Trial of Cellular Vehicle-to-Everything (C-V2X) Use Case Verification for Connected Autonomous Vehicle (CAV) with Radio Equipment Operating in the 5.9 GHz Band (T00823 & T00877)

Test Plan and Report

(25/04/2024- 24/10/2024 & 25/11/2024-24/05/2025)

Version 1.1

Hong Kong Applied Science and Technology Research Institute Company Limited (ASTRI)

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Executive Summary

This document specifies the testing plan and results of C-V2X Use Cases and V2X communication latency and success rate testing in STF project “PSRI/52/2210/RA - Evaluation of Smart Mobility Roadside Infrastructure for Connected Autonomous Vehicles”. The testing conducted at HK Science Park Trial Site from **25 April 2024 to 24 October 2024** and **25 November 2024 to 24 May 2025.**

Document Control

Revision	Date	Prepared By	Reviewed By	Description of Changes	Approved By
1	01 Aug 2025	Wu Siqiao	Andy, Zhou Zigan	Initial version	
2	21 Aug 2025	Shuhua Lin	Andy, Zhou Zigan	1st revised according to reviewer’s comments	Andy, Zhou Zigan

1 Preface

This document is about the communication stability and functionality testing of multi-brand OBUs' and the new 5G RSUs'(RS1000) under 20 MHz (5905 –5925MHz) bandwidth.

1.1 Abbreviations and Acronyms

V2X	Vehicle-to-Everything (V2V + V2I + V2P + V2N)
C-V2X	Cellular V2X
CAV	Connected Autonomous Vehicle
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2N	Vehicle-to-Network
HV	Host Vehicle
RV	Remote Vehicle
3GPP	3rd Generation Partnership Program
CAN	Controller Area Network
RSU	Roadside Unit
OBU	On-Board Unit
VRU	Vulnerable Road User
JSON	JavaScript Object Notation
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
REST	Representational State Transfer
MEC	Mobile Edge Computing
ICGW	In-Car Gateway
EGW	Edge Gateway

Table 1 Abbreviations and Acronyms

2 Introduction

2.1 Background

ASTRI started to develop C-V2X technology in 2016, and successfully conducted road test at the Hong Kong Science Park for the first time in June 2017.

To comprehensively study the application scenarios of the C-V2X technology in Hong Kong's roads, and the methodology to plan the network and infrastructure required for the application, ASTRI has been in close contact with the Transport Department from November 2019, through the Innovation and Technology Fund of the Innovation and Technology Commission. Carry out research and test projects related to the C-V2X technology.

With the support of Transport Department & Innovation and Technology Commission, on March 2021 ASTRI launches one of the world's largest C-V2X public road tests, promoting Smart Mobility to improve the city's mobility competence while enhancing road safety and efficiency. The site of the pilot project is 14 kilometres between the Hong Kong Science Park and Sha Tin Town Centre, and the project has received the support of the Sha Tin District Council, Transport Department, Highways Department, and other relevant government departments.

With the rapid development of autonomous vehicles, multiple vendors are likely to deploy vehicles using their own technologies and strategies. However, challenges during the real-world deployment are evident. In such cases, hazardous situations may arise, for example, potential collisions or traffic stagnation at intersections when autonomous vehicles from different systems encounter each other but cannot communicate to determine right-of-way.

Therefore, in this project (PSRI/52/2210/RA), we established a unified interface for accessing autonomous vehicles from multiple vendors, as well as the smart roadside system. This interface enables policy negotiation and centralized management, it also supports advanced features such as cooperative perception, enhancing the safety, efficiency, and operational effectiveness of autonomous vehicles, paving the way for the autonomous driving era in Hong Kong.

2.2 C-V2X System

C-V2X stands for Cellular Vehicle-to-Everything. It is a wireless communication technology that enables vehicles to communicate with various entities in their surroundings, including other vehicles (V2V), infrastructure (V2I), pedestrians (V2P), and networks (V2N). C-V2X is designed to enhance road safety, improve traffic efficiency, and enable new applications and services in the context of connected and autonomous vehicles (CAVs) and intelligent transportation systems (ITS).

C-V2X utilizes 5.9GHz dedicated channel for V2V and V2I communications, and utilizes cellular networks, specifically the LTE (Long-Term Evolution) and 5G networks, for V2P and V2N communications, or to establish the communication between vehicles and other elements of the transportation ecosystem.

The following figure is an illustration of the C-V2X Network System.

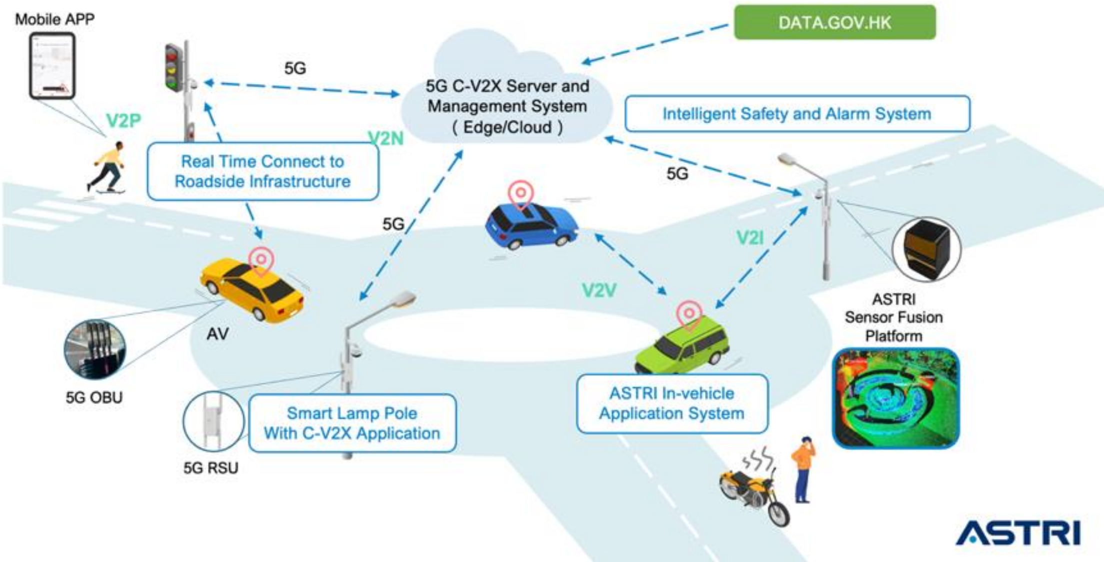

Figure 1 C-V2X System Demonstration

2.3 C-V2X Trial Site

2.3.1 Trial Site in HK Science Park

Total 6 RSUs were installed inside the Science Park. 5 Lenovo RSUs (RS1000) are configured to **20MHz (5905MHz ~ 5925MHz)** and 1 HUAWEI RSU(RSU5201) will be allocated under **10MHZ (5905MHz ~ 5915MHz)** Channel. This Trial Site will be the primary site for testing communication stability of V2X equipment and several V2X safety use cases in this report period.

Figure 2 Trial Site in HK Science Park

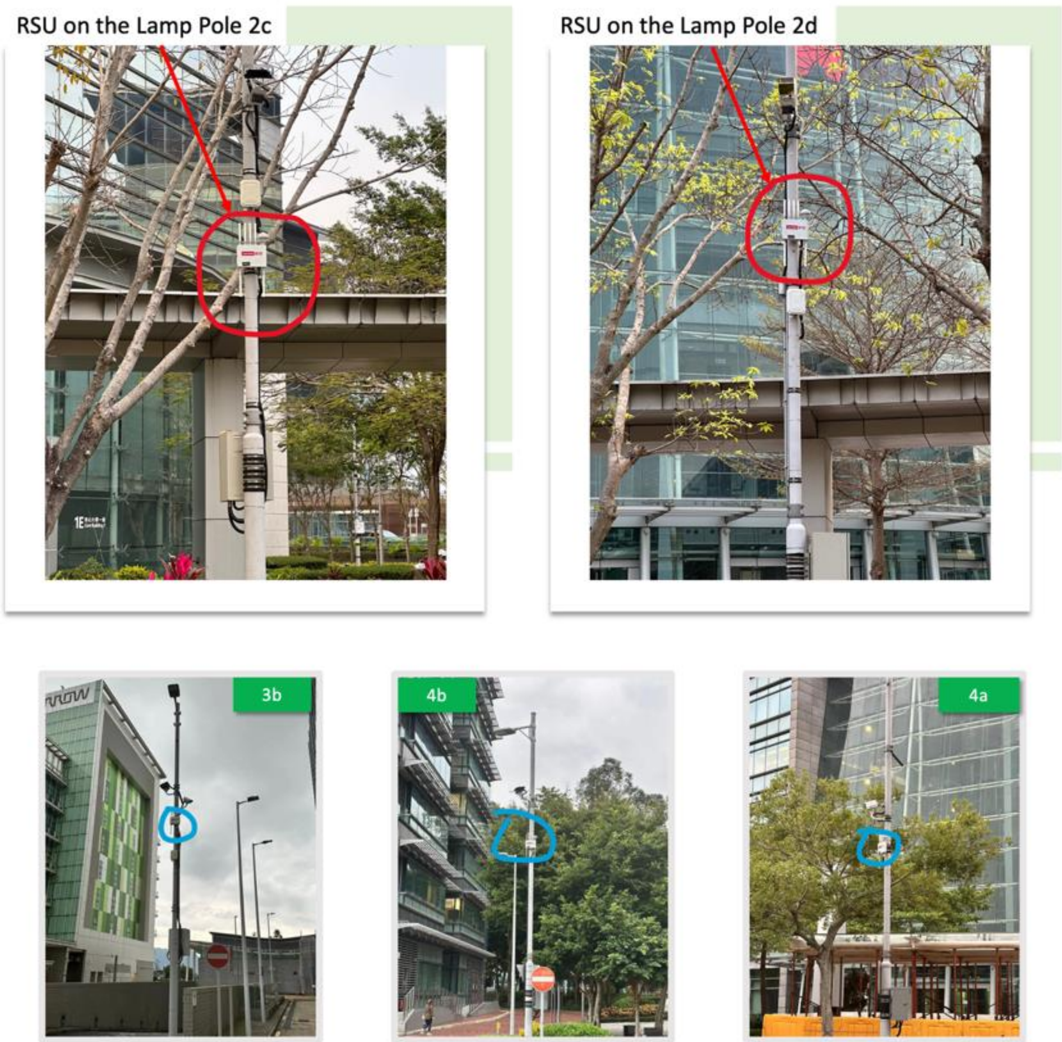

Figure 3 RSU field installation

2.3.2 Trial Site along HK Science Park to Shatin Center

Shatin C-V2X Trial site has total of 14 HUAWEI RSUs (model 6201) installed from HKSTP to Shatin center area. All the 14 RSUs currently operate at 10MHz, and all can be configured to operate at 20MHz. 5 of them are installed on the traffic light Post (red markers) and 9 are on lamppost (grey markers).

<u>This route is not the main testing site for this report period</u>, but we will continue the testing along this route in the coming C-V2X/CAV related project.

Figure 4 Trial Site along HK Science Park to Shatin Center

2.4 OBU and RSU Specification

2.4.1 RSU Model

The RSU model being used in HK Science Park is **Lenovo RSU1000** and **HUAWEI RSU5201**.

Figure 5 Lenovo RSU1000

Equipment Particulars	A. Roadside Unit Lenovo 5G Roadside Unit RS1000
Frequency and Maximum Frequency Tolerance	5905 – 5925 MHz (transmit and receive) +/- 0.1 ppm
Class of Emission	20M0G7W
Maximum Effective Radiated Power	25 dBm EIRP
Equipment Characteristics	3GPP Release 14

Table 2 Lenovo RSU1000 Specification

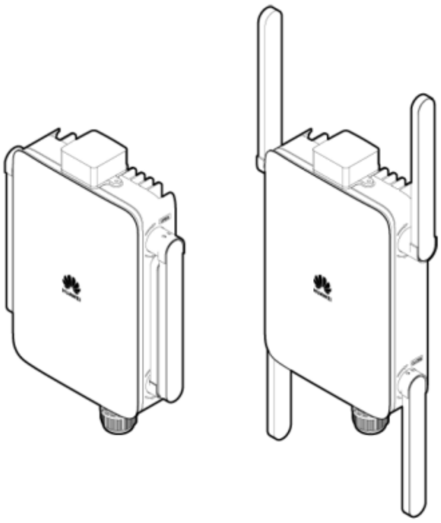

Figure 6 HUAWEI RSU5201

PC5 Transmit Power	23dBm±2dB0
SL - Frequency band	47
SL - bandwidth	10M
SL - Center Frequency	55090/55140
Min MC5	0
Max MC5	17
PC 5 Synchronization source	GNSS

Table 3 HUAWEI RSU5201 Specification

2.4.2 OBU Model

Lenovo RSU1000

The OBU model being used in HK Science Park is **Genvict LTE-V2X OBU (LB-LW10/10A)** and **Genvict 5G (CB-LS20B)**.

Figure 7 Genvict LTE-V2X OBU (Model: LB-LW10/10A)

Transmit Power		~20dBm±2dB
LTE-V	**Frequency Band**	C-V2X TDD B47
	Frequency	5.905GHz - 5.925GHz
	Distance	600m
	Bandwidth	10M/20M
GNSS	**Supporting Satellites**	Beidou, Galileo, GLONASS, GPS
	Refresh Rate	≤ 18Hz
	Positioning Accuracy	2,5m CEP 50%

Table 4 Genvict LTE-V2X OBU (Model: LB-LW10/10A) Specification

Figure 8 Genvict 5G (CB-LS20B)

Transmit Power		~23dBm±2dB
5G	**Frequency Band**	NR-V2X n78/n79
	Frequency	3.3GHz - 3.8GHz / 4.8GHz - 5.0GHz
	Distance	>1000m
	Bandwidth	20M/40M/100M
GNSS	**Supporting Satellites**	Beidou, Galileo, GLONASS, GPS
	Refresh Rate	≤ 20Hz
	Positioning Accuracy	Centimeter-level (IMU&RTK)

Table 5 Genvict 5G (CB-LS20B) Specification

3 Testing Plan and Methodology

The testing mainly focusses on the communication stability and functionality testing of multi-brand OBUs and the new 5G RSUs'(RS1000) under the 20MHz (5905 –5925MHz) bandwidth.

In this report period, we will mainly use RSU1000 installed inside HK Science Park to test with multi-brand OBUs at 20MHz. The test plan including:

- CAV use cases enabled by multi-brand OBUs and RSUs
  - Traffic Light Signal
  - Roundabout Warning
  - Platooning
- Communication latency and success rate

3.1 V2X Use Cases

3.1.1 V2X Use Cases Testing Configuration and Description

1	**Use Case**	Traffic Light Signal
	Bandwidth	20MHz
	Location	Intersection on East Avenue
	Description	• The CAV cooperative roadside subsystem sends the traffic light signal to the autonomous driving system through the common interface, and the autonomous driving system takes actions accordingly.
2	**Use Case**	Roundabout Warning
	Bandwidth	20MHz
	Location	Science Park Road - Roundabout – HKSTP East Ave
	Description	• When an autonomous vehicle enters a roundabout, the autonomous vehicle's view may be blocked by cars in adjacent lanes or green belts. • Since roundabouts have multiple entrances/exits, it can be dangerous if the AV does not have an overall awareness of the roundabout. The roadside subsystem can send the overall perception of the roundabout to the AV through the common interface, and the autonomous driving system takes actions based on the additional information to pass the roundabout safely.
3	**Use Case**	Platooning
	Bandwidth	20MHz
	Location	Science Park West Avenue & Science Park Road
	Description	• N2V policy, where the CAV central system considers the overall traffic situation and gives suggestions to all vehicles in the area. For example, the CAV central system can choose a leader among a group of AVs and plan a route for the group to build an AV platooning. When the AV group arrives at the endpoint, the CAV central system can dissolve the AV platooning.

Table 6 V2X Use Cases Testing Configuration and Description

3.1.2 V2X Use Cases Test Flow

Roles	RSU, OBU, Vehicles
prerequisites	RSU and OBU are power on and ready for use
Methodology	• Configure V2I event to RSU from V2X Server. • Drive vehicles along the trial site route heading to the event location. • Checking the OBU logs to verify whether alarms are received.
Expected Result	• The OBU logs show the alarms are received with timestamp and location information.

Table 7 V2X Use Cases Test Flow

3.2 Communication Latency and Success Rate

Communication test between OBU and RSU, RSU sends GPS message to the V2X server, establishes connection with the V2X server through MQTT, receives the messages from V2X server and forwards it to OBU via MQTT.

Test Flow:

- RSU and OBU perform clock synchronization with the server respectively and ensure that the time deviation is less than the specified range.
- Configure the event message and sending interval on V2X Server, and publish to MQTT with specific topic for RSU subscription.
- RSU subscribes the message from MQTT and publish to MQTT with specific topic for OBU subscription, RSU logs the timestamp of message sent.
- OBU subscribes the message from MQTT and logs the timestamp of message received.
- Calculate the latency by using receive time minus send time.
- Calculate the success rate by accumulating the ratio of the number of messages sent and received within a specific duration.

4 Test Cases and Results

4.1 V2X Use Cases Testing Result

4.1.1 Traffic Light Signal (V2I)

The AV successfully receives the traffic light information from RSU. It illustrates the result on the screen of vehicle, and the traffic light color at the same time.

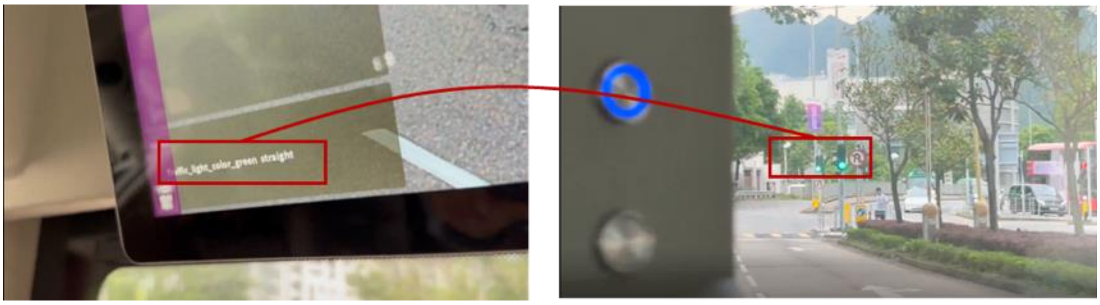

Figure 9 Road Work Alarm Success Rate Result

4.1.2 Roundabout Warning (V2I)

This use case is designed to demonstrate that the AV successfully receives the detection information from RSU and slows down. The figure illustrates the result on the screen of vehicle, the vehicle speed slows down when receiving the information from RSU on lamp post.

Firstly, refer to Figure 10. The AV is navigating within the roundabout at a normal operating speed of 10 km/h.

Figure 10 AV Original Speed

Next, refer to Figure 11. In this scenario, a pedestrian is crossing the roundabout. The left side shows a real-world (ground-level) photo of the scene, while the right side provides a top-down (aerial) view of the roundabout.

Figure 11 The real picture of roundabout

After that, the roadside system detects the pedestrian and generates a decision suggestion by combining data from the vehicle side, then transmits the information to the AV.

Refer to Figure 12. It presents LiDAR point cloud data collected from a roadside sensor (left) and an autonomous vehicle onboard sensor (right). The left side provides a comprehensive view of the roundabout environment from a fixed position, capturing objects and vehicles within the area. The right side shows the environment from the perspective of the autonomous vehicle as it navigates the roundabout.

The red arrows indicate the correspondence between objects detected in the two views, demonstrating how roadside and onboard perception complement each other.

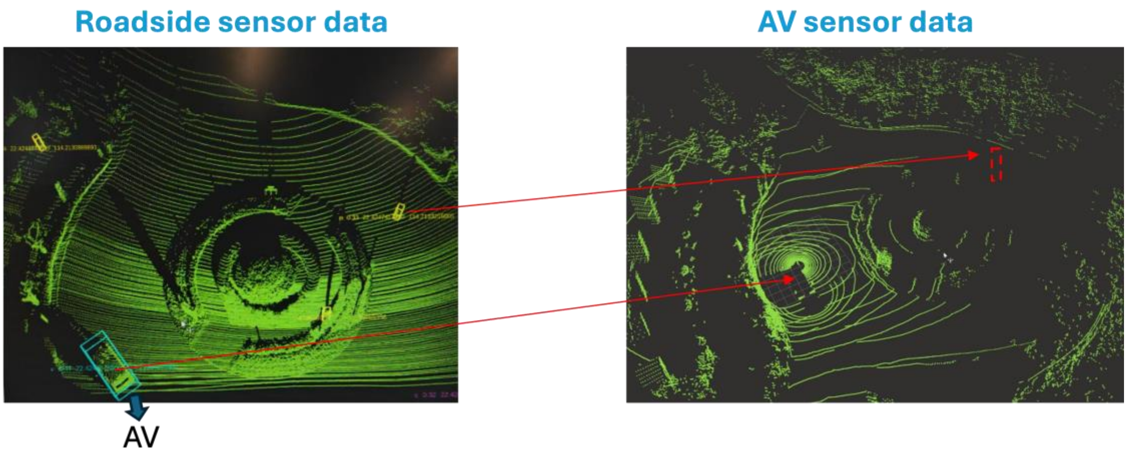

Figure 12 LiDAR Point Cloud Data from Roadside and AV Sensor

Finally, refer to Figure 13, which shows the result displayed on the vehicle screen. Upon receiving the information, the AV initiates a controlled deceleration to 5 km/h, yielding to the crossing pedestrian.

Figure 13 AV Speed Reduction Triggered by RSU Information

4.1.3 Platooning

The images illustrate the process of platoon formation and movement for autonomous vehicles (AVs) under the control of the CAV central system.

The first image on the left shows AV1, which acts as the leader vehicle in this scenario.

The central image shows the convoy's route, located along Science Park East Street. Here, the orange arrow indicates AV1 starting from its initial position and heading towards the rendezvous point. The red arrow represents AV2 following behind AV1 after joining the platoon at the rendezvous point. The vehicles then move together along the planned route. Finally, the green arrow shows the platoon reaching the endpoint, where the vehicles will disband and continue driving independently.

The images on the right display different moments during the platooning process. The top image captures AV1 and AV2 traveling together as a platoon, maintaining coordinated speed and distance. The bottom image shows the vehicles after reaching the endpoint, where they leave the platoon and proceed on their own routes.

In summary, these images collectively demonstrate how AV1 and AV2 meet, travel together as a platoon under centralized coordination, and then separate after reaching the endpoint.

Figure 14 The routes and results of platooning.

Refer to Figure 15, the platooning process of AV1 and AV2 can be seen in real time on the v2x cloud platform.

Figure 15 Platooning Process on the V2X Cloud Platform

4.2 Communication Latency and Success Rate Testing Result

4.2.1 Transmission latency through V2V and V2I less than 50ms

The testing primarily focuses on the communication stability of multiple onboard units (OBUs) and roadside units (RSUs) under the 20 MHz (5905–5925 MHz) bandwidth. In this test, we will mainly use RSUs installed within Hong Kong Science Park to evaluate performance with multiple OBUs at 20MHz. The test plan includes the following: Since all RSUs and OBUs are synchronized via satellite, no special time calibration will be conducted during the test process, ensuring the accuracy of the test timing. For V2I transmission latency, the test covers both RSU-to-OBU and OBU-to-RSU communication directions; for V2V transmission latency, it includes OBU A to OBU B and OBU B to OBU A communication directions.

4.2.1.1 V2I transmission latency test (RSU → OBU)

Latency from the message sent by RSU to receive by OBU

Duration	≈10s (13:30:12.368~ 13:30:21.390)
Sending interval	1s
Number of messages sent by RSU	10
Number of messages received by OBU	10
Minimum latency	8ms
Maximum latency	18ms
Average latency	**11.8ms**

Table 8 V2I (RSU to OBU) transmission latency testing result

The V2I (RSU to OBU) test achieved an average latency of 11.8ms, meeting the sub-50ms target. All 10 messages were successfully transmitted, confirming reliable performance.

Detailed logs& records

<table>
<tr><td colspan="2">1st Result</td></tr>
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B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 11
2025-05-07 13:30:12.376391:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da
2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20
00 00 11</td></tr>
<tr><td>Sending time</td><td>13:30:12.368</td></tr>
<tr><td>Receiving time</td><td>13:30:12.376</td></tr>
<tr><td>Latency</td><td>8ms</td></tr>
<tr><td colspan="2">2nd Result</td></tr>
<tr><td colspan="2">[2025-05-07 13:30:13.371]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2
B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 12
2025-05-07 13:30:13.383319:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da
2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20
00 00 12</td></tr>
<tr><td>Sending time</td><td>13:30:13.371</td></tr>
<tr><td>Receiving time</td><td>13:30:13.383</td></tr>
<tr><td>Latency</td><td>12ms</td></tr>
<tr><td colspan="2">3rd Result</td></tr>
<tr><td colspan="2">[2025-05-07 13:30:14.373]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2
B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 13
2025-05-07 13:30:14.384428:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da
2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20
00 00 13</td></tr>
<tr><td>Sending time</td><td>13:30:14.373</td></tr>
</table>

Receiving time	13:30:14.384
Latency	11ms
4th Result	
[2025-05-07 13:30:15.375]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 14 2025-05-07 13:30:15.393321:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 14	
Sending time	13:30:15.375
Receiving time	13:30:15.393
Latency	18ms
5th Result	
[2025-05-07 13:30:16.378]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 15 2025-05-07 13:30:16.392456:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 15	
Sending time	13:30:16.378
Receiving time	13:30:16.392
Latency	14ms
6th Result	
[2025-05-07 13:30:17.380]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 16 2025-05-07 13:30:17.394681:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 16	
Sending time	13:30:17.380
Receiving time	13:30:17.394
Latency	14ms
7th Result	
[2025-05-07 13:30:18.383]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 17 2025-05-07 13:30:18.396621:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 17	
Sending time	13:30:18.383
Receiving time	13:30:18.396
Latency	13ms
8th Result	
[2025-05-07 13:30:19.385]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 18 2025-05-07 13:30:19.395762:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 18	
Sending time	13:30:19.385
Receiving time	13:30:19.395
Latency	10ms
9th Result	
[2025-05-07 13:30:20.388]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 19 2025-05-07 13:30:20.397771:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 19	
Sending time	13:30:20.388
Receiving time	13:30:20.397
Latency	9ms
10th Result	
[2025-05-07 13:30:21.390]RW30_RSU7001[D]send wmm[ts](len = 0059): 04 00 8E 26 00 35 42 66 A6 90 68 70 00 00 00 00 02 00 DA 2 B 9B 96 FD DD 10 63 DF BB 3E 5E 7D 34 EF DC 83 0E CC 3C B6 E1 87 D8 D0 BC 5A 4D 50 08 00 00 20 02 00 02 00 20 00 00 20 2025-05-07 13:30:21.399914:[D]WMS_WNC->:ltev rx data:59:04 00 8e 26 00 35 42 66 a6 90 68 70 00 00 00 00 02 00 da 2b 9b 96 fd dd 10 63 df bb 3e 5e 7d 34 ef dc 83 0e cc 3c b6 e1 87 d8 d0 bc 5a 4d 50 08 00 00 20 02 00 02 00 20 00 00 20	
Sending time	13:30:21.390
Receiving time	13:30:21.399
Latency	9ms

Table 9 Logs and records of V2I transmission test 1

4.2.1.2 V2I transmission latency test (OBU → RSU)

Latency from the message sent by OBU to receive by RSU

Duration	≈2s (17:05:35.164~ 17:05:36.964)
Sending interval	200ms
Number of messages sent by OBU	10
Number of messages received by RSU	10
Minimum latency	26ms
Maximum latency	46ms
Average latency	**32.1ms**

Table 10 V2I (OBU to RSU) transmission latency testing result

The V2I (OBU to RSU) test achieved an average latency of 32.1ms, meeting the sub-50ms target. All 10 messages were successfully transmitted, confirming reliable performance.

Detailed logs & records

1st Result

```
2025-05-07 17:05:35.163678:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da e5
 af 45 5f 1e 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:35.190]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 E5 AF 45 5F 1E 10 00 80 00 01 00 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:35.164
Receiving time	17:05:35.190
Latency	26ms

2nd Result

```
2025-05-07 17:05:35.363675:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da e6
 af 45 5f 1d 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:35.392]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 E6 AF 45 5F 1D 10 00 80 00 01 00 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:35.364
Receiving time	17:05:35.392
Latency	28ms

3rd Result

```
2025-05-07 17:05:35.564051:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da e8
 af 45 5f 1b 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:35.592]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 E8 AF 45 5F 1B 10 00 80 00 00 80 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:35.564
Receiving time	17:05:35.592
Latency	28ms

4th Result

```
2025-05-07 17:05:35.764028:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da eb
 af 45 5f 19 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:35.801]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 EB AF 45 5F 19 10 00 80 00 01 00 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:35.764
Receiving time	17:05:35.801
Latency	37ms

5th Result

```
2025-05-07 17:05:35.963666:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da ed
 af 45 5f 16 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:35.993]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 ED AF 45 5F 16 10 00 80 00 01 00 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:35.964
Receiving time	17:05:35.993
Latency	29ms

6th Result

```
2025-05-07 17:05:36.164032:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da ef
 af 45 5f 14 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00
[2025-05-07 17:05:36.194]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA
 EF AF 45 5F 14 10 00 80 00 00 80 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00
```

Sending time	17:05:36.164
Receiving time	17:05:36.194
Latency	30ms

7th Result	
2025-05-07 17:05:36.363637:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da f0 af 45 5f 13 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 [2025-05-07 17:05:36.396]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA F0 AF 45 5F 13 10 00 80 00 00 80 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00	
Sending time	17:05:36.364
Receiving time	17:05:36.396
Latency	32ms
8th Result	
2025-05-07 17:05:36.563784:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da f2 af 45 5f 11 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 [2025-05-07 17:05:36.596]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA F2 AF 45 5F 11 10 00 80 00 00 80 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00	
Sending time	17:05:36.564
Receiving time	17:05:36.596
Latency	32ms
9th Result	
2025-05-07 17:05:36.764326:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da f4 af 45 5f 0f 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 [2025-05-07 17:05:36.797]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA F4 AF 45 5F 0F 10 00 80 00 00 80 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00	
Sending time	17:05:36.764
Receiving time	17:05:36.797
Latency	33ms
10th Result	
2025-05-07 17:05:36.964054:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 1e 00 00 c3 0f da f6 af 45 5f 0e 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 [2025-05-07 17:05:37.010]RW30_RSU7001[D]recv wmm[ts](len = 0051): 04 00 11 00 2E 02 80 00 00 00 00 00 00 1E 00 00 C3 0F DA F6 AF 45 5F 0E 10 00 80 00 01 00 00 7E 7D 07 D0 7F 7F FF BE 00 10 00 00 00 00 13 0C 00 00 00	
Sending time	17:05:36.964
Receiving time	17:05:37.010
Latency	46ms

Table 11 Logs and records of V2I transmission test 2

4.2.1.3 V2V Transmission Latency Test

Latency from the message sent by OBU A to receive by OBU B

Duration	≈2s (15:49:29.164~ 15:49:30.964)
Sending interval	200ms
Number of messages sent by OBU A	10
Number of messages received by OBU B	10
Minimum latency	9ms
Maximum latency	28ms
Average latency	**21.8ms**

Table 12 V2V (OBU A to OBU B) Transmission latency testing result

The V2V (OBU A to OBU B) test achieved an average latency of 21.8ms, meeting the sub-50ms target. All 10 messages were successfully transmitted, confirming reliable performance.

Latency from the message sent by OBU B to receive by OBU A

Duration	≈2s (15:35:29.185~ 15:35:30.984)
Sending interval	200ms
Number of messages sent by OBU B	10
Number of messages received by OBU A	10
Minimum latency	9ms
Maximum latency	16ms
Average latency	**12.4ms**

Table 13 V2V (OBU B to OBU A) transmission latency testing result

The V2V (OBU B to OBU A) test achieved an average latency of 12.4ms, meeting the sub-50ms target. All 10 messages were successfully transmitted, confirming reliable performance.

The average latency of V2V transmission is (21.8ms+12.4ms)/2 = 17.1ms.

Detailed logs & records

1st Result	
2025-05-07 15:49:29.163900:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 59 af 45 62 e5 10 00 80 00 03 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:29.191434:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 59 af 45 62 e5 10 00 80 00 03 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:29.164
Receiving time	15:49:29.191
Latency	27ms
2nd Result	
2025-05-07 15:49:29.363843:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 e5 10 00 80 00 02 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:29.385575:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 e5 10 00 80 00 02 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:29.363
Receiving time	15:49:29.385
Latency	22ms
3rd Result	
2025-05-07 15:49:29.564026:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 e2 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:29.586777:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 e2 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:29.564
Receiving time	15:49:29.586
Latency	22ms
4th Result	
2025-05-07 15:49:29.763963:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 54 af 45 62 e2 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:29.787901:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 54 af 45 62 e2 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:29.764
Receiving time	15:49:29.788
Latency	24ms
5th Result	
2025-05-07 15:49:29.963909:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 53 af 45 62 e0 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:29.992021:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 53 af 45 62 e0 10 00 80 00 01 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:29.964
Receiving time	15:49:29.992
Latency	28ms
6th Result	
2025-05-07 15:49:30.163876:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 54 af 45 62 de 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:30.189294:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 54 af 45 62 de 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:30.164
Receiving time	15:49:30.189
Latency	25ms

7th Result	
2025-05-07 15:49:30.363828:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 de 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:30.389526:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 de 10 00 80 00 00 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:30.364
Receiving time	15:49:30.389
Latency	25ms
8th Result	
2025-05-07 15:49:30.563973:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 56 af 45 62 dd 10 00 80 00 02 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:30.590752:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 56 af 45 62 dd 10 00 80 00 02 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:30.564
Receiving time	15:49:30.591
Latency	27ms
9th Result	
2025-05-07 15:49:30.763913:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 db 10 00 80 00 02 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:30.773422:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 57 af 45 62 db 10 00 80 00 02 00 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:30.764
Receiving time	15:49:30.773
Latency	9ms
10th Result	
2025-05-07 15:49:30.963996:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 56 af 45 62 d9 10 00 80 00 01 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-07 15:49:30.972704:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d3 56 af 45 62 d9 10 00 80 00 01 80 00 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:49:30.964
Receiving time	15:49:30.973
Latency	9ms

Table 14 Logs and records of V2V transmission test 1

1st Result	
2025-05-06 15:35:29.185165:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 c7 af 45 5f ac 10 00 80 00 04 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:29.194644:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 c7 af 45 5f ac 10 00 80 00 04 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:29.185
Receiving time	15:35:29.194
Latency	9ms
2nd Result	
2025-05-06 15:35:29.385359:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 c2 af 45 5f ac 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:29.397046:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 c2 af 45 5f ac 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:29.385
Receiving time	15:35:29.397
Latency	12ms
3rd Result	
2025-05-06 15:35:29.585292:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 bf af 45 5f ac 10 00 80 00 03 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:29.597908:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 bf af 45 5f ac 10 00 80 00 03 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:29.585
Receiving time	15:35:29.598
Latency	13ms
4th Result	
2025-05-06 15:35:29.785181:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 b7 af 45 5f a9 10 00 80 00 05 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:29.796276:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 b7 af 45 5f a9 10 00 80 00 05 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:29.785
Receiving time	15:35:29.796
Latency	11ms
5th Result	
2025-05-06 15:35:29.984220:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 b0 af 45 5f a9 10 00 80 00 06 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:29.996481:[D]WMS_WNC->:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 b0 af 45 5f a9 10 00 80 00 06 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:29.984
Receiving time	15:35:29.996
Latency	12ms

6th Result	
2025-05-06 15:35:30.184451:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 a8 af 45 5f a7 10 00 80 00 03 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:30.195710:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 a8 af 45 5f a7 10 00 80 00 03 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:30.184
Receiving time	15:35:30.195
Latency	11ms
7th Result	
2025-05-06 15:35:30.384445:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 9f af 45 5f a5 10 00 80 00 04 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:30.397071:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 9f af 45 5f a5 10 00 80 00 04 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:30.384
Receiving time	15:35:30.397
Latency	13ms
8th Result	
2025-05-06 15:35:30.585065:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 99 af 45 5f a4 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:30.600981:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 99 af 45 5f a4 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:30.585
Receiving time	15:35:30.601
Latency	16ms
9th Result	
2025-05-06 15:35:30.784968:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 97 af 45 5f a5 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:30.798224:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 97 af 45 5f a5 10 00 80 00 04 39 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:30.785
Receiving time	15:35:30.798
Latency	13ms
10th Result	
2025-05-06 15:35:30.983708:[D]WMS_WNC->:pc5_tx:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 8f af 45 5f a0 10 00 80 00 05 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00 2025-05-06 15:35:30.998507:[D]WMS_WNC→:ltev rx data:51:04 00 11 00 2e 02 80 00 00 00 00 00 00 00 1e 00 00 c3 0f d1 8f af 45 5f a0 10 00 80 00 05 b9 b8 7e 7d 07 d0 7f 7f ff be 00 10 00 00 00 00 13 0c 00 00 00	
Sending time	15:35:30.984
Receiving time	15:35:30.998
Latency	14ms

Table 15 Logs and records of V2V transmission test 2

Based on the test results, we verified that the communications between OBU and RSU at 20MHz are working properly.

- The V2I transmission (RSU-OBU) latency is 11.8ms.
- The V2I transmission (OBU-RSU) latency is 32.1ms.
- The V2V transmission latency is 17.1ms.

The V2I and V2V communication latency is less than 50ms in test samples.

The test results have successfully met the required KPI target for transmission latency through V2V and V2I, achieving less than 120ms.

5 Conclusion

In this project, all planned test scenarios were successfully completed, including traffic light information interaction (V2I), roundabout warning (V2I), and platooning (V2N).

Specifically, the autonomous vehicle was able to receive traffic signal information from the RSU in the traffic light scenario. This mechanism ensures that autonomous vehicles (CAVs) can accurately and safely comply with real-time traffic signals. This enhances road safety, promotes smoother traffic flow, and supports the effective integration of autonomous vehicles into existing transportation systems.

In roundabout scenario, where the AV's field of view is limited, the roadside subsystem can help the AV make smarter and more timely decisions. This reduces the risk of collisions and other hazards, enabling the AV to navigate complex intersections like roundabouts safely and efficiently.

During the platooning scenario, the CAV central system orchestrates the formation and management of vehicle groups, enabling autonomous vehicles to travel cooperatively along a planned route. By selecting meeting points, endpoints, and a leader vehicle, the system ensures that vehicles can join and leave the platoon efficiently. This coordinated approach improves traffic flow, increases road capacity, and enhances safety by enabling precise control of speed and distance between vehicles. Overall, platooning demonstrates how centralized coordination can optimize autonomous vehicle operations and contribute to a safer and more efficient transportation system.

In conclusion, using the 5.9 GHz band, this project implemented and validated key cooperative functions for connected and autonomous vehicles (CAVs). The project demonstrated real-time communication with traffic signals, enhanced awareness and safe navigation at roundabouts, and efficient platooning of vehicles. These achievements show that cooperative CAV systems, supported by reliable wireless communication, can significantly improve safety, traffic flow, and decision-making in complex transportation scenarios.

6 Appendix

This section includes some achievement of the project for reference.

Figure 16 Two Brands of AVs in HKSP

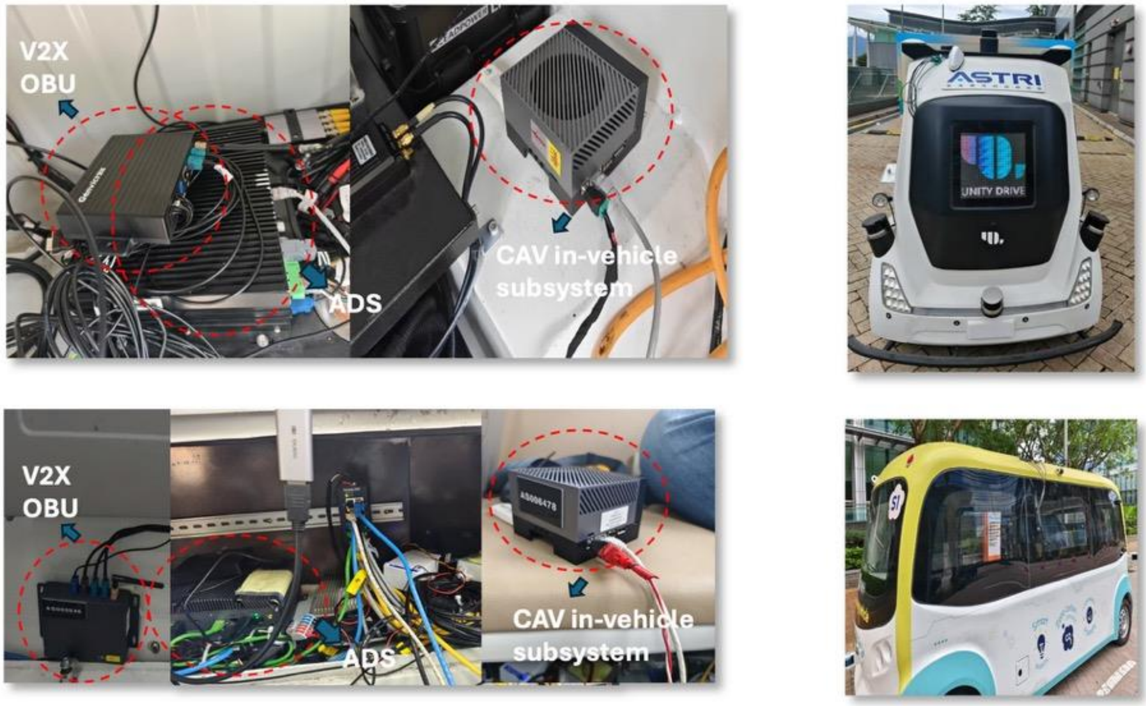

Figure 17 In-Vehicle V2X Setup

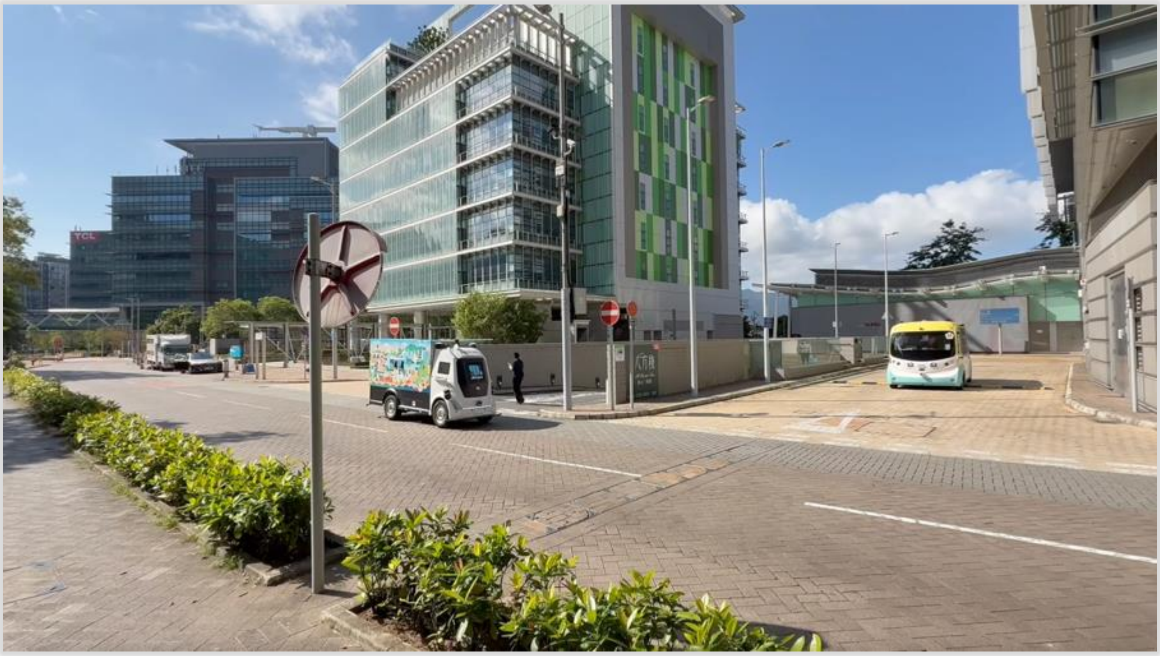

Figure 18 Scenario Testing between Two AV Brands

Figure 19 Real-Time Vehicle-Side Point Cloud Transmission via V2X

Figure 20 Real-Time Monitoring of AV Status via V2X