC N3-1-0 ～3-1-3 (Crossing the intersection) | ITS<br>①1.3ms<br>②2.0ms<br>③2.0ms<br><br>Radar<br>①13.4ms<br>②20.0ms<br>③23.0ms | ITS (for each target)<br>①3.0ms<br>②4.0ms<br>③6.0ms<br><br>Radar (multiple batches)<br>①1.9ms<br>②3.0ms<br>③5.0ms | ①32.2ms<br>②74.0ms<br>③91.0ms | ①2.4ms<br>②2.0ms<br>③3.0ms<br>(*2) | ①236.7ms<br>②330.0ms<br>③382.0ms<br>(*2)<br>(*3) |

【Usage Guide】
① Average value
② CDF 95%
③ CDF 99%

(* 1) Information source (sensor) and narrow-area server are directly connected
(* 2) Aggregate excluding delays of 500ms or more due to shielding (due to the inability to secure sufficient installation height due to the simple installation of roadside communication equipment)
(* 3) Includes waiting time for periodic processing (250ms) of identification processing

# Summary (proposals, future tasks, etc.)

| Item | Narrow area network | medium area network |
|---|---|---|
| Achievement status of KPI | ✓ Achieved **all KPIs** within the range of assumed UC and prerequisites this time<br>✓ Confirmed **the usefulness of the system architecture** considered, albeit under specific applications and conditions | ✓ **Achieved all KPIs** within the range of assumed UC and prerequisites this time<br>✓ Confirmed **the usefulness of the system architecture** considered, albeit under specific applications and conditions |
| Knowledge obtained in this research and development | ✓ Confirm that **there is no large difference in the series of processing times between the roadside processing method and the center processing method.**<br>✓ **Acquire knowledge on measures against time shift and position shift** when integrating multiple sensor information.<br>✓ In addition, it is possible to provide highly accurate and seamless information to the vehicles to be supported without duplication, and **confirm the effects of shielding and improving position accuracy**. | ✓ The load on the medium area network is limited within the range of the assumed UC and prerequisites this time.<br>✓ On the other hand, **the increase in application processing time** due to the increase in the number of distributions and the amount of distribution data **is large, and it is necessary to consider the design for practical use**. |
| Recommendations based on this research and development (Details will be described in the implementation guidelines) | ✓ **Common collection I / F** in consideration of dealing with a wide variety of information sources<br>✓ **Controlling the distribution target** according to the position and route of the distribution destination vehicle | ✓ Integration of narrow area network into mid area network and **standardization of I / F** for distribution to vehicles<br>✓ **Control the distribution target** according to the traveling speed of the distribution destination vehicle, etc. |
| Future tasks | ✓ It is necessary to consider and verify **further support for UC on the roadside** and **expansion of sensing targets**.<br>✓ In addition, **demonstration experiments including cooperation with automated vehicles and dynamic maps are required**. | ✓ It is necessary to **examine and verify a comprehensive medium network that includes** not only the target information this time but **also other traffic environment information**.<br>✓ In addition, **a large-scale demonstration experiment in the field** (several tens of vehicles) is required. |

EOF