Summary Report

Trial of C-V2X Radio Equipment Operating in the 5905-5925 MHz Band

Final Version

Applied Science and Technology Research Institute Limited
5th Floor, Photonics Centre
2 Science Park East Avenue
Hong Kong Science Park, Shatin
New Territories, Hong Kong
Telephone: +852 3406 2800
Fax: +852 3406 2801
Web: www.astri.org

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Executive Summary

This report documents the five trials of Cellular V2X(C-V2X) radio equipment operating in the 5905 – 5925 MHz band for the Smart Traffic Fund ("STF") Project conducted by ASTRI in collaboration with the Transport Department between November 2020 and November 2023.

Contained within the report are the following sections: Introduction, Overviews of the Completed Trials on C-V2X, Signal Strength and Packet Loss Tests with 10-MHz Channel, V2X Use Cases Test with 10-MHz and 20-MHz Channels, Success Rate and Latency Tests with 20-MHz Channel and Conclusions. The trials verified the communication stability of C-V2X radio equipment operating in a 10-MHz channel and a 20-MHz channel respectively. Furthermore, it is affirmed that the communication performances of the tested communication indicators satisfy the requirements for C-V2X safety use cases.

List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Program
AVW	Abnormal Vehicle Warning
BSW	Blind Spot Warning
C-V2X	Cellular V2X
DL	Downlink
DNPW	Do Not Passing Warning
FCW	Forward Collision Warning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HLW	Hazardous Location Warning
HV	Host Vehicle
ICGW	In-Car Gateway
IW	Intersection Warning
LTE	Long-Term Evolution
MQTT	Message Queuing Telemetry Transport
NLOS	Non-Line-of-Sight
OBU	On-Board Unit
PRR	Packet Reception Ratio
RSI	Roadside Information
RSRP	Reference Signal Received Power
RSU	Roadside Unit
RV	Remote Vehicle
STF	Smart Traffic Fund
TDD NR	Time Division Duplexing New Radio
TLC	Traffic Light Controller
TLI	Traffic Light Information
UL	Uplink
V2I	Vehicle-to-Infrastructure

V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything (V2V + V2I + V2P + V2N)
VRUCW	Vulnerable Road User Collision Warning
WIFI	Wireless Fidelity

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1. Introduction

1.1 C-V2X System

Vehicle to Everything (V2X) is a new generation wireless communication system technology for vehicles and different road users, which includes Vehicle to Vehicle (V2V), Vehicle to Pedestrian (V2P), Vehicle to Infrastructure (V2I) and Vehicle to Network (V2N). Cellular V2X (C-V2X) is based on communication technology such as 3G, 4G or even 5G, which provides a wireless network system connecting vehicles, including Long-Term Evolution (LTE)-V2X. The following figure illustrates the C-V2X network system.

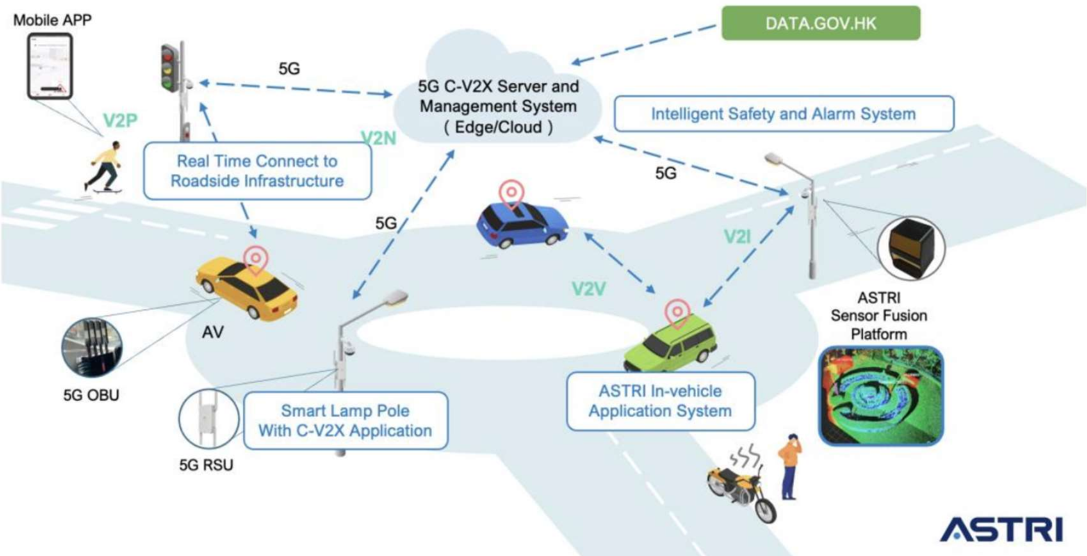


Figure 1-1 C-V2X System Conceptual Diagram

1.2 Background

ASTRI started to develop C-V2X technology in 2016 and successfully conducted road tests in partnership with Hong Kong Telecommunications Limited 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 and devise a methodology to plan for the network infrastructure required for the application, ASTRI has been in close contact with the Transport Department, through the Innovation and Technology Fund of the Innovation and Technology Commission, carried out research and trial projects related to the C-V2X technology since November 2019.

With the support of the Transport Department and Innovation and Technology Commission, ASTRI launched one of the world's largest C-V2X public road tests in March 2021 to promote Smart Mobility for improving the city's mobility competence while enhancing road safety and efficiency. The site of this pilot project spans a distance of 14 kilometres between the Hong Kong Science Park and Sha Tin Town Centre. The project has also received support from the Sha Tin District Council, Transport Department, Highways Department, and other relevant government departments.

1.3 Objectives and Organization of This Summary Report

This report aims to document the five trials of C-V2X radio equipment operating in the 5905 – 5925 MHz band for the STF Project, conducted by ASTRI since November 2020. It is divided into the following chapters:

- Chapter 2 provides an overall timeline with key objectives of the trials for this summary report.
- Chapter 3 provides the communication indicators test, including Signal Strength (Reference Signal Received Power (RSRP) and Packet Reception Ratio (PRR)) and Packet Loss tests with a 10-MHz channel in the 5905 – 5915 MHz band ("10-MHz Channel") from 2/11/2020 to 29/10/2021 and records the whole test procedures and test results.
- Chapter 4 provides the V2X use cases with the 10-MHz Channel and a 20-MHz channel in the 5905 – 5925 MHz band ("20-MHz Channel") from 1/5/2021 to 14/11/2023 and records the whole test procedures and test results.
- Chapter 5 provides the communication indicators test, including Success Rate and Latency tests with the 20-MHz Channel from 15/5/2023 to 14/11/2023 and records the whole test procedures and test results.

2. Overviews of the Completed Trials on C-V2X

2.1 Summary of Trial Periods and Other Information

Period	Key Objectives	Frequency Channel	Vehicle Type(s)
2/11/2020 - 30/4/2021 (Stage 1)	Performance tests in terms of Signal Strength (RSRP) and Packet Loss	10-MHz Channel (5905 – 5915 MHz)	7-seater car
1/5/2021 - 29/10/2021 (Stage 2)	Performance tests in terms of Signal Strength (RSRP & PRR), Packet Loss and V2I use cases	10-MHz Channel (5905 – 5915 MHz)	7-seater car
15/11/2021 - 14/5/2022 (Stage 3)	Performance tests in terms of V2X use cases	10-MHz Channel (5905 – 5915 MHz)	7-seater car
15/5/2022 - 14/11/2022 (Stage 4)	Performance tests in terms of V2X use cases	20-MHz Channel (5905 – 5925 MHz)	7-seater car, small shuttle bus, green minibus, engineering vehicle
15/5/2023 - 14/11/2023 (Stage 5)	Performance tests in terms of V2X use cases, success rate and latency	20-MHz Channel (5905 – 5925 MHz)	7-seater car, small shuttle bus, green minibus, engineering vehicle

Table 2-1 Summary of Trial Periods and Other Information

Please refer to Appendix IV for more details of the latest achievements of Stage 4 and 5.

Stage 1 was focused on testing communication indicators, including Signal Strength and Packet Loss. The results indicated that the communication performance on Yuen Wo Road was inferior compared to other locations, which could be attributed to environmental factors.

Stage 2 comprised three main parts: Roadside Unit (RSU) PC5 interface Signal Strength test, RSU PC5 interface Packet Loss test, and V2I use cases test. The results of the trials were successful, demonstrating effective Packet Loss and Signal Strength measurements from the Hong Kong Science Park to the Sha Tin Town Centre. In scenarios where the On-Board Units (OBUs) experienced Non-Line-of-Sight (NLOS) conditions, both packet reception and signal strength showed a significant decrease. Additionally, the V2I use cases test indicated that the vehicle's alarm system would be activated under various test conditions.

Stage 3 primarily tested V2X use cases, including several V2I and V2V scenarios. According to the results of the enhanced V2X use cases test, this trial successfully verified the algorithms of the V2X use cases along the 14km trial route in Shatin. Additionally, the interactive application for drivers was able to display alarms with the correct audio cues.

Furthermore, it was concluded that the current deployment of the RSUs adequately met the requirements for providing C-V2X services by enabling V2X use cases along the 14km Shatin trial route. This could be fully demonstrated in the Shatin Town Centre, where 11 RSUs (RSU4 to RSU14 in Figure 2-1) can all provide reliable and efficient C-V2X services in V2X use case tests, despite being located in dense and busy traffic areas. Vehicles equipped with OBUs could receive C-V2X messages throughout the route.

Stage 4 focused on testing V2X use cases. The results, which pertained to the communication performance of multi-brand OBUs operating in the 20-MHz Channel, confirmed that V2V communication functioned effectively. However, it identified frequency-related issues with the V2I communication in the current deployment. The communication capability was not stable when the bandwidth of OBUs and RSUs were configured to the 20-MHz Channel. The preliminary observation is that there is an incompatibility issue when operating HUAWEI RSU 6201 with Genvict OBU LB-LW10/10A and Lenovo OBU100 in the 20-MHz frequency band.

Stage 5 expanded upon previous V2X use case evaluations by including tests for communication latency and success rate. Test results confirmed that the communication between OBUs and RSUs at the 20-MHz Channel operated correctly, meeting the requirements for V2I safety use cases. The communication latency was recorded at less than 50ms for the test sample, and the message sending and receiving success rate reached 100% in the test sample. Additionally, three V2I safety use cases were successfully triggered. In this stage, we only used Lenovo RSU RS1000 to conduct tests with Genvict OBU LB-LW10/10A and Lenovo OBU100 in the 20-MHz Channel and we did not encounter any frequency issue caused by incompatibility of equipment, which was previously observed in Stage 4 when operating HUAWEI RSU with Genvict/Lenovo OBUs.

2.2 Trial Locations

2.2.1 Trial Site along Shatin

14 RSUs were installed at this Trial Site. The C-V2X Trial Site route was 14.1 km long. 5 RSUs were installed on Traffic Light Controller (TLC) poles (red marker) and 9 RSUs were installed on lamp poles (grey marker).

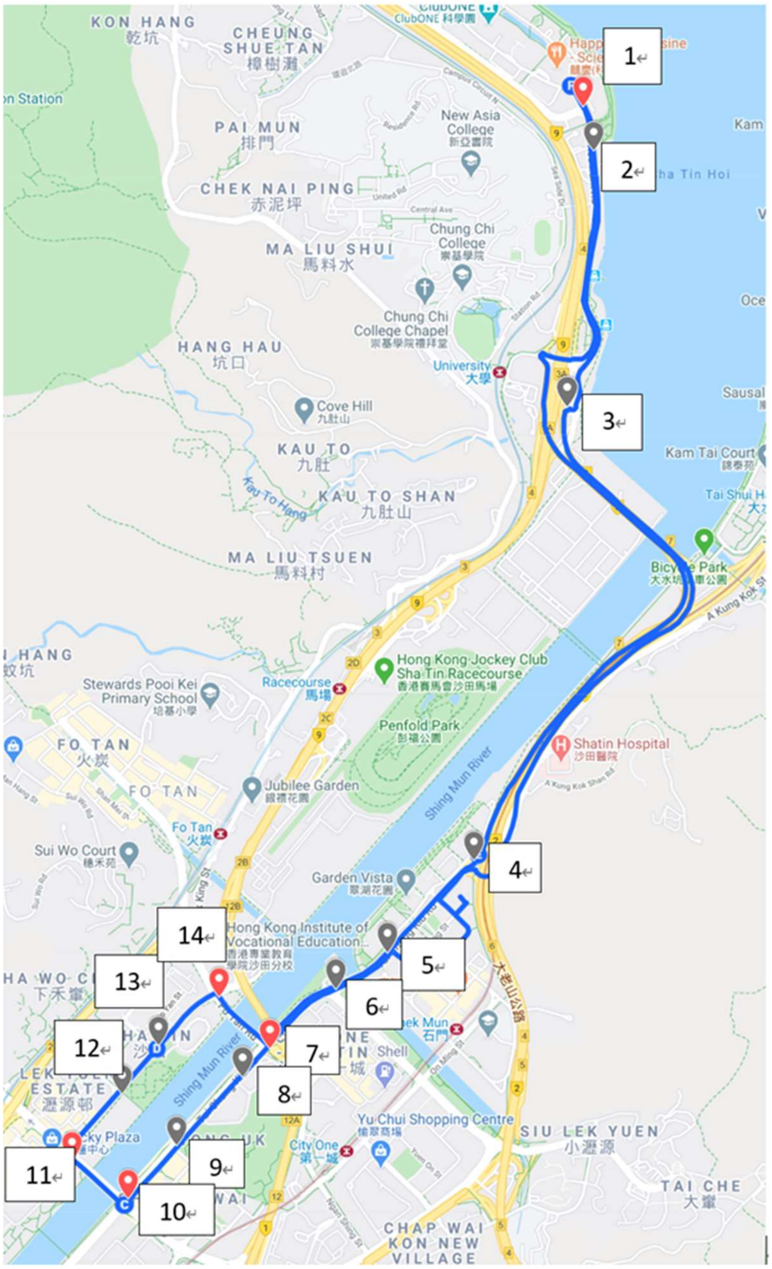


Figure 2-1 Trial Sites in Shatin

2.2.2 Trial Site in HK Science Park

4 RS1000 RSUs were installed inside the HK Science Park. All of them were configured to the 20-MHz Channel.

Figure 2-2 Trial Sites at Hong Kong Science Park

2.3 Device Configuration

2.3.1 RSU Configuration

- HUAWEI RSU6201

PC5 Transmit Power	23dBm ± 2dB
Frequency Band	C-V2X 3GPP Band47
Frequency Range	5905 – 5925 MHz
Bandwidth	10 MHz / 20 MHz
Centre Frequency	5910 MHz for the 10-MHz Channel 5915 MHz for the 20-MHz Channel

Table 2-2 HUAWEI RSU6201 Configuration

- Lenovo RS1000

PC5 Transmit Power	23dBm ± 2dB
Frequency Band	C-V2X 3GPP Band47
Frequency Range	5905 – 5925 MHz
Bandwidth	10MHz / 20 MHz
Centre Frequency	5910 MHz for the 10-MHz Channel 5915 MHz for the 20-MHz Channel

Table 2-3 Lenovo RS1000 Configuration

2.3.2 OBU Configuration

- Genvict OBU LB-LW10/10A supporting LTE-V, GNSS, WIFI, etc., operating in the 5905 – 5925 MHz band

Transmit Power		~ 20dBm ± 2dB
PC5	Standard	3GPP Rel-14 LTE-V2X
	Frequency	5905 – 5925 MHz
	Distance	600m
	Bandwidth	10 MHz / 20 MHz
GNSS	Supporting Satellites	Beidou, Galileo, GLONASS, GPS
	Refresh Rate	≤ 18 Hz
	Positioning Accuracy	2.5m CEP 50%

Table 2-4 Genvict OBU LB-LW10/10A Configuration

- Lenovo 5G-V2X On-board Unit, Model: OBU100, supporting 5G, GNSS, WIFI, etc., operating in the 5905 – 5925 MHz band

Transmit Power		~ 23dBm ± 2dB
PC5	Standard	3GPP Rel-14 LTE-V2X
	Frequency	5905 – 5925 MHz
	Distance	800m
	Bandwidth	10MHz / 20 MHz
GNSS	Supporting Satellites	Beidou, GPS
	Refresh Rate	10 Hz
	Positioning Accuracy	3m

Table 2-5 Lenovo OBU100 Configuration

3. Signal Strength and Packet Loss Tests with 10-MHz Channel

This phase of the trial spanned from 2/11/2020 to 29/10/2021 (i.e. from Stage 1 to Stage 2), lasting approximately for one year.

- In Stage 1, two communication indicators, Signal Strength (RSRP) and Packet Loss, were tested.
- In Stage 2, tests on the two indicators, Signal Strength (RSRP and PRR) and Packet Loss, were continued.

To evaluate the Signal Strength of the RSU PC5 interface, we used HUAWEI's test tools to measure the two parameters RSRP and PRR, which are key indicators in the industry for evaluating network performance and quality. For Packet Loss, we measured it through analysing the logs of ASTRI's OBU applications. Although PRR and Packet Loss are both indicators that describe packet reception performance, the test methods are different. The Packet Loss test can be used as a further verification of the PRR test results.

3.1 Test Plan and Methodology

3.1.1 Test Solution

Since the deployment environment of RSUs will affect working performance of RSUs, we use software tools to trigger RSU to broadcast a certain type of message, such as Roadside Information (RSI) messages periodically and use acceptance tool on PC to check the received messages by testing OBUs real time.

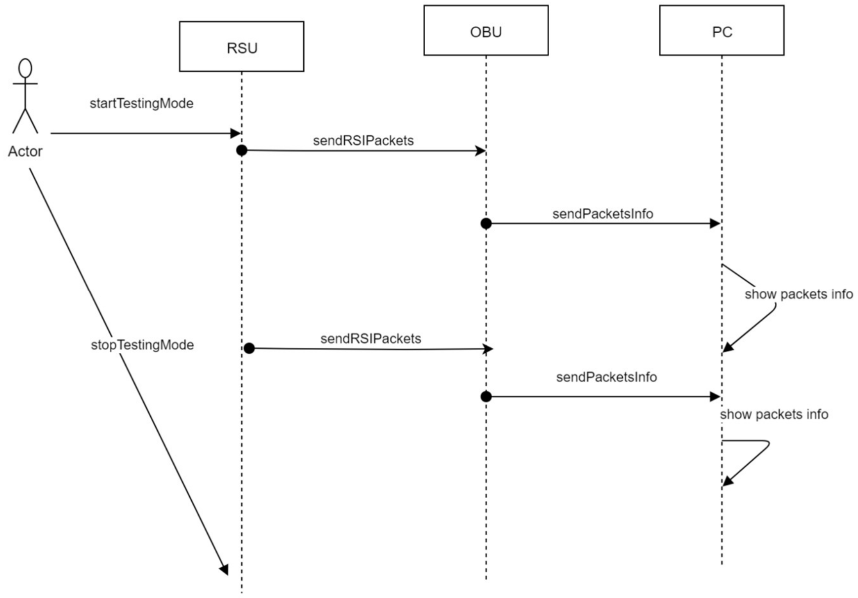


Figure 3-1 Signal Strength and Packet Loss Test Solution

3.1.2 Signal Strength Test Flow

We utilized motion mode to evaluate the Signal Strength of the RSU PC5 interface and monitor the PRR and RSRP values that the OBUs under test received during the RSU's cyclical message broadcasts.

Signal Strength Test Flow:

Objective: Testing V2I Signal Strength whether fulfill the expectations
Prerequisites • RSU and OBU synchronize with GNSS successfully. • RSU and OBU devices are working in normal condition. • OBU connectivity status is connected.
Procedure
Step 1: Connect with RSU portal
Step 2: Select menu "Maintenance > RSU Maintenance > Single Station Acceptance" on the RSU portal and click "Start Test" button to start the test
Step 3: Open RSU Test Tools in PC to test Signal Strength

Step 4: The vehicle was running along with test route which was installed with 14 RSUs ontraffic light and streetlamp posts
Step 5: Record the Signal Strength among the 14 RSUs
Step 6: Click "Stop Test" button on RSU portal after finished the test
Expected Results Record: The Signal Strength > -115 dBm

Table 3-1 RSU Signal Strength Test Flow

3.1.3 Packet Loss Test Flow

Fixed point testing is used in Packet Loss test. When RSU broadcasts message in cycle, the OBU checks the received packet counts at fixed points (100m, 200m, 300m to the broadcasting RSU).

Packet Loss Test Flow:

Objective: Under static vehicle condition, testing point-to-point V2I packet send/receive successful rate.
Prerequisites • V2I system bandwidth 10 MHz/20 MHz, working frequency 5.9 GHz. • RSU and OBU synchronize with GNSS successfully. • RSU and OBU devices are working in normal condition. • V2I package periods 100ms, packet size 300 Bytes.
Procedure
Step 1: Testing distance between testing vehicle and RSU is 100m
Step 2: Testing vehicle remains static, with the defined test conditions of package size/frequency, record both sending end and receiving end
Step 3: Stop sending packages until 5000 packets are sent
Step 4: Count the packet delivery successful rate
Step 5: Repeat step 1 to 4 by increasing the distance to 200m and 300m

Expected Results Record:
The wireless network layer packet delivery success rate > 99%

Table 3-2 Packet Loss Test Flow

3.2 Test Results

3.2.1 Signal Strength Test Results

3.2.1.1 Signal Strength Test Results (RSRP)

The Signal Strength test was conducted along the entire V2X demonstration route, covering the area from Hong Kong Science Park to Sha Tin City Centre.

- RSRP Test in Stage 1

We used OBUs and its *RsuTestTool* program to collect the data sets for all 14 RSUs. Screen shots of the *RsuTestTool* captured during our test runs are shown below as examples.

Figure 3-2 RsuTestTool Screenshots during Testing

- Summary Signal Strength Test Results

The test results for Signal Strength (RSRP) of the 14 RSUs are detailed in Appendix I. Presented below is a summary of the test outcomes.

Having in mind the expected range of RSU quoted by the manufacturer is around 200m to 300m radius, we could see that in many cases the range can reach up to 600m. Since all RSUs were well functioning, with the same installation height of 5m, the dominant factors on the coverage range were the landscape / altitude, and more importantly the attenuation caused by the surrounding and blockages of tall buildings.

In the Ma Liu Shui section of our demo route, RSU1-3 had been deployed but not fully covering the whole route of the region, since RSU2 and RSU3 were about 1.2km apart and we would have to deploy another RSU to cover the gap in-between. Signals from RSU1 and RSU2 could not quite reach within the Science Park area, due to the large commercial buildings causing blockages. RSU3 had the worst road coverage and was unable to cover all sections of the demo route within 200m range. This was due to the RSU being deployed at the bottom of the slope, causing signal blockages.

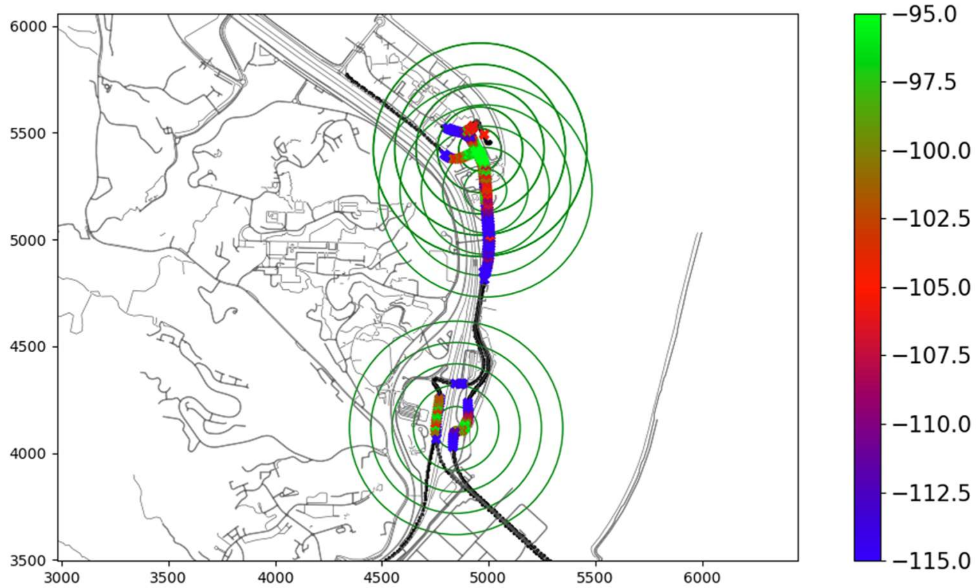


Figure 3-3 Overall Ma Liu Shui Area Coverage

In the Shing Mun River section, nearly full coverage of the demo route was obtained by RSU4-14 in that area. At later stages, we shall investigate not only the coverage of the demo route's main roads, but also all the inner roads and any location vehicles can access within Sha Tin.

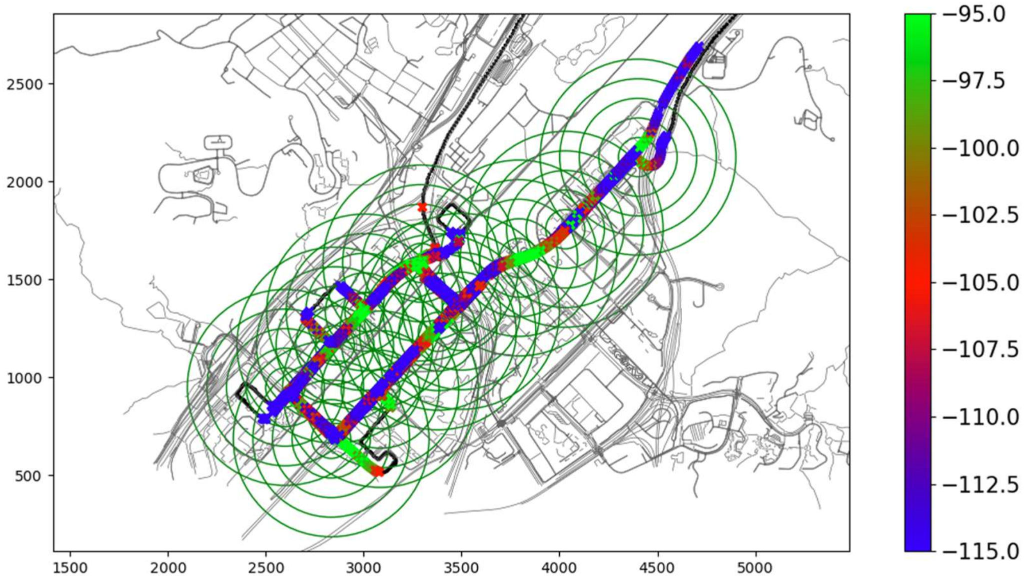


Figure 3-4 Overall Shing Mun River Area Coverage

3.2.1.2 Signal Strength Test Results (PRR)

The Signal Strength (PRR) was tested in Stage 2. The following screen captures were the test results of PRR.

Figure 3-5 Signal Strength Test Results – RSUTestTools Capture (RSU1-3)

Figure 3-6 Signal Strength Test Results – RSUTestTools Capture (RSU4-7)

Figure 3-7 Signal Strength Test Results – RSUTestTools Capture (RSU7-14)

3.2.2 Packet Loss Test Locations and Results

3.2.2.1 Packet Loss Test Locations and Results (Stage 1)

Until this stage, the Packet Loss test had been conducted on 5 RSUs that were connected to light controller connection. At a later stage, this test would be expanded to other RSUs in the project.

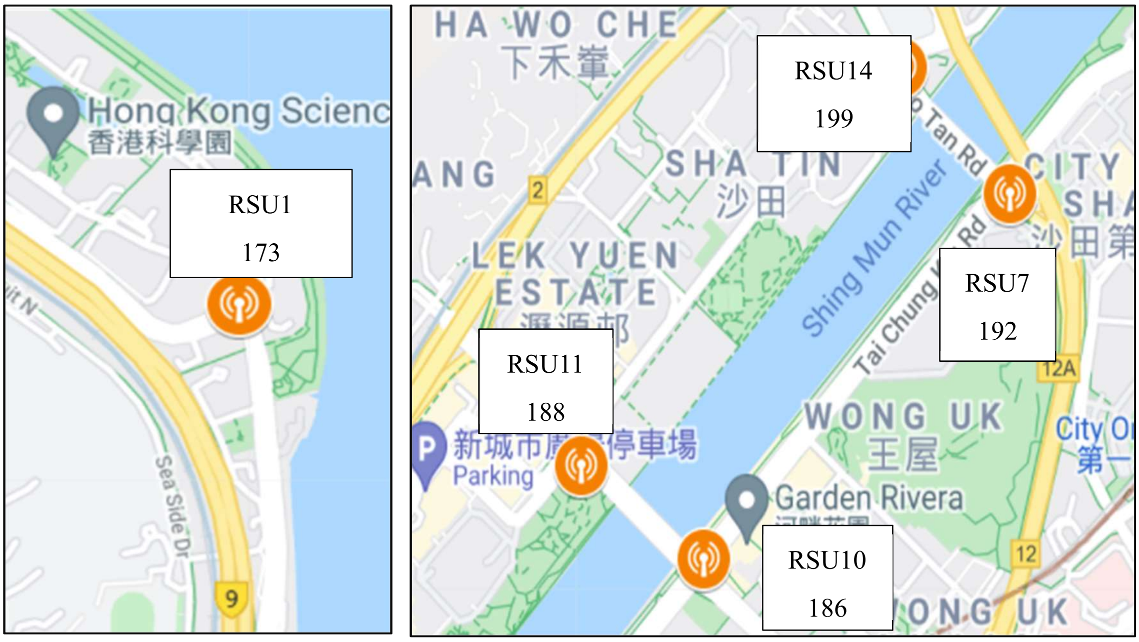


Figure 3-8 Tested RSUs Locations

Packet Loss Test Summary Results

Test Case No	RSUID	Location	Distance To RSU	Line-of-sight level	Packet Received Ratio
1	192	22.38883,114.20234	300m	Partial	81.12%
2	192	22.38827,114.20158	200m	Clear	99.66%
3	192	22.38761,114.20091	100m	Clear	100%
4	186	22.38263,114.19609	300m	Clear	100%
5	186	22.38196,114.19543	200m	Clear	100%
6	186	22.38129,114.19477	100m	Clear	100%
7	188	22.38083,114.19398	300m	Clear	99.06%
8	188	22.38145,114.19344	200m	Clear	100%
9	188	22.38352,114.19235	100m	Clear	100%
10	188	22.38422,114.19304	200m	Partial	95.68%
11	188	22.38490,114.19368	300m	Blocked	18%
12	199	22.38726,114.19590	300m	Blocked	6.32%
13	199	22.38795,114.19655	200m	Clear	99.11%
14	199	22.38860,114.19732	100m	Clear	99.68%
15	199	22.38728,114.20016	300m	Blocked	46.59%
16	173	22.422981,114.21421	100m	Partial	97.46%
17	173	22.422009,114.214236	200m	Clear	99.68%
18	173	22.42100,114.21430	300m	Clear	99.36%

Table 3-3 Packet Loss Test Summary Results

3.2.2.2 Packet Loss Test Locations and Results (Stage 2)

For each of the 14 installed RSUs, we selected three locations with different distances to RSU (100m, 200m, and 300m) to test the Packet Loss.

- Packet Loss Test Locations

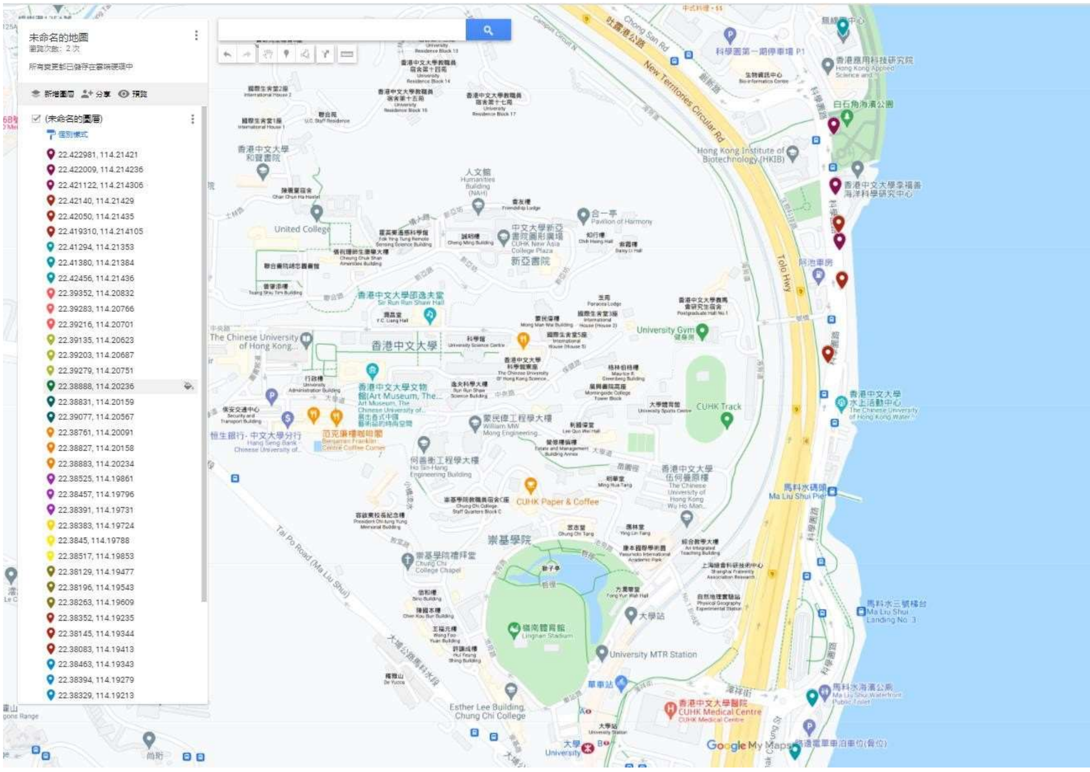


Figure 3-9 RSUs Packet Loss Test Locations (RSU1-3)

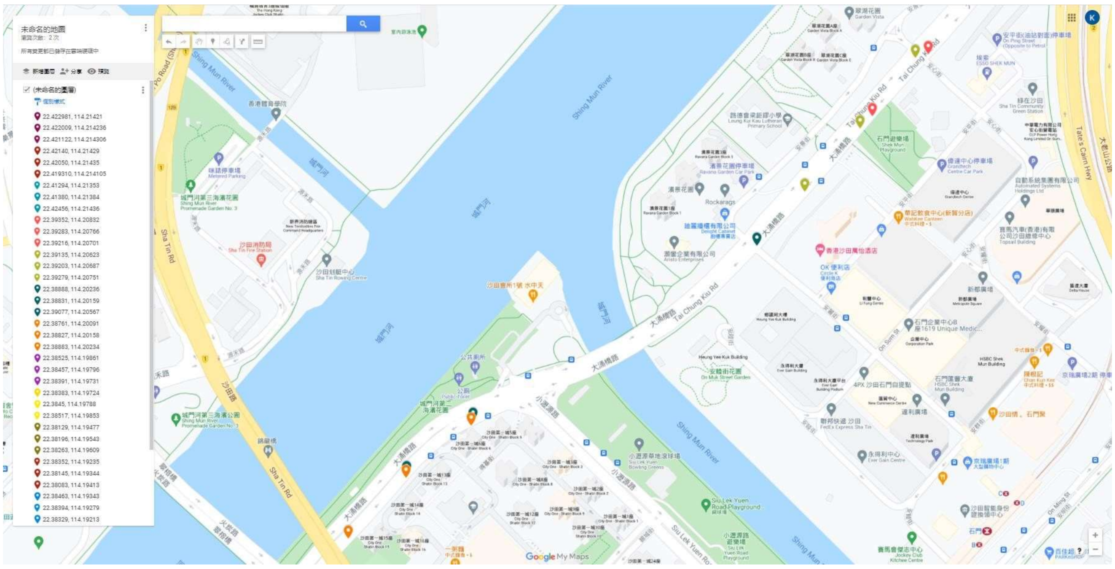


Figure 3-10 RSUs Packet Loss Test Locations (RSU4-7)

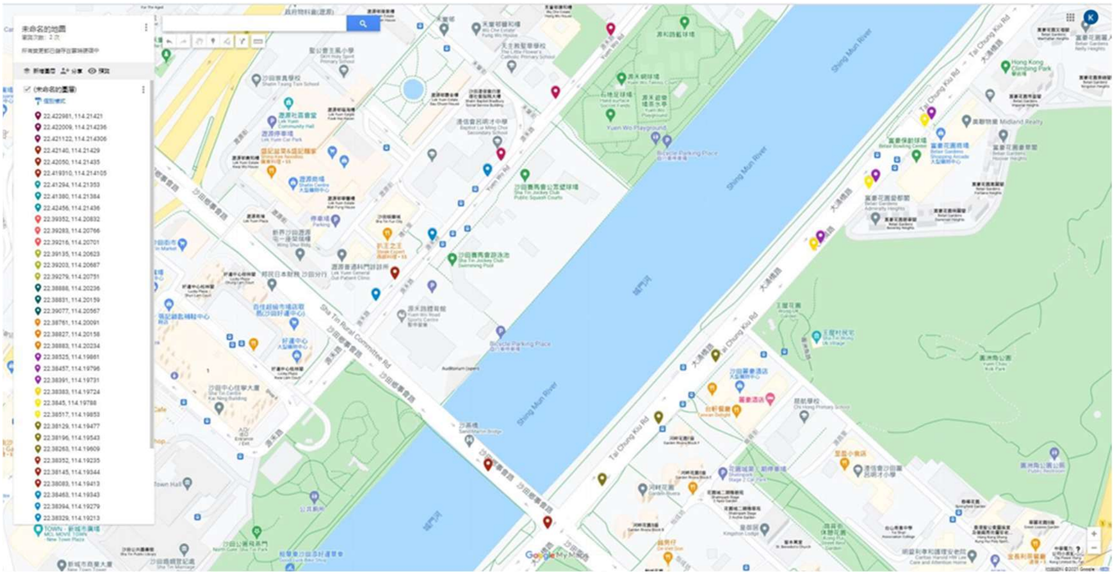


Figure 3-11 RSUs Packet Loss Test Locations (RSU8-14)

- RSUs Packet Loss Test Results

Presented below is a summary of the Packet Loss test results. Please refer to Appendix I for the detailed Packet Loss test results for Stage 2 trial.

The RSUs Packet Loss test results showed that when the broadcast distance between RSU and OBU became longer, the packet-received ratio would become smaller relatively. In particular, when the broadcast distance between RSU and OBU was 300m, the packet-received ratios for RSU14, RSU2, RSU9, and RSU7 were only 6%, 39%, 62%, and 69%, while the packet-received ratios for the remaining RSUs could reach above 80%. Environmental obstacles (trees, buildings, and large vehicles) were the main contributors to the differences in packet-received ratios in the same distance.

Broadcast distance (metre) between the RSU and OBU	Range of (Packet) Received Ratio
100	96-100%
200	80-100%
300	6-100%

Table 3-4 Summary of RSUs Packet Loss Test Results

4. V2X Use Cases Test with 10-MHz and 20-MHz Channels

The V2X use cases test, conducted with the 10-MHz and 20-MHz Channels, spanned from 1/5/2021 to 14/11/2023 (i.e. from Stage 2 to Stage 5):

- During the initial trials in Stage 2 and 3, the emphasis was on testing V2X use cases with the 10-MHz Channel.
- Subsequent trials in Stage 4 and 5 primarily focused on V2X use cases tested with the 20-MHz Channel.

The trials under different channels used different devices and trial sites.

4.1 Test Plan and Methodology

4.1.1 V2X Use Cases Configuration and Description

No	Use Cases	Channel	Test Location	Description
1	Speed Alert Warning (V2I)	10-MHz 20-MHz	RSU Set: 7 Chong San Road	• When host vehicle (Target vehicle with OBU installed and V2X application running) travels on the road with speed limit (e.g. 70km/h), the "Speed Alert" will be sent from C-V2X RSU to the ASTRI's In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. • ASTRI's In-vehicle software and Display App in host vehicle will generate and display the "Speed Alert" to alert the driver in host vehicle.
2	Congestion/ Traffic Control Warning(V2I)	10-MHz 20-MHz	RSU Set: 8,13 Science Park West Avenue & Science Park Road	• When host vehicle travels on the main road, if there is a "traffic congestion/control" ahead (says 300m ahead), the "Congestion/Traffic Control Warning" will be sent from C-V2X RSU to the ASTRI's In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. • ASTRI's In-vehicle software and Display App in host vehicle will generate and display the "Congestion/Traffic Control Warning" to alert the driver in host vehicle.
3	Road Works Warning (V2I)	10-MHz 20-MHz	RSU Set: 9,14	• When host vehicle travels on the main road, if there is a "road work" ahead (says 300m

No	Use Cases	Channel	Test Location	Description
			Chong San Road	ahead), the “Road Works Alert” will be sent from C-V2X RSU to the ASTRI’s In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. • ASTRI’s In-vehicle software and Display App in host vehicle will generate and display the “Road Works Alert” to alert the driver in host vehicle.
4	Hazardous Location Warning (V2I)	10-MHz	RSU Set: 3	• The scenario is when the host vehicle is driving towards the road section with dangerous situations including deeper stagnant water, pavement pit, slippery road, and sharp turn ahead, which will expose to a risk of an accident. • The “Hazardous Location Alert” will be sent from C-V2X RSU to the ASTRI’s In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. • ASTRI’s In-vehicle software and Display App in host vehicle will generate and display the “Hazardous Location Warning” to alert the driver in host vehicle.
5	Traffic Light Information (V2I)	10-MHz	1,7,10,11,14 (Road Junctions with Traffic Light Controllers)	• ASTRI’s Traffic Light Interface software will interface and read the real-time signal status of traffic lights from traffic light controllers (TLC) and send to C-V2X RSU. • C-V2X RSU will then send this traffic light info to the ASTRI’s In-vehicle software via C-V2X OBU in V2I PC5 communications channel. • ASTRI’s In-vehicle software and Display App will generate and display simulated Traffic Light and its count down information to the drivers inside the vehicles.
6	Intersection Warning (V2V)	10-MHz 20-MHz	Near Ma Liu Shui Waterfront Public Toilet& Sha Tin Fire Station HKSTP road	• The host vehicle is driving on the side road and trying to enter the main road, which exposes to a collision risk with the remote vehicles (A vehicle that cooperates with the host vehicle with OBU installed and V2X application running) coming from the main road.

No	Use Cases	Channel	Test Location	Description
				• Use V2V PC5 communications between the C-V2X OBUs installed in the host vehicle and the remote vehicle respectively to exchange vehicle info (e.g. GPS, speed, direction etc.) with ASTRI's In-vehicle software. • ASTRI's In-vehicle software and Display App in the host vehicle then generates and displays the "Intersection Collision Warning" to alert the driver.
7	Forward Collision Warning (V2V)	10-MHz 20-MHz	Between RSU set 2 & 3 HKSTP road	• The host vehicle travels on the main road, but its head vehicle suddenly brakes or reduces its speed, which causes the dangerous situation of potential "Forward Collision" between two vehicles. • Use V2V PC5 communications between the C-V2X OBUs installed in the host vehicle and its head vehicle respectively to exchange vehicle info (e.g. GPS, speed, direction etc.) with ASTRI's In-vehicle software. • ASTRI's In-vehicle software and Display App in the host vehicle then generates and displays the "Forward Collision Warning" to alert the driver.
8	Do Not Pass Warning (V2V)	10-MHz	RSU set: 1, 2	• The host vehicle is driving on the road and trying to pass the front vehicle through the reverse lane, which exposes it to a collision risk with the remote vehicles coming from the reverse lane. • Use V2V PC5 communications between the C-V2X OBUs installed in the host vehicle, its front vehicle and the remote vehicle respectively to exchange vehicle info (e.g. GPS, speed, direction etc.) with ASTRI's In-vehicle software. • ASTRI's In-vehicle software and Display App in the host vehicle then generates and displays the "Do Not Pass Warning" to alert the driver.
9	Blind Spot/ Lane Change Warning (V2V)	10-MHz 20-MHz	Between RSU set 2 & 3 HKSTP road	• The host vehicle travels on the main road, and it wants to change lane but there is a vehicle coming in a "blind spot", and which causes the dangerous situation of potential collision between two vehicles.

No	Use Cases	Channel	Test Location	Description
				• Use V2V PC5 communications between the C-V2X OBUs installed in the host vehicle and the vehicle in "blind spot" respectively to exchange vehicle info (e.g. GPS, speed, direction etc.) with ASTRI's In-vehicle software. • ASTRI's In-vehicle software and Display App in the host vehicle then generates and displays the "Blind Spot/Lane Change Warning" to alert the driver before he/she wants to change lanes.
10	Abnormal Vehicle Warning (V2V)	10-MHz	Between RSU set 2 & 3	• The host vehicle travels on the main road, and there is an "abnormal" vehicle (The vehicle experiences a malfunction, the driver activates the hazard lights and pulled over to the side of the road, etc.) ahead (or even in a blocking sight situation), which causes the dangerous situation of potential collision between the two vehicles. • Use V2V PC5 communications between the C-V2X OBUs installed in the host vehicle and the abnormal vehicle respectively to exchange vehicle info (e.g. GPS, speed, direction etc.) with ASTRI's In-vehicle software. • ASTRI's In-vehicle software and Display App in the host vehicle then generates and displays the "Abnormal vehicle Warning" to alert the driver.
11	Roundabout Pedestrian Warning (Lidar used in this case) (V2I)	10-MHz	Demonstrate this use case inside Hong Kong Science Park	• The pedestrian crosses the road with a blocking sight situation that the driver driving the incoming vehicle on the main road cannot see the pedestrian. • Use Lidar to detect the pedestrian crossing situation and send the detected info to the C-V2X RSU. • C-V2X RSU then sends this pedestrian crossing info to the ASTRI's In-vehicle software via C-V2X OBU using V2I PC5 communications channel.

Table 4-1 V2X Use Cases Test Description

4.1.2 V2X Use Cases Test Flow

- V2I Use Cases Test Flow

Roles	**RSU, OBU, Tablet (with V2X application), Vehicles**
Methodology	1. Configure RSI in specific RSUs. 2. RSU broadcasts RSI and collects traffic information (with sensors) as V2X message. 3. Install OBU in vehicles. 4. Start OBU to receive the broadcasted V2X message. 5. Install tablet (with V2X application) in vehicles. 6. Connect tablet with OBU WIFI network. 7. Drive the vehicles along the trial site route. 8. Check if tablet can receive V2I alarm.
Expected Results	Tablet could give warnings with pictures and sounds when vehicles are in RSU's broadcasting scope and meet the warning conditions.

Table 4-2 V2I Use Cases Test Flow

- V2V Use Cases Test Flow

Roles	**OBU, Tablet (with V2X application), Vehicles**
Methodology	1. Install OBU in vehicles. 2. Start OBU to receive the broadcasted V2X message. 3. Install tablet (with V2X application) in vehicles. 4. Connect tablet with OBU WIFI network. 5. Drive vehicles along the trial site route. 6. Check if tablet can receive V2V alarm.
Expected Results	Tablet could give warning with pictures and sounds when the vehicles are within other vehicles' broadcast scope and meet the warning conditions.

Table 4-3 V2V Use Cases Test Flow

4.2 V2X Use Cases Test Results

4.2.1 Speed Alert Warning (V2I)

Speed Alert Warning use case was successfully tested with both of the 10-MHz and 20-MHz Channels.

When host vehicle travelled on the road with a speed limit (e.g. 50km/h, 70km/h, etc.), the "Speed Alert" would be sent from C-V2X RSU to the ASTRI's In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. ASTRI's In-vehicle software and Display App in the host vehicle would generate and display the "Speed Alert" to alert the driver.

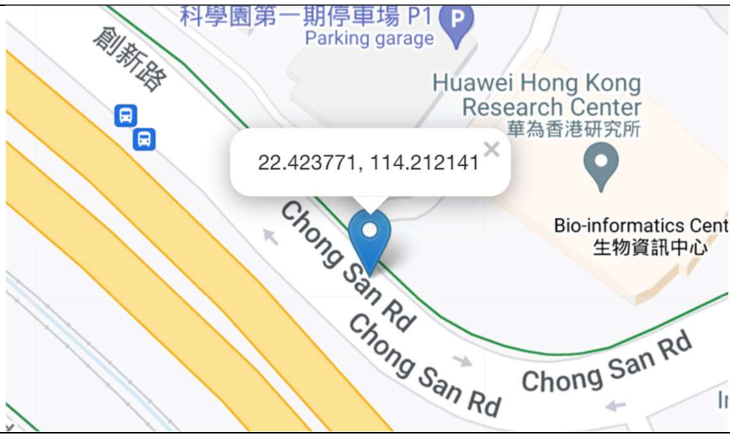
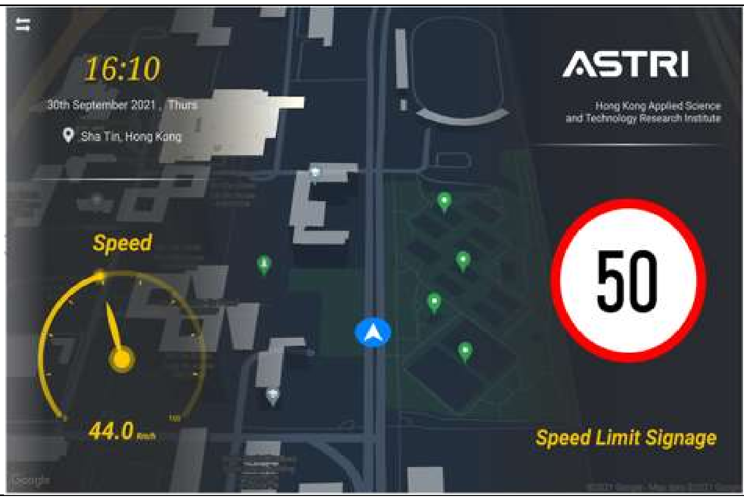
Simulated event location and vehicle direction (red arrow)	
Event sending interval	1s
Actual logged alarms	10 (02:42:31.533 ~ 02:42:40.476)
Alarm should be logged during the period (02:42:31.533 ~ 02:42:40.476)	10
Success rate	100%
Tablet App Capture	

Table 4-4 Speed Alert Warning Test Results

Please refer to Appendix II for test log.

4.2.2 Congestion/Traffic Control Warning (V2I)

Congestion/Traffic Control Warning use case was successfully tested with both of the10-MHz and 20-MHz Channels.
When host vehicle travelled on the main road, if there was a "traffic congestion/control" ahead (says 300m ahead), the "Congestion/Traffic Control Warning" would be sent from C-V2X RSU to the ASTRI's In-vehicle software via C-V2X OBU installed in the host vehicle, using V2I PC5 communications channel. ASTRI's In-vehicle software and Display App in the host vehicle would generate and display the "Congestion/Traffic Control Warning" to alert the driver.

Simulated event location and vehicle direction (red arrow)	
Event sending interval	1s
Actual logged alarms	6 (02:33:23.369 ~ 02:33:28.506)
Alarm should be logged during the period (02:33:23.369 ~ 02:33:28.506)	6
Success rate	100%

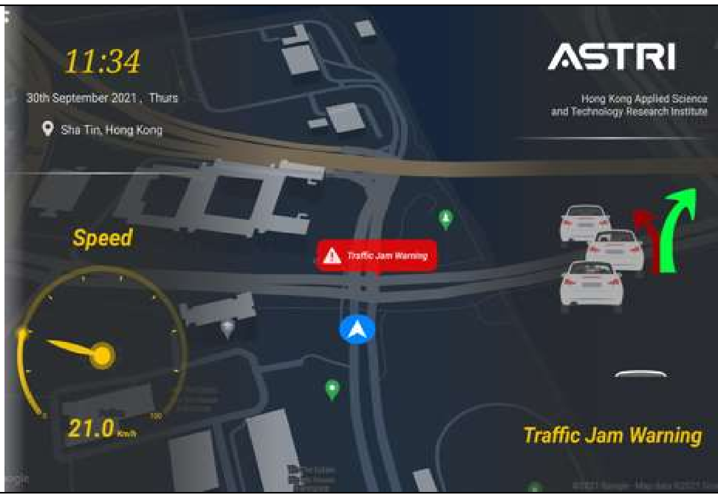
Tablet App Capture	

Table 4-5 Congestion/Traffic Control Warning Test Results

Please refer to Appendix II for test log.

4.2.3 Road Works Warning (V2I)

Road works warning use case was successfully tested with both of the 10-MHz and 20-MHz Channels.

The host vehicle (HV) was equipped with V2X devices.

When the host vehicle (HV) drove to the configured location, the application would broadcast messages of Road Works Warning including vehicle position, type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

Simulated event location and vehicle direction (red arrow)	
Event sending interval	1s
Actual logged alarms	10 (02:46:05.510 ~ 02:46:14.620)
Alarm should be logged	10

during the period (02:46:05.510 ~ 02:46:14.620)	
Success rate	100%
Tablet App Capture	

Table 4-6 Test Results of Road Works Warning

Please refer to Appendix II for test log.

4.2.4 Hazardous Location Warning (V2I)

Hazardous Location Warning use case was tested with the 10-MHz Channel only and the test results were successful.

The scenario was when the host vehicle was driving toward the road section with dangerous situations including deeper stagnant water, pavement pit, slippery road, and sharp turn ahead, which would expose to a risk of an accident.

The “Hazardous Location Alert” would be sent from C-V2X RSU to the ASTRI’s In-vehicle software via C-V2X OBU installed in the host vehicle, using the V2I PC5 communications channel. ASTRI’s In-vehicle software and Display App in the host vehicle would generate and display the “Hazardous Location Warning” (HLW) to alert the driver.

Field test photos

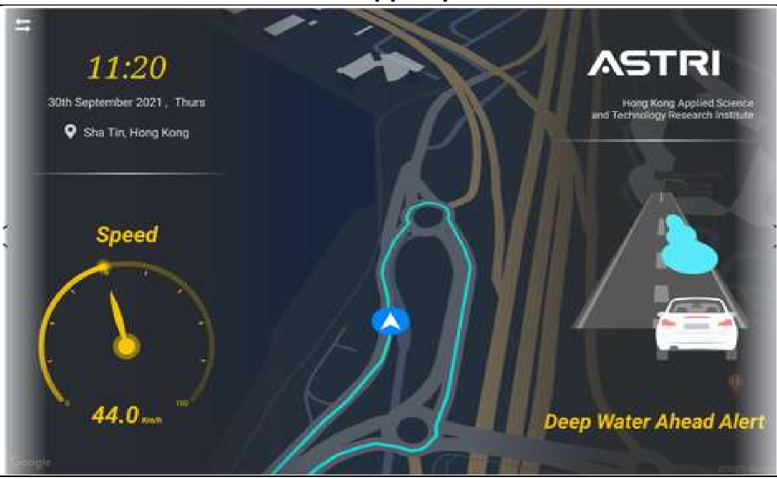
Tablet App Capture


Table 4-7 Hazardous Location Warning Test Results

4.2.5 Traffic Light Information (V2I)

Traffic Light Information use case, tested with the 10-MHz Channel only, successfully demonstrated that traffic light information could be broadcasted.

The scenario was that the host vehicle (HV) was equipped with V2X devices.

When the host vehicle (HV) drove to the configured location, the application would broadcast the messages of Traffic Light Information (TLI) including vehicle position, type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

Test Location

Field test photos

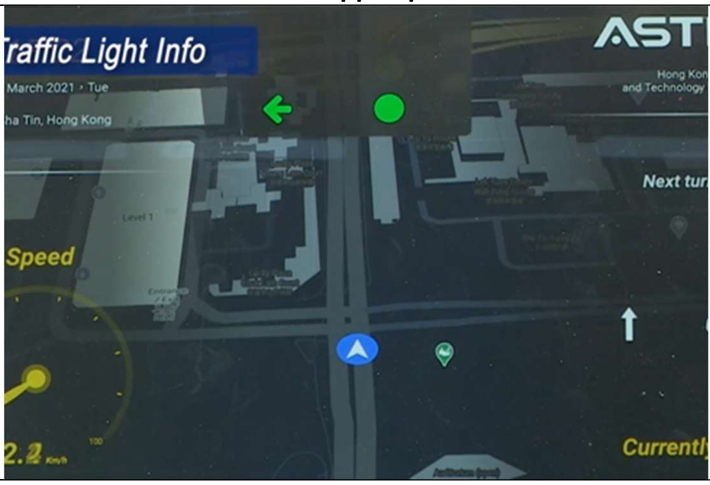
Tablet App Capture


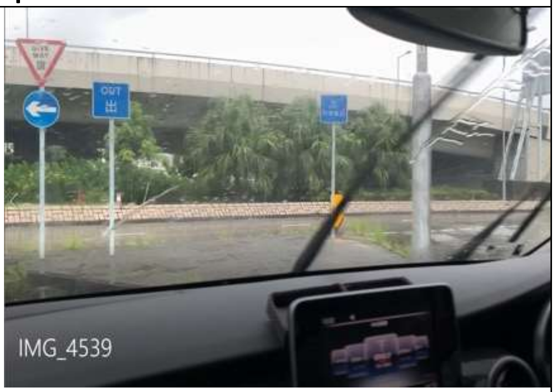
Table 4-8 Test Results of Traffic Light Information

Please refer to Appendix II for test log.

4.2.6 Intersection Warning (V2V)

Intersection Warning use case was tested with both of the 10-MHz and 20-MHz Channels. The test results under the two different bandwidths were both successful. The host vehicle (HV) and the remote vehicle (RV) were equipped with V2X devices. The HV was driving toward the intersection road while, at the same time, the RV was driving toward the sideways. When HV was ready to enter the intersection, the application detected the intersection alarm and would broadcast messages of Intersection Warning (IW) including vehicle position, type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

Test Location 1 (Near Ma Liu Shui Waterfront Public Toilet)

Field test photos	
	

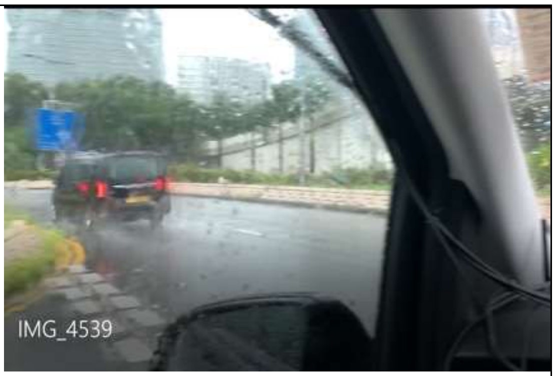
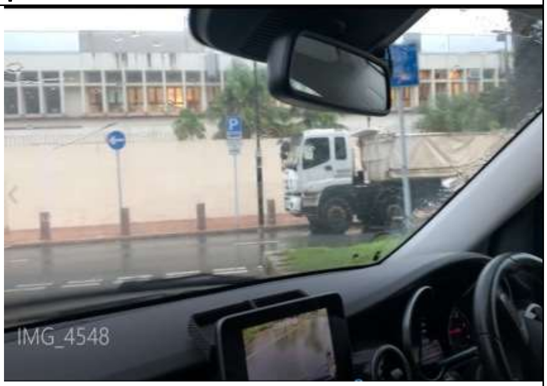
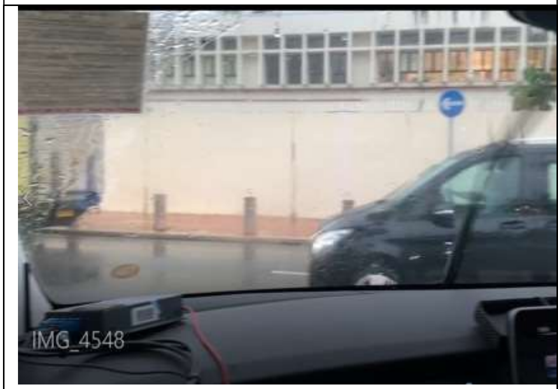
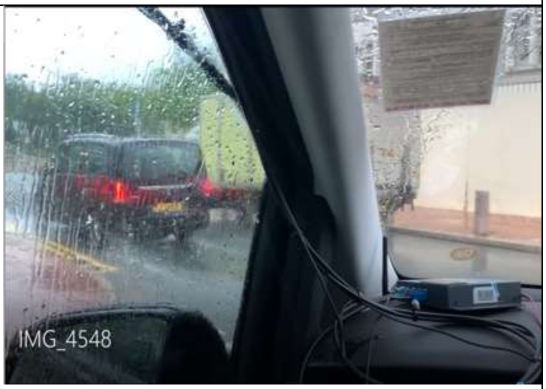
	

Table 4-9 Test Results of Intersection Warning – 1

Test Location 2 (Near Sha Tin Fire Station)

Field test photos	
	
	

Tablet App Capture


Table 4-10 Test Results of Intersection Warning – 2

Please refer to Appendix II for test log.

4.2.7 Forward Collision Warning (V2V)

Forward Collision Warning use case was tested with both of the 10-MHz and 20-MHz Channels. The test results under the two different bandwidths were both successful. The host vehicle (HV) and the remote vehicle (RV) were equipped with V2X devices. The host vehicle (HV) was following the remote vehicle (RV) at a very close distance. When the RV was driving slowly or decelerating, the application detected the front collision alarm and would broadcast messages of Forward Collision Warning (FCW) including vehicle position, type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

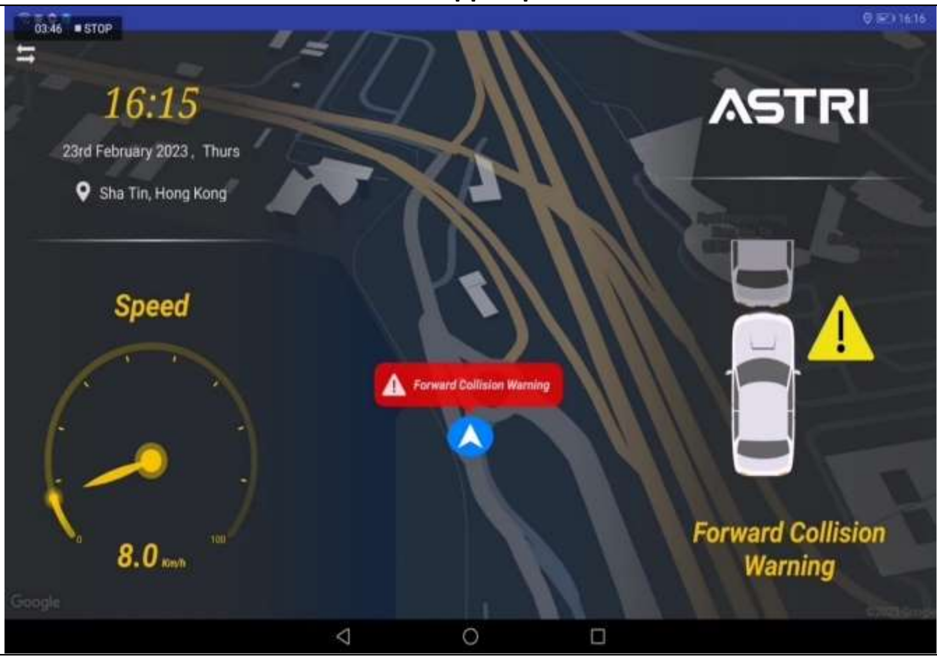
Field test photos	
	
	
Tablet App Capture	
	

Table 4-11 Test Results of Forward Collision Warning

Please refer to Appendix II for test log.

4.2.8 Do Not Pass Warning (V2V)

Do Not Pass Warning use case was tested with the 10-MHz Channel only and the test results were successful.

The host vehicle (HV), the remote vehicle 1 (RV-1) and the remote vehicle 2 (RV-2) were all equipped with V2X devices.

HV was following RV-1 and trying to pass RV-1. RV-2 was coming on the reverse lane (from the opposite direction with HV and RV-1) and RV-1 may block the view of HV. When HV sent out the lane change signal and prepared to enter the reverse lane, the application would warn the driver of HV with Do Not Passing Warning (DNPW) including vehicle position, type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, vehicle information and alert description would be generated in the backend server.

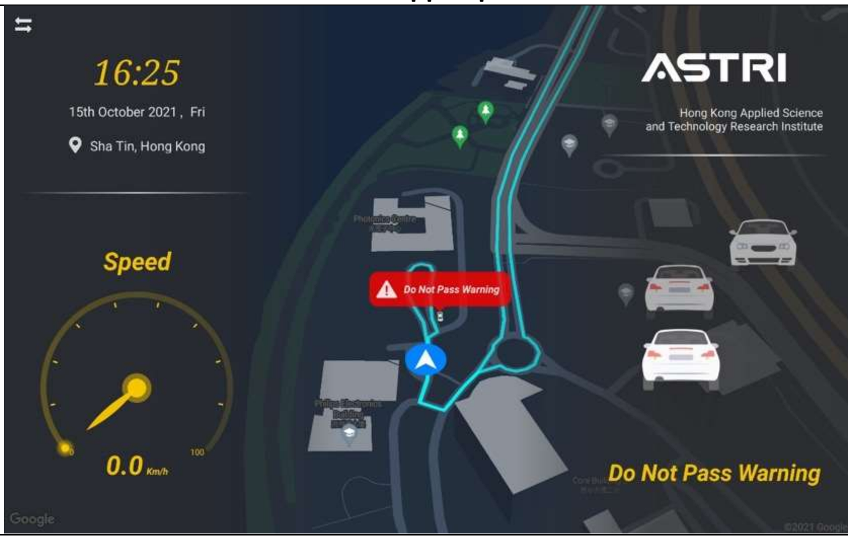
<table>
<tr><th colspan="2">Field test photos</th></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Tablet App Capture</th></tr>
<tr><td colspan="2">
</td></tr>
</table>

Table 4-12 Test Results of Do Not Pass Warning

Please refer to Appendix II for test log.

4.2.9 Blind Spot Warning (V2V)

Blind Spot Warning use case was tested with both of the 10-MHz and 20-MHz Channels. The test results under two different bandwidths were both successful. The host vehicle (HV) and the remote vehicle (RV) were all equipped with V2X devices.

When HV was travelling on the main road, there was RV coming in “blind spot” of HV on the adjacent road. In this case, the application would warn the driver of HV with Blind Spot Warning (BSW) including vehicle type, and description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, vehicle information and alert description would be generated in the backend server.

Field test photos

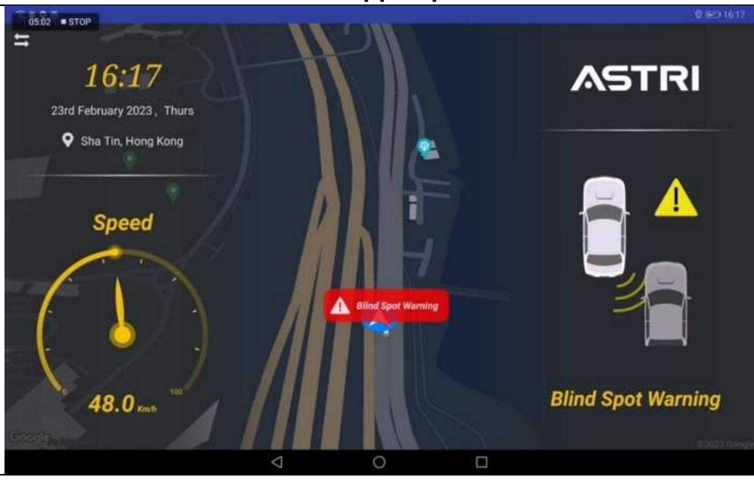
Tablet App Capture


Table 4-13 Test Results of Blind Spot Warning

Please refer to Appendix II for test log.

4.2.10 Abnormal Vehicle Warning (V2V)

This V2V use case was tested with the 10-MHz Channel only and the test results were successful.
The host vehicle (HV) and the remote vehicle (RV) were all equipped with V2X devices.
When the host vehicle (HV) was traveling on the main road, and there was an "abnormal" remote vehicle (RV) ahead (or even in a blocking sight situation). In this case, the application would warn the driver of HV with Abnormal Vehicle Warning (AVW) including vehicle type, description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

Field test photos

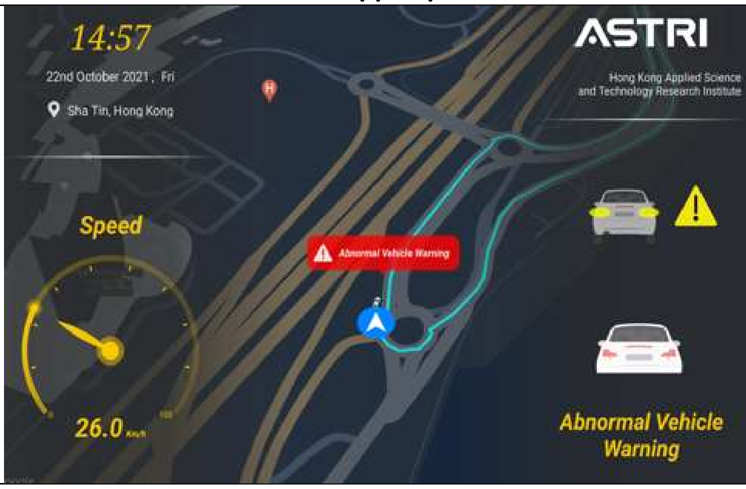
Tablet App Capture


Table 4-14 Test Results of Abnormal Vehicle Warning

Please refer to Appendix II for test log.

4.2.11 Roundabout Pedestrian Warning (V2I)

Roundabout Pedestrian Warning use case was tested with the 10-MHz Channel only and the test results were successful.
The host vehicle (HV) was equipped with V2X devices.
When the host vehicle (HV) was traveling on the main road, the pedestrians would cross the road by sight blocking situation (e.g. pedestrians are blocked by green belts, etc.) such that the incoming HV drivers on the main road could not see them. In this case, the application would warn the driver of HV with a Vulnerable Road User Collision Warning (VRUCW) including vehicle type, description, etc. In addition, the related alarm log which includes alert type, latitude, longitude, and alert description would be generated in the backend server.

Field test photos

Tablet App Capture


Table 4-15 Test Results of Roundabout Pedestrian Warning

Please refer to Appendix II for test log.

5. Success Rate and Latency Tests with 20-MHz Channel

Success rate and latency tests were conducted during the trial period from 15/5/2023 to 14/11/2023 (i.e. Stage 5).

5.1 Test Plan and Methodology

This test included the communication latency and success rate tests with the 20-MHz Channel.

Communication test between OBU and RSU is conducted. RSU sends GPS message to the V2X server, establishes connection with the V2X server through Message Queuing Telemetry Transport (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 publishes 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.

5.2 Test Results

5.2.1 Success Rate

5.2.1.1 1st Round Test

- Clock synchronization with Ali-Cloud

RSU		
12:07:39 ntpdate[30159]: adjust time server 120.25.115.20 offset -0.000704 sec		
OBU		
12:07:39 ntpdate[21260]: adjust time server 120.25.115.20 offset 0.000710 sec		
Time deviation with Ali-Cloud	OBU	0.710ms
	RSU	0.704ms
	Time deviation between RSU & OBU	0.006ms

Table 5-1 Clock Synchronization Results of Transmission Success Rate for 1st Round Test

- Statistical results of the number of RSU and OBU transmissions and receptions within five minutes

Duration	5mins (12:15:00:000 ~ 12:20:00:000)
Sending interval	1s
Number of messages sent by RSU	300
Number of messages received by OBU	300
Success rate	100%

Table 5-2 Transmission Success Rate for 1st Round Test

Please refer to Appendix III for test log.

5.2.1.2 2nd Round Test

- Clock synchronization with Ali-Cloud

RSU		
12:25:45 ntpdate[1735]: adjust time server 120.25.115.20 offset 0.000984 sec		
OBU		
12:25:44 ntpdate[30271]: adjust time server 120.25.115.20 offset 0.000314 sec		
Time deviation with Ali-Cloud	OBU	0.314ms

	RSU	0.984ms
	Time deviation between RSU & OBU	0.670ms

Table 5-3 Clock Synchronization Results of Transmission Success Rate for 2nd Round Test

- Statistical results of the number of RSU and OBU transmissions and receptions within five minutes

Duration	5mins (12:30:00:000 ~ 12:35:00:000)
Sending interval	1s
Number of messages sent by RSU	300
Number of messages received by OBU	300
Success rate	100%

Table 5-4 Transmission Success Rate for 2nd Round Test

Please refer to Appendix III for test log.

5.2.2 Latency

- Clock synchronization with Ali-Cloud

RSU		
12:42:04 ntpdate[5315]: adjust time server 120.25.115.20 offset -0.000227 sec		
OBU		
12:42:04 ntpdate[5761]: adjust time server 120.25.115.20 offset -0.000350 sec		
Time deviation with Ali-Cloud	OBU	-0.350ms
	RSU	-0.227ms
	Time deviation between RSU & OBU	0.123ms

Table 5-5 Clock Synchronization Results of Transmission Latency Test

- Latency from the message sent by RSU to OBU

Duration	9s (12:42:23:979 ~ 12:42:32:705)
Sending interval	1s
Number of messages sent by RSU	10
Number of messages received by OBU	10
Minimum latency	17ms

Maximum latency	27ms
Average latency	21.3ms

Table 5-6 Transmission Latency Test Results

Please refer to Appendix III for test log.

6. Conclusions

This report provides a comprehensive summary of the five trials conducted for the STF Project by ASTRI in collaboration with the Transport Department, focusing on C-V2X radio equipment operating in the 5905 – 5925 MHz band between 2 November 2020 and 14 November 2023. It includes detailed sections on the testing timeline and key objectives, communication indicators test, V2X use cases test, and the corresponding results for these trials.

From the communication frequency standpoint, the trials conducted from Stage 1 to Stage 3 operated with the 10-MHz Channel. Subsequently, in Stage 4 and Stage 5, the bandwidth was increased to the 20-MHz Channel. Our tests have been aligned with the updates to the domestic V2X standard[1].

According to the trial results, the communications between OBU and RSU operating with both of the 10-MHz Channel and the 20-MHz Channel can work stably and the tested communication indicators can meet the requirements of C-V2X safety use cases. It is important to highlight that, theoretically, the 20-MHz Channel has significant advantages over the 10-MHz Channel, with its greater bandwidth capable of better supporting concurrent message transmissions and more effectively managing complex scenarios in heavy traffic. Allocating a 20-MHz channel bandwidth in the 5905 – 5925 MHz band for C-V2X applications is also a trend both domestically and internationally. This is evidenced by Mainland China's announcement in 2018[2] that designated the 5905 – 5925 MHz band for C-V2X use. In recent years, many C-V2X devices in Mainland China have stopped supporting operations with a 10-MHz channel, and the trend is moving towards using a 20-MHz channel in future. However, due to the limitations of the test conditions in this project, it was not feasible to conduct communication tests with high levels of concurrency on a large scale of C-V2X devices. Consequently, the advantages of the 20-MHz Channel over the 10-MHz Channel could not be demonstrated in the tests.

[1] See http://csae.sae-china.org/ (membership subscription is required for standards download)
[2] See https://www.gov.cn/xinwen/2018-11/13/content_5339936.htm

6.1 Limitations of the Trials

- In the Stage 2 trial, the RSU3 was installed at a roundabout on Sui Cheung Street, surrounded by trees. This location might affect the OBU's ability to receive signals from the RSU when the OBU's line-of-sight was obstructed by trees or buildings. The Signal Strength test results clearly showed a substantial drop in signal strength when the OBU was in a Non-Line-of-Sight (NLOS) position. The physical environment could significantly influence the test outcome. Furthermore, identifying suitable test positions for conducting Packet Loss tests was challenging. Due to the heavy traffic conditions in Sha Tin, the only feasible locations for performing Packet Loss tests were pedestrian areas.

- In the Stage 3 trial, it was found that the GPS accuracy of the vehicles might affect the accuracy of the use cases. The GPS was not stable under the blocked area (e.g. under the bridge, surrounded by dense high buildings) which might cause wrong alarms or missing alarms.

- In the Stage 4 trial, it was found that the V2I communication had frequency issues with current deployment under 20-MHz Channel between HUAWEI RSU and Genvict/Lenovo OBUs. Based on the current test results, it is difficult to determine the cause of the frequency issues, and further investigation with the support of the suppliers may be needed to pinpoint the problem, depending on the future needs of the project. We will also consider replacing or upgrading the deployed equipment in future to try to solve this problem.

6.2 Prospect and Future Work

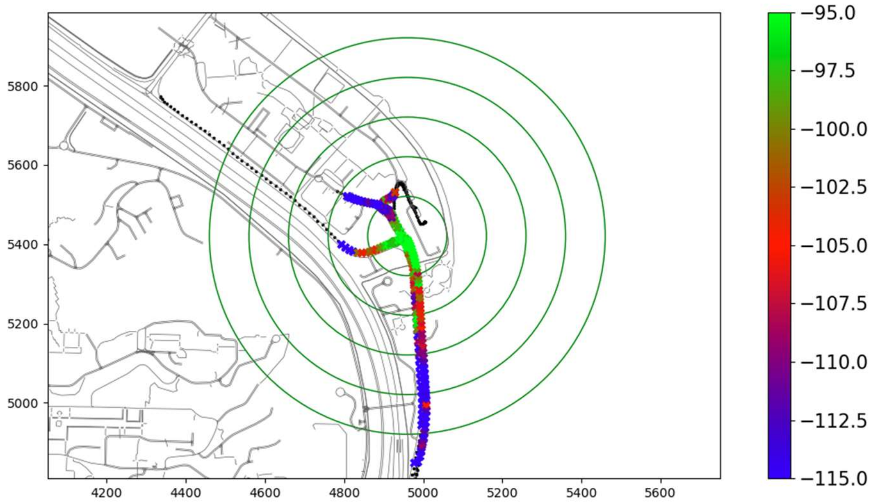
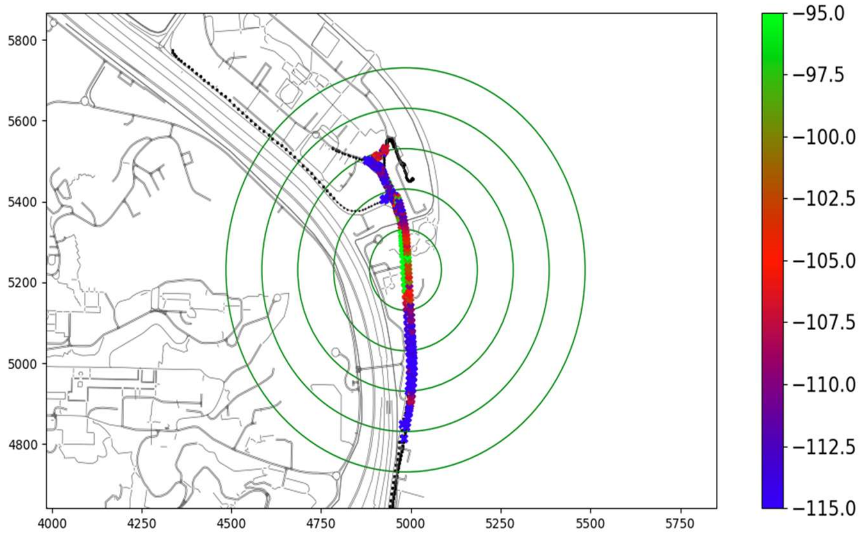
In future, depending on the specific project content, we hope to continue testing for the 5 remaining V2I / V2V use cases which had been tested in Stage 4 with the 10-MHz Channel only as shown in Table 6-1 with the 20-MHz Channel in future. In addition, we plan to introduce autonomous vehicles to the site and interface with ASTRI's C-V2X system to verify the ability of C-V2X to assist autonomous driving to enhance Hong Kong's smart transportation capabilities.

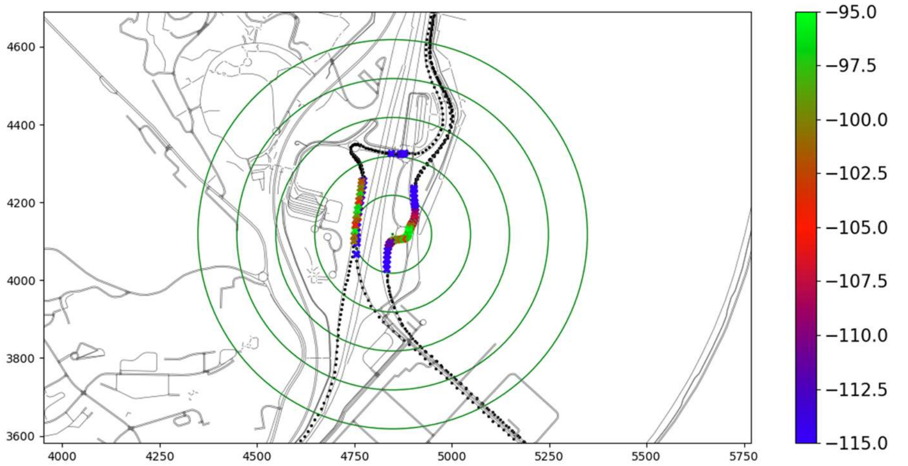
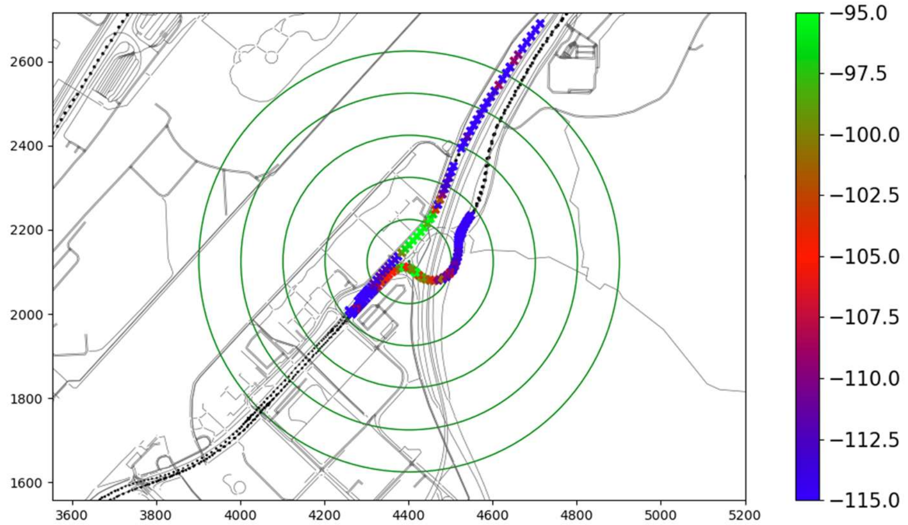
Type of V2X Use Case	**Description**
V2I	Hazardous Location Warning (see Section 4.2.4)
V2I	Traffic Light Information (see Section 4.2.5)
V2V	Do Not Pass Warning (see Section 4.2.8)
V2V	Abnormal Vehicle Warning (see Section 4.2.10)
V2I	Roundabout Pedestrian Warning (see Section 4.2.11)

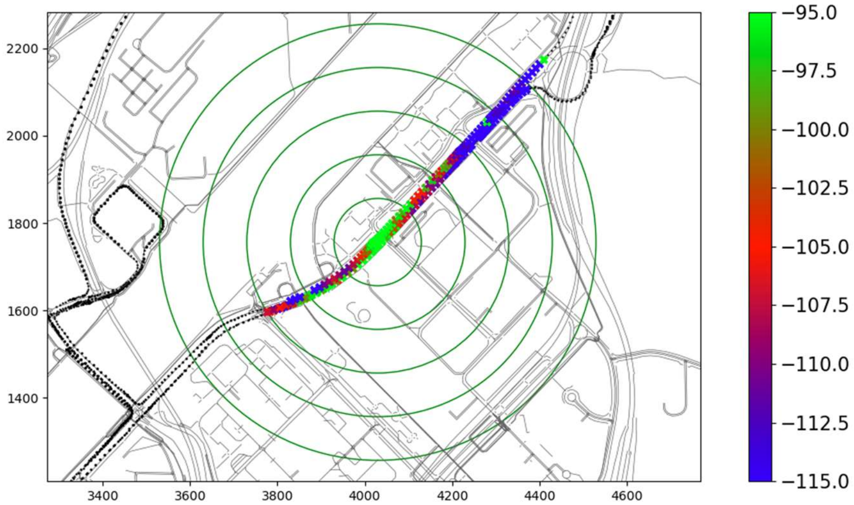
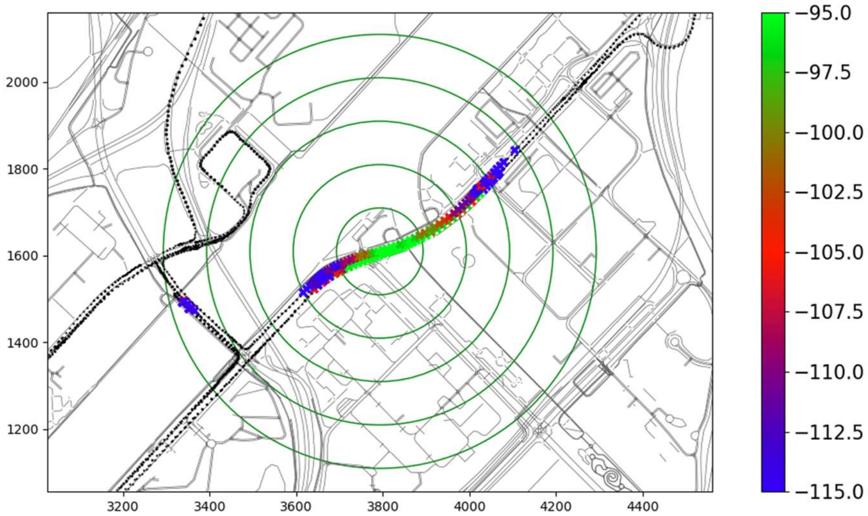
Table 6-1 Use Cases to be Tested at 20-MHz Channel in Future

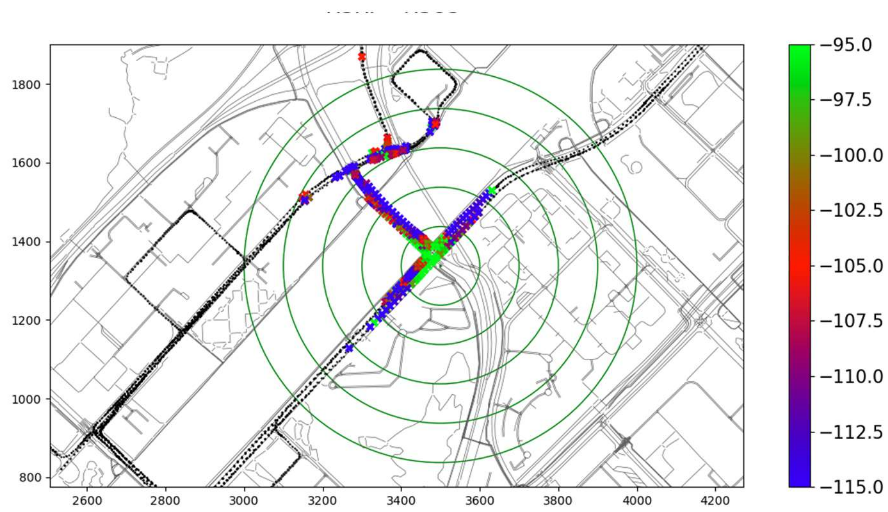
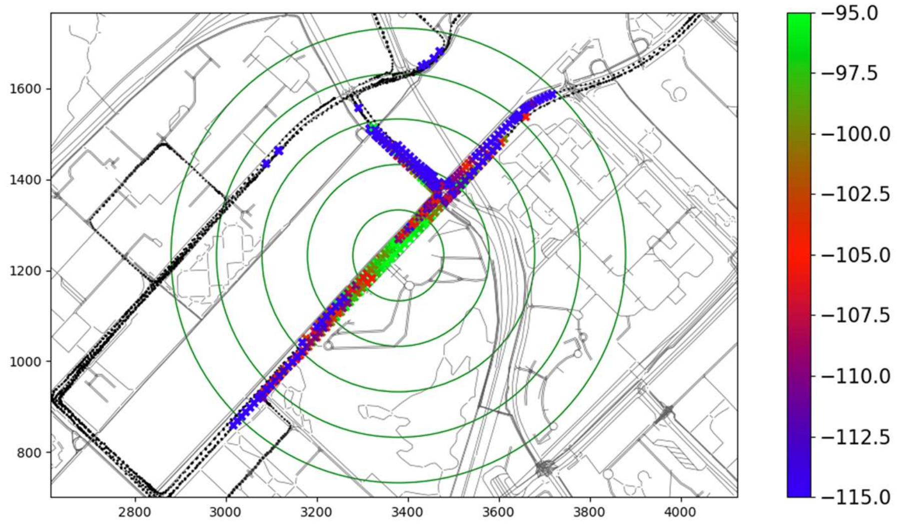
Appendix I Signal Strength and Packet Loss Test Results

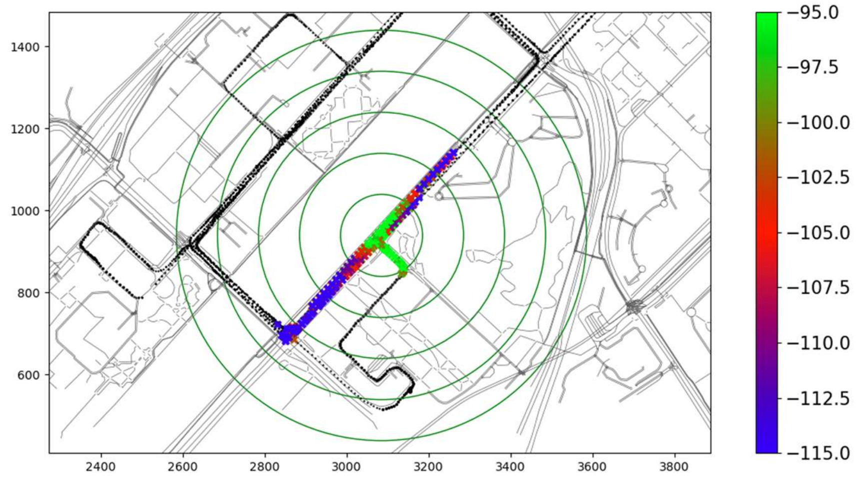
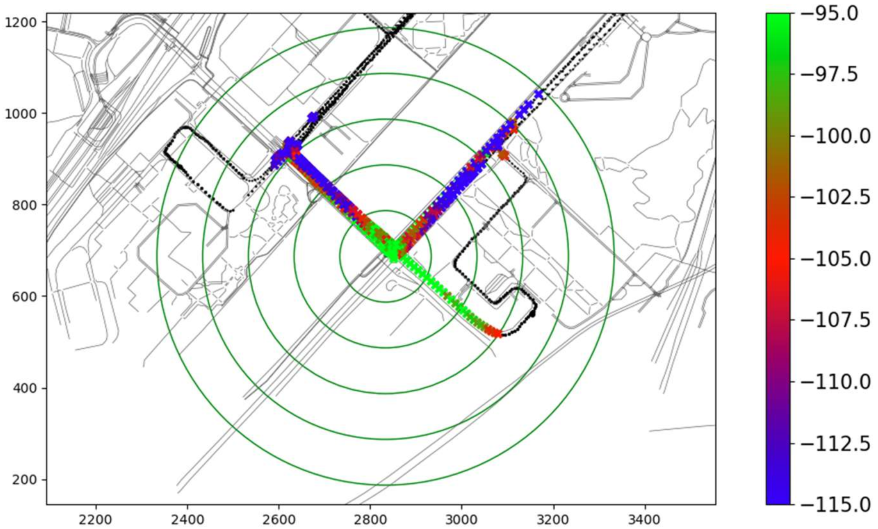
RSRP Test Results for Stage 1 Trial

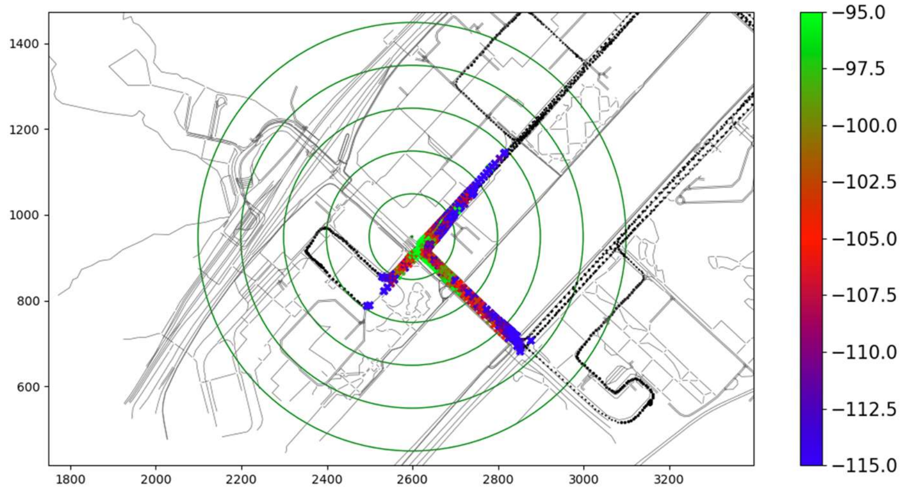
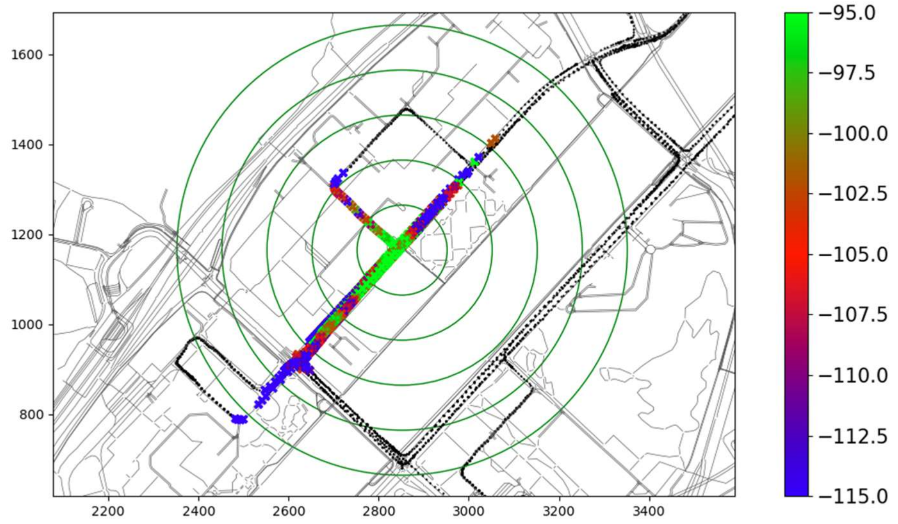
RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU1 創新路 x 科學園路 (173)	
RSU2 科學園路 (193)	

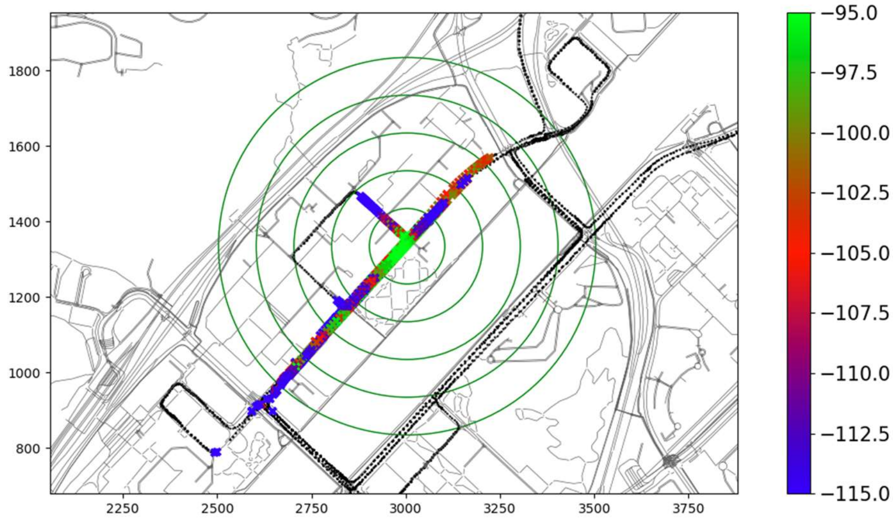
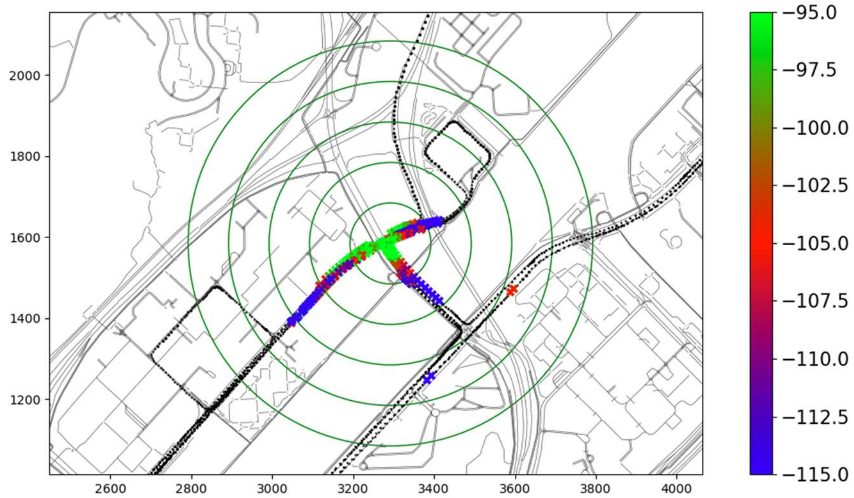
RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU3 瑞祥街 (161)	
RSU4 石門交匯處 (187)	

RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU5 大涌橋路 (183)	
RSU6 大涌橋路 (198)	

RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU7 大涌橋路 x 沙田路 (192)	
RSU8 大涌橋路 (181)	

RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU9 大涌橋路 (163)	
RSU10 大涌橋路 x 沙田圍路 (186)	

RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU11 源禾路 x 沙田鄉事會 路 (188)	
RSU12 源禾路 (174)	

RSU No. / Location	Signal Strength Results – RSRP *(Note each circle is 100m range from RSU)*
RSU13 源禾路 (179)	
RSU14 源禾路 x 火炭路 (199)	

RSRP Test Results for Stage 2 Trial

RSU No.	RSU ID	RSU Location	OBU Location	Distance (m)	RSRP
1	5667(173)	22.423906, 114.213837	22.423803. 114.213852	11.56	-94
2	25960(193)	22.422197, 114.214119	22.422512, 114.214165	35.34	-101

RSU No.	RSU ID	RSU Location	OBU Location	Distance (m)	RSRP
3	21576(161)	22.412134, 114.212990	22.412188, 114.213387	41.25	-95
4	22637(187)	22.394070, 114.209015	22.393837, 114.209167	30.26	-95
5	18905(183)	22.390686, 114.205475	22.392942, 114.207718	340.75	-97
6	25780(198)	22.389322, 114.203201,	22.388855, 114.202225	112.99	-106
7	10994(192)	22.386816, 114.200409	22.386904, 114.200203	23.33	-81
8	16351(181)	22.385851, 114.199257	22.385777, 114.199081	19.88	-84
9	6266(163)	22.383150, 114.196457	22.383434, 114.196640	36.76	-70
10	3435(186)	22.380833, 114.194061	22.381104, 114.194389	45.23	-77
11	4799(188)	22.383160, 114.191734	22.381201, 114.194023	320.69	-115
12	20928(174)	22.385149, 114.194153	22.385183, 114.194122	4.94	-46
13	25506(179)	22.386702, 114.195595	22.386518, 114.195381	30.05	-90
14	5181(199)	22.389008, 114.198349	22.388308, 114.198654	83.92	-105

Packet Loss Test Locations and Results for Stage 2 Trial

RSU NO	Distance Point	RSU ID	Pole	RSU Location	OBU Location	Broadcast Distance	Sent Packets	Received Packets	Received Ratio
1		173	TLC	22.4236350, 114.2136330	22.422981, 114.21421	100	2225	2225	100%
1		173	TLC	22.4236350, 114.2136330	22.422009, 114.214236	200	2320	2313	99%
1		173	TLC	22.4236350, 114.2136330	22.421122, 114.214306	300	2097	2084	99%
2		193	LAMP	22.4222890, 114.2141740	22.42140, 114.21429	100	5564	5562	100%
2		193	LAMP	22.4222890, 114.2141740	22.42050, 114.21435	200	5000	4994	100%
2		193	LAMP	22.4222890, 114.2141740	22.419310, 114.214105	300	5000	1939	39%
3		161	LAMP	22.4121450, 114.2130660	22.41294, 114.21353	100	5000	4976	100%
3		161	LAMP	22.4121450, 114.2130660	22.41380, 114.21384	200	5000	4818	100%
3		161	LAMP	22.4121450, 114.2130660	22.42456, 114.21436	300	5000	4886	98%
4		187	LAMP	22.3940030, 114.2091350	22.39352, 114.20832	100	5000	4984	100%
4		187	LAMP	22.3940030, 114.2091350	22.39283, 114.20766	200	5000	4983	100%
4		187	LAMP	22.3940030, 114.2091350	22.39216, 114.20701	300	5000	4981	98%

5		183	LAMP	22.3907090, 114.2055470	22.39135, 114.20623	100	5000	4973	99%
5		183	LAMP	22.3907090, 114.2055470	22.39203, 114.20687	200	5000	4938	99%
5		183	LAMP	22.3907090, 114.2055470	22.39279, 114.20751	300	5000	4945	99%
6		198	LAMP	22.3892890, 114.2032270	22.38888, 114.20236	100	5000	4965	99%
6		198	LAMP	22.3892890, 114.2032270	22.38831, 114.20159	200	5000	4002	80%
6		198	LAMP	22.3892890, 114.2032270	22.39077, 114.20567	300	5000	4964	99%
7		192	TLC	22.3869580, 114.2002550	22.38761, 114.20091	100	243	243	100%
7		192	TLC	22.3869580, 114.2002550	22.38827, 114.20158	200	291	290	100%
7		192	TLC	22.3869580, 114.2002550	22.38883, 114.20234	300	423	293	69%
8		181	LAMP	22.3859320, 114.1992390	22.38525, 114.19861	100	5000	4960	99%
8		181	LAMP	22.3859320, 114.1992390	22.38457, 114.19796	200	5000	4938	98%
8		181	LAMP	22.3859320, 114.1992390	22.38391, 114.19731	300	5000	4207	84%
9		163	LAMP	22.3831760, 114.1965610	22.38383, 114.19724	100	5000	4973	99%
9		163	LAMP	22.3831760,	22.3845,	200	5000	4026	84%

				114.1965610	114.19788				
9		163	LAMP	22.3831760, 114.1965610	22.38517, 114.19853	300	5000	3126	62%
10		186	TLC	22.3807360, 114.1940030	22.38129, 114.19477	100	325	325	100%
10		186	TLC	22.3807360, 114.1940030	22.38196, 114.19543	200	330	330	100%
10		186	TLC	22.3807360, 114.1940030	22.38263, 114.19609	300	344	344	100%
11		188	TLC	22.3826800, 114.1920120	22.38352, 114.19235	100	335	335	100%
11		188	TLC	22.3826800, 114.1920120	22.38145, 114.19344	200	322	322	100%
11		188	TLC	22.3826800, 114.1920120	22.38083, 114.19413	300	327	326	100%
12		174	LAMP	22.3852220, 114.1941570	22.38463, 114.19343	100	5000	4999	100%
12		174	LAMP	22.3852220, 114.1941570	22.38394, 114.19279	200	5000	4974	99%
12		174	LAMP	22.3852220, 114.1941570	22.38329, 114.19213	300	5000	4974	99%
13		179	LAMP	22.3867840, 114.1955640	22.38615, 114.19487	100	5000	4789	96%
13		179	LAMP	22.3867840, 114.1955640	22.38547, 114.19423	200	5000	4709	94%
13		179	LAMP	22.3867840, 114.1955640	22.38480, 114.19359	300	5000	4777	96%

14		199	TLC	22.3891180, 114.1980230	22.38860, 114.19732	100	310	309	100%
14		199	TLC	22.3891180, 114.1980230	22.38795, 114.19655	200	338	335	99%
14		199	TLC	22.3891180, 114.1980230	22.38726, 114.19590	300	174	11	6%

Appendix II V2X Use Cases Test Log

Speed Alert Warning (V2I) Test Log

Under 20-MHz Channel

02:42:31.533

```
02:42:31.509 [pool-4-thread-16] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - run process!!! receive gnss info!!!
02:42:31.520 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:31.518 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - send msg: {"lat":22.42407916666
02:42:31.524 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.064819999944
02:42:31.522 [pool-4-thread-16] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: ?q4 ?&$3?f$???@?B?R?;?Xt:??q4 ?&$ ?4_?4??@`??;x??:x??
02:42:31.529 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.953183789354739 distance 44.32742492122092 realD 9.9362061
02:42:31.533 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:31.536 [pool-5-thread-4] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:978
```

02:42:32.567

```
02:42:32.547 [pool-5-thread-5] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:32.554 [pool-4-thread-13] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: ?4?@?X?:~?H;X???%=?q4 +$f??3?
02:42:32.553 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.064819999944
02:42:32.560 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 61.67923098330806 distance 148.06957793848025 realD 130.34645562569173
02:42:32.562 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:42:32.556 [pool-5-thread-5] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.064819999944
02:42:32.565 [pool-5-thread-5] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.903799934995504 distance 44.334874618288936 realD 9.900632019108357
02:42:32.567 [pool-5-thread-5] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:32.570 [pool-5-thread-5] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1034
```

02:42:33.471

```
02:42:33.469 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.837371032181437 distance 44.353252716386656 realD 9.854604800547484
02:42:33.339 [pool-4-thread-16] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - run process!!! receive gnss info!!!
02:42:33.473 [pool-4-thread-16] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: .$??gJ???@?*Z;`??;?};4?b0

02:42:33.328 [pool-4-thread-8] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - run process!!! receive gnss info!!!
02:42:33.476 [pool-4-thread-8] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: ??\?@n??:??k??X????q4

02:42:33.471 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
```

02:42:34.437 (the red underline shows the GPS location of simulated event)

```
02:42:34.423 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:104
02:42:34.425 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: speed:50type104lat:22.423771lon:114.212141
02:42:34.427 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.4240785
02:42:34.429 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21241633333334
02:42:34.431 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:34.433 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.042595999963199994
02:42:34.435 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.755748414565346 distance 44.35742118883863 realD 9.793909621683612
02:42:34.437 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:34.398 [pool-5-thread-10] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 3, this is RSI message
```

02:42:35.409

```
02:42:35.395 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21241666666667
02:42:35.397 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - Sending PC5 message:0011002D0280000000000000001E0000C3028D90AF5D40861000
02:42:35.399 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:35.402 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - Sending PC5 message to 192.168.1.2:50001 completed!
02:42:35.403 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.018519999984
02:42:35.407 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.706431469008294 distance 44.365002483974465 realD 9.758335488416323
02:42:35.409 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:35.411 [pool-5-thread-2] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:972
```

02:42:36.695

```
02:42:36.666 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - Sending PC5 message to 192.168.1.2:50001 completed!
02:42:36.662 [pool-5-thread-5] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 RSI info, step 4, lat:224245670 lon:1142131770 type:109
02:42:36.683 [vert.x-eventloop-thread-2] INFO  org.astri.icgw.hw.ICGWNode - Send GPS to Kafka: {"lat":22.4240775,"lon":114.2124175,"yaw":232.37,"speed":0.0444479999616}
02:42:36.688 [vert.x-eventloop-thread-2] INFO  org.astri.icgw.hw.ICGWNode - V2V Broad Cast: Forming BSM for PC5 broadcast
02:42:36.680 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.544932548934355 distance 44.348529337561395 realD 9.632730255692538
02:42:36.695 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:36.697 [pool-5-thread-6] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1286
```

02:42:37.439

```
02:42:37.422 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: speed:50type104lat:22.423771lon:114.212141
02:42:37.430 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424077166666667
02:42:37.432 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21241816666667
02:42:37.433 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:37.435 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.18519999984000002
02:42:37.437 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.44636897124002 distance 44.3640056100755 realD 9.561581991235041
02:42:37.439 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
```

02:42:38.558

```
02:42:38.547 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:38.554 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.007407999993600001
02:42:38.556 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.267853831848129 distance 44.35912645225609 realD 9.425523670890346
02:42:38.545 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.007407999993600001
02:42:38.544 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 177.37842391140367 distance 95.04250176403693 realD 4.347165243611023
02:42:38.560 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 61.72171389753413 distance 148.54996967254672 realD 130.8215646632975
02:42:38.558 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
```

02:42:39.540

```
02:42:39.524 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:104
02:42:39.526 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: speed:50type104lat:22.423771lon:114.212141
02:42:39.527 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424075333333334
02:42:39.530 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21242016666666
02:42:39.531 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:39.533 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.0259279999776
02:42:39.536 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 12.073828201703122 distance 44.3405503150634 realD 9.274797389785022
02:42:39.538 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:39.540 [pool-5-thread-6] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:975
```

02:42:40.476

```
02:42:40.448 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:232.37
02:42:40.442 [pool-5-thread-5] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 2, delay:44
02:42:40.471 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:0.046299999960000005
02:42:40.474 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 11.895183209767026 distance 44.336570102475264 realD 9.138739068528453
02:42:40.476 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - Detected speed limit alarm
02:42:40.478 [pool-5-thread-8] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:938
```

Congestion/Traffic Control Warning (V2I) Test Log

Under 20-MHz Channel

02:33:23.369

```
02:33:23.358 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:16.9013519853984
02:33:23.349 [pool-5-thread-10] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 3, this is RSI message
02:33:23.366 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 20.543197746272 distance 78.19567858489032 realD 27.43991
02:33:23.360 [pool-4-thread-7] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: D???3#?@x??;Z??;?*Z?~o?q4 f?g???????@??r=?m??Z?????
    ?3'?@?o??V?
;?pQ??)?q4 ????,???
?f>?@?Y??!??<eq?;???q4 ?????
???@????z?2+????q4 ???+?f4?T?@?A?]Z?
02:33:23.369 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:23.367 [pool-5-thread-10] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 RSI info, step 4, lat:224237520 lon:1142119750 type:104
```

02:33:24.572 (the red underline shows the GPS location of simulated event)

```
02:33:24.516 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:109
02:33:24.517 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: Congestion/Traffic Control Warning#angel:135type109lat:22.424567lon:114.213177
02:33:24.504 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 1.1[B@819dd9
02:33:24.522 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 2, delay:25
02:33:24.524 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 3, this is RSI message
02:33:24.526 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 RSI info, step 4, lat:224237520 lon:1142119750 type:104
02:33:24.533 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:104
02:33:24.535 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: speed:50#angle:315type104lat:22.423752lon:114.211975
02:33:24.545 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424230166666668
02:33:24.546 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.2125605
02:33:24.548 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:38.67
02:33:24.550 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:17.6254839847728
02:33:24.552 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 170.12998145937684 distance 80.2544430246376 realD 13.756702473495507
02:33:24.559 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ----> rsiAngle -- angle:315 -- 83.67000000000002
02:33:24.561 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck: start check exceed speed: speed:50#angle:315 realD13.756702473495507distance80.2544430246376vspeed17.6254839847728
02:33:24.520 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424230166666668
02:33:24.565 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.2125605
02:33:24.566 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:38.67
02:33:24.568 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:17.6254839847728
02:33:24.570 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 20.744354459588592 distance 73.56304574503203 realD 26.055949467875205
02:33:24.572 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:24.574 [pool-5-thread-4] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1201
```

02:33:25.553

```
02:33:25.539 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:37.61
02:33:25.541 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:37.61
02:33:25.546 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:19.292283983332798
02:33:25.547 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:19.292283983332798
02:33:25.549 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 23.46399242270259 distance 68.61872138836252 realD 27.322099033826607
02:33:25.551 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 169.7489634425158 distance 85.51917669708382 realD 15.219107970039332
02:33:25.553 [pool-5-thread-7] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:25.555 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ----> rsiAngle -- angle:315 -- 82.61000000000001
```

02:33:26.415

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02:33:26.426 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - Sending PC5, lat: 224242684  lon: 1142125924  yaw: 3009 speed: 19.292283983332798
02:33:26.424 [pool-5-thread-3] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - V2X message: PC5 msg without DSMP 420240989CAC9EBE646E0200D225CB7E1C883
02:33:26.422 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 1.1[B@f49160
02:33:26.448 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 2, delay:29
02:33:26.420 [pool-4-thread-14] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - run process!!! receive gnss info!!!
02:33:26.415 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:26.389 [pool-4-thread-15] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: ?@V?>???Xt=T/?q4 Z?p??4O?3??@??
```

02:33:27.453

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02:33:27.449 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Left 163.32112092245433 distance 96.48132646393206 realD 27.690856448996783
02:33:27.447 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 36.69378494172031 distance 58.86948771609894 realD 35.176766092096834
02:33:27.452 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ----> rsiAngle -- angle:315 -- 74.5
02:33:27.450 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - Sending PC5 message:0011002D0280000000000000001E0000C302984CAF5D49BE10008
02:33:27.455 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck: start check exceed speed: speed:50#angle:315 realD27.690856448996783distance96.48132646393
02:33:27.453 [pool-5-thread-1] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:27.462 [pool-5-thread-1] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1008
```

02:33:28.506

```
02:33:28.490 [pool-5-thread-5] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ----> rsiAngle -- angle:315 -- 70.88999999999999
02:33:28.494 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:19.2811719833424
02:33:28.493 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - start to handler eventbus msg
02:33:28.500 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - send msg: {"lat":22.424397833333334,"lon"
02:33:28.493 [vert.x-eventloop-thread-2] INFO  org.astri.icgw.hw.ICGWNode - V2V Broad Cast: Forming BSM for PC5 broadcast
02:33:28.498 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 44.04984317612745 distance 54.8058041310941 2 realD 38.105592199147836
02:33:28.506 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - Detected front congestion alarm
02:33:28.509 [pool-5-thread-8] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1047
```

Road Works Warning (V2I) Test Log

Under 10-MHz Channel

RSICheck, AlertType:105
RSICheck, Description: road working#angle:221type105lat:22.380921lon:114.194404
RSICheck vlat:22.382478666666668
RSICheck vlon:114.19589566666667
RSICheck vyaw:225.35
RSICheck speed:43.3534679625456
RSICheck ---->Direction: Left 3.825194181258837 distance 231.20388003062712 realD 15.42422321557921
RSICheck ----> rsiAngle -- angle:221 -- 4.349999999999994
RSICheck:desroad working#angle:221
In vehicle sign alarm

Under 20-MHz Channel

02:46:05.510 (the red underline shows the GPS location of simulated event)

```
02:46:05.497 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:05.499 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:05.500 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.425316666666667
02:46:05.502 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21008966666666
02:46:05.504 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:125.74
02:46:05.505 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:52.2893679548256
02:46:05.507 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 0.9291756903192692 distance 129.26218349250132 realD 2.096175582756943
02:46:05.509 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:05.510 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:05.513 [pool-5-thread-4] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:137961
```

02:46:06.614

```
02:46:06.583 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:06.585 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:06.586 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.425241166666666
02:46:06.588 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21020333333334
02:46:06.590 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:125.62
02:46:06.609 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:51.7374719553024
02:46:06.611 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 1.17055696193421 distance 114.88671647904317 realD 2.346980737358687
02:46:06.613 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:06.614 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:06.617 [pool-5-thread-2] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1104
```

02:46:07.376

```
02:46:07.362 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:07.364 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:07.366 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.425165833333335
02:46:07.367 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.210317
02:46:07.369 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:125.48
02:46:07.371 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:51.8615559551952
02:46:07.373 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 1.4750906623606994 distance 100.52304070219023 realD 2.587698781076385
02:46:07.375 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:07.376 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:07.378 [pool-5-thread-6] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:761
```

02:46:08.376

```
02:46:08.501 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:08.503 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:08.505 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.425091666666667
02:46:08.506 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21043116666667
02:46:08.508 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:124.84
02:46:08.539 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:51.8337759552192
02:46:08.541 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 2.423769647018986 distance 86.19798313243226 realD 3.6453251894132546
02:46:08.543 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:08.545 [pool-5-thread-10] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:08.550 [pool-5-thread-10] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1172
```

02:46:09.434

```
02:46:09.423 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:109
02:46:09.421 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 1420240989CAC9EBE646E0400D00FCF865CB91D35618605031D5EBA6B82200
02:46:09.420 [pool-4-thread-8] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - run process!!! receive gnss info!!!
02:46:09.429 [pool-4-thread-8] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - Skip!! UDP GPS message: w??&?q4 ?y'?????4??@?m<??<W?
;?5?q4 ?y'33:??J?f??@?+=???;\Z;??q4 z'???4?????@??P???????q4 "z'33
    >4?
02:46:09.419 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 2.9537758585814373 distance 72.00990593270065 realD 3.71069072192242
02:46:09.433 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:09.434 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:09.437 [pool-5-thread-3] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:886
```

02:46:10.435

```
02:46:10.407 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 RSI info, step 4, lat:224246220 lon:1142110990 type:105
02:46:10.410 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:10.411 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:10.413 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424946
02:46:10.415 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.2106555
02:46:10.416 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:124.79
02:46:10.419 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:50.9966719559424
02:46:10.432 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 3.5297683542994633 distance 58.06706459574126 realD 3.5750218173567365
02:46:10.434 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:10.435 [pool-5-thread-2] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:10.397 [vert.x-eventloop-thread-2] INFO  org.astri.icgw.hw.ICGWNode - Send GPS to Kafka: {"lat":22.425018666666666,"lon":114.21054466666666,"yaw":124.79,"speed":50.9966719559424}
02:46:10.438 [pool-5-thread-2] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1002
```

02:46:11.520

```
02:46:11.495 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:105
02:46:11.499 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: road worktype105lat:22.424622lon:114.211099
02:46:11.501 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424873666666667
02:46:11.511 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21076383333333
02:46:11.513 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:125.78
02:46:11.514 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:49.344687957369594
02:46:11.516 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 3.3067141593973304 distance 44.35627758975402 realD 2.5585151768351926
02:46:11.518 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:11.489 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - start to handler eventbus msg
02:46:11.522 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - send msg: {"lat":22.424873666666667,"lon":1
02:46:11.520 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:11.497 [pool-5-thread-10] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - V2X message: PC5 msg without DSMP 420240989CAC9EBE646E0400D00FCF865CB91D356186050
```

02:46:12.504

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02:46:12.491 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:104
02:46:12.489 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:49.344687957369594
02:46:12.485 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - >>>>>>>>>>> Adding DSMP header, HEX CONTENT 028000000000000
02:46:12.495 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 4.53933458558808 distance 30.94214166458398 realD 2.4488
02:46:12.494 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, Description: speed:50type104lat:22.423771lon:114.212141
02:46:12.492 [pool-4-thread-1] DEBUG org.astri.icgw.hw.lenovo.GpsdUdpHandler - UDP GPS message: GPS info parsed:22.424802166666666|114.21086933333333|126.
02:46:12.500 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlat:22.424802166666666
02:46:12.498 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:12.497 [vert.x-eventloop-thread-2] DEBUG org.astri.icgw.hw.lenovo.MessageSenderLenovo - >>>>>>>>>>> Adding DSMP header, FULL MESSAGE 0011002d028000
02:46:12.504 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:12.503 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vlon:114.21086933333333
```

02:46:13.501

```
02:46:13.453 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 1420240989CAC9EBE646E0400D00FCF865CB91D35618605
02:46:13.450 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 3, this is RSI message
02:46:13.489 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 1.1[B@ffdfc5
02:46:13.487 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:13.486 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - start to handler eventbus msg
02:46:13.486 [vert.x-eventloop-thread-2] INFO  org.astri.icgw.hw.ICGWNode - V2V Broad Cast: Forming BSM for PC5 broadcast
02:46:13.504 [kafka-msg-consumer-vert.x-worker-thread-1-0] INFO  o.a.u.k.producer.KafkaProducerMessageSender$Messagehandler - send msg: {"lat":22.4247313333
02:46:13.502 [pool-5-thread-2] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 info, step 2, delay:49
02:46:13.501 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:13.497 [pool-5-thread-1] DEBUG org.astri.icgw.hw.lenovo.ServerHandlerLenovoPC5 - Parse PC5 RSI info, step 4, lat:224245670 lon:1142131770 type:109
```

02:46:14.620

```
02:46:14.596 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck vyaw:127.52
02:46:14.594 [pool-5-thread-9] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck, AlertType:104
02:46:14.613 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck speed:46.216659960072
02:46:14.617 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck ---->Direction: Right 18.95393147653293 distance 5.176558451491632 realD 1.6813866011949627
02:46:14.619 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - RSICheck:desroad work
02:46:14.620 [pool-5-thread-6] DEBUG org.astri.icgw.hw.ICGWNode - In vehicle sign alarm
02:46:14.622 [pool-5-thread-6] DEBUG org.astri.icgw.hw.WebSocketServer - WShandler delay:1101
```

Traffic Light Information (V2I) Test Log

Under 10-MHz Channel

```
STLmgmt: check streelightnode stlDelay: 310
STLmgmt:distance:181.63993548255056latitude: 22.387059longitude: 114.200266
Next step is turning in the coming light
STLmgmt: Vehicle coming from directionNo: 0part:7.2139999999999995 angleStreetLight324.63
turnTo 1
STLmgmt: allow change light direct: true
STLmgmt: Vehicle coming from directionNo: 12part:7.2139999999999995 angleStreetLight324.63
turnTo 1
STLmgmt: turnTo: 1
STLmgmt: focusLight: org.astri.icgw.hw.PathLight@18fe28a
STLmgmt: find focusLight info: org.astri.icgw.hw.PathLight@18fe28a , turnTo 1
STLmgmt: lightValue 5
STLmgmt: light now GreenLight, leftTime1
```

Intersection Warning (V2V) Test Log

Under 10-MHz Channel

```
SafeCheck point 1
GPS info delay is ==============>87 ms
SafeCheck: Using BSM msg, coming id:car30006
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.413690833333334
SafeCheck vlon:114.21390183333334
SafeCheck vyaw:308.32
SafeCheck speed:2.2149919980864
SafeCheck Info: coming vehicle22.4144485   114.2143457   202.8 self:  22.413690833333334
114.21390183333334   308.32
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 95.75042097217163 meter
SafeCheck:---->Position: Right 80.11880030109353 distance 95.75042097217163 Direction
105.51999999999998 RealD 94.33002932730543 HVspd 2.2149919980864 RVspd 42.768
SafeCheck: pedal status is0
SafeCheck: vType is0
SafeCheck: hazardStatus isfalse
SafeCheck: Loss Warning status is falsefalsefalsefalse
SafeCheck: Detected Intersection Alarm
```

```
SafeCheck point 1
GPS info delay is ==============>91 ms
SafeCheck: Using BSM msg, coming id:car30006
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.391579833333335
SafeCheck vlon:114.19944683333334
SafeCheck vyaw:138.16
SafeCheck speed:0.0018519999984000003
SafeCheck Info: coming vehicle22.3911754   114.1991557   30.900000000000002 self:
22.391579833333335   114.19944683333334   138.16
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 53.98733574759247 meter
SafeCheck:---->Position: Right 75.48700938745131 distance 53.98733574759247 Direction
107.25999999999999 RealD 52.26464559635128 HVspd 0.0018519999984000003 RVspd 32.184
```

```
SafeCheck: pedal status is0
SafeCheck: vType is0
SafeCheck: hazardStatus isfalse
SafeCheck: Loss Warning status is falsefalsefalsefalse
SafeCheck: Detected Intersection Alarm
```

Under 20-MHz Channel

```
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Using BSM msg, coming id:
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck point 2
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlat:22.413729833333335
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlon:114.21385233333334
16:04:43.493 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vyaw:307.96
16:04:43.494 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck speed:0.014815999987200002
16:04:43.494 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck Info: coming vehicle22.4144239   114.2143452   201.262500000
16:04:43.494 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 92
16:04:43.494 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck:---->Position: Right 85.32347795679573 distance 92.262547610
16:04:43.494 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: pedal status is0
16:04:43.495 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: vType is0
16:04:43.495 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: hazardStatus isfalse
16:04:43.495 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Loss Warning status is falsefalsefalsefalse
16:04:43.495 [pool-5-thread-3] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Detected Intersection Alarm
```

Forward Collision Warning (V2V) Test Log

Under 10-MHz Channel

```
SafeCheck point 1
GPS info delay is ==============>86 ms
SafeCheck: Using BSM msg, coming id:car30006
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.391711833333332
SafeCheck vlon:114.1999245
SafeCheck vyaw:129.17
SafeCheck speed:28.2207759756192
SafeCheck Info: coming vehicle22.3914561   114.2002557   116.92500000000001 self:
22.391711833333332   114.1999245   129.17
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 44.33533252966754 meter
SafeCheck:---->Position: Right 0.695434181731656 distance 44.33533252966754 Direction
12.244999999999976 RealD 0.5381120376126953 HVspd 28.2207759756192 RVspd 18.144
SafeCheck: Use speed difference to calculate alarm, sDif:10.076775975619203
SafeCheck: Detected front collision alarm
```

Under 20-MHz Channel

```
16:15:57.579 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Using BSM msg, coming id:
16:15:57.579 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
16:15:57.579 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck point 2
16:15:57.579 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlat:22.412458333333333
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlon:114.213516
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vyaw:200.17
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck speed:27.1095759765792
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck Info: coming vehicle22.4123029   114.2134549   202.5 self:  22.41
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Unhandled maneuver value:keep-right
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Now at cross road and about to turn(1-left,2-right)0
16:15:57.580 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 18.3777
16:15:57.581 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck:---->Position: Left 0.19876011174019936 distance 18.3777037704169
13.176
16:15:57.581 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Use speed difference to calculate alarm, sDif:13.9335759765792
16:15:57.581 [pool-5-thread-4] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Detected front collision alarm
```

Do Not Pass Warning (V2V) Test Log

Under 10-MHz Channel

```
SafeCheck: Using BSM msg, coming id:car30009
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.424869
SafeCheck vlon:114.21379733333333
SafeCheck vyaw:154.04
SafeCheck speed:0.0314839999728
SafeCheck Info: coming vehicle22.4247859   114.213737   327.70000000000005 self:  22.424869
114.21379733333333   154.04
SafeCheck: Now at cross road and about to turn(1-left,2-right)2
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 11.121404347700844 meter
SafeCheck:---->Position: Right 59.82679326546224 distance 11.121404347700844 Direction
173.66000000000005 RealD 9.614564549912858 HVspd 0.0314839999728 RVspd 18.432
SafeCheck: pedal status is0
SafeCheck: vType is0
SafeCheck: hazardStatus isfalse
SafeCheck: Loss Warning status is falsefalsefalsefalse
SafeCheck: Detected do not pass alarm
```

Blind Spot Warning (V2V) Test Log

Under 10-MHz Channel

```
SafeCheck point 1
GPS info delay is ==============>110 ms
SafeCheck: Using BSM msg, coming id:car30009
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.4211565
SafeCheck vlon:114.21417933333333
SafeCheck vyaw:354.95
SafeCheck speed:31.6117879726896
SafeCheck Info: coming vehicle22.4210037   114.2141577   355.125 self:  22.4211565
114.21417933333333   354.95
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 17.124722202496994 meter
SafeCheck:---->Position: Left 167.49368610441206 distance 17.124722202496994 Direction
0.17500000000001137 RealD 3.708310622346794 HVspd 31.6117879726896 RVspd 32.688
SafeCheck: pedal status is0
SafeCheck: vType is0
SafeCheck: hazardStatus isfalse
SafeCheck: Loss Warning status is falsefalsefalsefalse
SafeCheck: Detected blind spot alarm
```

Under 20-MHz Channel

```
16:06:01.112 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Using BSM msg, coming id:
16:06:01.112 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
16:06:01.112 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck point 2
16:06:01.112 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlat:22.414027166666667
16:06:01.113 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vlon:114.2135755
16:06:01.113 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck vyaw:78.71
16:06:01.113 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck speed:32.8767039715968
16:06:01.113 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck Info: coming vehicle22.4140272   114.2133725   85.05000000000001 self:  22.414
16:06:01.113 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 20.854172572194823 m
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck:---->Position: Left 168.6997842785908 distance 20.854172572194823 Direction 6.
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: pedal status is0
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: vType is0
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: hazardStatus isfalse
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Loss Warning status is falsefalsefalsefalse
16:06:01.114 [pool-5-thread-8] DEBUG org.astri.icgw.hw.ICGWNode - SafeCheck: Detected blind spot alarm
```

Abnormal Vehicle Warning (V2V) Test Log

Under 10-MHz Channel

```
SafeCheck point 1
GPS info delay is ==============>91 ms
SafeCheck: Using BSM msg, coming id:
SafeCheck: use Can bus Info, leftTurn:-1 rightTurn:-1
SafeCheck point 2
SafeCheck vlat:22.412693666666666
SafeCheck vlon:114.21354016666666
SafeCheck vyaw:178.21
SafeCheck speed:19.6256439830448
SafeCheck Info: coming vehicle22.4122861   114.213435   192.07500000000002 self:
22.412693666666666   114.21354016666666   178.21
SafeCheck: Unhandled maneuver value:keep-right
SafeCheck: Now at cross road and about to turn(1-left,2-right)0
SafeCheck: >>>>>>>>>>>>>Vehicle/Pedestrian is in safty check range! 46.561666339809506 meter
SafeCheck:---->Position: Right 15.206861815175472 distance 46.561666339809506 Direction
13.865000000000009 RealD 12.213346172432127 HVspd 19.6256439830448 RVspd 13.176
SafeCheck: pedal status is0
SafeCheck: vType is0
SafeCheck: hazardStatus istrue
SafeCheck: Front vehicle brake when current vehicle still moving
SafeCheck: Detected Abnormal vehicle alarm
```

Roundabout Pedestrian Warning (V2I) Test Log:

Under 10-MHz Channel

```
rsmCheck: 64 bit relative pos,type:1 lat:224246644 lon:1142133376
rsmCheck vlat:22.424582666666666
rsmCheck vlon:114.21325766666666
rsmCheck vyaw:315.86
rsmCheck speed:17.6884519847184
rsmCheck Info type: 1 coming object,distance:12.243907280394575 angle:86.25434370436409 lat
22.4246644 lon 114.2133376 yaw 0.0 self:  22.424582666666666   114.21325766666666   315.86
rsmCheck Info: coming object is right
rsmCheck: In dangerArea >>> true
rsmCheck: Detected Pedestrian in danger area alarm
```

Appendix III Success Rate and Latency Test Log

Success Rate

1st Round Test

```
[12:19:59.063] INFO [0x1962931280:GpsTask.c] [createJsonObject:170] data transfer json successfully

[12:19:59.063] INFO [0x1962931280:GpsTask.c] [addHead:214] Add head successfully

[12:19:59.079] INFO [0x1962931280:GpsTask.c] [getESN:79] esn data get successfully

[12:19:59.080] INFO [0x1962931280:GpsTask.c] [sendHeartDataByMqtt:202] Successful send message by mqtt, target topic: HUALI_RSU_HL00BDE6CB216

[12:19:59.080] INFO [0x1962931280:GpsTask.c] [getGpsData_1:243] gps data get successfully

[12:19:59.286] INFO [0x1974674512:V2XApiadapter.c] [deliveryComplete:37] Message delivery completed: Token 23

[12:19:59.615] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:50] Message arrived on topic: V2X_SERVER/RSI/HL00BDE6CB2162

[12:19:59.615] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:51] Message payload length: 67

[12:19:59.615] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:52] Message payload:
[12:19:59.615] DEBUG [0x1974674512:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84
[12:19:59.615] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:60] mde_cv2x_custom_send is ok >>>B@@@@   f


[12:20:00.000] INFO [0x1954542672:custom.c] [customTask:70] In past time, during 15 --> 20, send 300 messages successfully

[12:20:00.608] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:50] Message arrived on topic: V2X_SERVER/RSI/HL00BDE6CB2162

[12:20:00.609] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:51] Message payload length: 67

[12:20:00.609] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:52] Message payload:
[12:20:00.609] DEBUG [0x1974674512:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84
[12:20:00.609] INFO [0x1974674512:V2XApiadapter.c] [messageArrived:60] mde_cv2x_custom_send is ok >>>B@@@@   f
```

```
[12:19:59.661] DEBUG [0x1991025744:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx

[12:19:59.662] INFO [0x1991025744:custom.c] [cv2x_custom_recv_handle:86] recv from api successfully >>> 4202404040409098BE660A00D023CF86
5CB91D35608F0EECFB32BA62DDC6180B44557AEBC6E880001ABD75E376180B445357AEBC6EC301688A7D00, buffer length 59

[12:19:59.662] INFO [0x1991025744:custom.c] [sendPC5DataTOICGWByUdp:61] send obu api data to app, api message length: 63

[12:19:59.662] INFO [0x1991025744:custom.c] [cv2x_custom_recv_handle:96] finished send custom to udp, and  process time is469


[12:19:59.966] INFO [0x1982633040:GpsTask.c] [getGpsData_1:138] GPS SEND successfully, send gps message is $GNRMC,041959.60,A,2232.03831
,N,11356.54722,E,0.253,,301123,3.20,W,D*2D


[12:19:59.966] INFO [0x1982633040:GpsTask.c] [getGpsData_1:142] GPS SEND successfully, send gps message is $GNGGA,041959.60,2232.03831,N
,11356.54722,E,2,10,1.15,141.6,M,-2.7,M,,0000*57


[12:20:00.000] INFO [0x1974244432:custom.c] [customTask:158] In last 5 minutes, during 15 --> 20, received 300 messages successfully

[12:20:00.369] INFO [0x1982633040:GpsTask.c] [getGpsData_1:138] GPS SEND successfully, send gps message is $GNRMC,042000.00,A,2232.03829
,N,11356.54722,E,0.187,,301123,3.20,W,D*2E


[12:20:00.369] INFO [0x1982633040:GpsTask.c] [getGpsData_1:142] GPS SEND successfully, send gps message is $GNGGA,042000.00,2232.03829,N
,11356.54722,E,2,10,1.15,141.7,M,-2.7,M,,0000*5F
```

2nd Round Test

```
[12:34:58.636] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:50] Message arrived on topic: V2X_SERVER/RSI/HL00BDE6CB2162

[12:34:58.639] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:51] Message payload length: 67

[12:34:58.639] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:52] Message payload:
[12:34:58.639] DEBUG [0x1974088784:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84
[12:34:58.639] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:60] mde_cv2x_custom_send is ok >>>B@@@@   f


[12:34:59.636] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:50] Message arrived on topic: V2X_SERVER/RSI/HL00BDE6CB2162

[12:34:59.689] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:51] Message payload length: 67

[12:34:59.689] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:52] Message payload:
[12:34:59.690] DEBUG [0x1974088784:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84
[12:34:59.690] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:60] mde_cv2x_custom_send is ok >>>B@@@@   f


[12:35:00.000] INFO [0x1953494096:custom.c] [customTask:70] In past time, during 30 --> 35, send 300 messages successfully

[12:35:00.625] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:50] Message arrived on topic: V2X_SERVER/RSI/HL00BDE6CB2162

[12:35:00.643] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:51] Message payload length: 67

[12:35:00.643] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:52] Message payload:
[12:35:00.643] DEBUG [0x1974088784:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84
[12:35:00.644] INFO [0x1974088784:V2XApiadapter.c] [messageArrived:60] mde_cv2x_custom_send is ok >>>B@@@@   f
```

```
[12:34:59.713] DEBUG [0x1991222352:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx

[12:34:59.714] INFO [0x1991222352:custom.c] [cv2x_custom_recv_handle:86] recv from api successfully >>> 4202404040409098BE660A00D023CF86
5CB91D35608F0EECFB32BA62DDC6180B44557AEBC6E880001ABD75E376180B445357AEBC6EC301688A7D00, buffer length 59

[12:34:59.714] INFO [0x1991222352:custom.c] [sendPC5DataTOICGWByUdp:61] send obu api data to app, api message length: 63

[12:34:59.714] INFO [0x1991222352:custom.c] [cv2x_custom_recv_handle:96] finished send custom to udp, and  process time is318

[12:34:59.945] INFO [0x1982829648:GpsTask.c] [getGpsData_1:138] GPS SEND successfully, send gps message is $GNRMC,043459.60,A,2232.03832
,N,11356.54061,E,0.099,,301123,3.20,W,D*25


[12:34:59.946] INFO [0x1982829648:GpsTask.c] [getGpsData_1:142] GPS SEND successfully, send gps message is $GNGGA,043459.60,2232.03832,N
,11356.54061,E,2,08,1.56,73.1,M,-2.7,M,,0000*62


[12:35:00.000] INFO [0x1974441040:custom.c] [customTask:158] In last 5 minutes, during 30 --> 35, received 300 messages successfully

[12:35:00.360] INFO [0x1982829648:GpsTask.c] [getGpsData_1:138] GPS SEND successfully, send gps message is $GNRMC,043500.00,A,2232.03833
,N,11356.54036,E,0.138,,301123,3.20,W,D*27


[12:35:00.360] INFO [0x1982829648:GpsTask.c] [getGpsData_1:142] GPS SEND successfully, send gps message is $GNGGA,043500.00,2232.03833,N
,11356.54036,E,2,08,1.41,72.9,M,-2.7,M,,0000*65
```

Latency Test

<table>
<tr><td colspan="2">1st Result</td></tr>
<tr><td colspan="2"><code>12:42:23.979] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84</code>
<code>12:42:24.000] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx</code></td></tr>
<tr><td>Sending time</td><td>12:42:23.979</td></tr>
<tr><td>Receiving time</td><td>12:42:24.000</td></tr>
<tr><td>Latency</td><td>21ms</td></tr>
<tr><td colspan="2">2nd Result</td></tr>
<tr><td colspan="2"><code>12:42:24.668] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84</code>
<code>12:42:24.689] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx</code></td></tr>
<tr><td>Sending time</td><td>12:42:24.668</td></tr>
</table>

Receiving time	12:42:24.689
Latency	21ms
3rd Result	
12:42:25.654] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:25.681] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:25.654
Receiving time	12:42:25.681
Latency	27ms
4th Result	
12:42:26.664] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:26.689] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:26.664
Receiving time	12:42:26.689
Latency	25ms
5th Result	
12:42:27.683] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:27.705] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:27.683
Receiving time	12:42:27.705
Latency	22ms
6th Result	
12:42:28.667] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:28.687] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:28.667
Receiving time	12:42:28.687
Latency	20ms
7th Result	
12:42:29.685] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:29.703] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:29.685
Receiving time	12:42:29.703
Latency	18ms

8th Result	
12:42:30.692] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:30.709] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:30.692
Receiving time	12:42:30.709
Latency	17ms
9th Result	
12:42:31.664] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:31.685] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:31.664
Receiving time	12:42:31.685
Latency	21ms
10th Result	
12:42:32.684] DEBUG [0x1973937232:v2x_tx.c] [cv2x_send_packet:94] g_sdk_udp_sockfd send success, ret:84 12:42:32.705] DEBUG [0x1991062608:v2x_rx.c] [cv2x_rx:127] sdk upd msgrcv 80 bytes from unix domain /tmp/unix_domain_cv2x_stack_tx	
Sending time	12:42:32.684
Receiving time	12:42:32.705
Latency	21ms

Appendix IV Latest Achievements of Stage 4 and 5

OBUs Installed on Public Vehicles

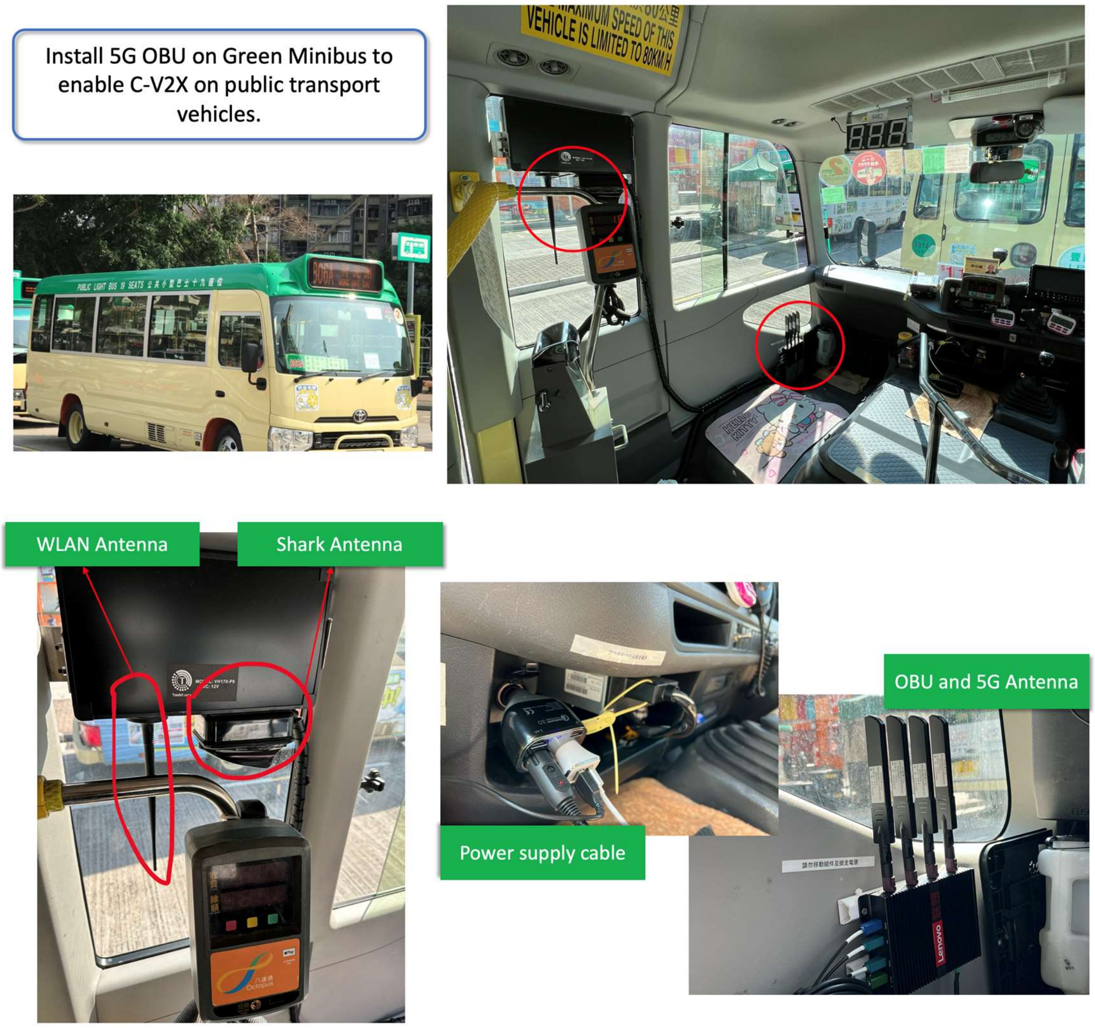

Figure A-1 OBU Installed on Green Minibus

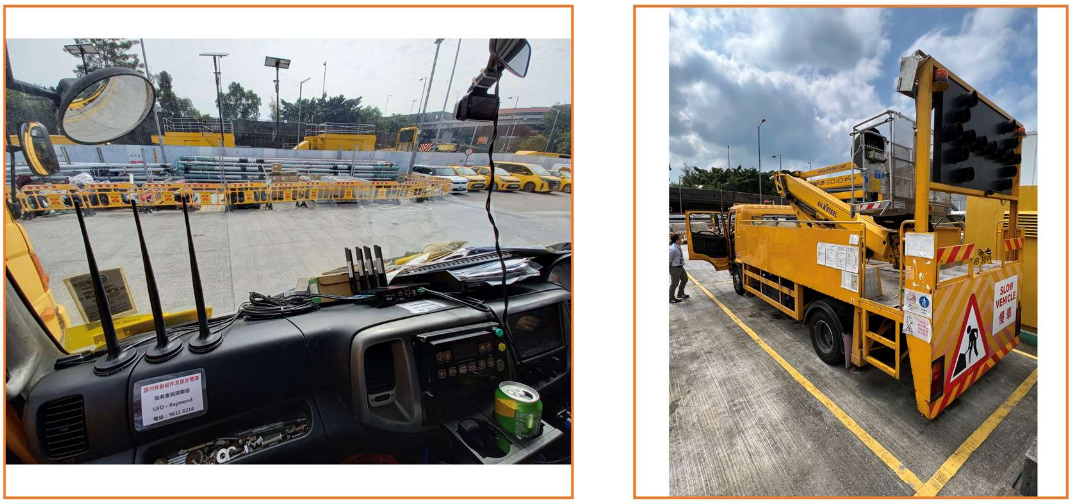

Figure A-2 OBU Installed on Engineering Vehicle

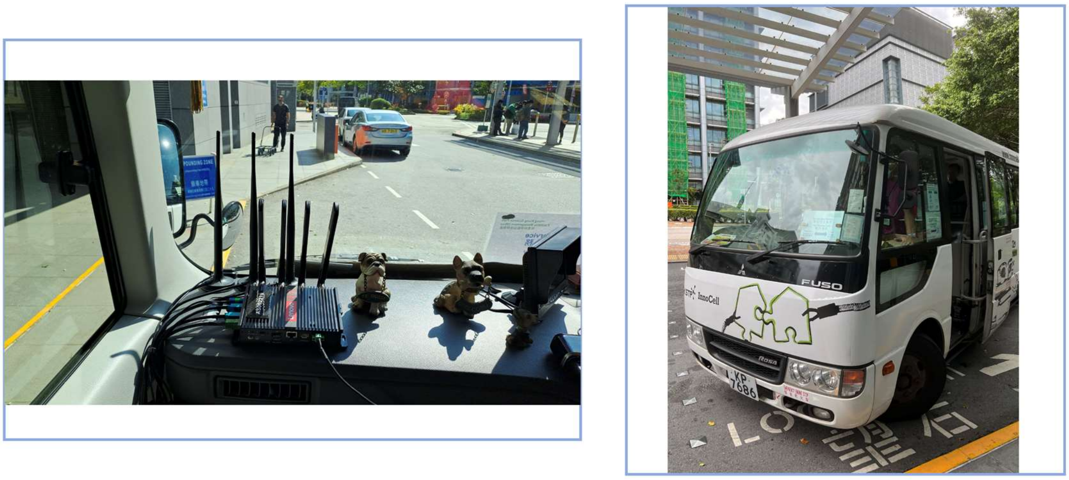

Figure A-3 OBU Installed on Shuttle Bus

Portal of Public Transportation

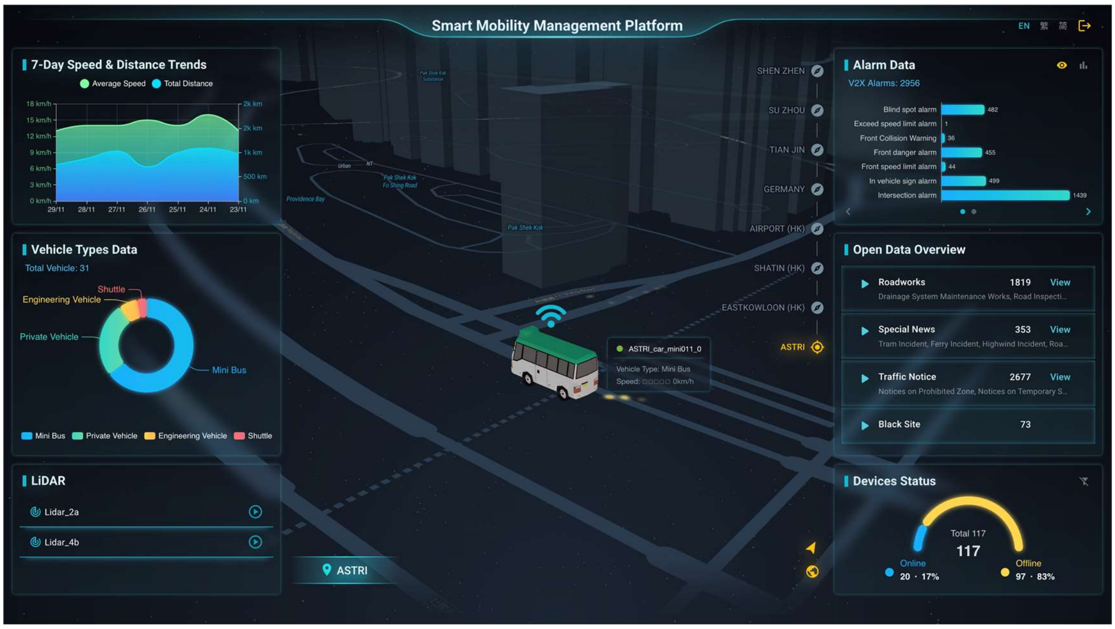

Figure A-4 Real-Time Monitoring of Green Minibus

Figure A-5 Historical V2X Alarm Analysis and Visualization Dashboard

V2X Mobile App

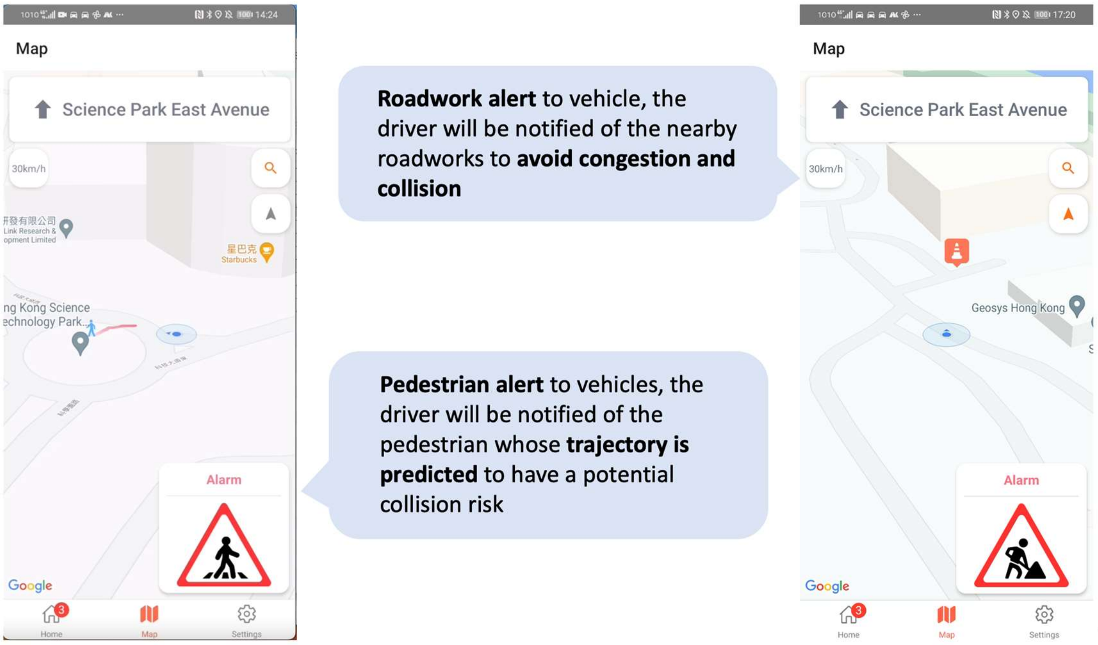

Figure A-6 V2X Mobile App for Driver and Pedestrian