# Cross-Ministerial Strategic Innovation Promotion Program (SIP) — Phase 2 / Autonomous Driving (Expansion of Systems and Services) / A Study on V2X Communication for Achieving Use Cases of Cooperative Driving Automation: Evaluation of 700 MHz band ITS

2021 Report of Outcomes

March 2022

Kyocera Corporation

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# 1.1. Purpose of project

## Purpose of project

**The purpose of this project** is to clearly identify specific requirements for wireless communication technology and to **verify the technical feasibility** of using 700 MHz band ITS communication, an existing communications system, for the cooperative autonomous driving use case in which V2X is expected to be utilized, which was created by the Task Force on V2X Communication for Cooperative Driving Automation (hereinafter, “TF”) for studying cooperative autonomous driving communication systems.

## Project overview

a. **Evaluating applicability** of existing 700 MHz band ITS to narrowband communication requirements

b. As a result of the study in a., **extracting and summarizing technical issues** to meet communications requirements for narrow-area communications that are not supported

c. Based on the issues acquired in b., **formulating measures to deal with the issues (measures to improve existing communications methods, etc.)**

d. Reporting to TF and ITS Info-communications Forum (hereinafter, "ITS Forum") and supporting preparation of documents

## Correlation diagram

### TF, ITS Forum

- Cooperative autonomous driving use cases
- Communications requirements

Instructions

Reporting /Discussion

### The work of Kyocera

To implement the following for 700 MHz band ITS

a. Evaluating compatibility
b. Extraction and summary of technical issues
c. Planning future actions for issues
d. Documentation and reporting

### Kyocera research goals & deliverables

**Clearly identifying the technical feasibility** of 700 MHz band ITS for communications

Co-ordination

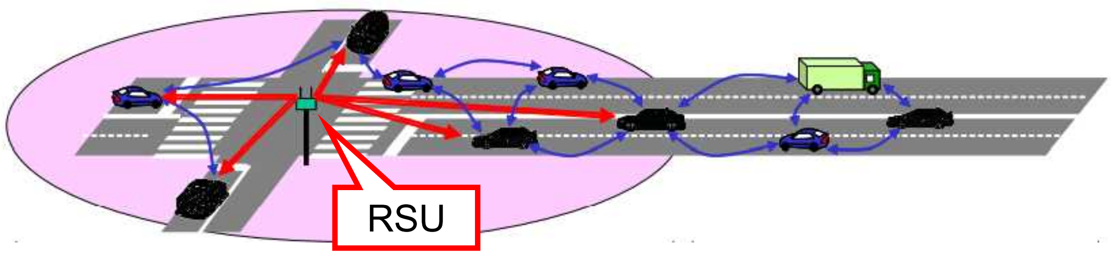
### Other research goals & deliverables

- Clearly identifying the technical feasibility of cellular communications
- Creating a roadmap for achieving cooperative autonomous driving use cases

# 1.3 Overview of 700 MHz band ITS

■ 700 MHz band safe driving support system

- Instituted in December 2011, this assists drivers in preventing accidents through inter-vehicle (V2V) communication and roadside-to-vehicle (R2V) communication using frequencies in the 700 MHz band (755.5 MHz to 764.5 MHz).
- The 700 MHz band is characterized by good reach of radio waves even when obstructed by buildings, vehicles, and other objects, and it is expected to see a variety of uses.
- There are two types of terminals: roadside units (RSU) and onboard units (OBU). RSU transmit within the transmission radio slot for RSU (TDMA) to ensure quality, while OBU transmit using CSMA/CA when RSU are not in use.

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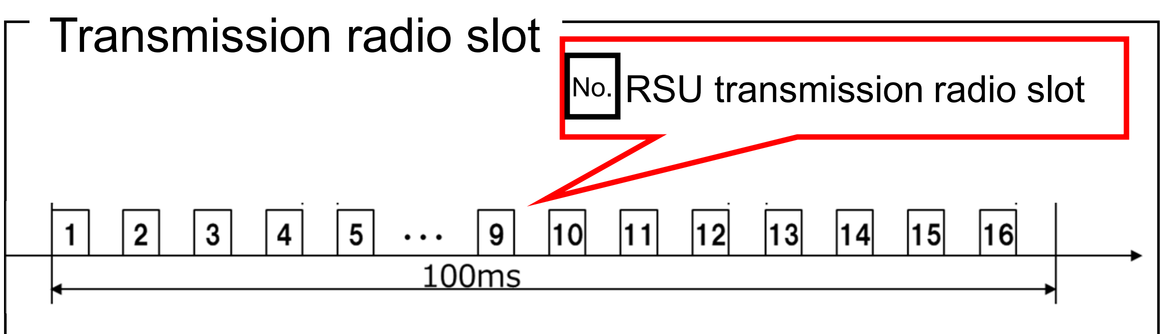


| Item | RSU | OBU |
|---|---|---|
| Frequency band | Over 755.5 MHz, but under 764.5 MHz | |
| Occupied bandwidth | 9 MHz or less | |
| Antenna power | 10 mW/MHz or less | |
| Modulation method | BPSK/OFDM, QPSK/OFDM, 16QAM/OFDM | |
| Error correction | Convolution FEC R = 1/2, 3/4 | |
| Communication method | Broadcast | |
| Transmission cycle | 100 ms | |
| Data transmission speed | 3, 4, 5, 6, 9, 12, 18 Mbit/s | |
| Access method | TDMA | CSMA/CA |
| Security method | Electronic signature | MAC method |
| Transmission time | Total transmission time for any 100 ms period is 10.5 ms or less | Total transmission time for any 100 ms period is 0.66 ms or less, and the length of the transmission burst is 0.33 ms or less |

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# 2. Targets of evaluation (target use cases, communications requirements)

Of 25 use cases (UCs), the 700 MHz band ITS will cover 20 use cases related to vehicle-to-infrastructure (V2I) and V2V. The communication requirements presented by the Radio System Technology TG (hereinafter, “TG”) for each use case are shown below.

| No. | Broad category | Middle category | Name of use case | Communication format | Communication requirements presented by TG (Distance , Delay , PAR) ※1 |
|---|---|---|---|---|---|
| 1 | Use cases in which information outside the detection range of on-board sensors must be obtained | a. Merging / lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | V2I | 95m, 100ms, 99% |
| 2 | | | a-1-2. Merging assistance by targeting the gap on the main lane | V2I | 116.7m, 100ms, 99% |
| 3 | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | V2I | 206.3m, 5m section, 99% |
| 4 | | | b-1-2. Driving assistance by using traffic signal information (V2N) | V2N | |
| 5 | | c. Lookahead information: collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops | V2V | 250m, 100ms, 99% |
| 6 | | | c-2-1. Driving assistance based on intersection information (V2V) | V2V | 190m, 100ms, 99% |
| 7 | | | c-2-2. Driving assistance based on intersection information (V2I) | V2I | 76.3m, 100ms, 99% |
| 8 | | | c-3. Collision avoidance assistance by using hazard information | V2V | 250m, 100ms, 99% |
| 9 | | d. Lookahead information: trajectory change | d-1. Driving assistance by notification of abnormal vehicles | V2I、V2N | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% |
| 10 | | | d-2. Driving assistance by notification of wrong-way vehicles | V2I、V2N | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% |
| 11 | | | d-3. Driving assistance based on traffic congestion information | V2I、V2N | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% |
| 12 | | | d-4. Traffic congestion assistance at branches and exits | V2I、V2N | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% |
| 13 | | | d-5. Driving assistance based on hazard information | V2I、V2N | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% |
| 14 | | e. Lookahead information: emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | V2V、V2N | 150m, 100ms, 99% |
| 15 | Use cases in which information of one’s own vehicle must be provided | f. Information collection / distribution by infrastructure | f-1. Request for rescue (e-Call) | V2N | |
| 16 | | | f-2. Collection of information to optimize the traffic flow | V2I、V2N | 33.3m, 1s, 99% |
| 17 | | | f-3. Update and automatic generation of maps | V2N | |
| 18 | | | f-4. Distribution of dynamic map information | V2N | |
| 19 | Use cases in which V2V and V2I interaction must be ensured | a. Merging / lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | V2I | Expressway, main route<br>120km/h, 266.7m, 100ms, 99%<br>20km/h, 44.4m, 100ms, 99%<br>Expressway, connecting route<br>70km/h, 116.7m, 100ms, 99%<br>20km/h, 33.3m, 100ms, 99% |
| 20 | | | a-1-4. Merging assistance based on negotiations between vehicles | V2V | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% |
| 21 | | | a-2. Lane change assistance when the traffic is heavy | V2V | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% |
| 22 | | | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | V2V | 60km/h, 111.1m, 100ms, 99%<br>7.2km/h, 3.4m, 100ms, 99% |
| 23 | | g. Platooning / adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | V2V | 60m, 100ms, 99% |
| 24 | | | g-2. Adaptive cruise control and manned platooning of following vehicles | V2V | 141m, 10m section, 95% |
| 25 | | h. Teleoperation | h-1. Operation and management of mobility service cars | V2N | |

※1： The communication requirements are tentative. Communication requirements will be presented in RC-017, which will be issued in “https://itsforum.gr.jp/Public/Eguideline/Top.html”.

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# 3.1 Desk study: Approach

The perspectives and judgment criteria for desk study are as follows.

3.1. Communication area : From the link budget viewpoint, whether the communication distance requirement can be achieved

3.2. Evaluation of transmission time constraints : From the data size viewpoint, whether the latency requirements can be achieved (transmission packet length)

3.3. Evaluation of RSU installation constraints: Both the existing services and SIP use cases (hereinafter, "SIP-UC") are formulated for the RSU slot (Slot allocation = Whether slot allocation is possible)

3.4. & 3.5. Message sets: Confirm the message format of the message sent by the RSU/OBU

| | Item for evaluation | Evaluation method | Judgment criteria |
|---|---|---|---|
| 3.2. | Communication area | Confirm communication quality at the borders of the communication area (assuming no interference) | Desirable wave reception power at the borders of the communication area<br>Reception power with a reception success rate of ≧99% |
| 3.2. | Evaluation of transmission time constraints (transmission packet length) | Confirm the wireless usage time required to convey the message | Wireless usage time required for message transmission ≤ Slot usage time in ARIB STD-T109 (RSU: 10.5 ms, OBU: 0.33 ms) |
| 3.3. | Evaluation of RSU installation constraints (slot allocation) | Confirm separation distance between RSU | DU ratio (*) at border of communication area ≧ Separation distance that is the DU ratio threshold |
| 3.4.<br>3.5. | Message sets | Organize messages by various UCs | OBU messages ≤ 100 bytes<br>(TD-001 maximum message size)<br>RSU message: No judgement criteria |


(*) Reception power ratio between desirable waves and undesirable waves (hereinafter, “DU ratio”)

## Communication area requirements were met in all UCs, while transmission time constraints were not met in the interaction UCs (excluding g-2).

| No. | Broad category | Middle category | Name of use case | Communication mode | Evaluation of communication area | | Evaluation of transmission time constraints | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Line margin[dB] | Compatibility | Transmission time[us] | Compatibility |
| 1 | Use cases in which information outside the detection range of on-board sensors must be obtained | a. Merging / lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | V2I | 5.4 | ✓ | 1,272 | ✓ |
| 2 | | | a-1-2. Merging assistance by targeting the gap on the main lane | V2I | 5.4 | ✓ | 2,320 | ✓ |
| 3 | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | V2I | 10.4 | ✓ | 960 | ✓ |
| 4 | | | b-1-2. Driving assistance by using traffic signal information (V2N) | V2N | | | | |
| 5 | | c. Lookahead information: collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | V2V | 3.3 | ✓ | 248 | ✓ |
| 6 | | | c-2-1. Driving assistance based on intersection information (V2V) | V2V | 6.0 | ✓ | 208 | ✓ |
| 7 | | | c-2-2. Driving assistance based on intersection information (V2I) | V2I | 24.4 | ✓ | 1,200 | ✓ |
| 8 | | | c-3. Collision avoidance assistance by using hazard information | V2V | 3.3 | ✓ | 248 | ✓ |
| 9 | | d. Lookahead information: trajectory change | d-1. Driving assistance by notification of abnormal vehicles | V2I、V2N | 25.5 | ✓ | 584 | ✓ |
| 10 | | | d-2. Driving assistance by notification of wrong-way vehicles | V2I、V2N | 25.5 | ✓ | 584 | ✓ |
| 11 | | | d-3. Driving assistance based on traffic congestion information | V2I、V2N | 25.5 | ✓ | 584 | ✓ |
| 12 | | | d-4. Traffic congestion assistance at branches and exits | V2I、V2N | 25.5 | ✓ | 584 | ✓ |
| 13 | | | d-5. Driving assistance based on hazard information | V2I、V2N | 25.5 | ✓ | 584 | ✓ |
| 14 | | e. Lookahead information: emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | V2V、V2N | 10.3 | ✓ | 216 | ✓ |
| 15 | Use cases in which information of one's own vehicle must be provided | f. Information collection / distribution by infrastructure | f-1. Request for rescue (e-Call) | V2N | | | | |
| 16 | | | f-2. Collection of information to optimize the traffic flow | V2I、V2N | 17.5 | ✓ | 200 | ✓ |
| 17 | | | f-3. Update and automatic generation of maps | V2N | | | | |
| 18 | | | f-4. Distribution of dynamic map information | V2N | | | | |
| 19 | Use cases in which V2V and V2I interaction must be ensured | a. Merging / lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | V2I | 6.4 | ✓ | 304*vehicles | - |
| 20 | | | a-1-4. Merging assistance based on negotiations between vehicles | V2V | 3.1 | ✓ | 216*vehicles | - |
| 21 | | | a-2. Lane change assistance when the traffic is heavy | V2V | 3.1 | ✓ | 216*vehicles | - |
| 22 | | | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | V2V | 3.0 | ✓ | 216*vehicles | - |
| 23 | | g. Platooning / adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | V2V | 25.4 | ✓ | 840(296x5) | - |
| 24 | | | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | V2V | 15.1 | ✓ | 296 | ✓ |
| 25 | | h. Teleoperation | h-1. Operation and management of mobility service cars | V2N | | | | |

- Line margin: Margin power up to the reception limit at the border of the communication area. If this is less than 0 dB, the requirement is not met
- Transmission time: Transmission time in ARIB STD-T109, calculated from data size. If the upper limit of the standard is exceeded, the requirement is not met



✓ : TG presented requirement is met, - : TG presented requirement is not met

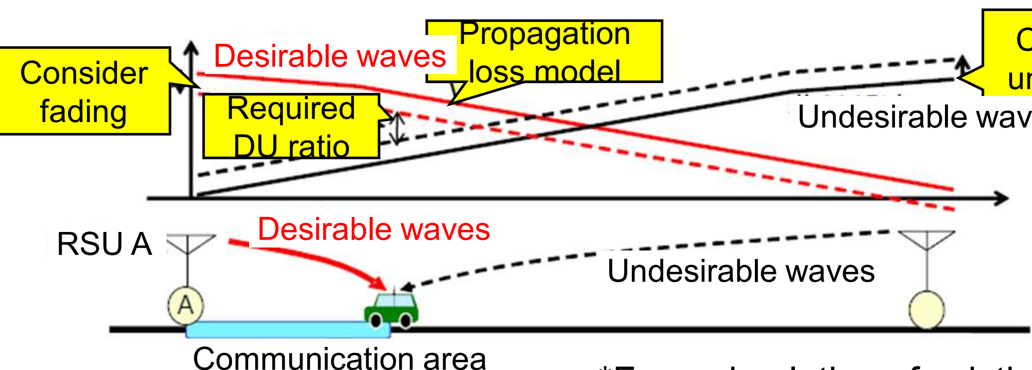
# 3.3. Evaluation of RSU installation constraints (slot allocation) (1/2)

■ Purpose
- Clarify the RSU installation conditions where SIP-UC (expressway) and existing services can coexist.
  (*) SIP-UC (general roads) are being considered to extend existing services.

■ An approach to RSU installation conditions that supports coexistence
- Separation distance must be ensured between RSU transmitting at the same slot timing (for at least the distance that satisfies the required DU ratio at the border of each service area)

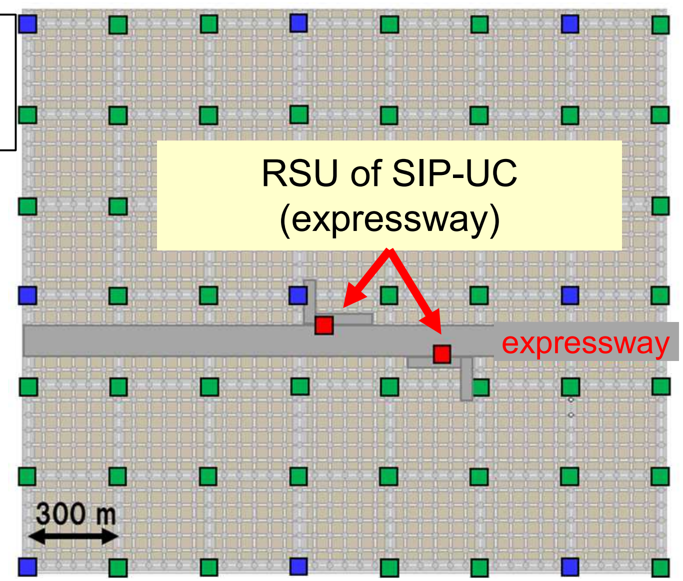
■ Conditions of review
- An expressway with a 300-meter plane layout was installed in an urban structure, with 2 slots for existing RSU at critical intersections and 1 slot at general intersections
- RSU of SIP-UC (expressway) require 2 slots per unit, using a total of 4 slots

< Separation distance between RSU in same slot >
- With line-of-sight (LOS): At least 1,185 meters
- Without LOS: 600 m with LOS + At least 300 m without LOS;
  or 300 m with LOS + At least 600 m without LOS




*From simulation of existing 2016 model

■: RSU at critical intersection
■: RSU at general intersection
■: RSU of SIP-UC (expressway)

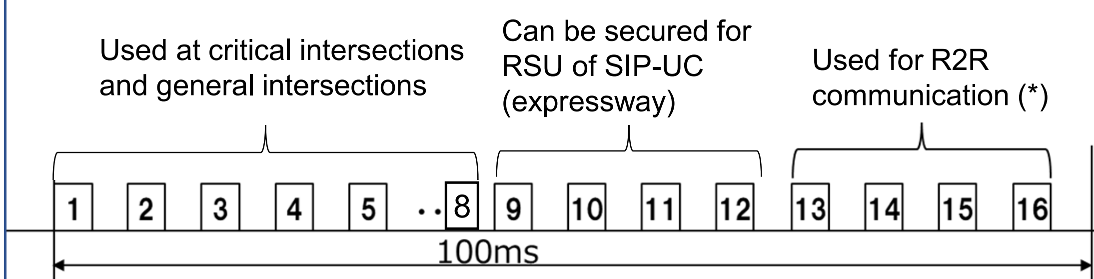



**SIP-UC review model**

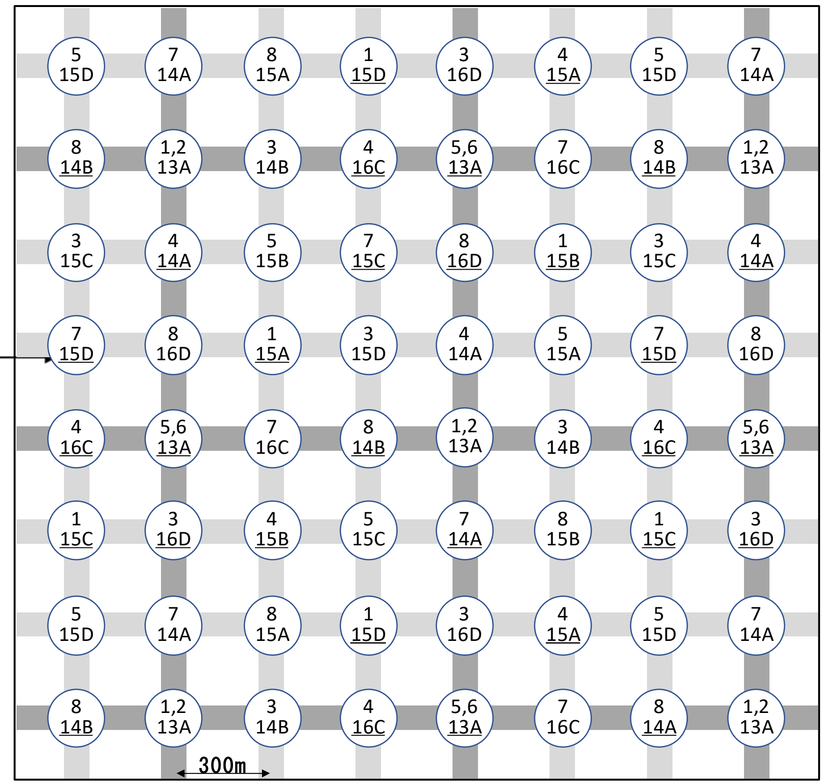
# 3.3. Evaluation of RSU installation constraints (slot allocation) (2/2)

- Since 4 slots need to be secured for 2 RSU of SIP-UC (expressway), we will consider whether it is possible to allocate 8 slots for critical intersections and general intersections.
- An example of slot allocation will be discussed, using slots 1–8 for critical intersections and general intersections and slots 9–12 for RSU of SIP-UC (expressway).

## Slot allocation example




(*) Since the time slot numbers for inter-roadside (R2R) communication must be larger than the time slot numbers for R2V communication,
the slots for R2R communication are fixed at 13–16




**Since existing services (critical intersections and general intersections) can be assigned in 8 slots, 4 slots can be secured for RSU of SIP-UC (expressway)**

# 3.4. Message sets (OBU transmissions) (1/3)

## ■ Confirm feasibility of TD-001 for SIP-UC OBU transmission message set

Examine whether messages sent by the OBU (excluding a-1-3, a-1-4, a-2, a-3) can be achieved within 100 bytes, which is the maximum size for each message using ITS Connect TD-001 Message sets that integrate messages will be likewise examined.

- Method of examining message sets sent by OBU

SIP-UC (Example: c-3 ※1)

| Information element | | Explanation | Size |
|---|---|---|---|
| Management information | Message ID | Message type identifier | 16 bit |
| Vehicle information | OBU ID | Transmission source vehicle identifier | 32 bit |
| | Information update time | Time when the information was updated | 32 bit |
| | Vehicle location | Latitude/longitude/altitude information for own vehicle | 88 bit |
| | Vehicle speed | Moving speed of own vehicle | 16 bit |
| | Vehicle acceleration/deceleration information | Acceleration/deceleration information for own vehicle | 16 bit |
| | Vehicle length | Length information for own vehicle | 16 bit |
| Event information | Time of occurrence of emergency action | Time when sudden deceleration/emergency lane change was performed | 32 bit |
| | Type of emergency action | Type of emergency action | 8 bit |
| | Target object information | Vehicle speed, vehicle type | 24 bit |
| | Event location information | Latitude/longitude/altitude information for event occurrence | 88 bit |
| | Event distance information | Distance to event occurrence point | 16 bit |
| | Lane information | Lane information for event occurrence point | 8 bit |
| | Road type information | Road type at event occurrence point | 8 bit |
| | Traffic passability information | Information on traffic passability at event occurrence point | 8 bit |
| | Transmission source OBU ID | Target vehicle ID for event occurrence | 32 bit |
| | Target lane information for distribution | Target lane for relay destination | 8 bit |
| | Valid time of information | Time considered valid when relaying a message | 32 bit |
| | Redelivery distance | Range considered valid when relaying a message | 16 bit |
| Total | | | 62 bytes |

※1 : Message sets are tentative.

ITS Connect TD-001

**Table 4-1 Configuration of Basic Message**

| Field | Data structure | DF | Size (bytes) | | Remarks |
|---|---|---|---|---|---|
| Common field | Common application header field | DF_CommonFieldManagementInformation | 8 | | Mandatory |
| | Common application data field | DF_TimeInformation | 4 | 28 | Mandatory. If no proper value is available, set the "unavailable" value. |
| | | DF_PositionInformation | 11 | | |
| | | DF_VehicleStatusInformation | 9 | | |
| | | DF_VehicleAttributeInformation | 4 | | |
| | | DF_PositionOptional Information (*) | 2 | 0 to 26 | Optional. Setting sequence may not be changed. |
| | | DF_GNSSStatusOptional Information (*) | 4 | | |
| | | DF_PositionAcquisitionOptional Information (*) | 2 | | |
| | | DF_VehicleStatusOptional Information (*) | 7 | | |
| | | DF_IntersectionInformation (*) | 10 | | |
| | | DF_ExtendedInformation (*) | 1 | | |
| Free field | Free application header field | DF_FreeFieldManagement Information | 0 to 1 | 0 to 22 | Optional. Size depends on number of individual application data set. |
| | | DF_IndividualAppData ManagementInformationSet | 0 to 21 | | |
| | Free application data field | (Not specified) | 0 to 60 | | Optional. Setting sequence as specified by DF_IndividualAppDataManagementInformationSet. |
| | | | Total 36 to 100 | | (*): Optional information |

Classify into those that fall under the common field and those that do not fall under the common field (those assigned to the free field).

# 3.4. Message sets (OBU transmissions) (2/3)

■ Results of examining feasibility of message sets sent by OBU (individual study)

- Feasible for all SIP-UC
  (However, UCs that require 16 bytes or more in the free field will have restrictions on the use of the free field.)

- SIP-UC individual message sets

| No. | SIP-UC | Common field | Free field | Total |
|---|---|---|---|---|
| c-2-1 | Intersection information | 36 bytes | 2 bytes | 38 bytes |
| c-3 / c-1 | Collision avoidance assistance by using hazard information / Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 36 bytes | 37 bytes | 73 bytes |
| d-1 to d-5 | Notification of abnormal vehicles / wrong-way vehicles / traffic congestion information, etc. | 36 bytes | 24 bytes | 60 bytes |
| e-1 | Emergency vehicle information | 36 bytes | 36 bytes | 72 bytes |
| g-1 | Electronic towbar | 36 bytes | 7 bytes | 43 bytes |
| g-2 | Adaptive cruise control | 36 bytes | 7 bytes | 43 bytes |
| f-2 | Optimize the traffic flow | 36 bytes | 4 bytes | 39 bytes |

# 3.4. Message sets (OBU transmissions) (3/3)

■ Results of examining feasibility of message sets sent by OBU (integrated study)

- Feasible in all integrated cases
  (However, UCs that require 16 bytes or more in the free field will have restrictions on the use of the free field.)

- SIP-UC integrated message sets

| No. | SIP-UC (general roads) | Common field | Free field | Total |
|---|---|---|---|---|
| 1 | Total of c-2-1, c-3 / c-1, d-1 to d-5, e-1 | 36 bytes | 40 bytes | 76 bytes |
| 2 | Total of c-2-1, c-3 / c-1, d-1 to d-5, e-1, f-2 | 36 bytes | 42 bytes | 78 bytes |
| 3 | Total of g-1, g-2, f-2 | 36 bytes | 11 bytes | 47 bytes |
| 4 | Total of all UCs (other than interaction messages) | 36 bytes | 50 bytes | 86 bytes |

# 3.5. Message sets (RSU transmissions) (1/3)

■ Messages were organized by each message set transmitted by SIP-UC (expressway) RSU.

- Expressway-related message set: Expressway UC (a-1-1, a-1-2, a-1-3, d-1 to d-5)

- Method of examining message sets sent by RSU (※1)

d-5 message composition

a-1-2 message composition

a-1-1 message composition

| Information element | | Data size |
|---|---|---|
| Common information | Message ID | 16 bit |
| | Increment ID<br>Or information update time | 32 bit |
| | Roadside control information | 8 bit |
| | RSU ID | 32 bit |
| | Confluence starting point information | 16 bit |
| | Road number | 32 bit |
| | Number of traveling vehicles | 8 bit |
| Location information (varies depending on the number of traveling vehicles) | Vehicle ID | 16 bit |
| | Vehicle location (latitude, longitude, altitude) | — |
| | Driving lane | 8 bit |
| | Driving speed | 16 bit |
| | Vehicle length | 14 bit (+ empty 2 bit) |
| | Estimated arrival time at confluence point | 32 bit |
| | Sensor information acquisition time | 32 bit |
| | Information reliability | 8 bit |

Organize into a single table, and check the message sizes of individual version and integrated version

| Information element | Every SIP-UC |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

※1 : Message sets are tentative.

# 3.5. Message sets (RSU transmissions) (2/3)

- Individual data size and integrated data size of outgoing messages sent from RSU of SIP-UC (expressway)

- The table below shows the results of organizing message sets

- SIP-UC individual message sets

| No. | SIP-UC (expressway) | Maximum size | Remarks |
|---|---|---|---|
| a-1-1 | Preliminary acceleration/deceleration merging support | 754 bytes | Location information is for a maximum of 46 vehicles |
| a-1-2 | Main route gap aiming merging support | 2,502 bytes | Location information is for a maximum of 92 vehicles |
| a-1-3 | Main route vehicle cooperative merging support by roadside control | 4,986 bytes | Location information is for a maximum of 184 vehicles |
| d-1 to d-5 | Notification of information on vehicle error, reversing vehicles, traffic jams, etc. | 445 bytes | Hazard information is for up to 20 hazards |

- SIP-UC integrated message sets

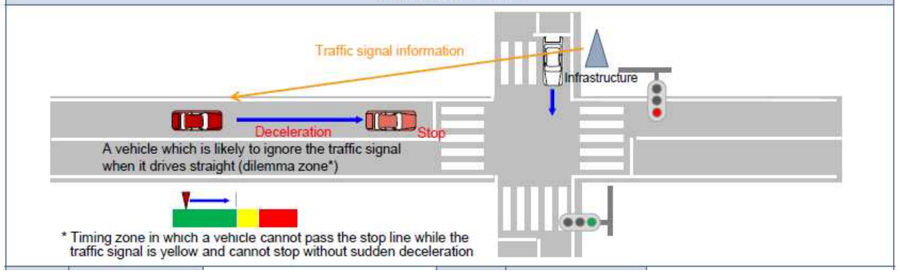
| No. | SIP-UC (expressway) | Maximum size | Remarks |
|---|---|---|---|
| 1 | a-1-3 (a-1-1, a-1-2) integrated<br>Main route vehicle cooperative merging support by roadside control | 4,986 bytes | Location information is for a maximum of 184 vehicles |
| 2 | d-1 to d-5 integrated<br>Notification of information on vehicle error, reversing vehicles, traffic jams, etc. | 445 bytes | Hazard information is for up to 20 hazards |
| 3 | All message sets integrated | 5,426 bytes | Location information is for a maximum of 184 vehicles<br>Hazard information is for up to 20 hazards |

# 3.5. Message sets (RSU transmissions) (3/3)

■ Results of examining message sets transmitted by SIP-UC (general road) RSU

- b-1-1 (Driving assistance by using traffic signal information (V2I)): Available by partially expanding the 700 MHz band ITS R2V communication service

| | | | |
|---|---|---|---|
| Classification by function | b. Traffic signal information | | |
| Name of the use case | b-1-1. Driving assistance by using traffic signal information (V2I) | | |
| Target areas | General roads + Expressways | Target vehicles | Privately owned vehicles |
| Overview | Current traffic signal color and traffic signal phase and timing information (the next traffic signal color and the time until change), etc. at intersections are provided by the roadside infrastructure to vehicles that enter intersections to assist deceleration and stopping, and thereby avoid a dilemma. | | |
| Image of the use case | | | |




**2.4.1.6 Communication content （※1）**

The message content is based on the signal information of the "ITS wireless RSU DSSS R2V communication application standard" according to [1], with generation time and the number of seconds remaining from generation time added. This assumes that V2I message size can be transmitted at an assumed rate of about 1 Kbyte/intersection.

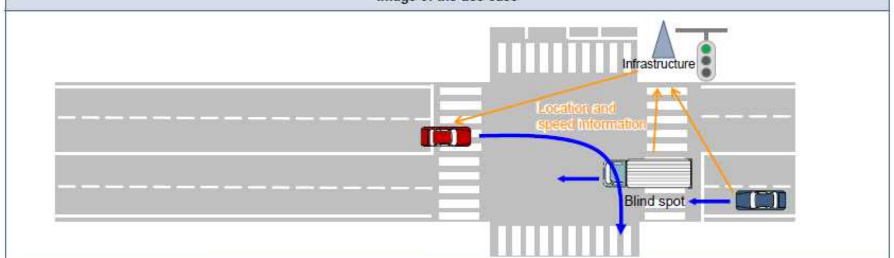
Reference materials

[1] *Report on Research and Development for the Provision of Signal Information by Methods Other Than R2V Communications, including ITS Wireless Roadside Devices, 2019 Research and Development*
https://www.sip-adus.go.jp/rd/rddata/rd03/205.pdf

※1：Communication content is tentative.

- c-2-2 (Driving assistance based on intersection information (V2I)): Since 700 MHz band ITS R2V communication service is included, it can be supported.

| | | | |
|---|---|---|---|
| Classification by function | c. Lookahead information: collision avoidance | | |
| Name of the use case | c-2-2. Driving assistance based on intersection information (V2I) | | |
| Target areas | General roads | Target vehicles | Privately owned vehicles |
| Overview | Location and speed information of vehicles that approach intersections, which is obtained from roadside sensors or vehicles, is provided by the infrastructure to other vehicles that approach or pass through intersections to assist them to pass through or make a right turn at intersections with many blind spots. | | |
| Image of the use case | | | |

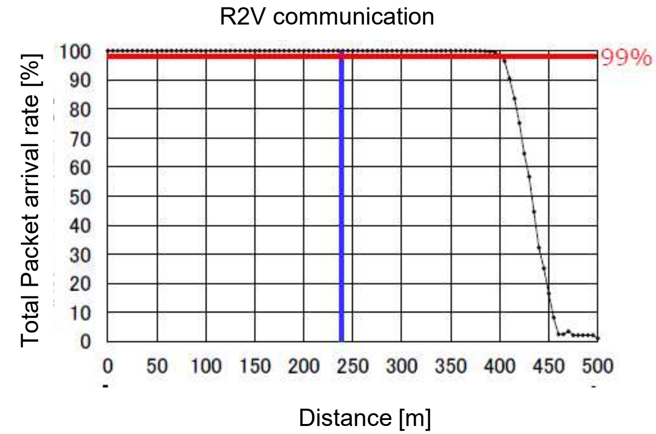


# Contents

# 4.1. Simulation-based evaluation method (evaluation items)

## ■ Packet arrival rate (PAR)

- The packet arrival rate is defined as the ratio of packets transmitted by the application versus the packets successfully received. In addition, transmission failure due to CSMA is regarded as a reception failure.
- With the evaluation vehicles placed at regular intervals, packet arrival rate measurements are performed at each location to obtain the packet arrival rate for each distance.
- Based on the results, it is evaluated whether the required communication distance for each service is satisfied.



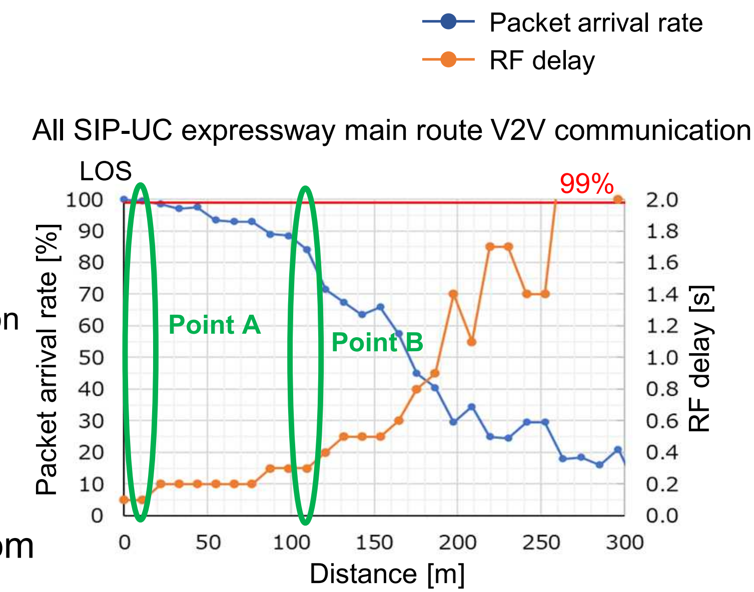

Graph image

## ■ RF delay (or other delay)

- **RF delay is defined as the time required to reach the desired packet arrival rate (PAR 99%).**
- This value represents the maximum delay amount during 100 ms cycle transmission, and indicates that at least one packet is able to be received within this RF delay.
- Evaluate whether the wireless communication time is within the allowable delay of the radio communication requirement.

$$\text{RF delay} = \ln(1-DPx) / \ln(1-Px) \times 100\ \text{ms}$$

DPx: Desired packet arrival rate
Px: Packet arrival rate per transmission



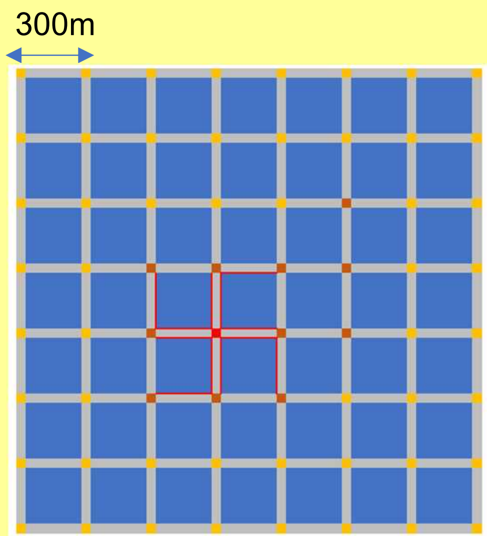

Example) Calculated as follows in the graph on the right.

- Point A: Since the desired packet arrival rate of 99% is achieved in one transmission, the RF delay is 100 ms.
- Point B: The packet arrival rate at one time is about 85%, and in order to achieve a packet arrival rate of 99%, the RF delay is 300 ms, calculated from the formula above.

## ■ Regarding Simulation-based evaluation

- With reference to pattern number 9 (300 m plane layout) of the existing 2016 model simulation (*1), a model was constructed including an expressway (SIP-UC study model).
- SIP-UC and existing services OBU and RSU are installed.
- In the SIP-UC study model, the packet arrival rate and RF delay are evaluated with the SIP-UC and existing services in close proximity, and the compatibility of SIP-UC and coexistence with existing services were confirmed.

### Existing 2016 model simulation pattern No. 9




Existing 2016 model simulation model installation conditions (commonly known as Ginza model)
("✓" means existed, and "-" means not existed.)

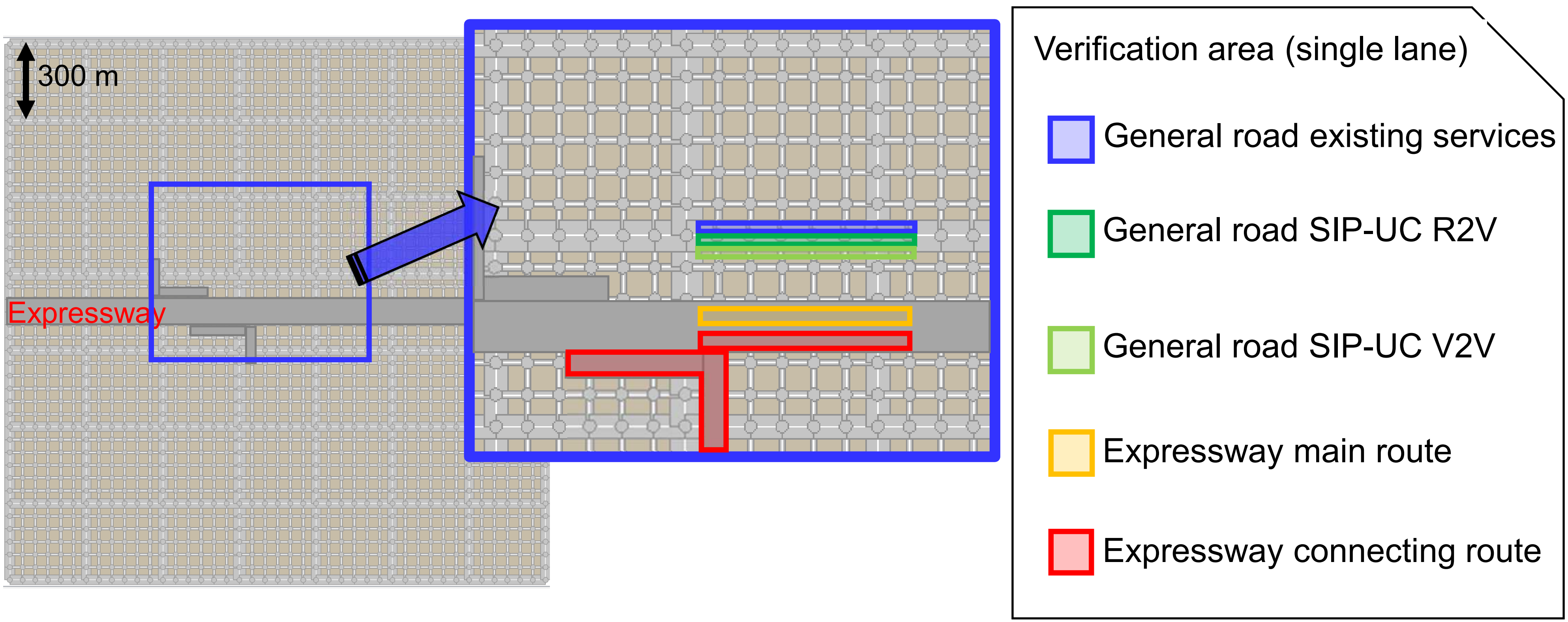
| Pattern number | RSU placement | R2V | R2V and R2R | | R2R | Vehicle density | Number of wireless slots | | Evaluation contents | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Emergency vehicle | Approaching signal | | | R2V | R2R | Communication success rate | Delay time |
| **1** | **300 m interval cross** | ✓ | ✓ | - | ✓ | **43 vehicles/km** | **8** | **2** | V2V, R2V, R2R | R2R |
| 2 | 300 m interval cross (difference in vehicle density) | ✓ | ✓ | - | ✓ | 23 vehicles/km | 8 | 2 | V2V, R2V, R2R | R2R |
| 3 | 300 m interval cross (R2V only) | ✓ | ✓ | - | - | 43 vehicles/km | 8 | | V2V, R2V | |
| 4 | 200 m interval cross | ✓ | ✓ | - | ✓ | 43 vehicles/km | 10 | 2 | V2V, R2V, R2R | R2R |
| 5 | Broadcast once every 200 m interval | ✓ | ✓ | - | ✓ | 43 vehicles/km | 12 | 3 | V2V, R2V, R2R | R2R |
| 6 | Broadcast once every 200 m interval (with proximity signal information) | ✓ | ✓ | ✓ | ✓ | 43 vehicles/km | 12 | 3 | V2V, R2V, R2R | R2R |
| 7 | Broadcast once every 200 m interval (General intersection R is R2R only) | - (Partially) | ✓ | - | ✓ | 43 vehicles/km | 12 | 3 | V2V, R2V, R2R | R2R |
| 8 | Broadcast twice every 200 m interval | ✓ | ✓ | - | ✓ | 43 vehicles/km | 12 | 4 | V2V, R2V, R2R | R2R |
| 9 | 300 m interval plane layout | ✓ | ✓ | - | ✓ | 43 vehicles/km | 9 | 4 | V2V, R2V, R2R | R2R |

(*1) The existing 2016 model simulation described in this document refers to the following materials.
Report of the Land Radio Communications Committee, Information and Communication Technology Subcommittee, Ministry of Internal Affairs and Communications / Consultation No. 2029, dated July 28, 2009: "Technical Conditions for Advanced 700 MHz Band Intelligent Transport Systems, " in "Technical Conditions for ITS Radio Systems"
https://www.soumu.go.jp/main_content/000477035.pdf

# 4.1. Simulation-based evaluation method (evaluation area)

## ■ Simulation-based evaluation area and vehicle density of OBU

- Assuming actual operations, vehicle density is set to reflect possible stringent conditions.
- On expressways, assuming low-speed driving, density was set at 95 vehicles/km from 20 km/h at 1-second vehicle intervals
- For SIP general roads, R2V communication was set at 36 vehicles /km, and V2V communication was set at 143 vehicles /km
- For general roads, the conditions of 43 vehicles /km for the existing 2016 model simulation were applied.
- Perform with the vehicle density outlined above, and examine with additional conditions depending on the results.



# 4.1. Simulation-based evaluation method (simulation conditions)

## ■ Simulation conditions

- Message size

Of the message sets considered, the largest set was adopted for the simulation

| | | RSU | OBU |
|---|---|---|---|
| SIP-UC | Expressway | 4986 bytes | 73 bytes |
| | General road | 1150 bytes | |
| Existing UC | Critical intersection | 2750 bytes | |
| | General intersection | 1150 bytes | |

- Vehicle density

| Maximum density conditions | SIP-UC | | | Existing use case |
|---|---|---|---|---|
| | Expressway main route | Expressway connecting route | General road | |
| for low-speed driving | 95 vehicles/km (20 km/h) | 95 vehicles/km (20 km/h) | 143 vehicles/km (10 km/h) | 43 vehicles/km (25 km/h) |
| for regulated speed | 17 vehicles/km (120 km/h) | 23 vehicles/km (70 km/h) | 23 vehicles/km (70 km/h) | 23 vehicles/km (70 km/h) |

- Communication requirements / propagation model

| | RSU | OBU |
|---|---|---|
| Frequency | 760 MHz | |
| Transmission power | 19.2 dBm | |
| Modulation method | 16QAM1/2 | QPSK1/2 |
| Transmission cycle | 100 ms | 100 ms |
| Antenna height | Road height + 6 m | Road height + 1.5 m |
| Antenna gain | 0 dBi | 0 dBi |
| Power loss | 0 dB | 3 dB |
| Reception judgment threshold | -75.9 dBm (16QAM1/2), -81 dBm (QPSK1/2) | |
| Required DU ratio | 14 dB (16QAM1/2), 9 dB (QPSK1/2) | |
| Carrier sense level | — | -85 dBm |
| CW size | — | 63 |
| Propagation loss model | 700 MHz ITS R2V and R2R model | Ito / Taga model |
| | General road → Expressway: Ito / Taga model<br>Expressway → General road: ITU-R P.1411 | |
| Fading | R2V: 4.4 dB | V2V: 6.4 dB |
| Vehicle shielding loss | — | 0.5 dB / vehicles (maximum 8 dB) |
| Shielding loss by expressway anti-noise barrier | 10 dB | |

Ordinary vehicles only (does not include large vehicles)
Security overhead uses 700 MHz band ITS

# 4.2. Simulation results to confirm simultaneous coexistence for all SIP-UC

**All R2V communication achieved the communication requirements. In some R2V communication UCs (d1 to d4, f-2), the communication requirements were achieved, while other R2V communication (a-1-3) and V2V communication did not achieve the communication requirements presented by TG.**

| # | Broad category | Middle category | Name of use case | TG Communication requirement (Distance , Delay , PAR) | Compatibility with 700 MHz ITS (*2) | RF delay satisfied the PAR and TG communication distance requirement (Distance , Delay) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Maximum density condition for regulated speed | Maximum density condition when moving at low speed |
| 1 | Use cases in which information outside the detection range of on-board sensors must be obtained | a. Merging / lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | 95m, 100ms, 99% | ✓ | See right column | I→V 95m, 100ms(*1) |
| 2 | | | a-1-2. Merging assistance by targeting the gap on the main lane | 116.7m, 100ms, 99% | ✓ | See right column | I→V 116.7m, 100ms(*1) |
| 3 | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | 206.3m, 5m section, 99% | ✓ | See right column | I→V 206.3m, 100ms(*1) |
| 4 | | | b-1-2. Driving assistance by using traffic signal information (V2N) | | | | |
| 5 | | c. Lookahead information: collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops | 250m, 100ms, 99% | - | V→V 250m, 1.5s | V→V 250m, 15.2s |
| 6 | | | c-2-1. Driving assistance based on intersection information (V2V) | 190m, 100ms, 99% | - | V→V 190m, 1.9s | V→V 190m, 10.1s |
| 7 | | | c-2-2. Driving assistance based on intersection information (V2I) | 76.3m, 100ms, 99% | ✓ | See right column | I→V 76.3m, 100ms(*1) |
| 8 | | | c-3. Collision avoidance assistance by using hazard information | 250m, 100ms, 99% | - | V→V 250m, 1.5s | V→V 250m, 15.2s |
| 9 | | d. Lookahead information: trajectory change | d-1. Driving assistance by notification of abnormal vehicles | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% | ✓ | V→I 66.6m, 200ms<br>I→V See right column | V→I 11.1m, 900ms<br>I→V 66.6m, 100ms(*1) |
| 10 | | | d-2. Driving assistance by notification of wrong-way vehicles | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% | ✓ | V→I 66.6m, 200ms<br>I→V See right column | V→I 11.1m, 900ms<br>I→V 66.6m, 100ms(*1) |
| 11 | | | d-3. Driving assistance based on traffic congestion information | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% | ✓ | V→I 66.6m, 200ms<br>I→V See right column | V→I 11.1m, 900ms<br>I→V 66.6m, 100ms(*1) |
| 12 | | | d-4. Traffic congestion assistance at branches and exits | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% | ✓ | V→I 66.6m, 200ms<br>I→V See right column | V→I 11.1m, 900ms<br>I→V 66.6m, 100ms(*1) |
| 13 | | | d-5. Driving assistance based on hazard information | 120km/h, 66.6m, 1s, 99%<br>20km/h, 11.1m, 1s, 99% | ✓ | See right column | I→V 66.6m, 100ms(*1) |
| 14 | | e. Lookahead information: emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 150m, 100ms, 99% | - | V→V 150m, 800ms | V→V 150 m/5.2 s |
| 15 | Use cases in which information of one's own vehicle must be provided | f. Information collection / distribution by infrastructure | f-1. Request for rescue (e-Call) | | | | |
| 16 | | | f-2. Collection of information to optimize the traffic flow | 33.3m, 1s, 99% | ✓ | V→I 33.3m, 200ms | V→I 33.3m, 900ms |
| 17 | | | f-3. Update and automatic generation of maps | | | | |
| 18 | | | f-4. Distribution of dynamic map information | | | | |
| 19 | Use cases in which V2V and V2I interaction must be ensured | a. Merging / lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Expressway, main route<br>120km/h, 266.7m, 100ms, 99%<br>20km/h, 44.4m, 100ms, 99%<br>Expressway, connecting route<br>70km/h, 116.7m, 100ms, 99%<br>20km/h, 33.3m, 100ms, 99% | - | Expressway, main route<br>V→I 266.7m, 800ms<br>I→V See right column<br>Expressway, connecting route<br>V→I 116.7m, 900ms<br>I→V See right column | Expressway, main route<br>V→I 44.4m, 900ms<br>I→V 266.7m, 100ms(*1)<br>Expressway, connecting route<br>V→I 33.3m, 900ms<br>I→V 116.7m, 100ms(*1) |
| 20 | | | a-1-4. Merging assistance based on negotiations between vehicles | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% | - | V→V 255m, 1.4s | V→V 66.1m, 600ms |
| 21 | | | a-2. Lane change assistance when the traffic is heavy | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% | - | V→V 255m, 1.4s | V→V 66.1m, 600ms |
| 22 | | | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | 60km/h, 111.1m, 100ms, 99%<br>7.2km/h, 3.4m, 100ms, 99% | - | V→V 111.1m, 1.0s | V→V 3.4m, 700ms |
| 23 | | g. Platooning / adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | 60m, 100ms, 99% | - | V→V 60m, 200ms | Outside scope of consideration |
| 24 | | | g-2. Adaptive cruise control and manned platooning of following vehicles | 141m, 10m section, 95% | - | V→V 141m, 700ms | Outside scope of consideration |
| 25 | | h. Teleoperation | h-1. Operation and management of mobility service cars | | | | |

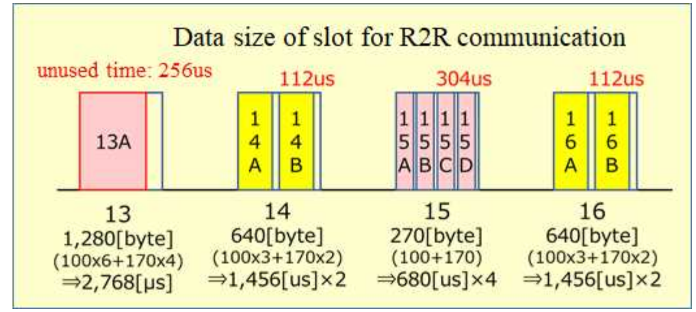
Security overhead is the size specified by the 700 MHz ITS Security Committee

(*1) Satisfies the communication requirements for maximum density conditions when moving at low speed under maximum density conditions at the regulated speed.
(*2) "✓" means supported, and "-" means not supported.

# 4.3. Simulation with condition changes (list of conditions)

## ■ Purpose

Although the communication requirements presented by TG represent the most stringent conditions, since it is unlikely that these conditions are common to all UCs, the following additional simulations were conducted as a study of practical applications.




## ■ List of conditions

- **Condition 1: Reference**

  4.2. Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at regulated speeds)

- **Condition 2: Change of reception sensitivity**
  - Purpose: To evaluate with reception sensitivity at the level achieved in the market
  - Changes: QPSK1/2: Changed from -82 dBm to -90 dBm, 16QAM1/2: Changed from -77 dBm to -85 dBm
  - Expected effect: Expansion of communication area

- **Condition 3: Change of reception sensitivity + use of OBU for R2R communication slot**
  - Purpose: To evaluate in line with the current situation in which R2R communication is not implemented
  - Changes: All 4 slots allocated for R2R communication (see the figure on the right) are opened for R2V and V2V communication
  - Expected effect: Improvement of communication quality by lowering the probability of conflicts in OBU transmission timing

- **Condition 4: Change of reception sensitivity + Use of OBU for R2R communication slot + Review of vehicle density**
  - Purpose: To evaluate assuming an environment with average vehicle density
  - Changes: Changed the density of surrounding vehicles to match the density of key cities (From approximately 2000 to 1000 interfering units)
  - Expected effect: Improvement of communication quality by lowering the probability of conflicts in OBU transmission timing

# 4.3. Simulation with condition changes (summary of results)

By changing the conditions, delay was improved by 0.1 second to 1.4 seconds. UC g-2 achieved the communication requirements presented by TG. Other UCs did not achieve the communication requirements presented by TG.

| No. | Broad category | Middle category | Name of use case | TG communication requirements (Distance , Delay , PAR) | Compatibility with 700 MHz ITS (*1) | RF delay satisfied the PAR and TG communication distance requirement (Distance , Delay)<br>(*) Maximum vehicle density conditions at regulated speeds<br>Before change of conditions (Condition 1) | After change of conditions (Condition 4) |
|---|---|---|---|---|---|---|---|
| 1 | Use cases in which information outside the detection range of on-board sensors must be obtained | a. Merging / lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | | | | |
| 2 | | | a-1-2. Merging assistance by targeting the gap on the main lane | | | | |
| 3 | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | | | | |
| 4 | | | b-1-2. Driving assistance by using traffic signal information (V2N) | | | | |
| 5 | | c. Lookahead information: collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 250m, 100ms, 99% | - | 250m, 1.5s<br>distance per 1.5s: 29.2m | 250m, 600ms<br>distance per 600ms: 11.7m |
| 6 | | | c-2-1. Driving assistance based on intersection information (V2V) | 190m, 100ms, 99% | - | 190m, 1.9s<br>distance per 1.9s: 36.9m | 190m, 400ms<br>distance per 400ms: 7.8m |
| 7 | | | c-2-2. Driving assistance based on intersection information (V2I) | | | | |
| 8 | | | c-3. Collision avoidance assistance by using hazard information | 250m, 100ms, 99% | - | 250m, 1.5s<br>distance per 1.5s: 29.2m | 250m, 600ms<br>distance per 600ms: 11.7m |
| 9 | | d. Lookahead information: trajectory change | d-1. Driving assistance by notification of abnormal vehicles | | | | |
| 10 | | | d-2. Driving assistance by notification of wrong-way vehicles | | | | |
| 11 | | | d-3. Driving assistance based on traffic congestion information | | | | |
| 12 | | | d-4. Traffic congestion assistance at branches and exits | | | | |
| 13 | | | d-5. Driving assistance based on hazard information | | | | |
| 14 | | e. Lookahead information: emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 150m, 100ms, 99% | - | 150m, 500ms<br>distance per 500ms: 9.7m | 150m, 200ms<br>distance per 200ms: 3.9m |
| 15 | Use cases in which information of one's own vehicle must be provided | f. Information collection / distribution by infrastructure | f-1. Request for rescue (e-Call) | | | | |
| 16 | | | f-2. Collection of information to optimize the traffic flow | | | | |
| 17 | | | f-3. Update and automatic generation of maps | | | | |
| 18 | | | f-4. Distribution of dynamic map information | | | | |
| 19 | Use cases in which V2V and V2I interaction must be ensured | a. Merging / lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Expressway, main route<br>120km/h, 266.7m, 100ms, 99%<br>20km/h, 44.4m, 100ms, 99%<br>Expressway, connecting route<br>70km/h, 116.7m, 100ms, 99%<br>20km/h, 33.3m, 100ms, 99% | - | main route 120km/h<br>266.7m, 800ms<br>distance per 800ms: 26.7m<br>connecting route 70km/h<br>116.7m, 900ms<br>distance per 900ms: 17.5m | main route 120km/h<br>266.7m, 400ms<br>distance per 400ms: 13.3m<br>connecting route 70km/h<br>116.7m, 500ms<br>distance per 500ms: 9.7m |
| 20 | | | a-1-4. Merging assistance based on negotiations between vehicles | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% | - | 255m, 1.4s<br>distance per 1.4s: 27.2m | 255m, 600ms<br>distance per 600ms: 11.7m |
| 21 | | | a-2. Lane change assistance when the traffic is heavy | 120km/h, 255m, 100ms, 99%<br>20km/h, 66.1m, 100ms, 99% | - | 255 m, 1.4s<br>distance per 1.4s: 27.2m | 255m, 600ms<br>distance per 600ms: 11.7m |
| 22 | | | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | 60km/h, 111.1m, 100ms, 99%<br>7.2km/h, 3.4 m, 100ms, 99% | - | 111.1m, 1.0s<br>distance per 1.0s: 19.4m | 111.1m, 500ms<br>distance per 500ms: 9.7m |
| 23 | | g. Platooning / adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | normal: 60m, 100ms, 99%<br>emergency: 60m, 20ms, 99% | - | 60m, 200ms<br>distance per 200ms: 3.89m | 60m, 100ms<br>distance per 100ms: 1.9m |
| 24 | | | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | 141m, 10m section, 95 %<br>* 10m section = 500ms, @70km/h | ✓ | 141m, 700ms<br>distance per 700ms: 13.6m | 141m, 300ms<br>distance per 300ms: 5.8m |
| 25 | | h. Teleoperation | h-1. Operation and management of mobility service cars | | | | |

Improvements

(*1) "✓" means supported, and "-" means not supported.

# Contents

# 5.1. Summary of results

## ■ Summary of results

### ○ Results of desk study

For 20 UCs out of 25 UCs designated by SIP, the communication area, transmission time constraints, RSU installation constraints, and message sets were evaluated based on the communication requirements presented by TG.

- Some of the UCs that required interaction (a-1-3, a-1-4, a-2, a-3) did not meet the communication requirement for number of vehicles.
- A transmission cycle for emergencies in UC g-1 is specified as 20 ms, but since the T109 standard used in this evaluation specifies a communication cycle of 100 ms, the transmission requirement was not met.
- As a result of examining wireless slot allocation for RSU, it became possible to allocate the 4 slots required for SIP-UC.
  Accordingly, it was confirmed that R2V communication and R2R communication can be established even if SIP-UC is added on to existing ITS services.
- As a result of studying the possibility of adding SIP-UC message sets to the existing 700 MHz band ITS, it was confirmed that SIP-UC message sets can be added by utilizing the free field (optional area) of ITS Connect TD-001.

### ○ Simulation results

Based on the communication requirements presented by TG, a simulation-based evaluation was conducted to see if SIP-UC could be added to the existing 700 MHz band ITS.

- R2V communication met the requirements and was able to be added.
- Vehicle-to-roadside (V2R) communication, and some aspects of V2V communication, did not meet the requirements due to the impact of interference among OBU.
  Regarding these, the communication delay time required to satisfy the PAR and required communication distance requirements is shown.
- For the UCs where requirements were not met, as a basis for future consideration of realistic requirements when implementing these services, evaluation was also conducted to reflect changes in reception sensitivity, availability of slots for R2R communication, and vehicle density.

# 5.2. Issues and future actions (1)

## (1) Deeper examination of service requirements for SIP-UC

The communication requirements presented by TG include the following requirements.

- Since the details of service requirements are not yet decided, the PAR and RF delay are assumed values.
- More stringent communication distance requirements are needed because the single service requirement encompasses multiple situations, such as differences in vehicle congestion, driving conditions, surrounding environment, etc.

For each use case, it is necessary to work with related organizations that have studied it to further specify service requirements based on congestion of surrounding vehicles, behavior and control methods of autonomous vehicles, etc., and to define practical and optimal communication requirements (communication distance, RF delay, transmission cycle, etc.) based on service requirements.

# 5.2. Issues and future actions (examples with relaxed communication requirements)

## ■ Examples of relaxed communication requirements to enable achievement of services

(*1) Advanced messages not achieved, Basic messages achieved
(*2) Not achieved in times of emergency, achieved in normal times
(*3) "✓" means supported, and "-" means not supported.

| | Broad category | Middle category | Name of use case | Proposed communication requirements (Distance , Delay , PAR) | Compatibility with 700 MHz ITS (*3) | Kyocera simulation results (Distance , Delay , PAR) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | When traveling 120 km/h | When traveling 70 km/h | When traveling 20 km/h |
| 1 | Use cases in which information outside the detection range of on-board sensors must be obtained | a. Merging / lane change assistance | a-1-1. Merging assistance by preliminary acceleration and deceleration | | | | | |
| 2 | | | a-1-2. Merging assistance by targeting the gap on the main lane | | | | | |
| 3 | | b. Traffic signal information | b-1-1. Driving assistance by using traffic signal information (V2I) | | | | | |
| 4 | | | b-1-2. Driving assistance by using traffic signal information (V2N) | | | | | |
| 5 | | c. Lookahead information: collision avoidance | c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly | 120km/h, 81.7m, 200ms, 99%<br>20km/h, 17.8m, 600ms, 99% | ✓ | → | 87.7m, 200ms, 99%<br>distance per 200ms : 3.89m | 18.9m, 600ms, 99%<br>distance per 600ms : 3.33m |
| 6 | | | c-2-1. Driving assistance based on intersection information (V2V) | 70km/h, 157.6m, 900ms, 99%<br>20km/h, 45.1m, 2.9s, 99% | ✓ | | 157.6m, 900ms, 99%<br>distance per 900ms : 17.5m | 45.1m, 2.9s, 99%<br>distance per 2.9s : 16.1m |
| 7 | | | c-2-2. Driving assistance based on intersection information (V2I) | | | | | |
| 8 | | | c-3. Collision avoidance assistance by using hazard information | 120km/h, 81.7m, 200ms, 99%<br>20km/h, 17.8m, 600ms, 99% | ✓ | → | 87.7m, 200ms, 99%<br>distance per 200ms : 3.89m | 18.9m, 600ms, 99%<br>distance per 600ms : 3.33m |
| 9 | | d. Lookahead information: trajectory change | d-1. Driving assistance by notification of abnormal vehicles | | | | | |
| 10 | | | d-2. Driving assistance by notification of wrong-way vehicles | | | | | |
| 11 | | | d-3. Driving assistance based on traffic congestion information | | | | | |
| 12 | | | d-4. Traffic congestion assistance at branches and exits | | | | | |
| 13 | | | d-5. Driving assistance based on hazard information | | | | | |
| 14 | | e. Lookahead information: emergency vehicle notification | e-1. Driving assistance based on emergency vehicle information | 120km/h, 150m, 800ms, 99%<br>20km/h, 150m, 5.2s, 99% | ✓ | → | 150m, 800ms, 99%<br>distance per 800ms : 15.6m | 150m, 5.2 s, 99%<br>distance per 3.5s : 28.9m |
| 15 | Use cases in which information of one's own vehicle must be provided | f. Information collection / distribution by infrastructure | f-1. Request for rescue (e-Call) | | | | | |
| 16 | | | f-2. Collection of information to optimize the traffic flow | | | | | |
| 17 | | | f-3. Update and automatic generation of maps | | | | | |
| 18 | | | f-4. Distribution of dynamic map information | | | | | |
| 19 | Use cases in which V2V and V2I interaction must be ensured | a. Merging / lane change assistance | a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control | Expressway main route<br>120km/h, 266.7m, 800ms, 99%<br>20km/h, 44.4m, 900ms, 99%<br>Expressway connecting route<br>120km/h, 116.7m, 600ms, 99%<br>20km/h, 33.3m, 900ms, 99% | ✓ | main route<br>266.7m, 800ms, 99%<br>distance per 800ms :26.7m | connecting route<br>116.7m, 900ms, 99%<br>distance per 900ms : 17.5m | main route<br>44.4m, 900ms, 99%<br>distance per 900ms : 5m<br>connecting route<br>33.3m, 900ms, 99%<br>distance per 900ms : 5m |
| 20 | | | a-1-4. Merging assistance based on negotiations between vehicles | 70km/h, 124.4m, 2s, 99%<br>20km/h, 65.8m, 2s, 99% | - (*1) | | 255m, 1.4s, 99%<br>distance per 1.4s : 27.2m | 66.1m, 600ms, 99%<br>distance per 600ms : 3.33m |
| 21 | | | a-2. Lane change assistance when the traffic is heavy | Relative speed60km/h, 166.6m, 2s, 99%<br>Relative speed20km/h, 77.7m, 2s, 99% | - (*1) | | 170m, 600ms, 99%<br>distance per 600ms : 11.6m | 115m, 1.6s, 99%<br>distance per 1.6s : 8.9m |
| 22 | | | a-3. Entry assistance from non-priority roads to priority roads during traffic congestion | 60km/h, 127.8m, 2s, 99%<br>7.2km/h, 34.8m, 2s, 99% | - (*1) | | 130m, 1.7s, 99%<br>distance per 1.7s : 33.1m | 7.2km/h, 35m, 700ms, 99%<br>distance per 1.3s : 1.4m |
| 23 | | g. Platooning / adaptive cruise control | g-1. Unmanned platooning of following vehicles by electronic towbar | normal: 60m, 200ms, 99%<br>emergency: 60m, 20ms, 99.99% | - (*2) | → | 60m, 200ms, 99%<br>distance per 200ms : 3.89m | Outside scope of consideration |
| 24 | | | g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control | 100km/h, 141m, 800ms, 95% | ✓ | → | 141m, 300ms, 95%<br>distance per 300ms : 5.8m | Outside scope of consideration |
| 25 | | h. Teleoperation | h-1. Operation and management of mobility service cars | | | | | |

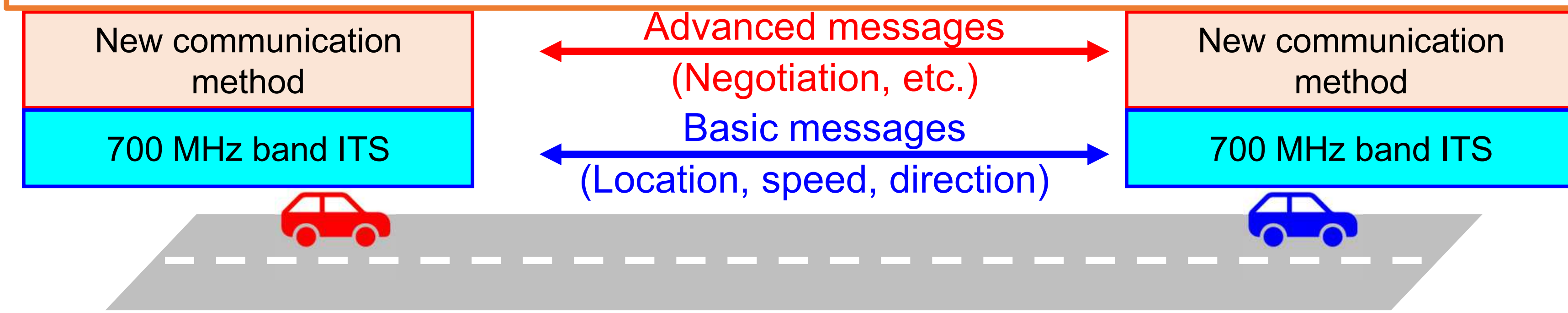
## (2) Support in use cases that require interaction

Since the current 700 MHz band ITS specification is a broadcast protocol, supporting interaction is difficult. However, radio waves in the 700 MHz band, with their distant reach and ability to travel around obstacles, are ideally used for basic exchanges for confirmation of positioning, and deeper discussion is needed on how to use 700 MHz band ITS.

**Proposal 1: New communication method only**
When using a new communication method that includes recognition of surrounding conditions (location, speed information, etc.), bandwidth and propagation need to considered. In addition, relationships with existing safe driving support services need to be considered (in the case of coexistence, the impact of cost and installation is significant. Deployment and dissemination of vehicles and quality assurance are issues when transitioning to a new system).

**Proposal 2: 700 MHz band ITS + new communication method**
This proposal is for the concept of "Basic Message (BM) + Advanced Message," in which basic recognition of the surrounding situation (location, speed information, etc.) is performed by the 700 MHz band ITS, and the subsequent interactive sequence is performed by new communication methods.

These will need to be considered in the future.




Proposal 2: Conceptual diagram of BM + advanced message

### (3) Definitions for practical application of system

For practical application of the system, message set standardization, security requirements, etc. need to be defined.

➡ Consult with relevant organizations to formulate guidelines and promote standardization

### (4) Formulate placement rules (guidelines) for RSU transmission slot allocation

At present, there is no slot allocation rule for RSU. Therefore, with the spread of RSU in the future, it will be necessary to create rules (formulate guidelines) for efficient slot allocation.

➡ Promote rule-making in consultation with various relevant organizations

### (5) Support for vehicle platooning use cases

Normally, 700MHz band ITS can be used. The problem is the 20 ms cycle transmission during sudden braking (in emergencies)

➡ Change of the ARIB STD-T109 standard or change of requirements after deep examination of use case requirements

# Contents

# 6. Future prospects

## ■ Promote verification testing and social implementation of 700 MHz band ITS, which can be utilized over the long term.

Other than items requiring interaction in SIP-UC (a-1-3, a-1-4, a-2, a-3), the basic information such as vehicle location, speed, direction, etc. handled in most UCs is the same as that of the ITS Connect service currently in use. In addition, the ability of the 700 MHz band to reach far and travel around obstacles is said to be extremely advantageous for Japan's road conditions, which include poor visibility and vehicle antenna design.
Therefore, we believe it is important to maximize the use of the 700 MHz band ITS for cooperative autonomous driving, while still taking international trends into consideration.
To this end,
- For each SIP-UC, defining more detailed service requirements and communication requirements based on various situations such as road conditions; and
- In line with the UC roadmap, giving priority to services that are essential for autonomous driving vehicles to operate, and steadily implementing these services in society, as well as more advanced communications, are also required.

We believe it is important to continue discussions on ways to achieve utilization of the 700 MHz band ITS as a form of communication for cooperative autonomous driving.

## ■ For use cases in which interaction is necessary, new communication methods must be considered based on the assumed timing of their realization.

Since SIP-UC requiring interaction cannot be handled by the 700 MHz band ITS, which is a broadcast based on the assumption of one-way sending of information, it is necessary to use new communication methods that enable two-way communication to achieve interaction. As this study continues, it will be important to discuss new communication methods, including proposals incorporating the idea that the 700 MHz band ITS is responsible for Basic messages that broadcast basic information, while new communication methods are responsible for advanced messages that exchange information necessary for interaction through two-way communication. After gaining an understanding of the current situation, considering the future will also be necessary.

END

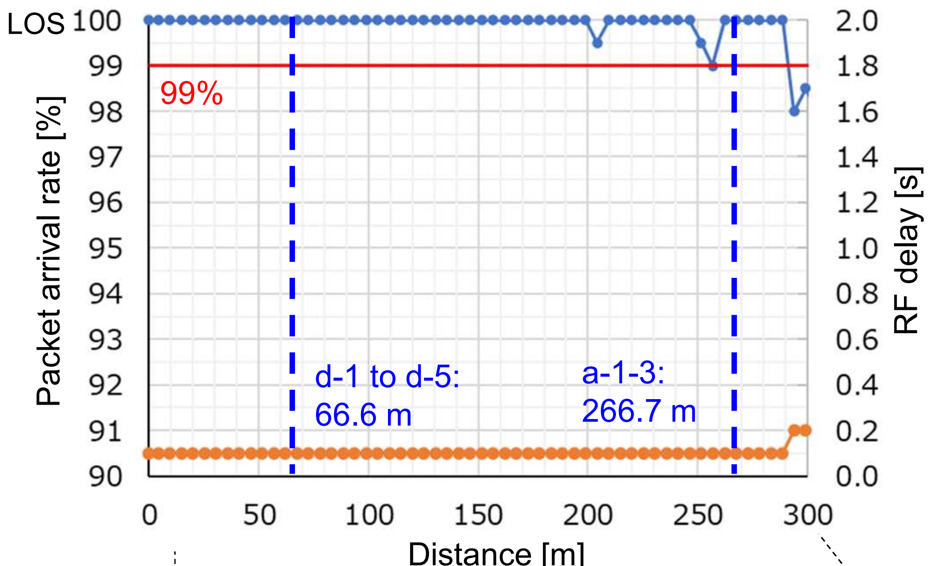
# Appendices

# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at low speeds) (1/9)

■ All SIP-UC: Simulation results for expressway main route R2V communication

- Communication requirements for **a-1-3 R2V (main route) and d-1 to d-5 R2V were achieved with a delay of 100 ms and PAR of 99 % (confirmed at maximum communication distance)**

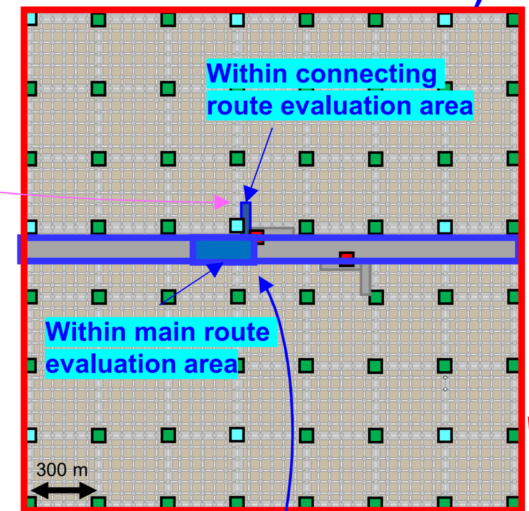
All SIP-UC expressway, main route, R2V communication




Evaluation area

Packet arrival rate

RF delay

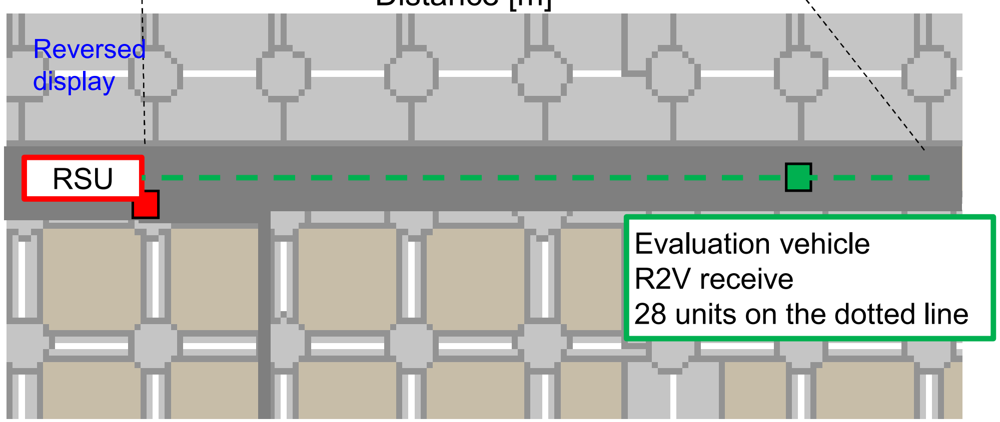



Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-3 | 100 ms | 0.6 m |
| d-1 to d-5 | 100 ms | 0.6 m |

[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU: 95 vehicles/km (20 km/h)



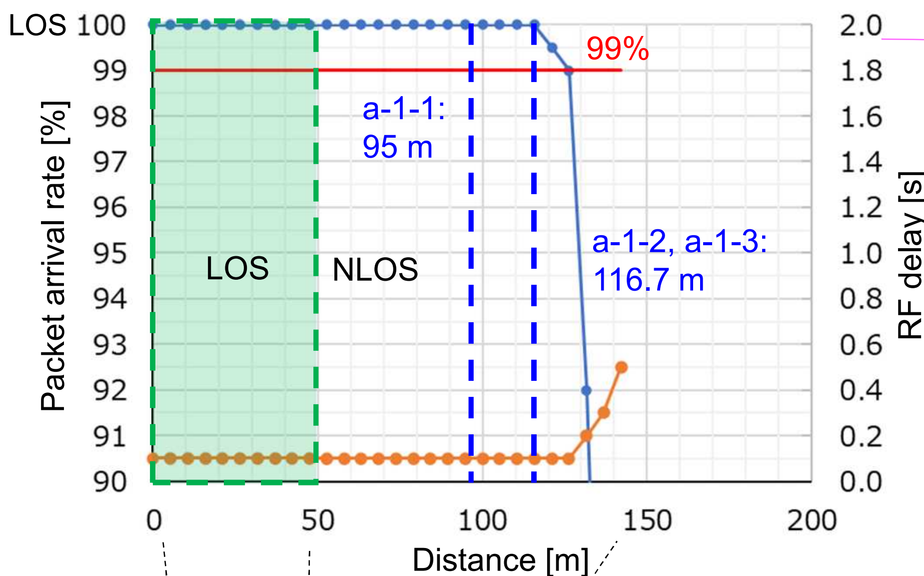

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

## ■ All SIP-UC: Simulation results for expressway connecting route R2V communication

- **Communication requirements for a-1-1, a-1-2, a-1-3 R2V (connecting route) were achieved with a delay of 100 ms and PAR of 99 % (confirmed at maximum communication distance)**

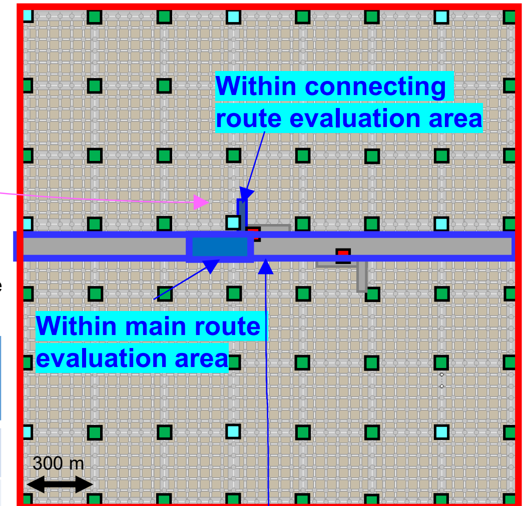
All SIP-UC expressway, connecting route, R2V communication

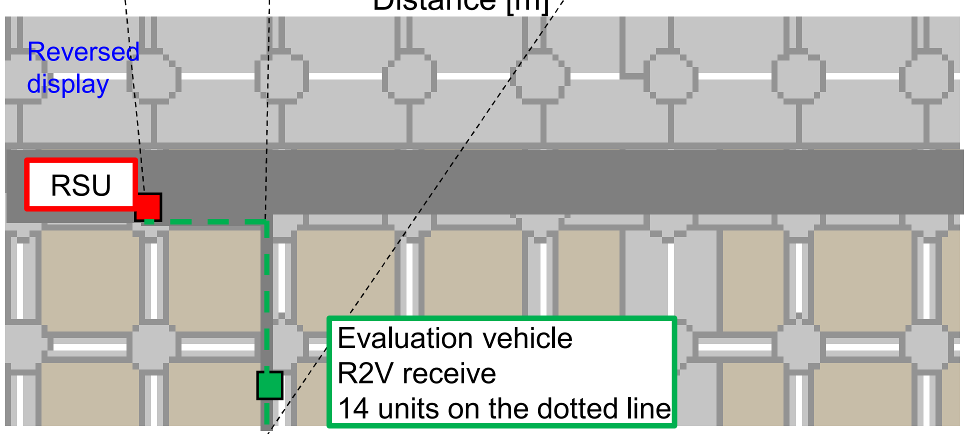



Evaluation area

Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-1 | 100 ms | 0.6 m |
| a-1-2 | 100 ms | 0.6 m |
| a-1-3 | 100 ms | 0.6 m |




[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU: 95 vehicles/km (20 km/h)

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

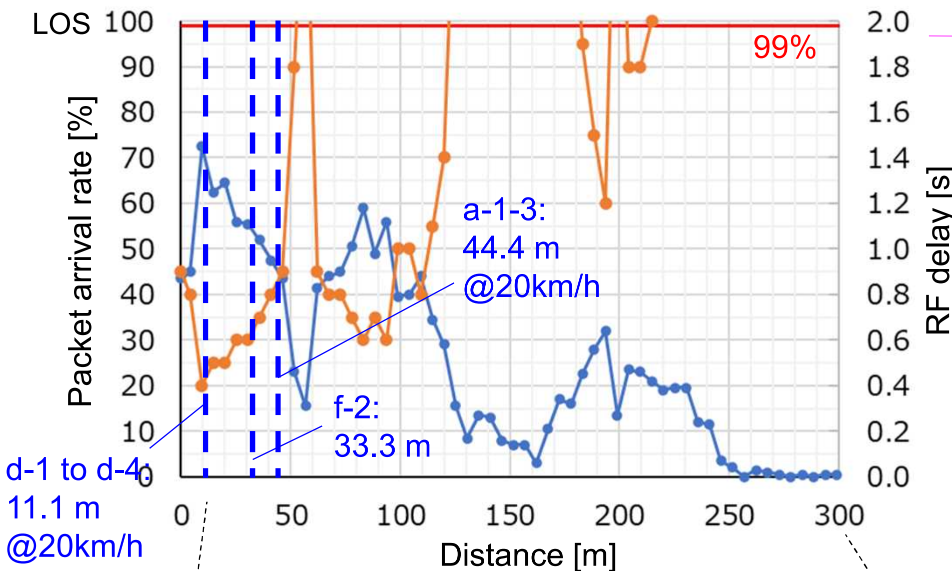
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

## Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at low speeds) (3/9)

■ All SIP-UC: Simulation results for expressway main route V2R communication

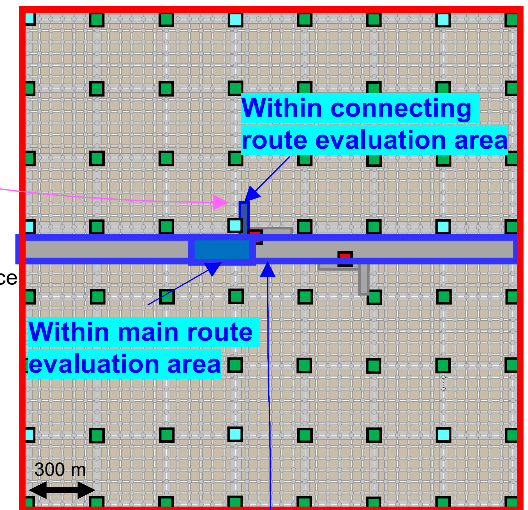
- **Communication requirements were not achieved for a-1-3 at delay of 100 ms and PAR of 99%**
- **Communication requirements were achieved for d1 to d4 and f-2 with delay of 1 s and PAR of 99%**

All SIP-UC expressway, main route, V2R communication



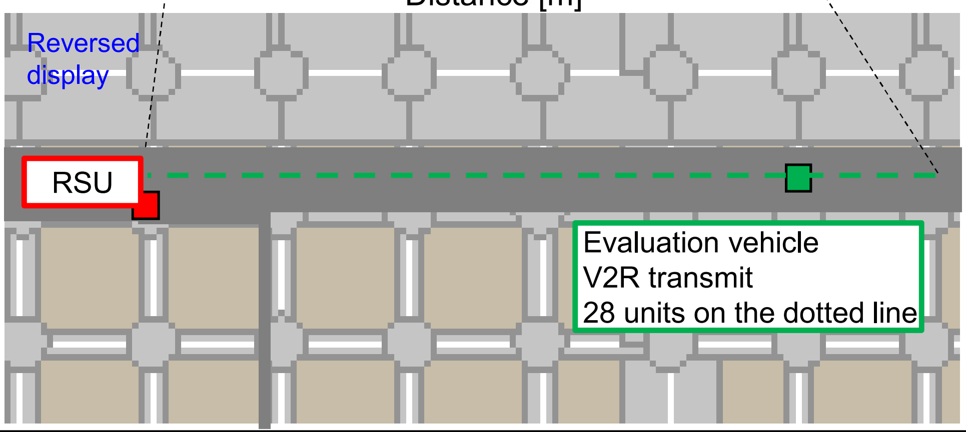

Packet arrival rate
RF delay

Evaluation area




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-3 | 900 ms | 5.0 m |
| d-1 to d-4 | 900 ms | 5.0 m |
| f-2 | 900 ms | 5.0 m |




[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU: 95 vehicles/km (20 km/h)

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

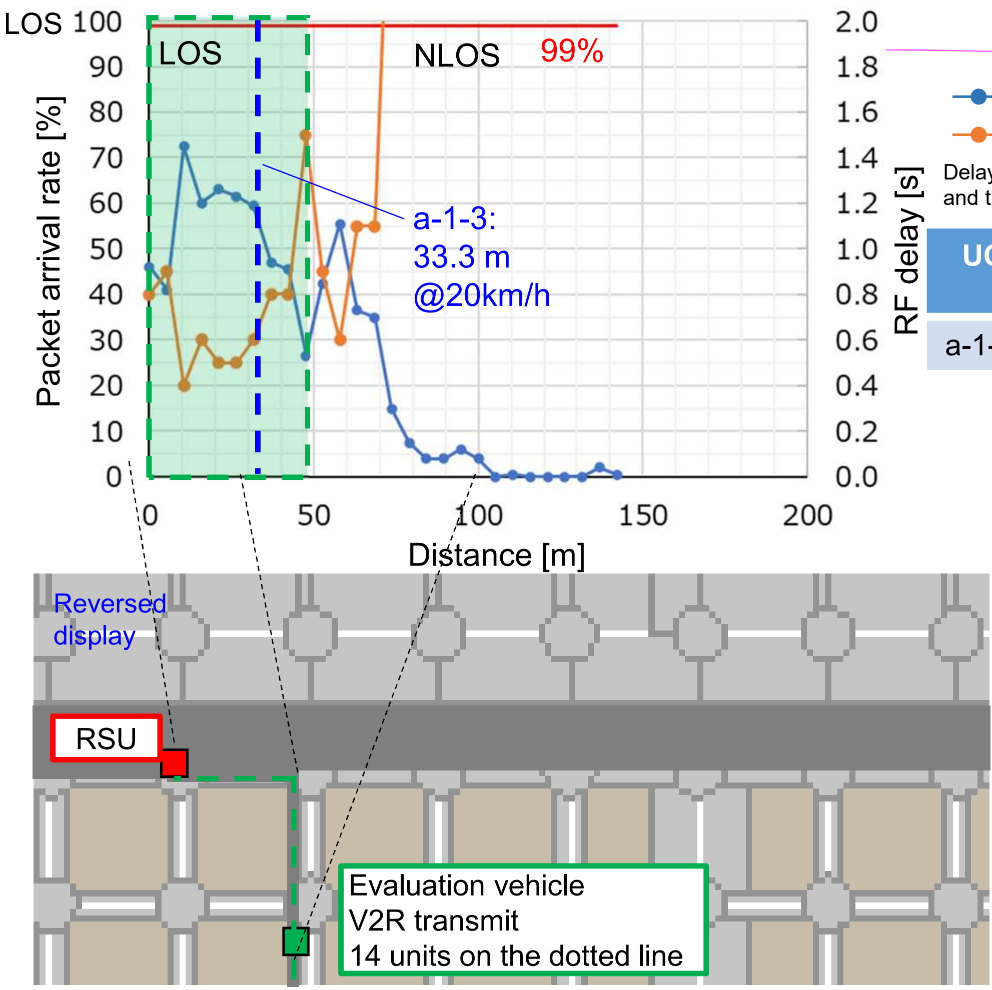
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at low speeds) (4/9)

■ All SIP-UC: Simulation results for expressway connecting route V2R communication

**- Communication requirements were not achieved for a-1-3 at delay of 100 ms and PAR of 99%**

All SIP-UC expressway, connecting route, V2R communication

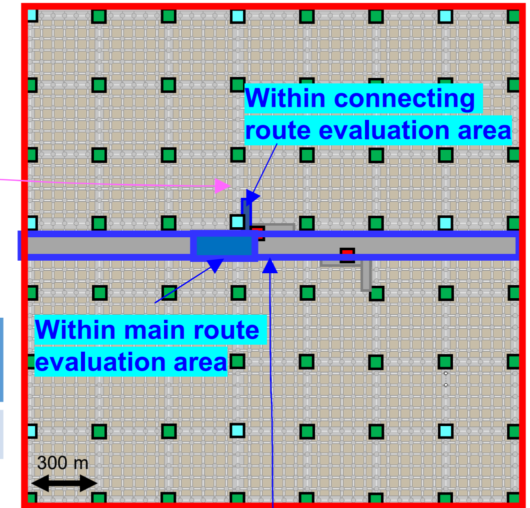



Packet arrival rate
RF delay

Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-3 | 900 ms | 5.0 m |

Evaluation area




[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU: 95 vehicles/km (20 km/h)

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

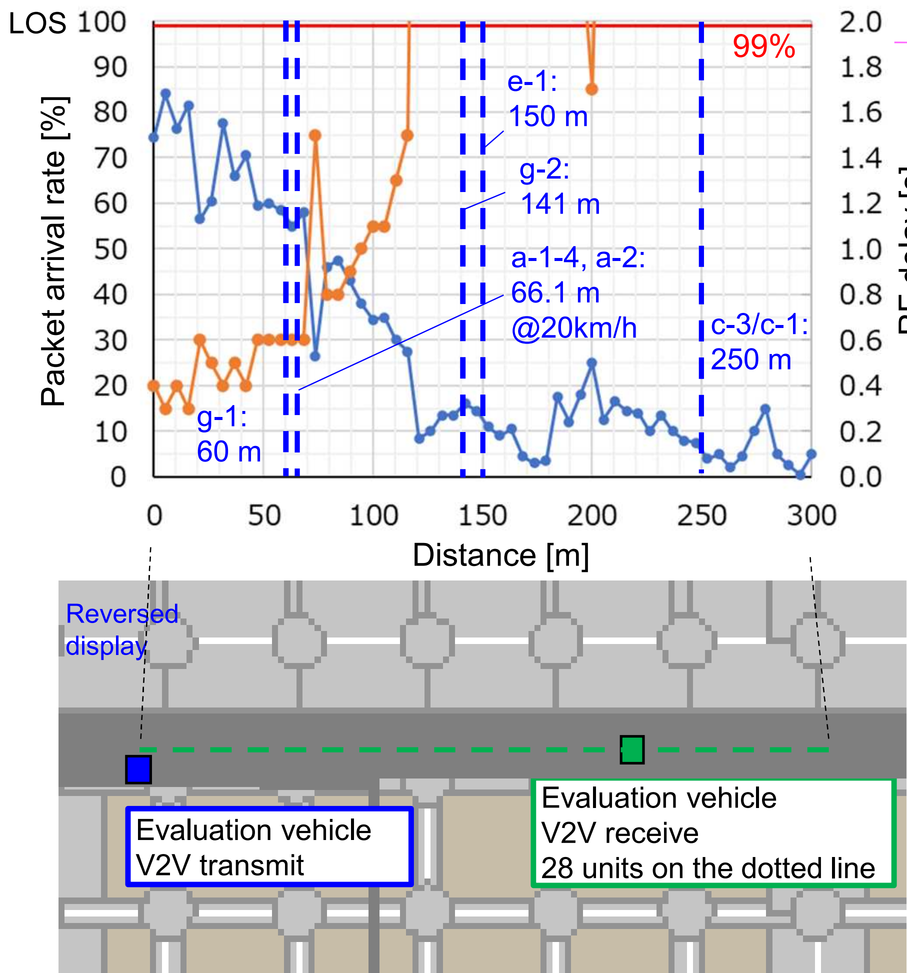
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at low speeds) (5/9)

- All SIP-UC: Simulation results for expressway main route V2V communication

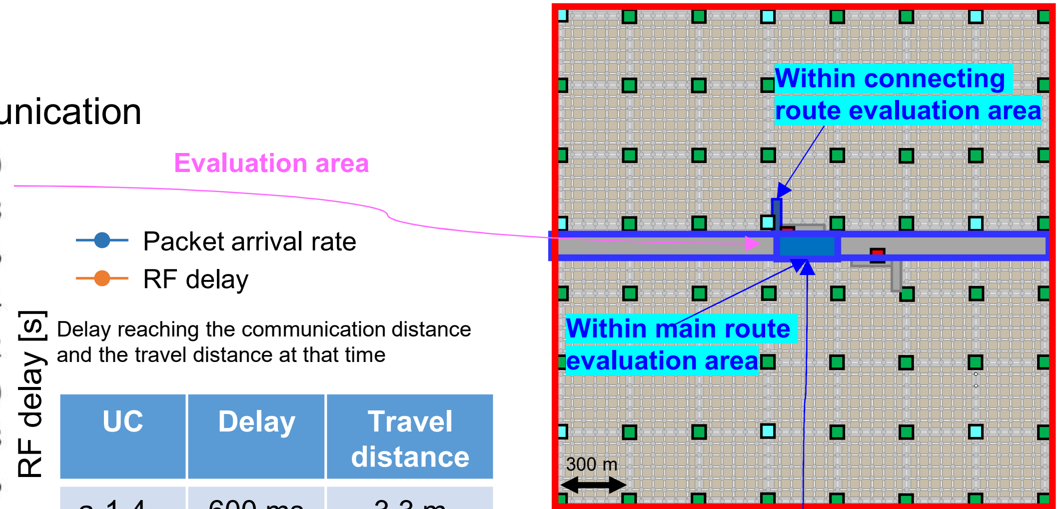
- **Communication requirements were not achieved for a-1-4/a-2, c-3/c-1, e-1, g-1, and g-2 at delay of 100 ms and PAR of 99%**

All SIP-UC expressway, connecting route, V2R communication




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-4 | 600 ms | 3.3 m |
| a-2 | 600 ms | 3.3 m |
| c-3 /c-1 | 15.2 s | 84.4 m |
| e-1 | 5.2 s | 28.9 m |
| g-1 | 600 ms | 3.3 m |
| g-2 | 5.2 s | 28.9 m |




[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU: 95 vehicles/km (20 km/h)

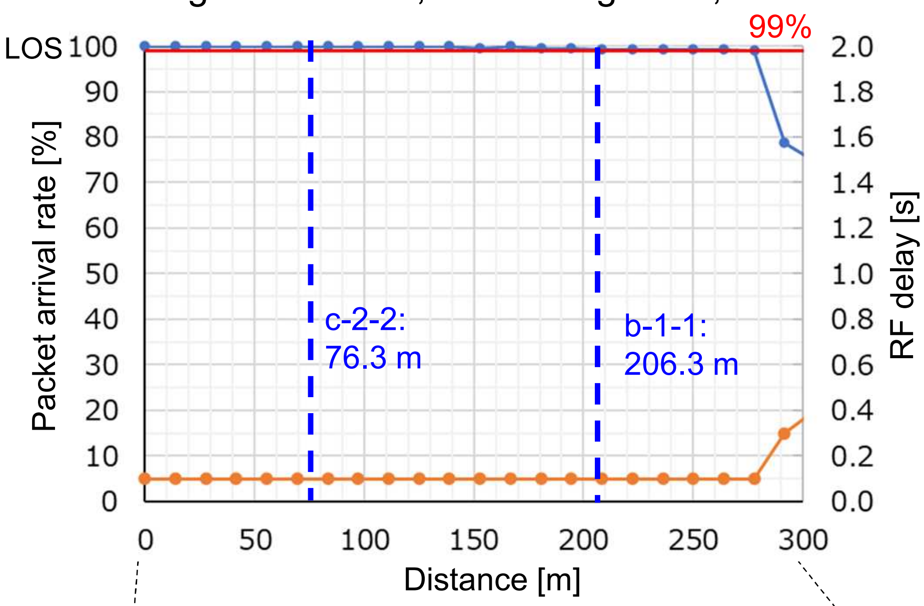
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

## ■ All SIP-UC: Simulation results for general road R2V communication

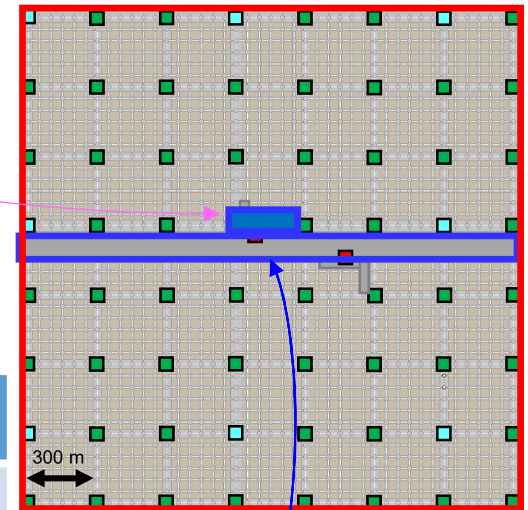
- **Communication requirements were achieved for c-2-2 and b-1-1 with delay of 100 ms and PAR of 99%**

All SIP-UC general roads, connecting route, R2V communication




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| b-1-1 | 100 ms | 1.1 m |
| c-2-2 | 100 ms | 1.1 m |

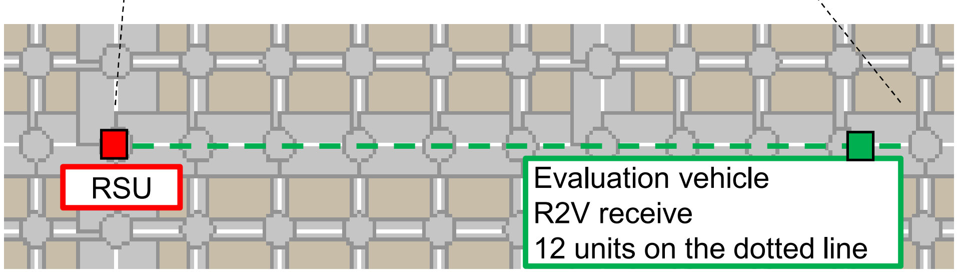



[SIP general roads: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

[SIP general roads: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 143 vehicles/km (10 km/h)

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

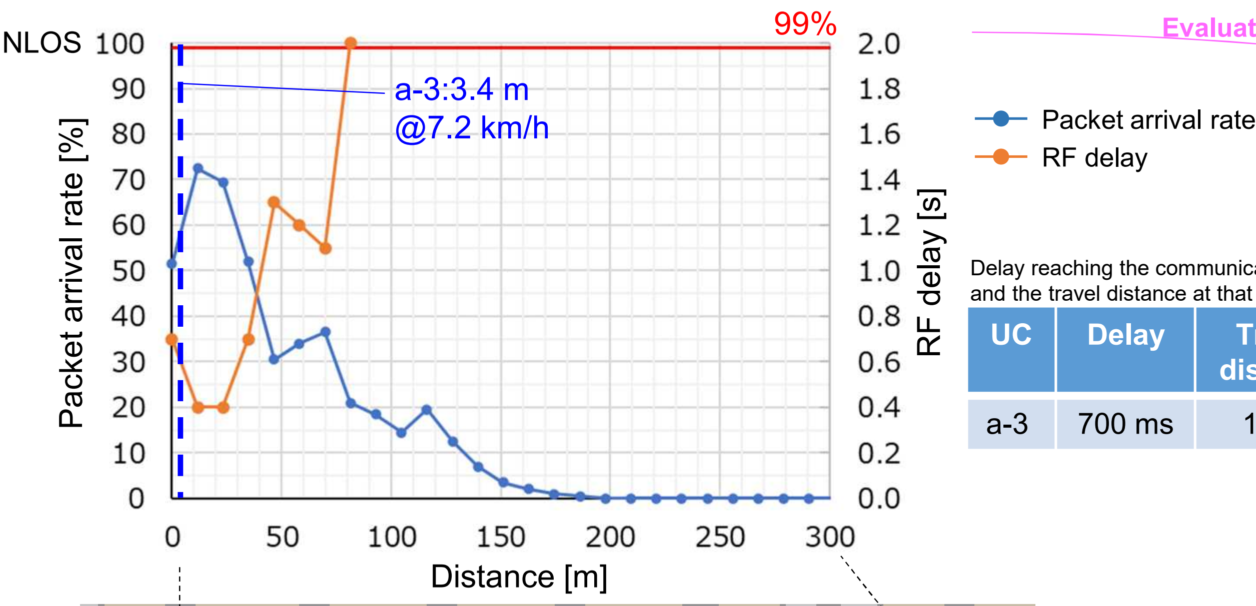
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

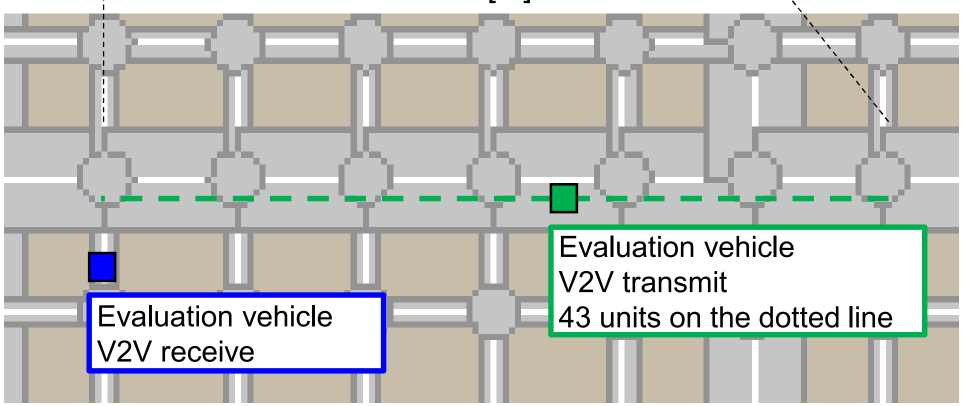


# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at low speeds) (7/9)

- All SIP-UC: Simulation results for general road V2V communication
  - **Communication requirements were not achieved for a-3 at delay of 100 ms and PAR of 99%**

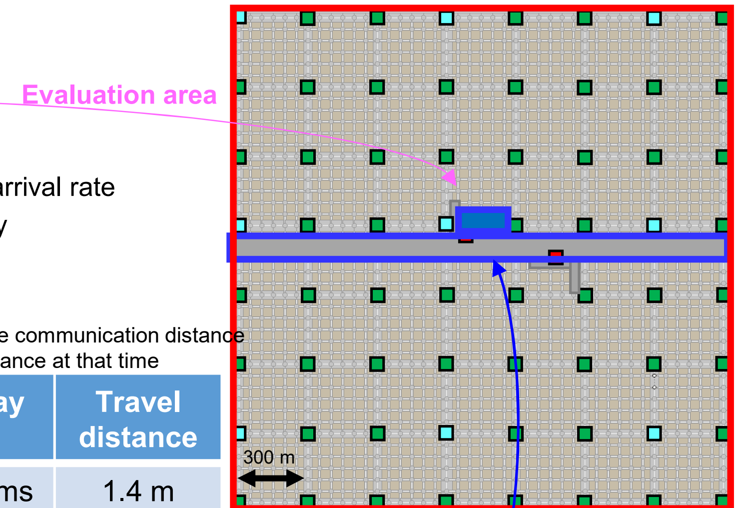
All SIP-UC general roads, connecting route, V2V communication




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-3 | 700 ms | 1.4 m |




[SIP general roads: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

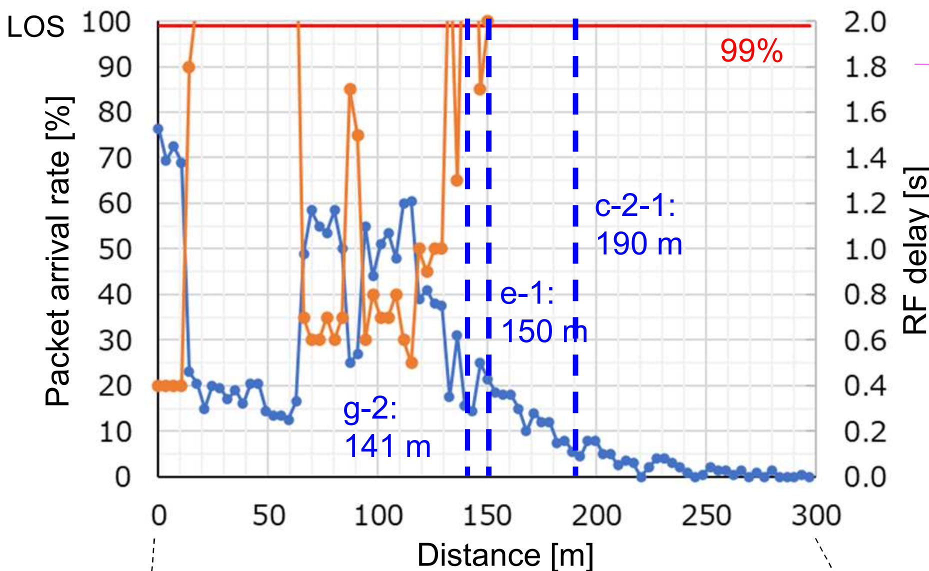
[SIP general roads: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 143 vehicles/km (10 km/h)

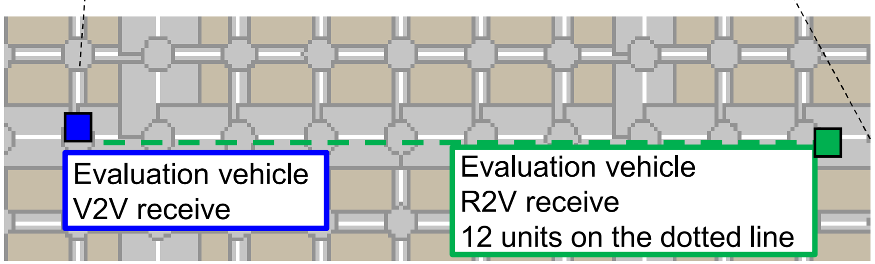
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

- All SIP-UC: Simulation results for general road V2V communication (within line of sight)
  - **Communication requirements were not achieved for c-2-1 and e-1 at delay of 100 ms and PAR of 99%**

All SIP-UC general roads, connecting route, V2V communication

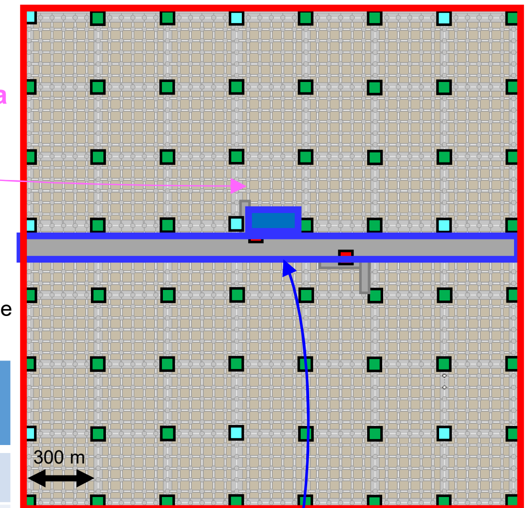



Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| c-2-1 | 10.1 s | 56.1 m |
| e-1 | 3.5 s | 19.4 m |
| g-2 | 3.5 s | 19.4 m |

Evaluation area




[SIP general roads: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

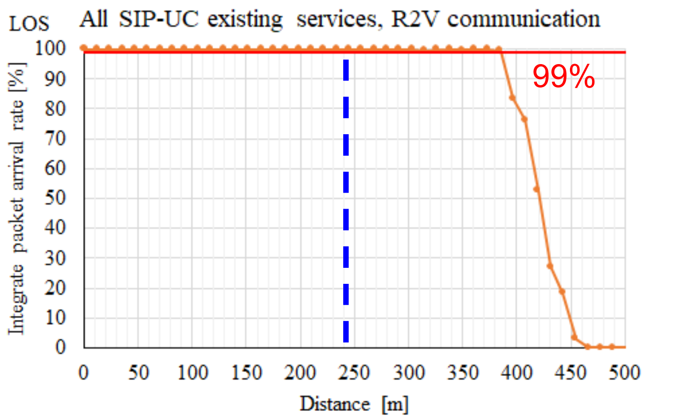
[SIP general roads: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 143 vehicles/km (10 km/h)

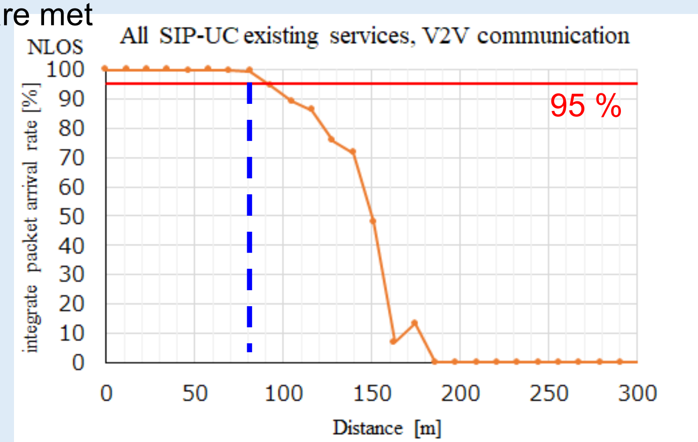
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

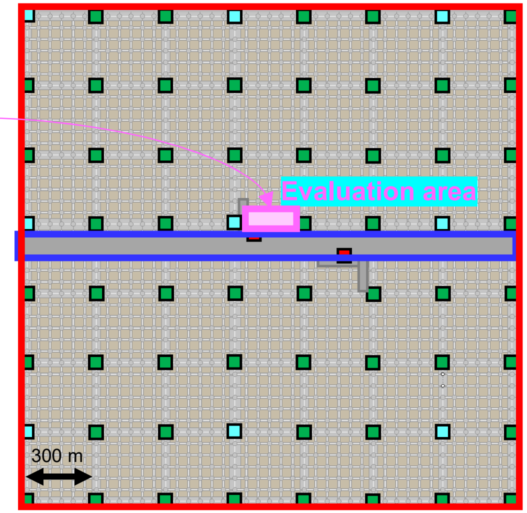
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

## ■ All SIP-UC: Simulation results confirming impact on existing services

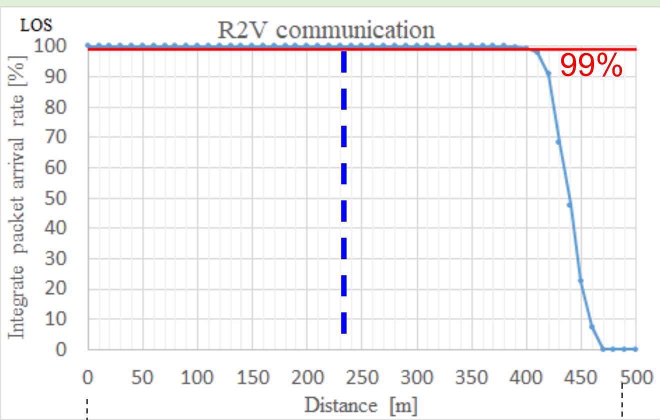
- Existing services: Confirm that requirements are met

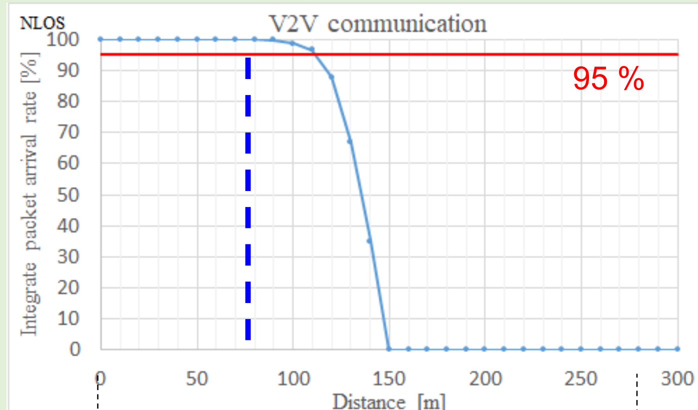


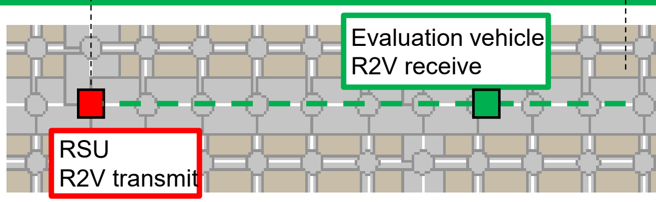



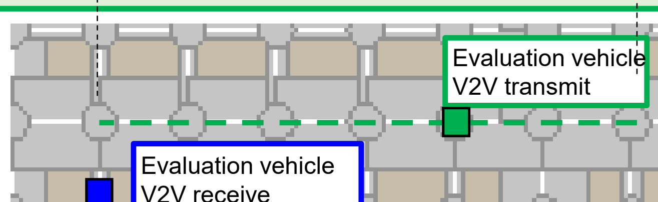




- Existing services only



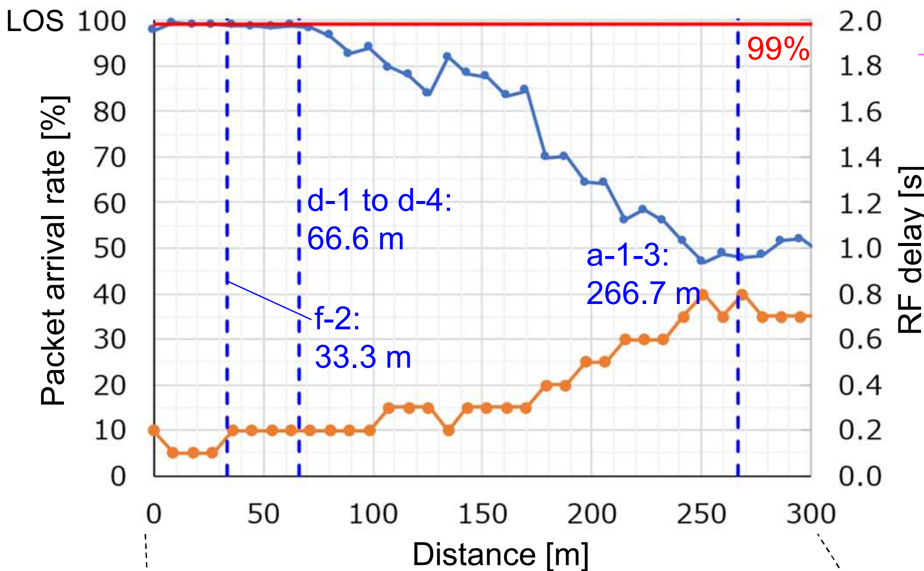

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

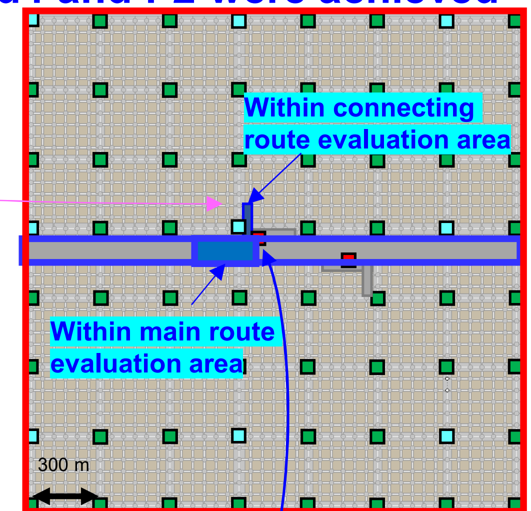
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 43 vehicles/km (25 km/h, approx. 5000 units)

■ All SIP-UC: Simulation results for expressway main route V2R communication

- **Communication requirements for a-1-3 V2R (main route) were not achieved with a delay of 100 ms and PAR of 99%, while communication requirements for d1 to d4 and f-2 were achieved with a delay of 1 s and PAR of 99%.**

All SIP-UC expressway, main route, V2R communication




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-3 | 800 ms | 26.7 m |
| d-1 to d-4 | 200 ms | 6.7 m |
| f-2 | 200 ms | 6.7 m |

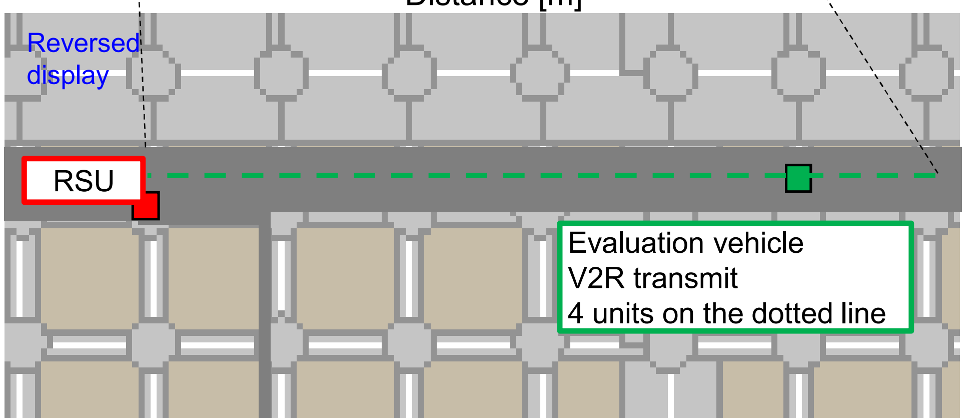
[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
- OBU (connecting route): 23 vehicles/km (70 km/h)

[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)

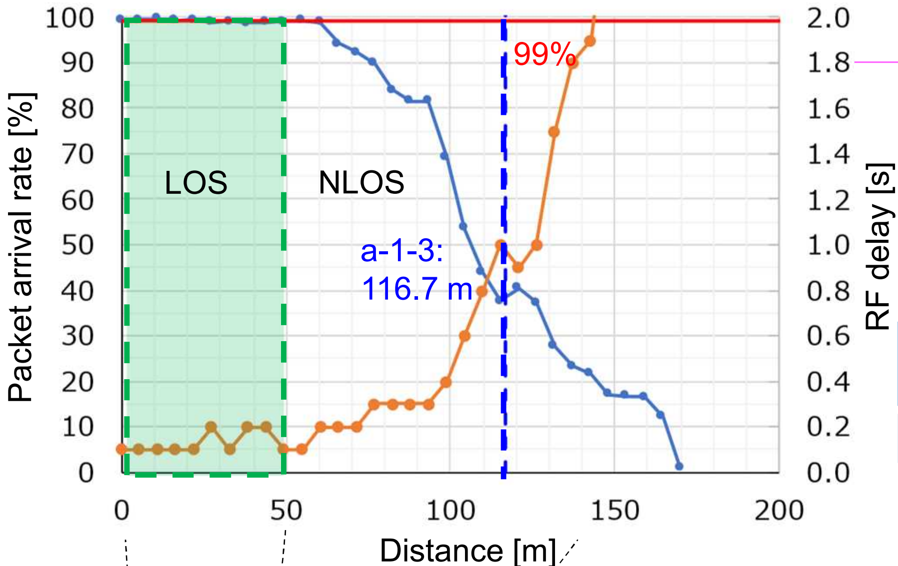


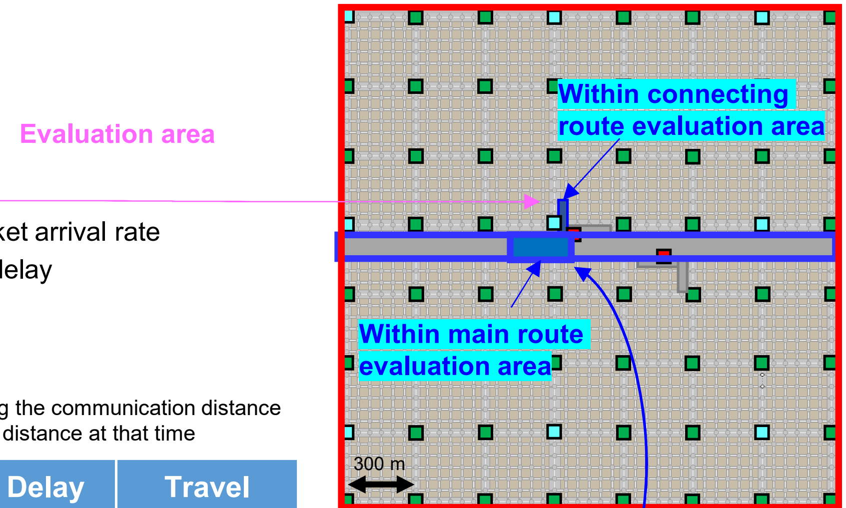
# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at regulated speeds) (2/5)

■ All SIP-UC: Simulation results for expressway connecting route V2R communication

- **Communication requirements were not achieved for a-1-3 V2R (connecting route) at a delay of 100 ms and PAR of 99%**

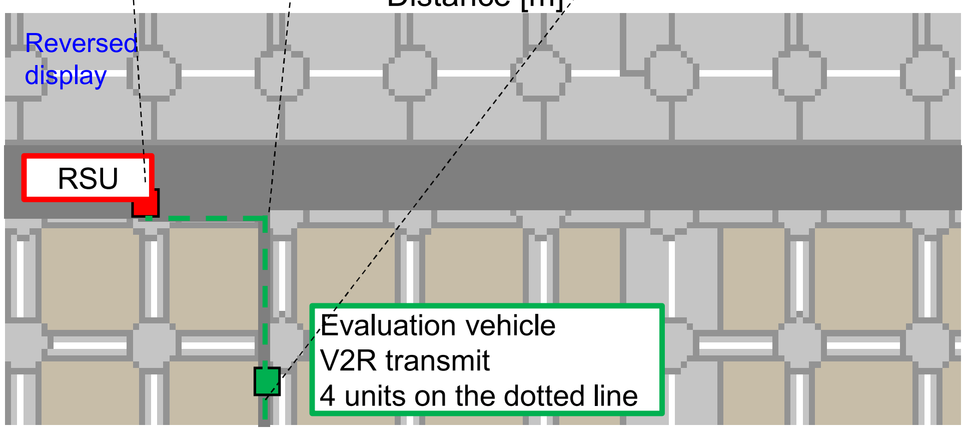
All SIP-UC expressway, connecting route, V2R communication




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-3 | 900 ms | 17.5 m |




[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
- OBU (connecting route): 23 vehicles/km (70 km/h)

[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

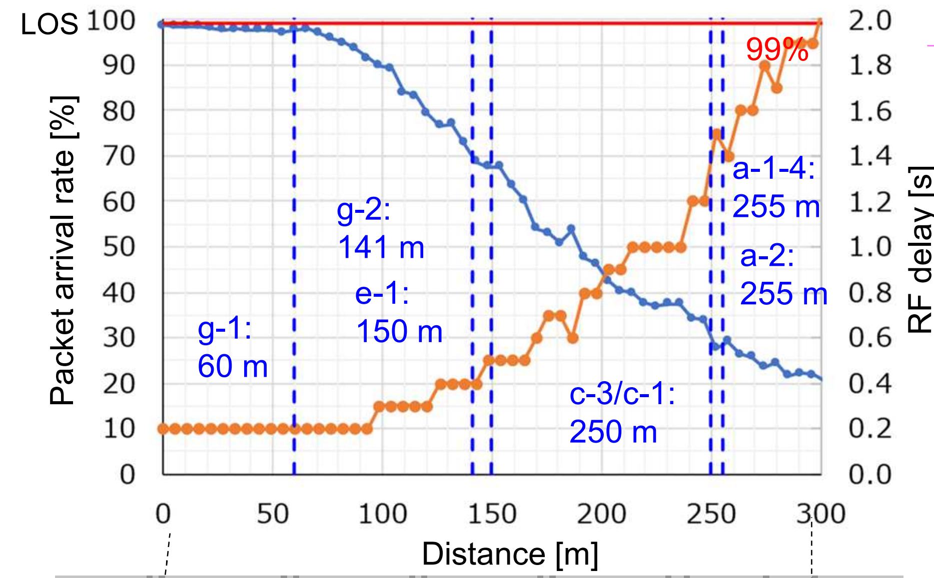
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)

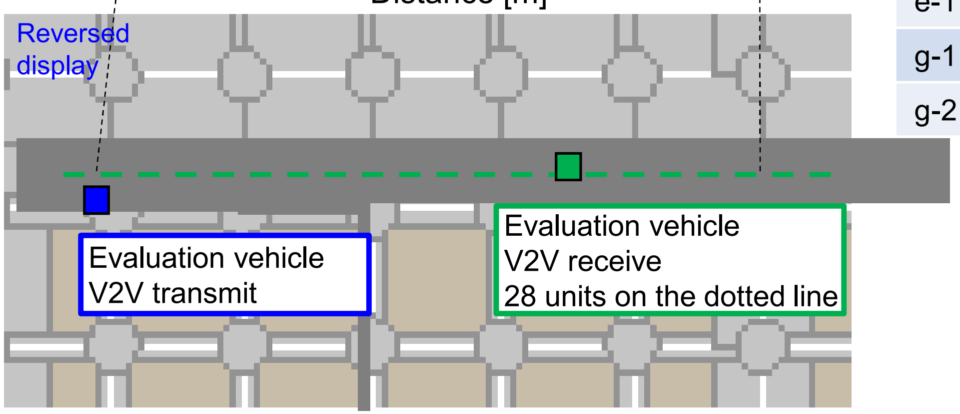
# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at regulated speeds) (3/5)

■ All SIP-UC: Simulation results for expressway main route V2V communication

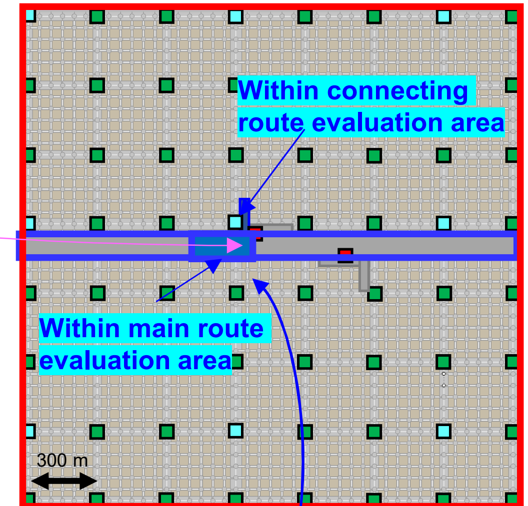
- **Communication requirements were not achieved for a-1-4, a-2, c-3/c-1, e-1, g-1, and g-2 at delay of 100 ms and PAR of 99%**

All SIP-UC expressway, main route, V2V communication




Evaluation area




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| a-1-4 | 1.4 s | 27.2 m |
| a-2 | 1.4 s | 27.2 m |
| c-3 /c-1 | 1.4 s | 29.2 m |
| e-1 | 500 ms | 9.7 m |
| g-1 | 200 ms | 3.9 m |
| g-2 | 400 ms | 7.8 m |

[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
- OBU (connecting route): 23 vehicles/km (70 km/h)

[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

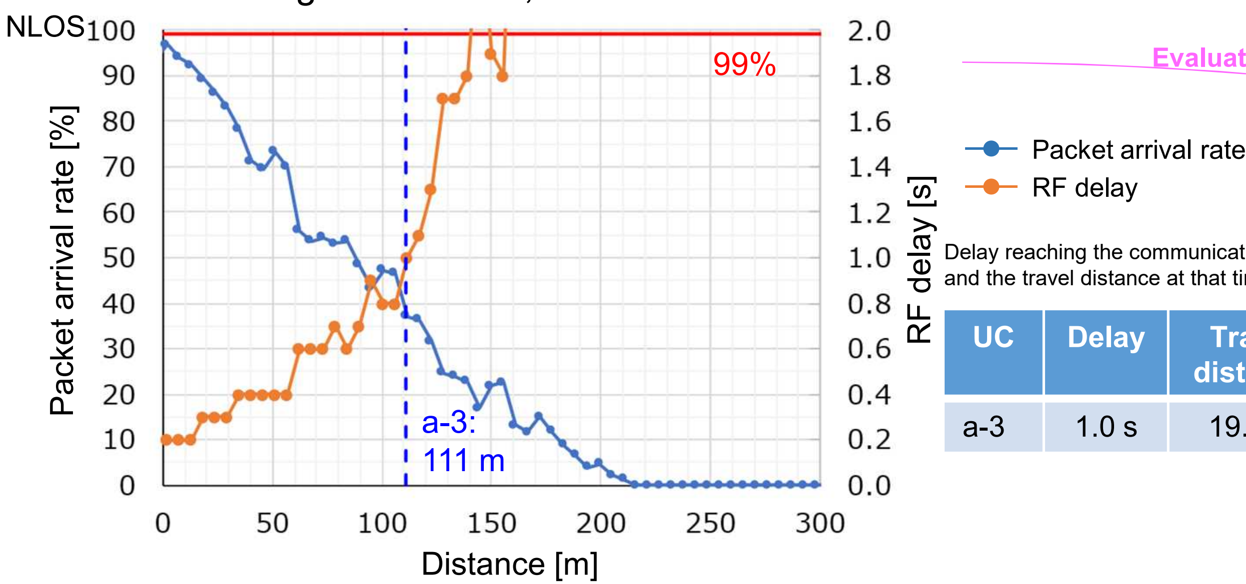
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

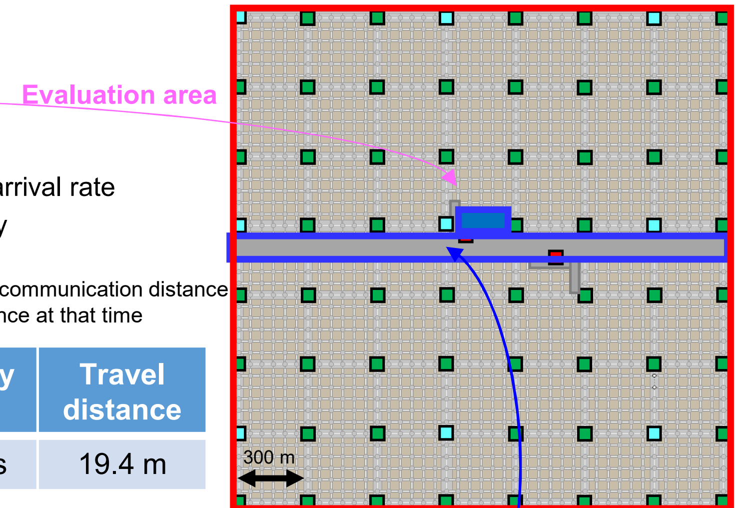
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)

■ All SIP-UC: Simulation results for general road V2V communication

- **Communication requirements were not achieved for a-3 at delay of 100 ms and PAR of 99%**

All SIP-UC general roads, V2V communication




Delay reaching the communication distance and the travel distance at that time

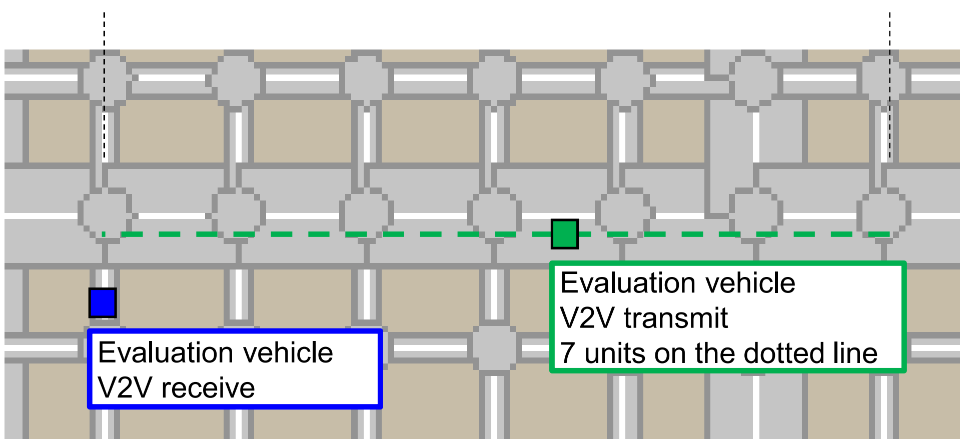
| UC | Delay | Travel distance |
|---|---|---|
| a-3 | 1.0 s | 19.4 m |

[SIP expressways: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 23 vehicles/km (70 km/h)

[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

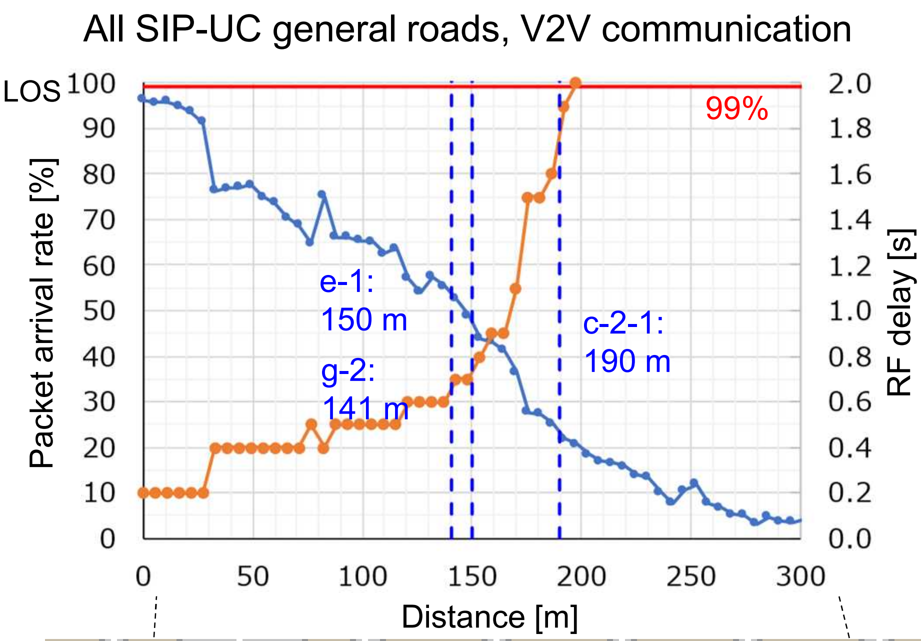
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)

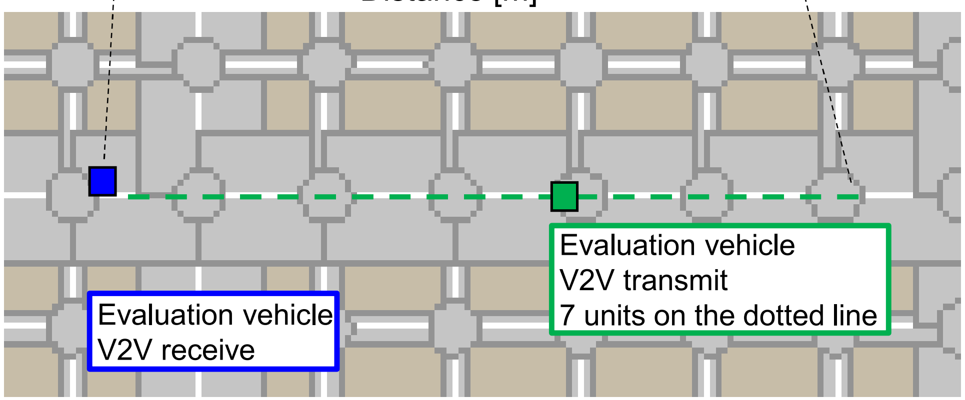


# Appendix: Simulation results to confirm simultaneous coexistence for all SIP-UC (maximum vehicle density conditions at regulated speeds) (5/5)

■ All SIP-UC: Simulation results for general road V2V communication (within line of sight)

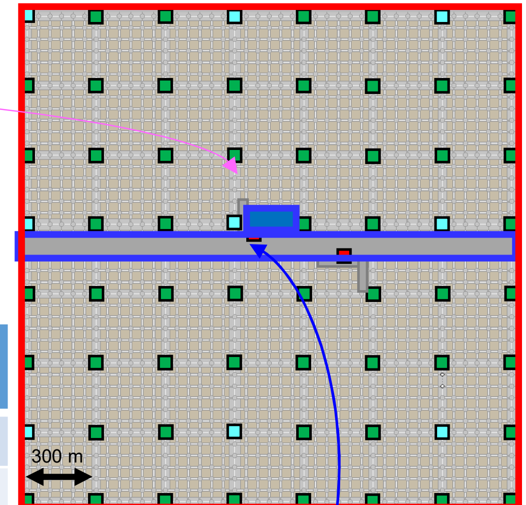
- **Communication requirements were not achieved for c-2-1, e-1, and g-2 at delay of 100 ms and PAR of 99%**




Delay reaching the communication distance and the travel distance at that time

| UC | Delay | Travel distance |
|---|---|---|
| c-2-1 | 1.9 s | 36.9 m |
| e-1 | 800 ms | 13.6 m |
| g-2 | 700 ms | 15.6 m |



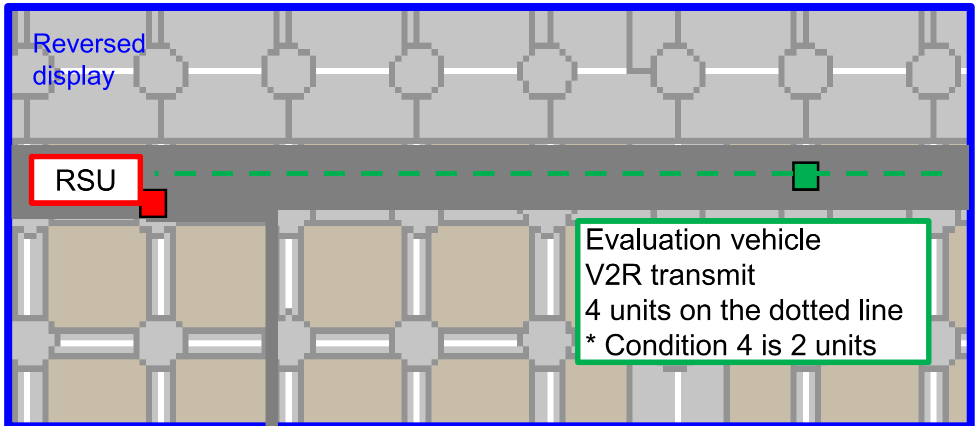

[SIP expressways: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 23 vehicles/km (70 km/h)

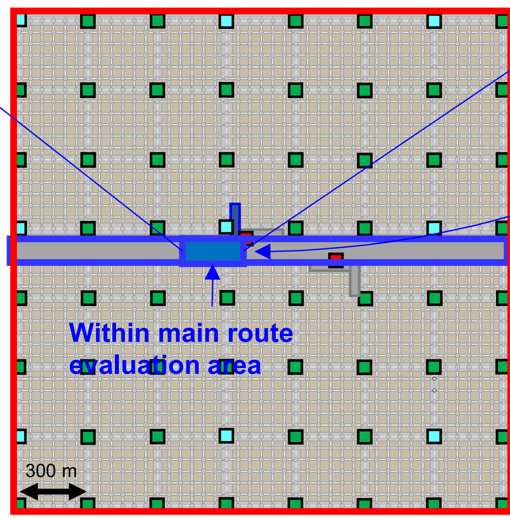
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)

- All SIP-UC: Simulation conditions for expressway main route V2R communication




Evaluation area




Overview of simulation

[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
  <exception> Condition 4 is 7 vehicles/km
- OBU (connecting route): 23 vehicles/km (70 km/h)
  <exception> Condition 4 is 12 vehicles/km

[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

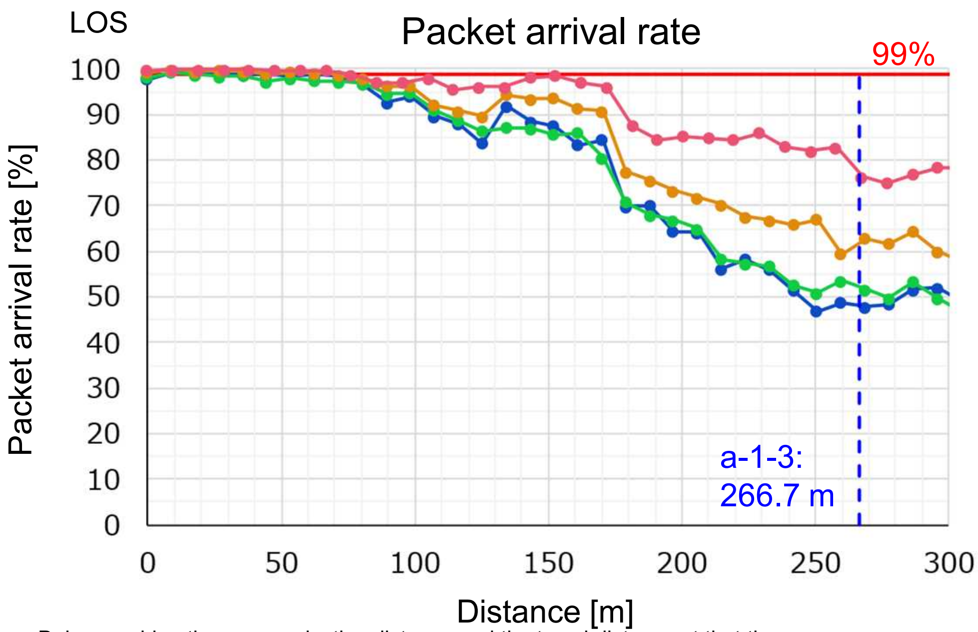
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

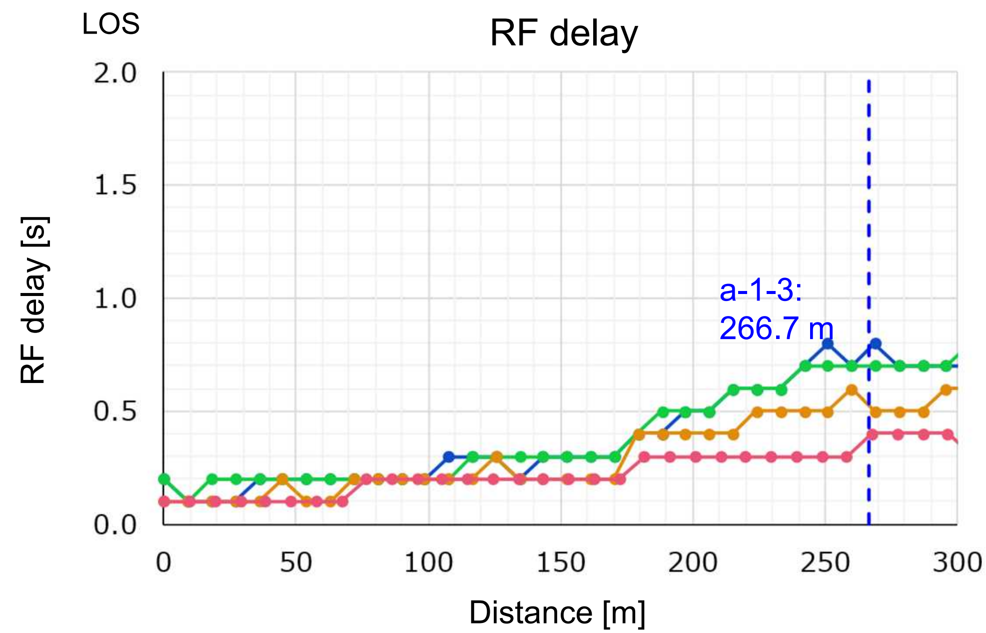
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)
  <exception> Condition 4 is 12 vehicles/km (approx. 1000 units)

# Appendix: Results of simulation with condition changes (2/10)

■ All SIP-UC: Simulation results for expressway main route V2R communication

- **Packet arrival rate improves with each new condition applied, in the following order: Condition 2, Condition 3, and Condition 4.**
- **Communication requirements were not achieved for a-1-3 V2R (main route) from the table below at a delay of 100 ms and PAR of 99%**



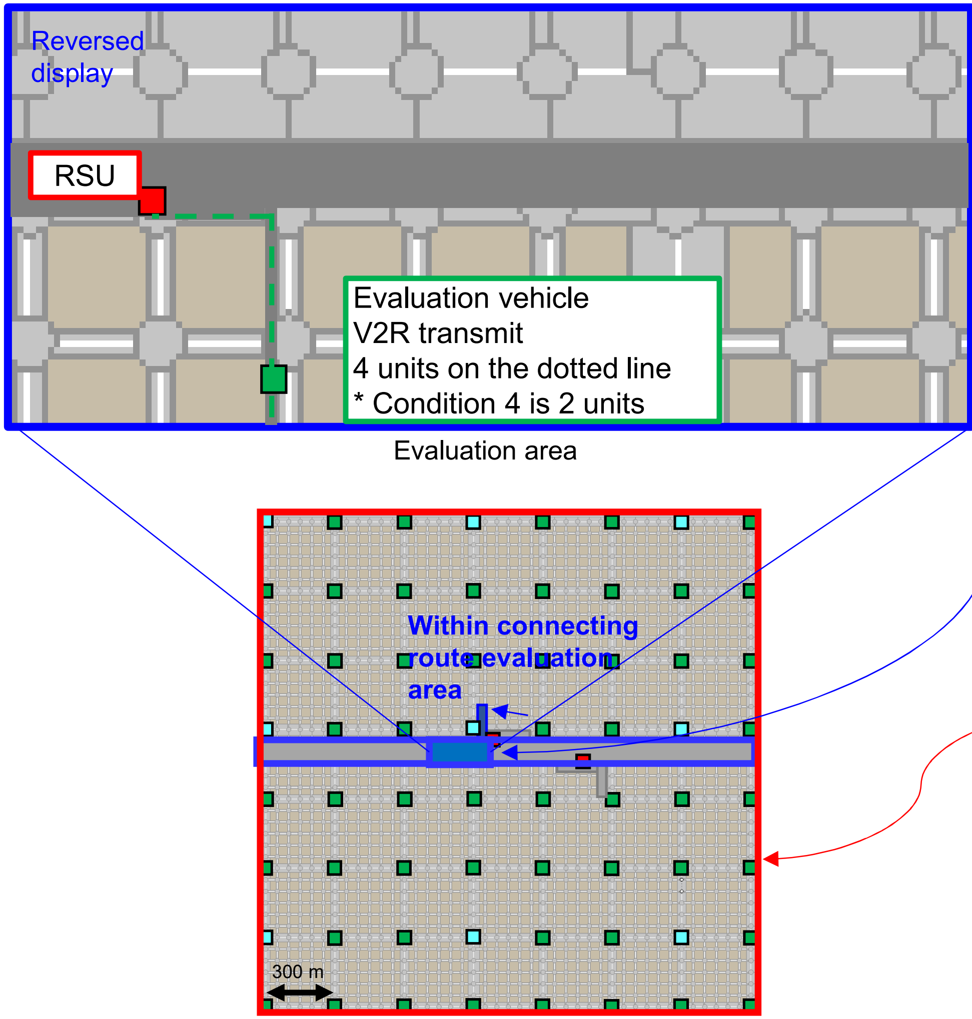




Delay reaching the communication distance and the travel distance at that time

| UC | Condition 1 | | Condition 2 | | Condition 3 | | Condition 4 | |
|---|---|---|---|---|---|---|---|---|
| | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance |
| a-1-3 | 800 ms | 26.7 m | 700 ms | 23.3 m | 500 ms | 16.7 m | 400 ms | 13.3 m |

- Condition 1: All SIP-UC normal driving
- Condition 2: Change of reception sensitivity
- Condition 3: Change of reception sensitivity + R2R communication OFF
- Condition 4: Change of reception sensitivity + R2R communication OFF + Vehicle density review

- All SIP-UC: Simulation results for expressway connecting route V2R communication




Overview of simulation

[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
  <exception> Condition 4 is 7 vehicles/km
- OBU (connecting route): 23 vehicles/km (70 km/h)
  <exception> Condition 4 is 12 vehicles/km

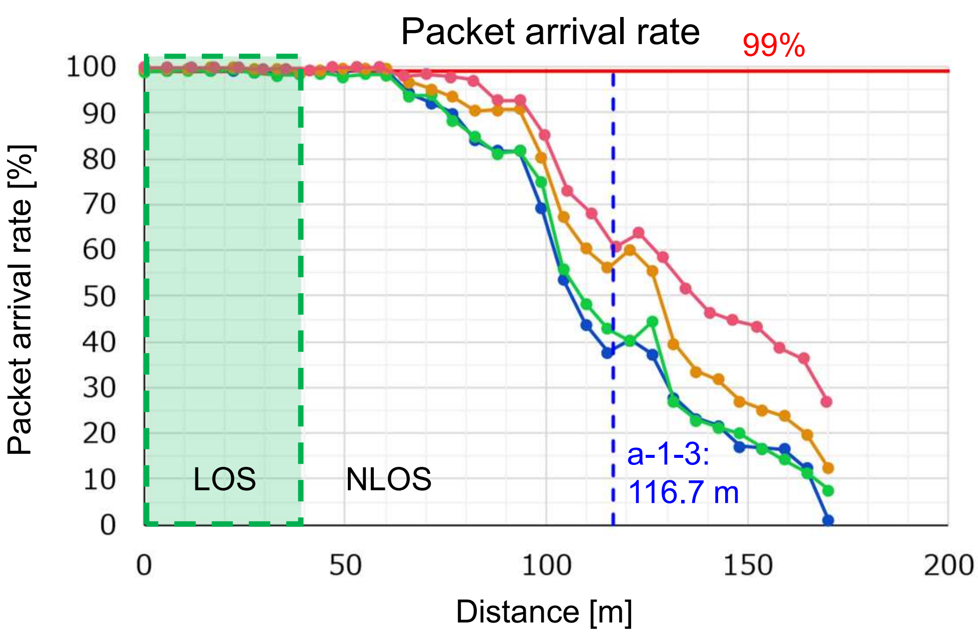
[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

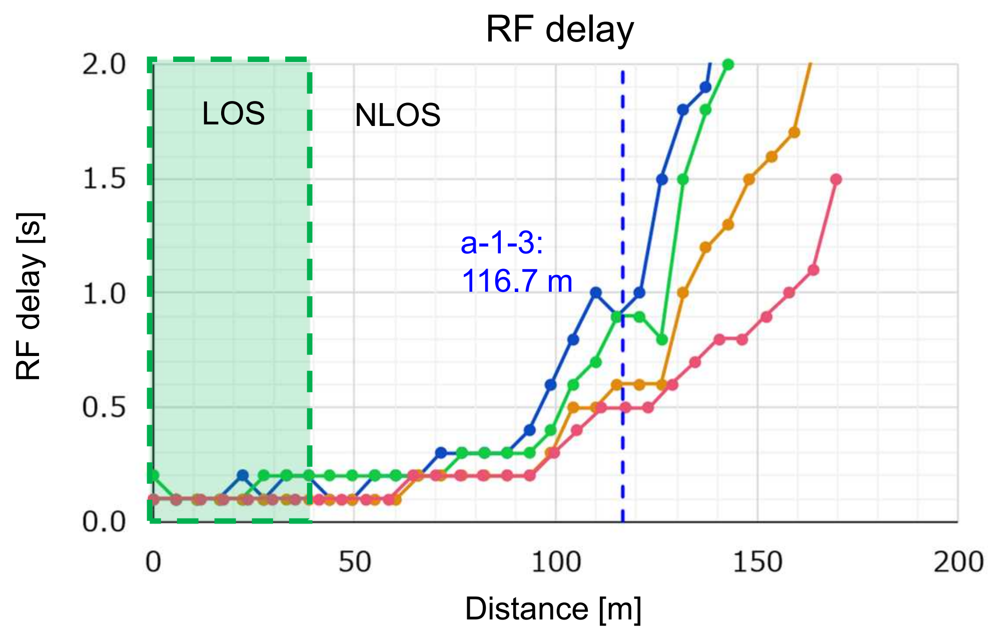
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)
  <exception> Condition 4 is 12 vehicles/km (approx. 1000 units)

■ All SIP-UC: Simulation results for expressway connecting route V2R communication

- **Packet arrival rate improves with each new condition applied, in the following order: Condition 2, Condition 3, and Condition 4.**
- **Communication requirements were not achieved for a-1-3 V2R (connecting route) from the table below at a delay of 100 ms and PAR of 99%**



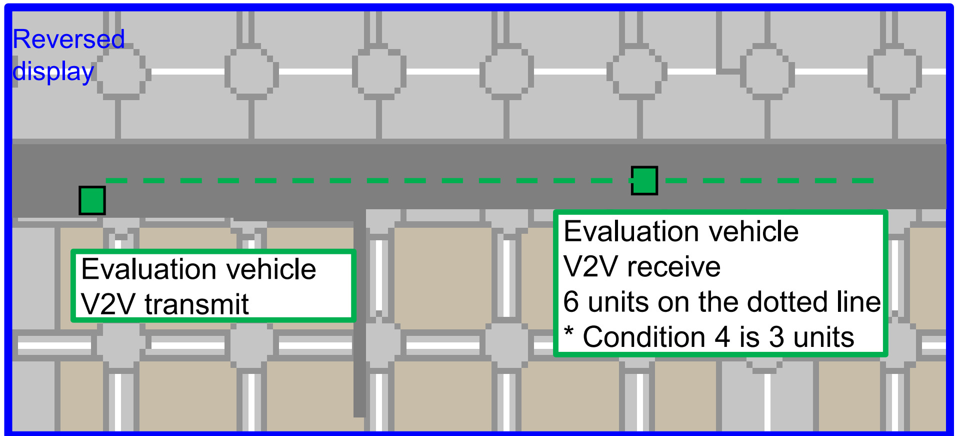

Delay reaching the communication distance and the travel distance at that time

| UC | Condition 1 | | Condition 2 | | Condition 3 | | Condition 4 | |
|---|---|---|---|---|---|---|---|---|
| | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance |
| a-1-3 | 900 ms | 17.5 m | 900 ms | 17.5 m | 600 ms | 11.7 m | 500 ms | 9.7 m |

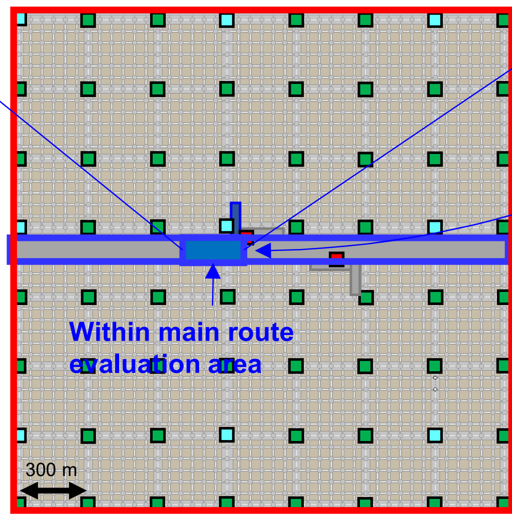
Condition 1: All SIP-UC normal driving
Condition 2: Change of reception sensitivity
Condition 3: Change of reception sensitivity + R2R communication OFF
Condition 4: Change of reception sensitivity + R2R communication OFF + Vehicle density review

# Appendix: Results of simulation with condition changes (5/10)

■ All SIP-UC: Simulation results for expressway main route V2V communication



Evaluation area



Overview of simulation

[SIP expressways: Message size]
- RSU: 4986 bytes
- OBU (in SIP evaluation area): 73 bytes
- OBU (outside SIP evaluation area): 73 bytes

[SIP expressways: Number of RSU and OBU]
- RSU: 2 units
- OBU (main route): 14 vehicles/km (120 km/h)
  <exception> Condition 4 is 7 vehicles/km
- OBU (connecting route): 23 vehicles/km (70 km/h)
  <exception> Condition 4 is 12 vehicles/km

[SIP expressways: RSU antenna conditions]
- Directional antenna (100 degrees) used

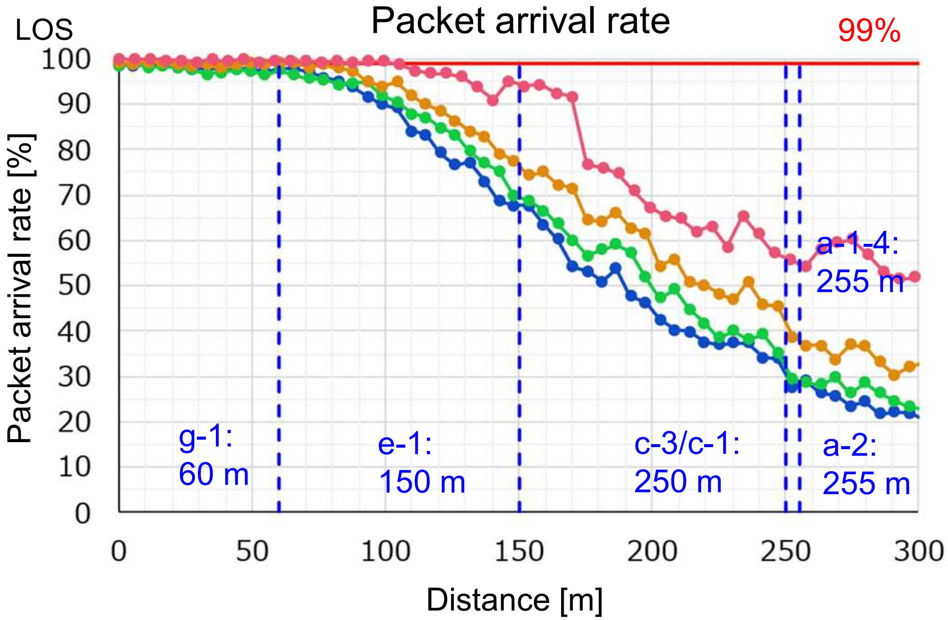
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

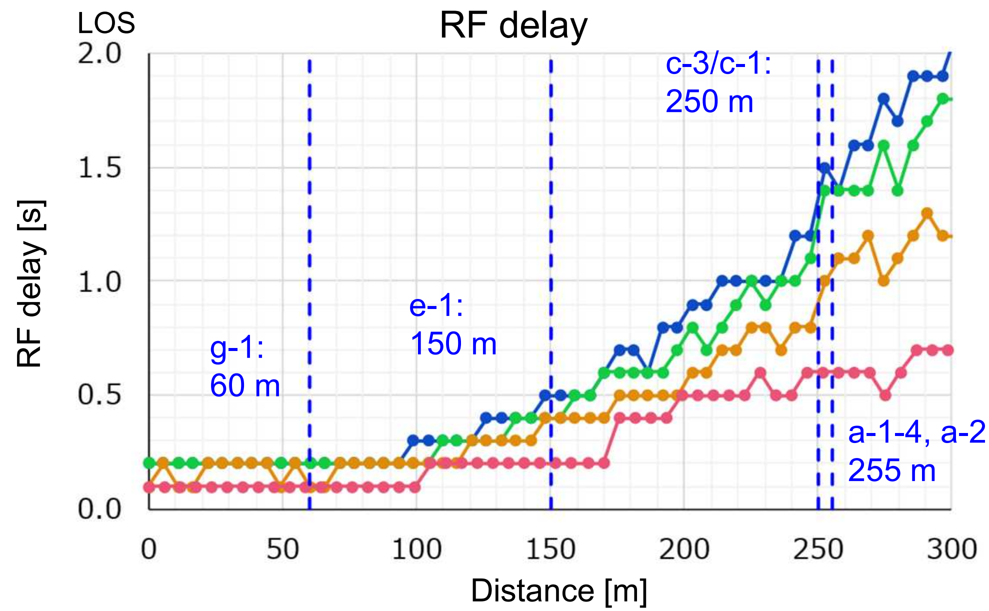
[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)
  <exception> Condition 4 is 12 vehicles/km (approx. 1000 units)

# Appendix: Results of simulation with condition changes (6/10)

■ All SIP-UC: Simulation results for expressway main route V2V communication

- **Packet arrival rate improves with each new condition applied, in the following order: Condition 2, Condition 3, and Condition 4.**
- **Communication requirements were not achieved for a-1-4, a-2, c-3/c-1, and e-1 from the table below at delay of 100 ms and PAR of 99%.**
- **From desk study, g-1 did not achieve the emergency communication requirements of 20 ms and 99%.**



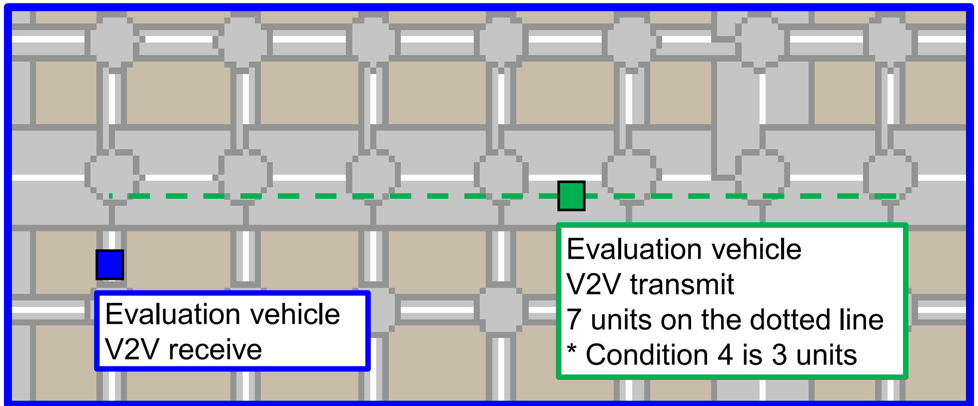

Delay reaching the communication distance and the travel distance at that time

| UC | Condition 1 | | Condition 2 | | Condition 3 | | Condition 4 | |
|---|---|---|---|---|---|---|---|---|
| | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance |
| a-1-4 | 1.4 s | 27.2 m | 1.4 s | 27.2 m | 1.1 s | 21.4 m | 600 ms | 11.7 m |
| a-2 | 1.4 s | 27.2 m | 1.4 s | 27.2 m | 1.1 s | 21.4 m | 600 ms | 11.7 m |
| c-3/c-1 | 1.5 s | 29.2 m | 1.4 s | 27.2 m | 1.1 s | 21.4 m | 600 ms | 11.7 m |
| e-1 | 500 ms | 9.7 m | 400 ms | 7.8 m | 400 ms | 7.8 m | 200 ms | 3.9 m |
| g-1 | 200 ms | 3.9 m | 200 ms | 3.9 m | 100 ms | 1.9 m | 100 ms | 1.9 m |

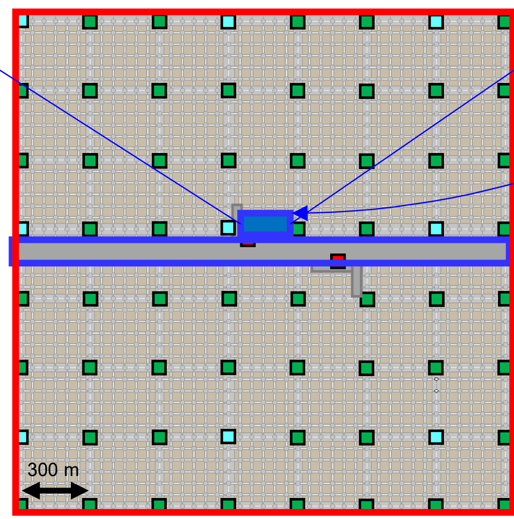
- Condition 1: All SIP-UC normal driving
- Condition 2: Change of reception sensitivity
- Condition 3: Change of reception sensitivity + R2R communication OFF
- Condition 4: Change of reception sensitivity + R2R communication OFF + Vehicle density review

# Appendix: Results of simulation with condition changes (7/10)

■ All SIP-UC: Simulation conditions for general road V2V communication (non-line of sight)




Evaluation area




Overview of simulation

[SIP general roads: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

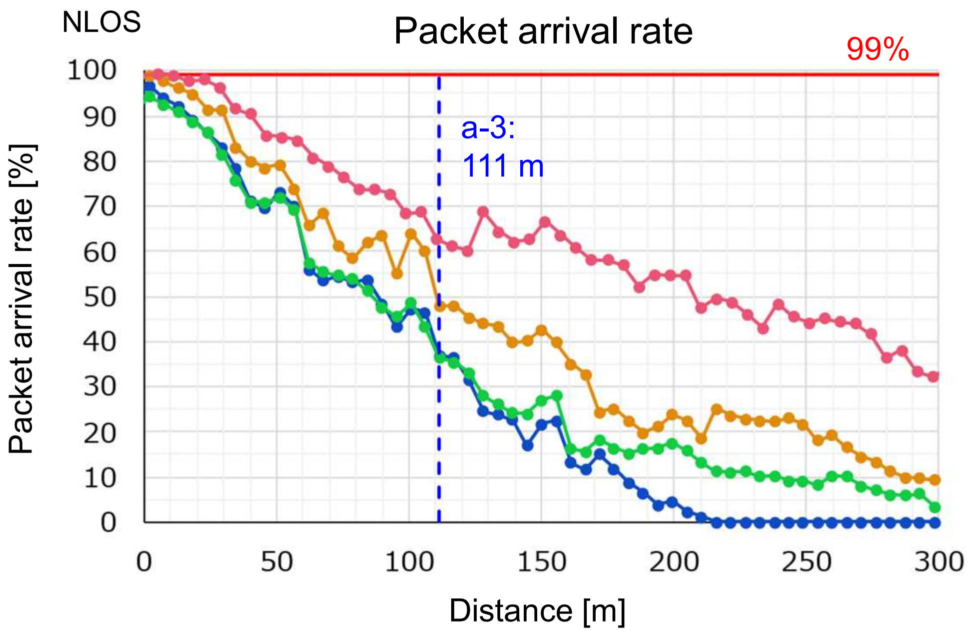
[SIP general roads: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 23 vehicles/km (70 km/h)
  <exception> Condition 4 is 12 vehicles/km

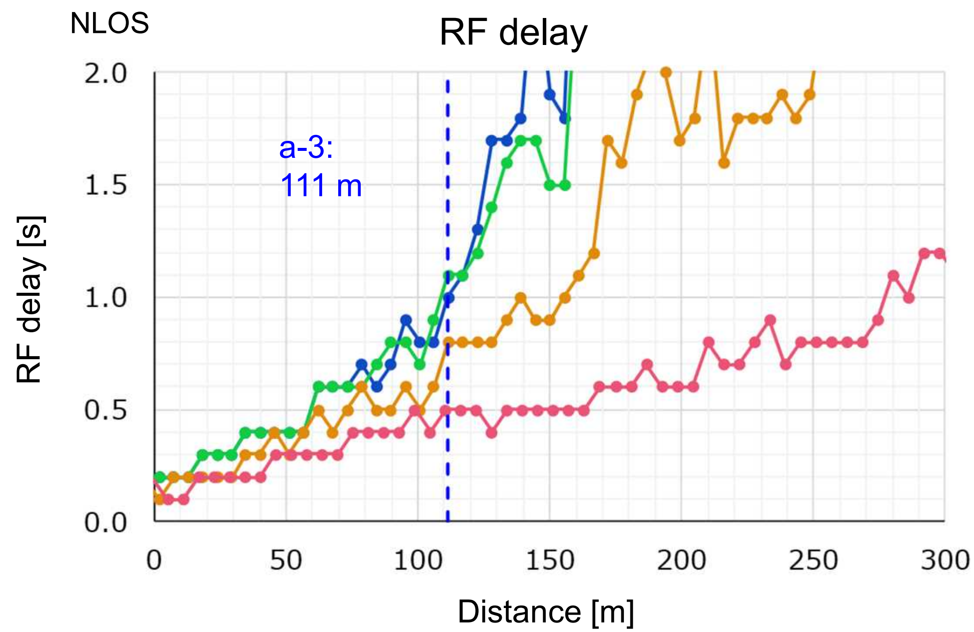
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)
  <exception> Condition 4 is 12 vehicles/km (approx. 1000 units)

■ All SIP-UC: Simulation results for general road V2V communication (non-line of sight)

- **Packet arrival rate improves with each new condition applied, in the following order: Condition 2, Condition 3, and Condition 4.**
- **Communication requirements were not achieved for a-3 from the table below at a delay of 100 ms and PAR of 99%**

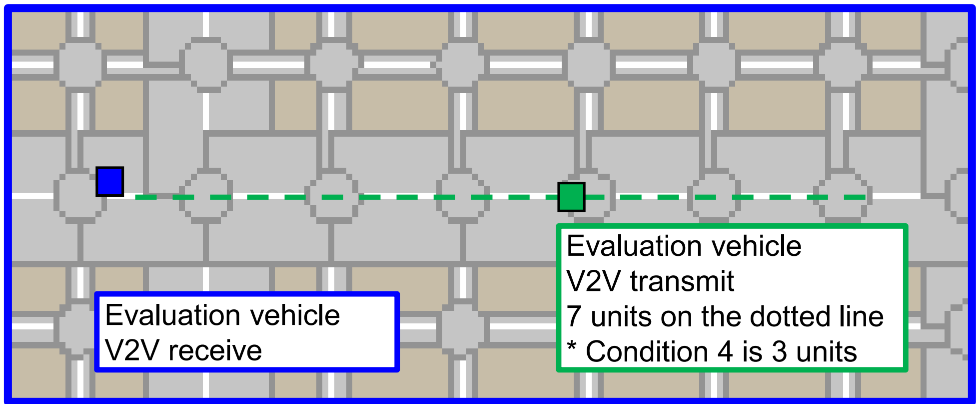


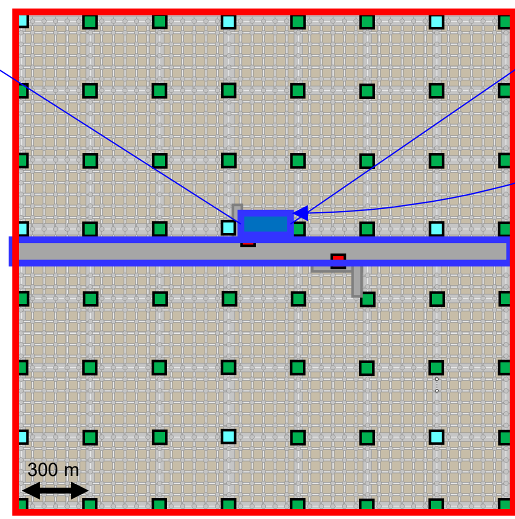

Delay reaching the communication distance and the travel distance at

| UC | Condition 1 | | Condition 2 | | Condition 3 | | Condition 4 | |
|---|---|---|---|---|---|---|---|---|
| | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance |
| a-3 | 1.0 s | 19.4 m | 1.1 s | 21.4 m | 800 ms | 15.6 m | 500 ms | 9.7 m |

■ All SIP-UC: Simulation results for general road V2V communication (within line of sight)




Evaluation area




Overview of simulation

[SIP general roads: Message size]
- RSU: 1150 bytes
- OBU (in SIP evaluation area): 73 bytes

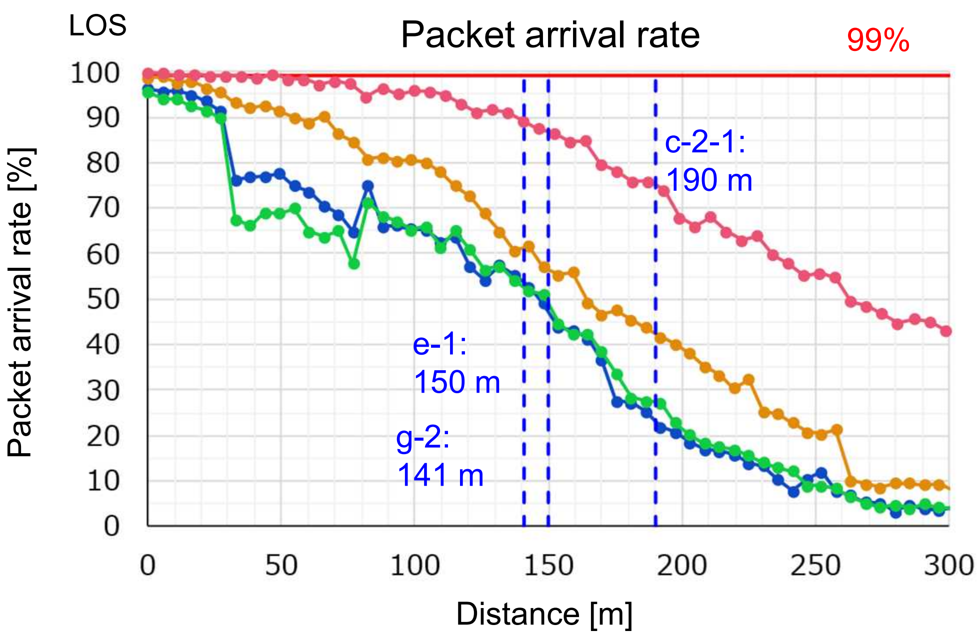
[SIP general roads: Number of RSU and OBU]
- RSU: 1 unit (shared with existing services)
- OBU: 23 vehicles/km (70 km/h)
  <exception> Condition 4 is 12 vehicles/km

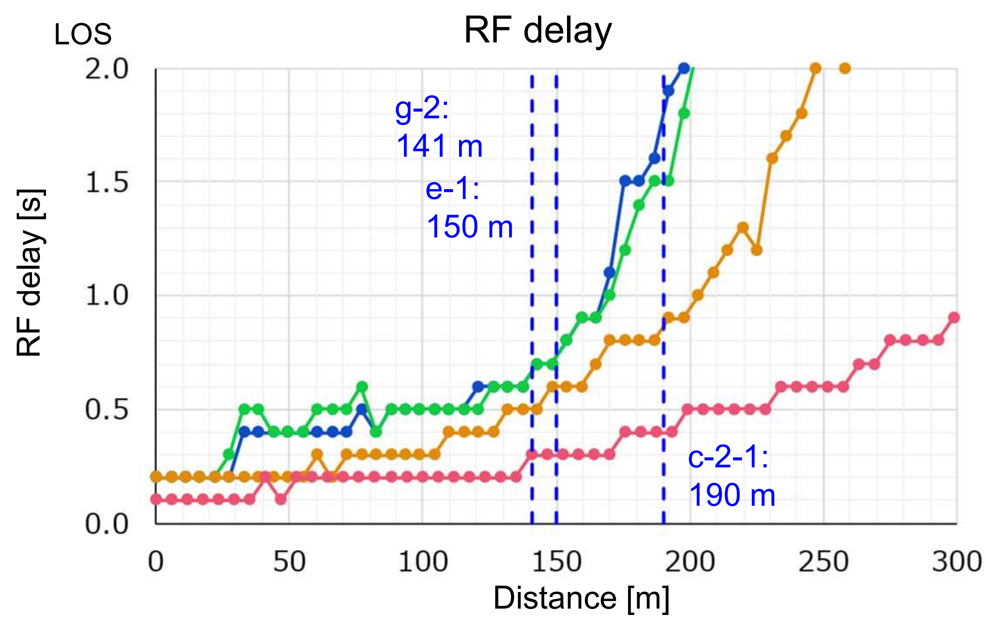
[Existing services: Message size]
- RSU (critical intersections): 2750 bytes
- RSU (general intersections): 1150 bytes
- OBU : 73 bytes

[Existing services: Number RSU and OBU]
- RSU (critical intersections): 9 units
- RSU (general intersections): 55 units
- OBU: 23 vehicles/km (32 km/h, approx. 2000 units)
  <exception> Condition 4 is 12 vehicles/km (approx. 1000 units)

# Appendix: Results of simulation with condition changes (10/10)

- All SIP-UC: Simulation results for general road V2V communication (within line of sight)
  - **Packet arrival rate improves with each new condition applied, in the following order: Condition 2, Condition 3, and Condition 4.**
  - **Communication requirements were not achieved for c-2-1 and e-1 from the table below at a delay of 100 ms and PAR of 99%**
  - **Communication requirements were achieved for g-2 at a delay of 500 ms and PAR of 95%**




Delay reaching the communication distance and the travel distance at that time

| UC | Condition 1 | | Condition 2 | | Condition 3 | | Condition 4 | |
|---|---|---|---|---|---|---|---|---|
| | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance | Delay | Travel distance |
| c-2-1 | 1.9 s | 36.9 m | 1.5 s | 29.2 m | 900 ms | 17.5 m | 400 ms | 7.8 m |
| e-1 | 800 ms | 15.6 m | 800 ms | 15. 6m | 600 ms | 11.7 m | 300 ms | 5.8 m |
| g-2 | 700 ms | 13.6 m | 700 ms | 13.6 m | 500 ms | 9.7 m | 300 ms | 5.8m |

- Condition 1: All SIP-UC normal driving
- Condition 2: Change of reception sensitivity
- Condition 3: Change of reception sensitivity + R2R communication OFF
- Condition 4: Change of reception sensitivity + R2R communication OFF + Vehicle density review

# Appendix: Evaluation of communication area & communication quality (1/5)

- Results of evaluation of communication area & communication quality for R2V communication related UC

| # | Use case | a-1-1, a-1-2 | b-1-1 | c-2-2 | d-1, d-2, d-3, d-4, d-5 | Remarks |
|---|---|---|---|---|---|---|
| | Communication format | V2I（I→V) | V2I（I→V) | V2I（I→V) | V2I（I→V) | |
| A | Transmission power | 19.2dBm | 19.2dBm | 19.2dBm | 19.2dBm | |
| B | Antenna gain | 0dBi | 0dBi | 0dBi | 0dBi | |
| C | Power loss | 0dB | 0dB | 0dB | 0dB | |
| D | Radio section distance | **116.7m (47+69.7m)** | **206.3m** | **75.2m** | **66.6m** | Required communication distance |
| E | Radio propagation loss | 85.3dB | 80.3dB | 66.3dB | 65.2dB | Only for "700 MHz ITS R2V and R2R model" |
| F | Fading loss | 4.4dB | 4.4dB | 4.4dB | 4.4dB | |
| G | Shadowing loss | N/A | N/A | N/A | N/A | In the case of "700 MHz ITS R2V and R2R model", it is included in "Radio propagation loss". |
| H | Reception power = A + (B-C) - (E+F+G) | -70.5dBm | -65.5dBm | -51.5dBm | -50.4dBm | |
| I | Reception judgment threshold | -75.9dBm | -75.9dBm | -75.9dBm | -75.9dBm | 16QAM1/2 |
| J | Line margin =H-I | **5.4dB** | **10.4dB** | **24.4dB** | **25.5dB** | |
| | Compatibility J≧0dB | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | |

# Appendix: Evaluation of communication area & communication quality (2/5)

■ Results of evaluation of communication area & communication quality for V2V communication related UC

| # | Use case | c-1, c-3 | c-2-1 | e-1 | g-1 | g-2 | Remarks |
|---|---|---|---|---|---|---|---|
| | Communication format | V2V | V2V | V2V | V2V | V2V | |
| A | Transmission power | 19.2dBm | 19.2dBm | 19.2dBm | 19.2dBm | 19.2dBm | |
| B | Antenna gain | 0dBi | 0dBi | 0dBi | 0dBi | 0dBi | |
| C | Power loss | 3dB | 3dB | 3dB | 3dB | 3dB | |
| D | Radio section distance | **250m** | **190m** | **150m** | **60m** | **141m** | Required communication distance |
| E | Radio propagation loss | 83.5dB | 80.8dB | 76.5dB | 65.4dB | 75.7dB | Ito / Taga model |
| F | Fading loss | 6.4dB | 6.4dB | 6.4dB | 6.4dB | 6.4dB | |
| G | Shadowing loss | 4dB | 4dB | 4dB | 0dB | 0dB | |
| H | Reception power<br>= A + (B-C) - (E+F+G) | -77.7dBm | -75.0dBm | -70.7dBm | -55.6dBm | -65.9dBm | |
| I | Reception judgment threshold | -81dBm | -81dBm | -81dBm | -81dBm | -81dBm | QPSK1/2 |
| J | Line margin<br>=H-I | **3.3dB** | **6.0dB** | **10.3dB** | **25.4dB** | **15.1dB** | |
| | Compatibility<br>J≧0dB | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | |

# Appendix: Evaluation of communication area & communication quality (3/5)

■ Results of evaluation of communication area & communication quality for V2R communication related UC

| # | Use case | d-1, d-2, d-3, d-4 | f-2 | Remarks |
|---|---|---|---|---|
| | Communication format | V2I（V→I） | V2I（V→I） | |
| A | Transmission power | 19.2dBm | 19.2dBm | |
| B | Antenna gain | 0dBi | 0dBi | |
| C | Power loss | 3dB | 3dB | |
| D | Radio section distance | **66.6m** | **150m** | Required communication distance |
| E | Radio propagation loss | 65.2dB | 75.3dB | Only for "700 MHz ITS R2V and R2R model" |
| F | Fading loss | 4.4dB | 4.4dB | |
| G | Shadowing loss | N/A | N/A | In the case of "700 MHz ITS R2V and R2R model", it is included in "Radio propagation loss". |
| H | Reception power<br>= A + (B-C) - (E+F+G) | -53.4dBm | -63.5dBm | |
| I | Reception judgment threshold | -81dBm | -81dBm | QPSK1/2 |
| J | Line margin<br>=H-I | **27.6dB** | **17.5dB** | |
| | Compatibility<br>J≧0dB | **Requirement achieved** | **Requirement achieved** | |

# Appendix: Evaluation of communication area & communication quality (4/5)

■ Results of evaluation of communication area & communication quality for negotiation-related UC (a-1-3)

| # | Use case | a-1-3 | | | | Remarks |
|---|---|---|---|---|---|---|
| | Communication format | (1) V2I (I→V)<br>< BM > Provide location information (main route) | (2) V2I (I→V)<br>< BM > Provide location information (connecting route) | (3) V2I (I→V)<br>< Negotiation > Request adjustment/update (main route) | (4) V2I (V→I)<br>< Negotiation > Response adjustment/update (main route) | |
| A | Transmission power | 19.2dBm | 19.2dBm | 19.2dBm | 19.2dBm | |
| B | Antenna gain | 0dBi | 0dBi | 0dBi | 0dBi | |
| C | Power loss | 0dB | 0dB | 0dB | 3dB | |
| D | Radio section distance | **266.7m** | **116.7m (47+69.7m)** | **266.7m** | **266.7m** | Required communication distance Main route: LoS ; Connecting route: NLoS |
| E | Radio propagation loss | 84.3dB | 82.5dB | 84.3dB | 84.3dB | Only for "700 MHz ITS R2V and R2R model" |
| F | Fading loss | 4.4dB | 4.4dB | 4.4dB | 4.4dB | |
| G | Shadowing loss | N/A | N/A | N/A | N/A | In the case of "700 MHz ITS R2V and R2R model", it is included in "Radio propagation loss". |
| H | Reception power<br>= A + (B-C) - (E+F+G) | -69.5dBm | -67.7dBm | -69.5dBm | -72.5dBm | |
| I | Reception judgment threshold | -75.9dBm (*1) | -75.9dBm (*1) | -75.9dBm (*1) | -81dBm (*2) | (*1) R2V, 16QAM1/2<br>(*2) V2V, QPSK1/2 |
| J | Line margin<br>=H-I | **6.4dB** | **8.2dB** | **6.4dB** | **8.5dB** | |
| | Compatibility<br>J≧0dB | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | |

# Appendix: Evaluation of communication area & communication quality (5/5)

- Results of evaluation of communication area & communication quality for negotiation-related UC (a-1-4, a-2, a-3)

| # | Use case | a-1-4, a-2 | | a-3 | | Remarks |
|---|---|---|---|---|---|---|
| | Communication format | (1) V2V<br>< Negotiation ><br>Request adjustment/update | (2) V2V<br>< Negotiation ><br>Response adjustment/update | (1) V2V<br>< Negotiation ><br>Request adjustment/update | (2) V2V<br>< Negotiation ><br>Response adjustment/update | |
| A | Transmission power | 19.2dBm | 19.2dBm | 19.2dBm | 19.2dBm | |
| B | Antenna gain | 0dBi | 0dBi | 0dBi | 0dBi | |
| C | Power loss | 3dB | 3dB | 3dB | 3dB | |
| D | Radio section distance | **255m** | **255m** | **111.1m** | **111.1m** | Required communication distance |
| E | Radio propagation loss | 83.7dB | 83.7dB | 83.8dB | 83.8dB | Ito / Taga model<br>a-3：NLoS |
| F | Fading loss | 6.4dB | 6.4dB | 6.4dB | 6.4dB | |
| G | Shadowing loss | 4dB | 4dB | 4dB | 4dB | |
| H | Reception power<br>= A + (B-C) - (E+F+G) | -77.9dBm | -77.9dBm | -78dBm | -78dBm | |
| I | Reception judgment threshold | -81dBm | -81dBm | -81dBm | -81dBm | QPSK1/2 |
| J | Line margin<br>=H-I | **3.1dB** | **3.1dB** | **3.0dB** | **3.0dB** | |
| | Compatibility<br>J≧0dB | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | **Requirement achieved** | |

This report documents the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 2nd Phase, Automated Driving for Universal Services (SIP-adus, NEDO management number: JPNP18012) that was implemented by the Cabinet Office and was served by the New Energy and Industrial Technology Development Organization (NEDO) as a secretariat.