Report on

C-V2X Technology Trial

Version 1.4

Date: 15 Mar 2018

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Executive Summary

This document specifies the report for Technology Trial of C-V2X in Hong Kong Science Park, conducted by Smart Mobility Consortium (SMC).

In May 2017, HKT has applied from OFCA the below 3 temporary operating permits for the purpose of technical trial of C-V2X technology:

Permit No	**Frequency specified**	**Period**
T00544	5850 - 5860 MHz	8 May to 31 Oct, 2017
T00550	2655 - 2665 MHz	22 May to 31 Oct, 2017
T00551	2665 - 2670 MHz	24 May to 30 Jun, 2017

With these temporary assignments, HKT has successfully conducted the C-V2X Technology Trial in Science Park at end June, 2017.

Abbreviations and Acronyms

HV	Host Vehicle
RV	Remote Vehicle
ITS	Intelligent Transport System
IoV	Internet-of-Vehicles
C-V2X	Cellular-Vehicle-To-Everything
V2X	Vehicle-to-Everything (V2V + V2I)
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
CAN	Controller Area Network
OBD	On-Board Diagnostics
ECU	Electronic Control Units
RSU	Road Side Unit
VRU	Vulnerable Road User
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
REST	Representational State Transfer
NCE	Network Co-operation Engine
ICGW	In-Car Gateway
EGW	Edge Gateway
EPC	Evolved Packet Core
OBDii	On Board Diagnostics 2
RTK	Real Time Kinetic
ITS	Intelligent Transportation System

1 Background & Objectives

In Hong Kong, over 60% of all road accidents involve vehicle-to-vehicle (V2V) or vehicle-to-pedestrian (V2P) collision. Over 40% of cyclist casualties involve accidents on or around carriageways. Some of the most common contributors to traffic accidents include stationary or parked vehicles on busy roads, driving too close to the vehicle in front, inappropriate changing of lanes, careless cycling, jaywalking by pedestrians, and drivers losing control of their vehicles.

A C-V2X powered smart mobility system not only allows vehicles to connect to the cloud, but also enables vehicles to communicate with one another as well as with pedestrians, and to synchronize with infrastructure. With C-V2X, "co-operative awareness" between vehicles, pedestrians and the road environment makes it possible to realize mobility safety as well as autonomous driving. Furthermore, it can also support law enforcers, traffic and urban management institutions, and transportation companies to plan and monitor the safety and efficiency of traffic movements.

C-V2X technologies, based upon the 3rd Generation Partnership Project (3GPP) release 14 specification, operates through both network-based communications on commercial cellular infrastructure, as well as direct communications over the 5.9GHz band.

In order to look closer to the benefits of C-V2X, in Mar 2017, ASTRI, HKT, Huawei and Qualcomm have jointly formed the **Smart Mobility Consortium (SMC)**.

http://www.hkt.com/About+HKT/Press+information/Press%20Information%20Detail?pop=Y&guid=92d03c424d0da510VgnVCM1000006a8ba8c0____&language=en_US

The Consortium aims to use C-V2X to introduce a series of Intelligent Transport Services (ITS) in Hong Kong including a warning mechanism for collision and control, assistance for cruise control and parking, and alert systems for speed and lane violations. In addition, it will help drivers and traffic administrators to identify potential loopholes and risks in aspects like road intersections, pedestrian crossings and traffic queues.

The Consortium plans to work alongside the Government, automobile industry, and other relevant industry stakeholders to make this happen. Upon successful completion and rollout, the project is expected to lead to further opportunities for related sectors including shipment, ridesharing, home-delivery, insurance, infotainment, and mobile healthcare, etc.

To begin with, the Consortium has conducted the 1st C-V2X technology trial at Science Park, during the ITS AP Forum 2017 (www.itsap2017.com) at end June of 2017.

2 Introduction on C-V2X Technology Demo

2.1 Introduction

2.2 Overview of End-to-End C-V2X Network Architecture

As from the definitions of 3GPP Release 14 (TR22-885 V14.0.0) as shown in Figure 1, Vehicle-to-Everything (V2X) communications consists of:

- Vehicle-to-Vehicle (V2V) Communications
- Vehicle-to-Infrastructure (V2I) Communications
- Vehicle-to-Pedestrian (V2P) Communications
- Vehicle-to-Network (V2N) Communications

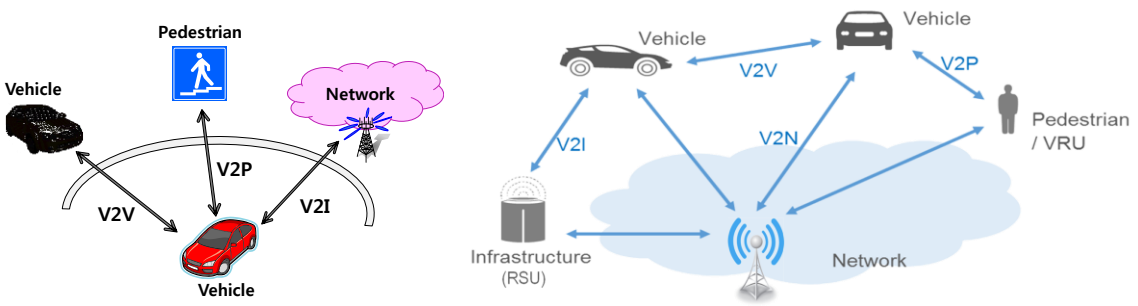


Figure 1. Vehicle-to-Everything (V2X) Communications.

Figure 2 shows the end-to-end V2X network architecture. It mainly consists of V2X device equipped in the vehicles to enable direct Vehicle-to-Vehicle (V2V) communications between vehicles, which is the PC5 communications channel of LTE-Direct mode as defined in R12 of 3GPP standard. Similarly, the V2X device in vehicle also communicates with V2X device of road users (like pedestrians), and enables the Vehicle-to-Pedestrian (V2P) communications, also via the PC5 communications channel. The V2X devices of vehicles are also connected to the network infrastructure, enabling Vehicle-to-Infrastructure (V2I) communications via the Uu communications channel, with is indeed the 3GPP LTE air interface, by using Road Side Units (RSUs). For the backend, there is also a V2X application and management server, which enables different V2X use cases and applications for road safety and traffic management etc.

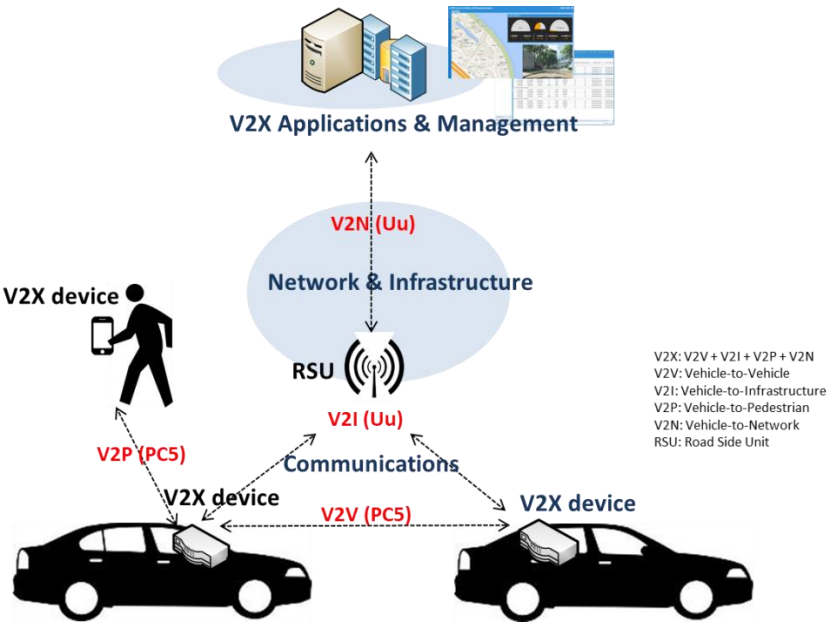


Figure 2. End-to-End Vehicle-to-Everything (V2X) Network Architecture.

In Hong Kong, “Vehicle-to-Vehicle” and “Vehicle-to-Pedestrian” are the two major types of traffic accident which contribute to the majority of the traffic accidents. The consortium therefore selected from the set of 3GPP defined road safety use cases, the following 5 user cases which are relevant to the Hong Kong situation for technology trial:

- V2V Do Not Pass Alarm
- V2V Blind Spot Warning (BSW)
- V2I Emergency Stop Warning
- V2P Vulnerable Road Users (VRU)
- V2I Blind Intersection Alarm

Details about each use case can be found in the Appendix A.

3 Preparation & Setup for the Technology Trial

3.1 Introduction

In this section, the C-V2X trial preparation and setup will be discussed. The overview for the selected trial site, trial route and the corresponding plan and schedule will also be discussed. Prior to the road tests in trial site in Hong Kong Science Park, the project team also performed preliminary tests for use case functional and LTE-V connectivity tests in Huawei Xian test site as well. The corresponding findings and results will be discussed as well. After that, the project team carried out trial network installation and extensive road tests, with trial network and system setup, trial network RF coverage and latency measurement, RTK-GPS integration test, network optimization and enhancement, road safety use case functional tests, advanced V2X software function development for performance enhancements. During the road test period, the project team also experienced various challenging environment limitations in trial site and severe weather conditions. The final rehearsal was also performed with extensive trial runs according to planned schedule and rundown as final preparation for the ITS AP forum trials.

3.2 Trial Site, Route and Plan

3.2.1 Overview of Trial Site - Hong Kong Science Park

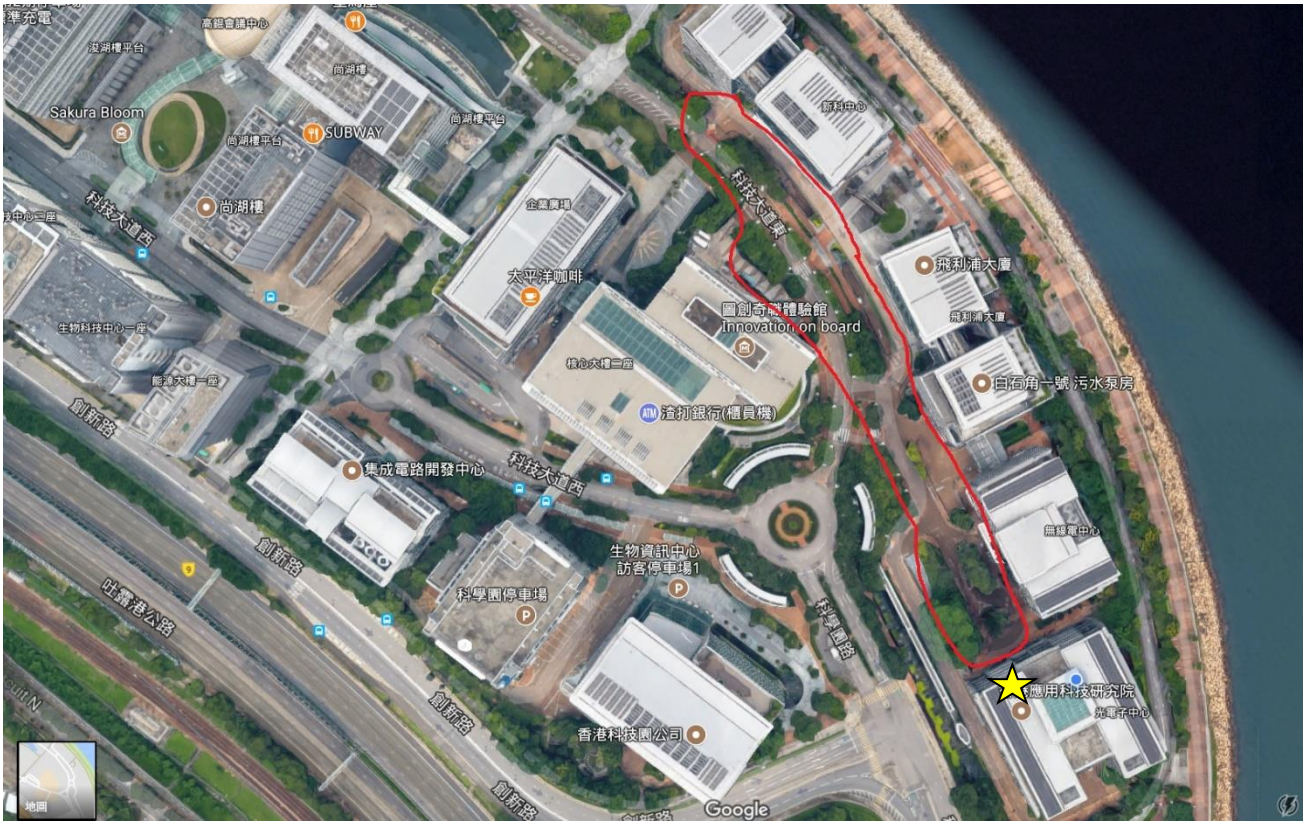


Figure 3. Map View of Trial Site in Hong Kong Science Park.

The selected trial site is at Hong Kong Science Park, mainly in the area in front of the Photonics Building, and in the area around the SAE and Philips Buildings, along the Science Park West Avenue as indicated in Figure 3. The test route of the test was conducted in area marked by the red line.

3.2.2 Trial Route and Rundown

Figure 4. Trial Route and Rundown.

There are total five use cases to be performed for three laps of trial route, with one or two use cases per lap, as shown in Figure 4. The total duration is estimated around 20 mins. There are total 3 vehicles and 1 pedestrian needed in this trial. The estimated speed is around 20 to 30 km/h within speed limit inside Hong Kong Science Park. The rundown is in the order of (1) Do Not Pass Warning (DNPW), (2) V2I Emergency Stop, (3) Blind Spot Warning (BSW), (4) V2P Vulnerable Road Users (VRU), and (5) V2I Intersection Collision Warning.

3.3 Trial Network

3.3.1 Overview of Trial Network Architecture

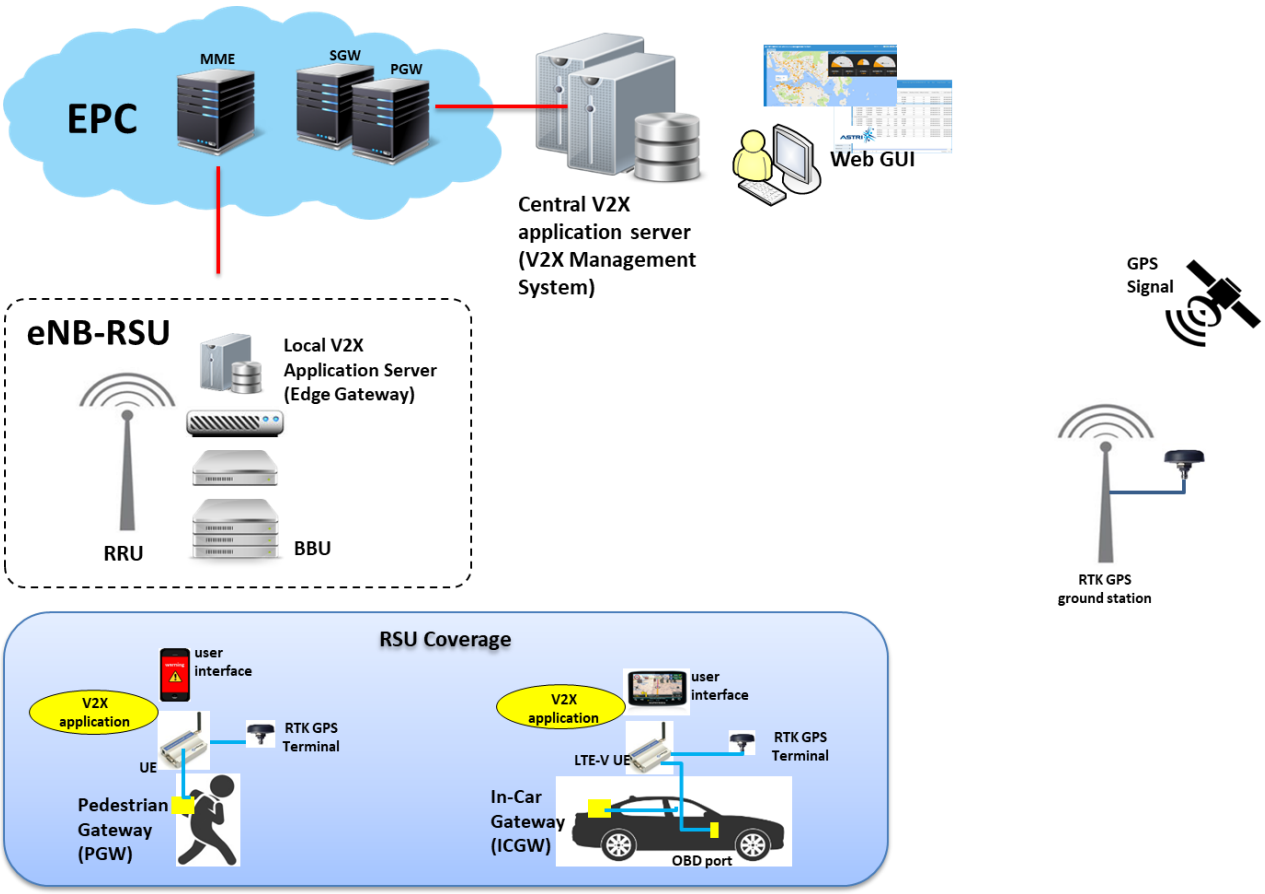


Figure 5. Overview of Trial Network Architecture.

Figure 5 shows the end-to-end trial network architecture. It mainly consists of in-car V2X system with In-Car Gateway (ICGW), pedestrian V2X system with Pedestrian Gateway (PGW), LTE eNB (both BBU and RRU) for Road Side Unit (RSU) with local Edge Gateway (EGW), LTE core network with EPC, and Central V2X management system. The V2X application is also developed and run to realize different road safety use cases for road users. In addition, the high precision GPS system (namely RTK GPS), with reference station and mobile terminal are also integrated in the in-car V2X system for high precision positioning purpose. After the logistics and delivery of C-V2X equipment, the project team started working on the trial network installation and integration.

In the technology trial, two (2) V2X communication channels were used between the V2X system and the in-vehicle unit, as well as, between in-vehicle units, with the use of frequency as follow:

V2X Communication Channel	Description	Frequency (MHz)	Band Description
V2V	LTE PC5	5850-5860	FSS/ISM 5.9GHz
V2I	LTE Uu	2665-2670	3GPP Band 41

For the technical trial, a TDD-LTE base station (eNB and antenna) was installed on the roof-top of Photonics Building in Hong Kong Science Park (the start showed in Figure 3). The baseband unit (BBU) of the eNB and the EPC were installed in the ASTRI's server room as well, located on the 3rd floor of the same building. There is a fiber connection established between the roof-top and the server room. Figure 6 below show the setup of the equipment.

Figure 6 Setup of V2X test equipment

3.3.2 Test Setup – In-Car System Setup

To conduct the road tests, in-car V2X system is installed inside each of the tested vehicles with all necessary equipment, including C-V2X UE terminal, In-Car Gateway (ICGW), RTK GPS terminal, and corresponding antennas, OBD adaptor, router, battery and tablets for alarm display etc. Figure 7 shows the highlights of in-car V2X system setup in tested vehicles.

Figure 7. In-Car V2X System Setup.

Further, the in-car V2X system architecture is shown in Figure 8. The In-Car Gateway (ICGW) is integrated with the RTK GPS terminal. It is also connected to the OBDii adaptor via in-car Wi-Fi network. The ICGW is also integrated with C-V2X UE terminal as the communications interface with other vehicles (via V2V PC5 communications channels), and with the RSU (via V2I Uu communications channel). The V2X mobile app running on the tablets provides the alarm notifications to the drivers for different road safety use cases.

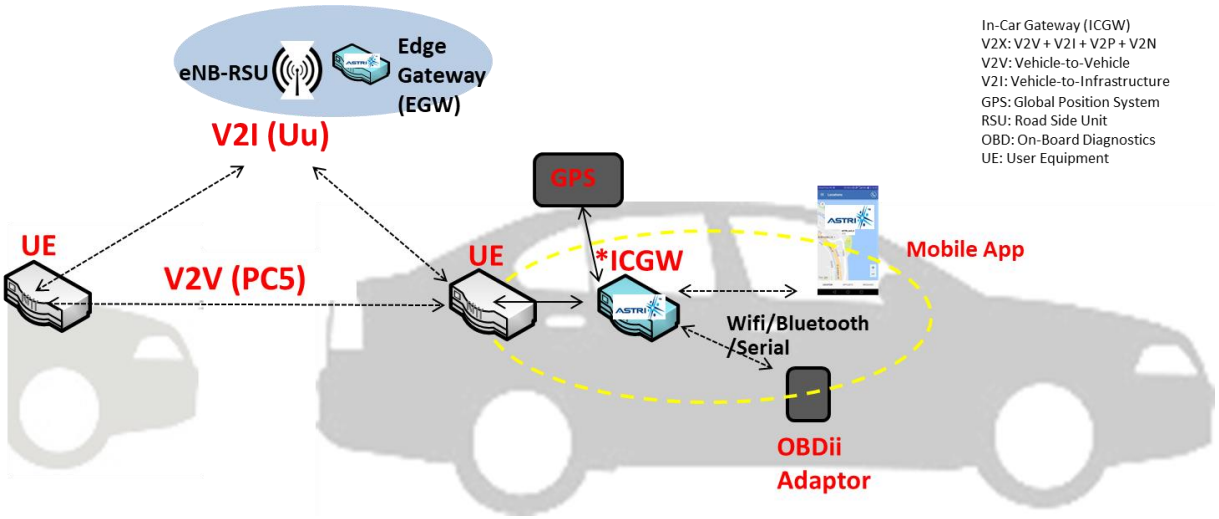


Figure 8. In-Car V2X System Architecture.

4 C-V2X Technology Trial Results

In this section, the results for the C-V2X technology trial will be discussed. It includes the results and outcomes for the five road safety use cases trials.

4.1 Road Safety Use Cases & Trial Results

As in 3GPP Release 14 (TR22-885 V14.0.0), there are different defined V2X use cases, which cover all different V2X communications and use case scenarios, i.e. Vehicle-to-Pedestrian (V2P), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) with RSU, Vehicle-to-Network (V2N). In this trial, the project team mainly focuses on road safety V2X use cases, which are more specific to the environment and deployment considerations in Hong Kong.

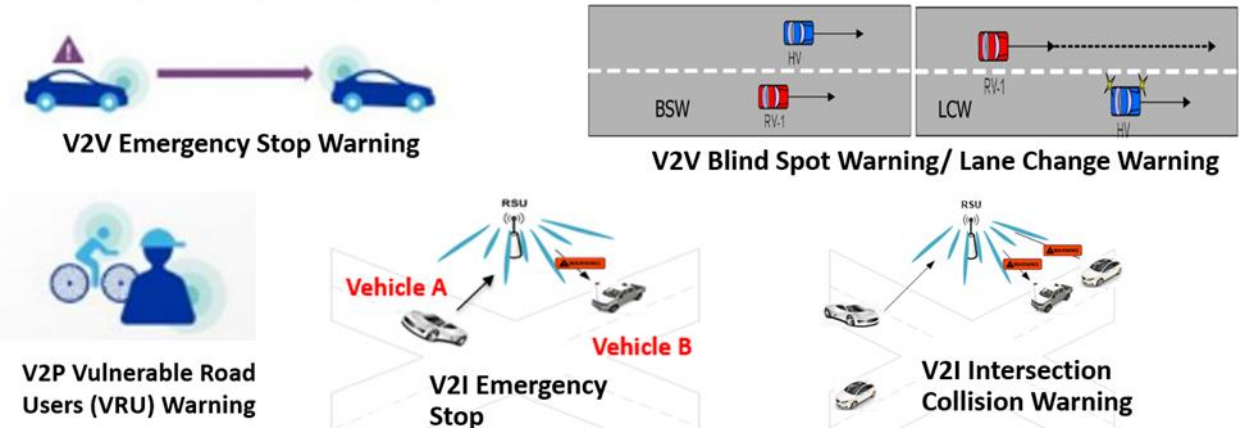


Figure 9. Target Road Safety V2X Use Cases in Hong Kong.

The project team successfully demonstrated five road safety use cases, in more than 20 sessions on the three trial days of ITS AP Forum, and achieved 100% success rate with zero failure and false alarm case.

- V2V Do Not Pass Alarm
- V2V Blind Spot Warning (BSW)
- V2I Emergency Stop Warning
- V2P Vulnerable Road Users (VRU)
- V2I Blind Intersection Alarm

The use case trial results have been recorded and please refer to the video link – https://www.youtube.com/watch?v=ZrBM8cSQz-M

4.1.1 Use Case: V2V Do Not Pass Alarm

Descriptions

Do Not Pass Warning (DNPW) warns the driver not to overtake a slower moving vehicle when a vehicle in the opposite lane is approaching.

Pre-conditions

- The Host Vehicle (HV) is equipped with UE supporting V2V Service.
- There are several cars (including Remote Vehicles RV-1 and RV-2) in HV vicinity also equipped with UEs supporting V2V Service.

Service Flow

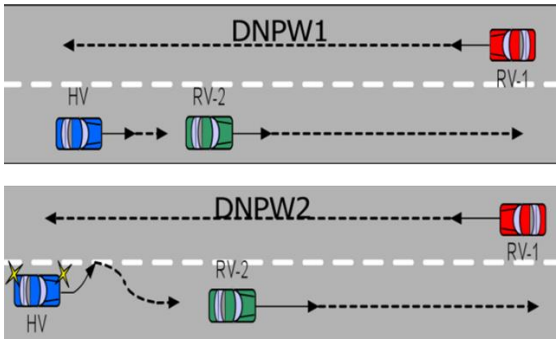


Figure 10. Use Case: V2V Do Not Pass Alarm.

1. Host Vehicle (HV)'s ICGW broadcasts its message via V2V channel (with LTE-V2X UE) containing its current status, (e.g., GPS location, speed, & trajectory etc.).
2. Remote Vehicle 1 (RV-1)'s ICGW also broadcasts its message via V2V channel (with LTE-V2X UE) containing its current status, (e.g., GPS location, speed, & trajectory etc.).
3. HV's ICGW receives messages from RV-1's V2X device (via V2V channel); it then determines whether to trigger "Do not Pass Warning" to notify its driver.
4. The decision of alarm triggering on HV's ICGW will be made based on distance (measured by high precision GPS), direction (determined whether RV-1 is in adjacent lane, moving in reverse direction), and whether turning signal of HV is on, indicating the driver of HV has intention to pass (optional) etc.

Post-conditions

- The driver of Host Vehicle is alerted (with the Remote Vehicle RV-1 coming) with a "Do Not Pass" warning, who can take appropriate action.

RSU & V2X UEs

- RSU is NOT required
- V2X UEs support PC5
- V2X application for this use case

Other requirements

- User Interface, and GPS at V2X UE
- In-Car Gateway (ICGW), Edge Gateway (EGW), and IoV Management System

Procedure

- Car 1 is moving slowing on the road. Car 2 follows Car 1.
- The driver in Car 2 wants to overtake Car 1 via the opposite lane, while Car 3 is approaching from the opposite lane.

Figure 11. Demo Location for Use Case – Do No Pass Warning (DNPW).

Test Results:

- Do Not Pass Warning was promptly shown on the on-board media pad to warn the driver not to overtake a slower moving vehicle.

Figure 12. Trial for V2V Do Not Pass Alarm.

Figure 13. Trial for V2V Do Not Pass Alarm.

4.1.2 Use Case: V2V Blind Spot Warning (BSW)

Descriptions

During a lane change attempt, the Blind Spot Warning (BSW) or Lane Change Warning (LCW) application will warn the driver of the host vehicle if the blind spot zone into which the host vehicle intends to switch, is occupied by another vehicle traveling in the same direction. This use case provides advisory information to the driver whenever a vehicle in an adjacent lane is positioned in a blind spot zone of the host vehicle.

This use case also addresses the frequent road accidents occurred in Hong Kong, when head vehicles on inner lane want to exit the roundabout, and hit by the rear vehicles on the outer adjacent lane, or careless lane changing.

Pre-conditions

- The Host Vehicle (HV) is equipped with UE supporting V2V Service.
- There are several cars (including Remote Vehicle RV) in HV vicinity also equipped with UEs supporting V2V Service.

Service Flow

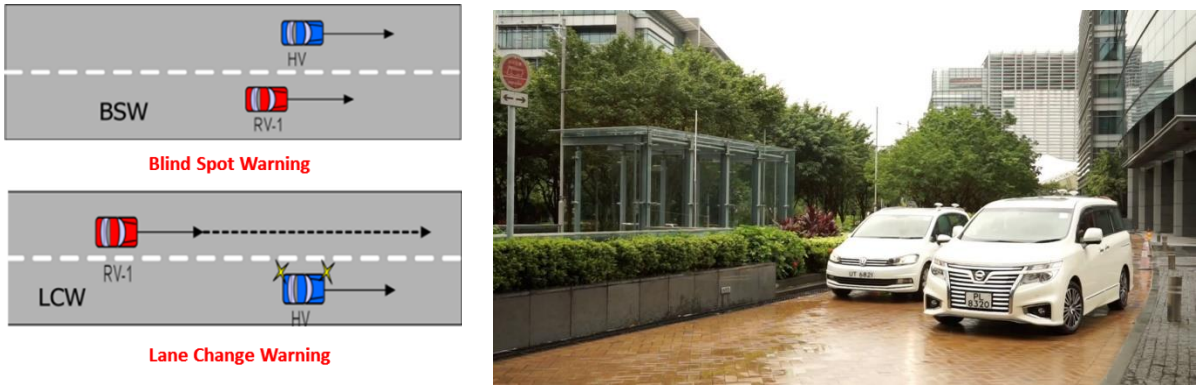


Figure 14. Use Case: V2I Blind Spot Warning.

1. Host Vehicle (HV)'s ICGW broadcasts its message via V2V channel (with LTE-V2X UE) containing its current status, (e.g., GPS location, speed, & trajectory etc.).
2. Remote Vehicle 1 (RV-1)'s ICGW also broadcasts its message via V2V channel (with LTE-V2X UE) containing its current status, (e.g., GPS location, speed, & trajectory etc.).
3. HV's ICGW receives messages from RV-1's V2X device (via V2V channel); it then determines whether to trigger "Blind Spot Warning" or "Lane Change Warning" to notify its driver.
4. The decision of alarm triggering on HV's ICGW will be made based on distance (measured by high precision GPS), direction (determined whether RV-1 is in adjacent lane, moving in same

direction), and whether turning signal of HV is on, indicating the driver of HV has intention to change lane (optional) etc.

Figure 15. Service Flow for Use Case: V2I Blind Spot Warning

Post-conditions

- The driver of Host Vehicle is alerted (with the Blind spot vehicle coming), who can take appropriate action.

RSU & V2X UEs

- RSU is NOT required
- V2X UEs support PC5
- V2X application for this use case

Other requirements

- User Interface, and GPS at V2X UE
- In-Car Gateway (ICGW), Edge Gateway (EGW) and IoV Management System

Procedure

- The driver in Car 2 wants to change lane.
- Car 3 is traveling on the lane that the driver in Car 2 wants to change to. And, Car 3 is approaching but it is within the “Blind Spot Zone” of Car 2.

Figure 16. Demo Location for Use Case – V2V Blind Spot Warning (BSW).

Test Results:

- Blind Spot Warning was promptly shown on the on-board media pad to warn the driver not to change lane.

Figure 17. Trial for V2V Blind Spot Warning (BSW).

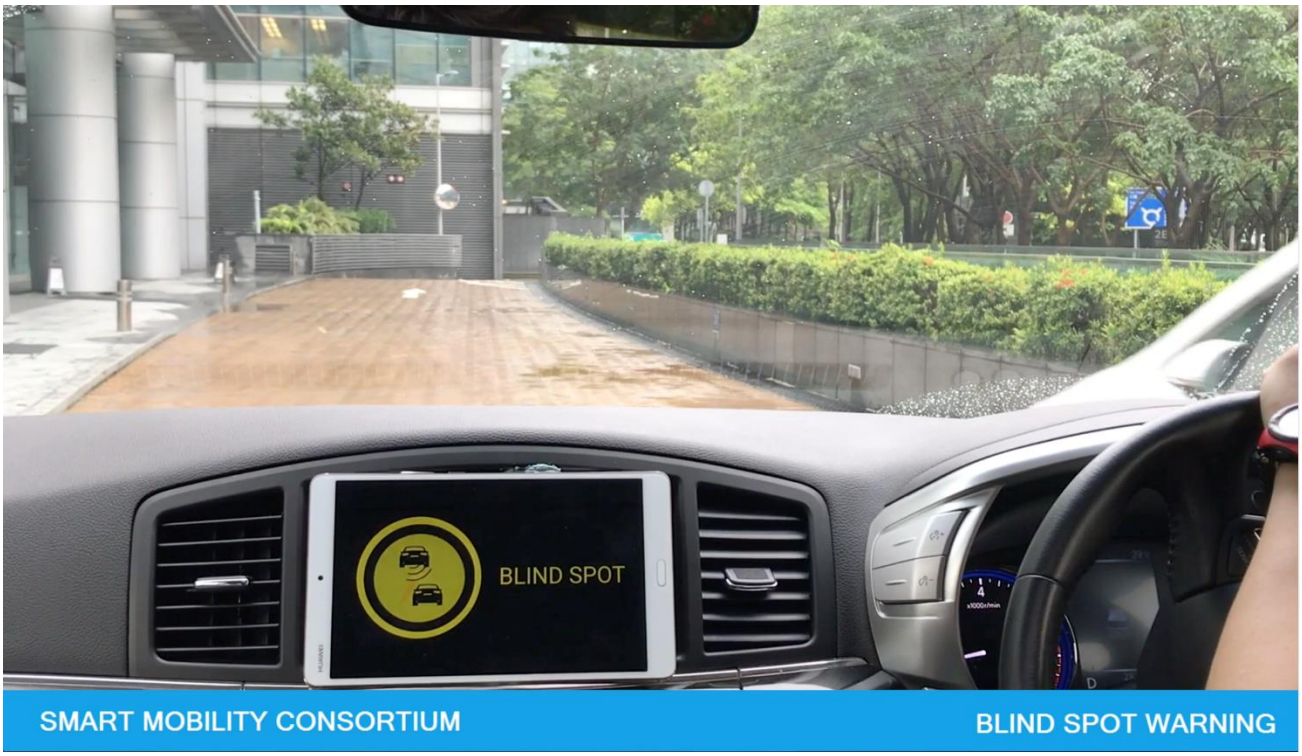


Figure 18. Trial for V2V Blind Spot Warning (BSW).

4.1.3 Use Case: V2I Emergency Stop Warning

Descriptions

This use case describes V2I communication where a RSU notifies vehicles in vicinity in case of emergency stop to trigger safer behavior. This use case also addresses the frequent road accidents occurred in Hong Kong that when the vehicles turn at the intersection point, it cannot see the stopped vehicle or even the pedestrian suddenly crossing the road behind the stopped vehicle, and as a result hitting them.

Pre-conditions

- The driver is driving the Vehicle A on the street. The Vehicle A is equipped with V2X UE supporting V2I service.
- There are several Service RSUs in his vicinity equipped with UEs supporting V2I Service.

Service Flow

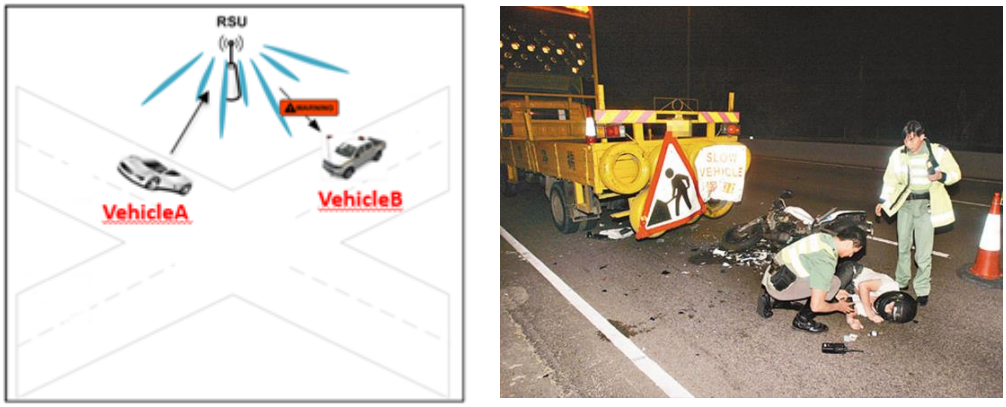


Figure 19. Use Case: V2I Emergency Stop Alarm.

1. Vehicle A malfunctions and stops near a road intersection/junction. The vehicle A generates a “Stationary vehicle warning” DENM message to the nearby RSU.
2. A RSU in the vicinity of vehicle A is able to receive the “Stationary vehicle warning” DENM message.
3. The RSU relays the message to its surrounding vehicles.
4. All vehicles within the transmission range from the RSU receive the message.

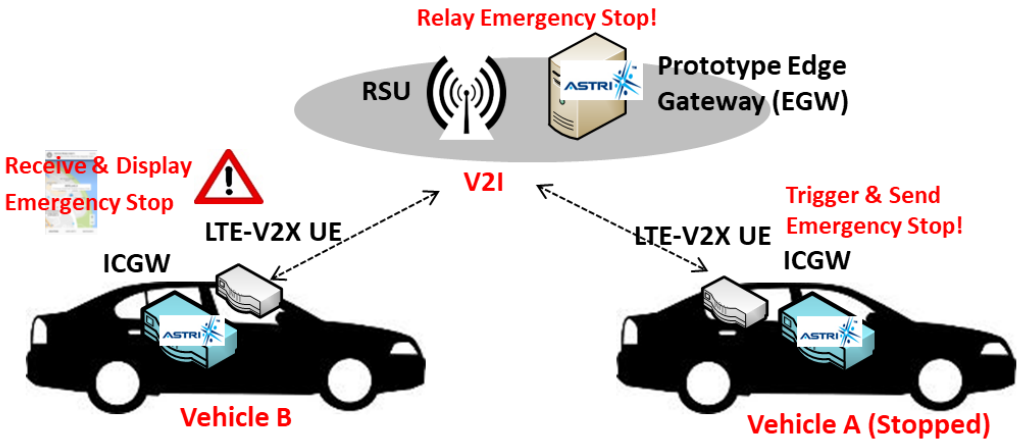


Figure 20. Service Flow for Use Case: V2I Emergency Stop Alarm.

Post-conditions

- Vehicles (which are in the vicinity of the RSU) deliver the information to the nearby RSU for further relaying the message to drivers travelling in the vicinity for taking appropriate action where necessary.

RSU & V2X UEs

- RSU supports Uu
- V2X UEs support both Uu and PC5

Other requirements

- User Interface, and GPS at V2X UE
- In-Car Gateway (ICGW), Edge Gateway (EGW) and IoV Management System

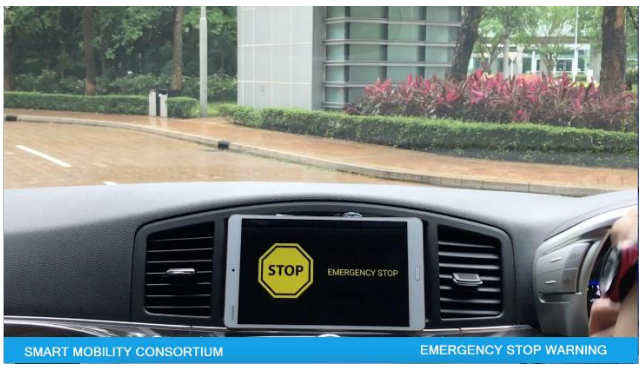
Procedure

- Car 2 has stopped on a road.
- Car 3 is approaching Car 2, but Car 2 is not within the line of sight (LOS) of the driver in Car 3.

Figure 21. Demo Location for Use Case – V2I Emergency Stop.

Test Results:

- V2I Emergency Stop Warning was promptly shown on the on-board media pad to warn the driver that another vehicle has stopped nearby.



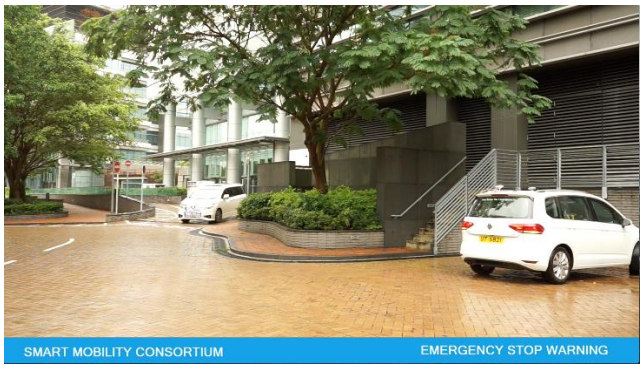


Figure 22. Trial for V2I Emergency Stop Warning.

4.1.4 Use Case: V2P Vulnerable Road Users (VRU)

Descriptions

This use case describes the vehicle and pedestrian are in non-line-of-sight situation, and both equipped with V2P communications. The vehicle detects the pedestrian's presence in “danger zone” and alerts the driver with “Pedestrian Crossing Warning”. This capability extends the safety benefit of V2X to pedestrians and other vulnerable road users, e.g. bicyclists etc. The statistics shown in 2015 that Vehicle to Pedestrian collision is one of the major types of Road accidents (~20%) in Hong Kong like careless bicyclists, among vehicle-to-vehicle collision accidents (~44%) and other types. http://www.td.gov.hk/en/road_safety/road_traffic_accident_statistics/2015/index.html

Pre-conditions

- Vehicle A and VRU B's smartphone are supporting V2P Service
- Vehicle A and VRU B are in proximity (within each other's V2P communication range)

Service Flow

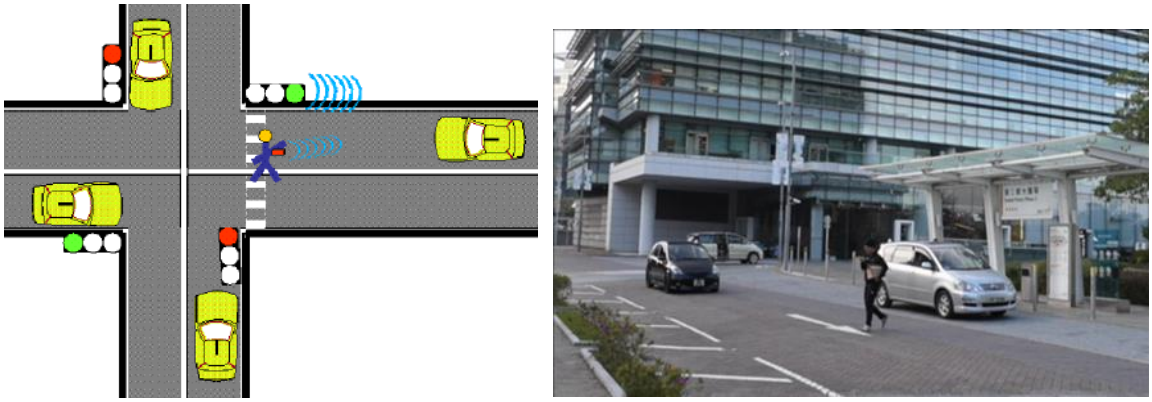


Figure 23. Use Case: V2P Vulnerable Road Users (VRU).

1. Vehicle A broadcasts a message containing its current status, e.g., location, speed, acceleration and trajectory;
2. VRU B's handheld device determines whether it is in a vulnerable situation with potential traffic hazard, e.g., by checking user outdoor/indoor status, proximity to Vehicle A, user activity state, e.g., texting, looking at the screen, listening to music;
3. VRU B's handheld device broadcasts a pedestrian message containing its status, e.g. location, speed, acceleration and optionally user behaviour state;
4. Vehicle A receives messages from VRU B's handheld device and determines that it needs to notify its driver of potential pedestrian conflicts at least [4] seconds of Time-To-Collision (TTC).

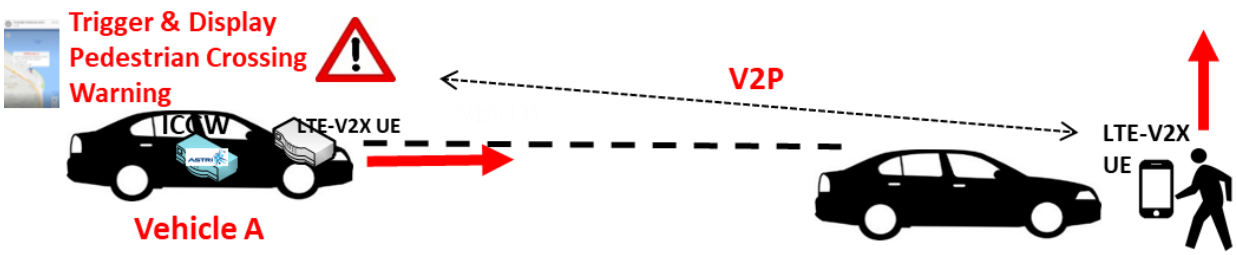


Figure 24. Service Flow for Use Case: V2P Vulnerable Road Users (VRU) Warning.

Pre-conditions

- The driver of Vehicle A is informed of the potential hazard, and can take necessary actions.

RSU & V2X UEs

- RSU is NOT required
- V2X UE and VRU UE both supports PC5
- V2X application for this use case

Other requirements

- User Interface, and GPS at V2X UE & VRU UE
- In-Car Gateway (ICGW) and IoV Management System

Procedure

- Car 1 has stopped on the right lane of a road.
- Car 2 travels on the left lane of the same road.
- A negligent pedestrian is crossing the road in front of Car 1.
- The pedestrian is not within the line of sight (LOS) of the driver in Car 2 because Car 1 has blocked the view.

Figure 25. Demo Location for Use Case – V2P Vulnerable Road Users (VRU).

Test Results:

- V2P Vulnerable Road Users (VRU) Warning was promptly shown on the on-board media pad to warn the driver when a negligent pedestrian is crossing the road.

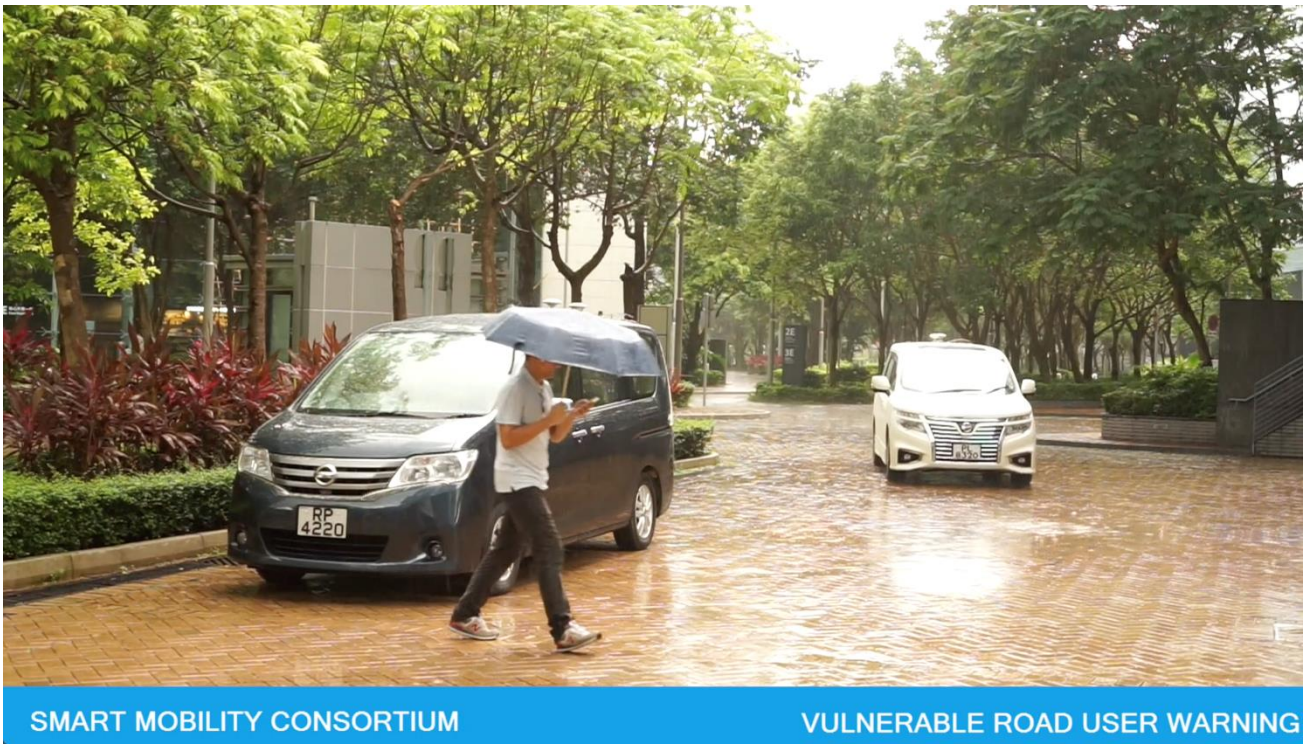


Figure 26. Trial for V2P Vulnerable Road Users (VRU).

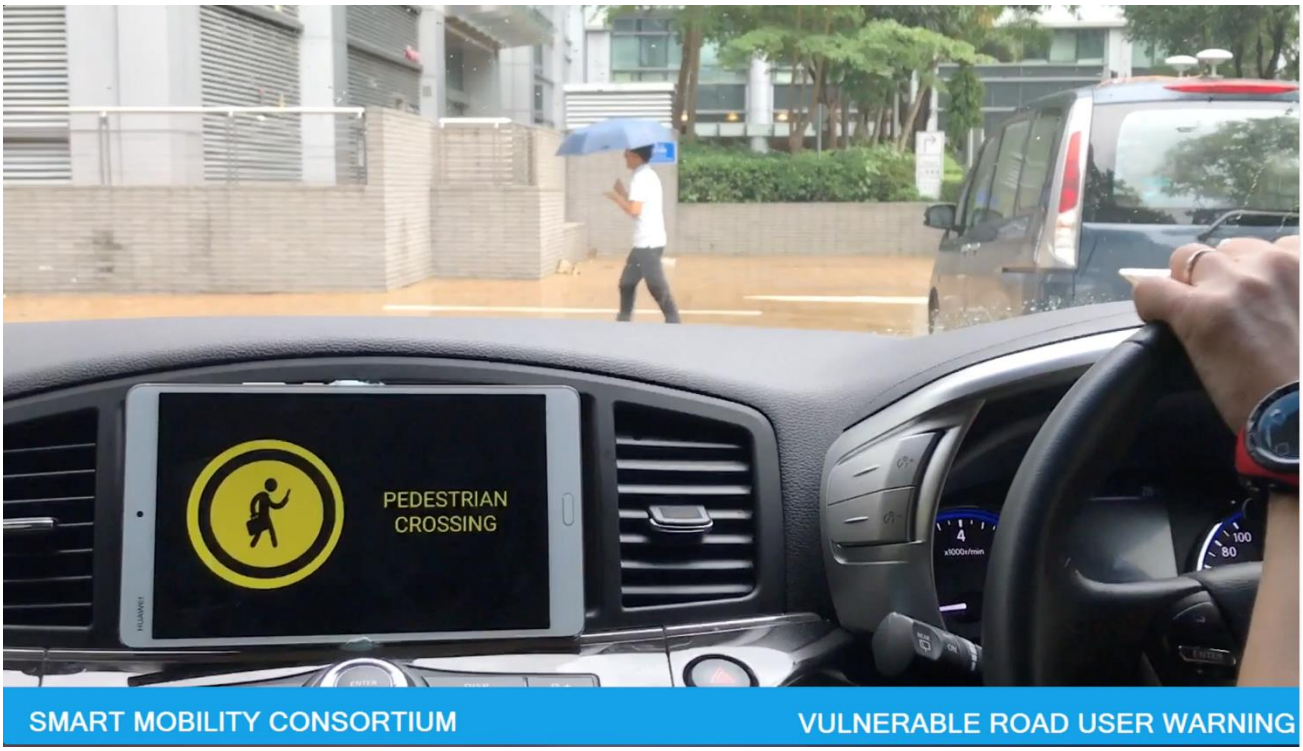


Figure 27. Trial for V2P Vulnerable Road Users (VRU).

4.1.5 Use Case: V2I Blind Intersection Alarm

Descriptions

- When Vehicle A and Vehicle B, C are approaching the intersection point, in where, the **V2V communications is out of coverage**, or the vehicles are in **non-line-of-sight** situation. Then RSU is in place to relay the vehicles' messages via **V2I communications** channel, and the application processing could also be done by Edge Gateway (EGW), in order to trigger "Intersection Collision Warning" to alerts all the vehicles drivers in potential hazard of collision happening.
- This use case also addresses the frequent road accidents occurred in Hong Kong that when the vehicles do not follow the traffic signal and rules at the intersection point, and go out without seeing the vehicles from other lanes, and cause the accidents.
- Technically, V2X messages are delivered from one UE supporting V2I Service to other UEs supporting V2I Service via an RSU. The RSU receives V2X messages transmitted from UEs supporting V2I Service and transmits the received V2X messages to UEs within a local area. A UE receives V2X messages transmitted by the RSU. After processing the received V2X messages, the UE notifies the driver of relevant information.

Pre-conditions

- The driver is driving the Vehicle A on the street. The Vehicle A is equipped with UE supporting V2I Service.
- There are several Service RSUs in his vicinity equipped with UEs supporting V2I Service.

Service Flow

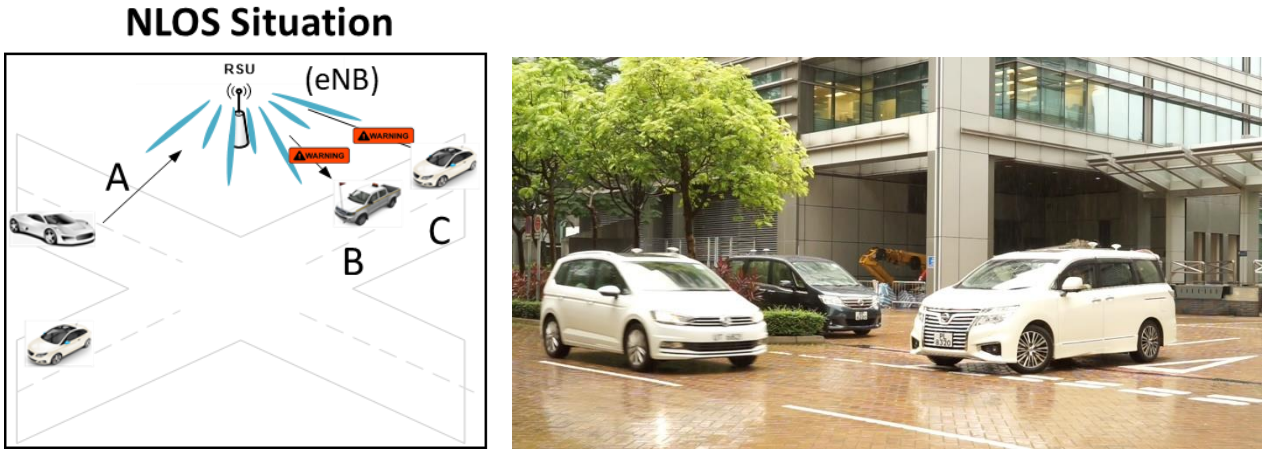


Figure 28. Use Case: V2I Blind Intersection Collision Alarm.

1. Vehicle A and Vehicle B's UEs determine a cell which is controlled by an eNB operating as an RSU for active road safety services.
2. Vehicle A's UE triggers transmission of a V2X message periodically or based on a certain event that happens at the vehicle, e.g. collision risk warning.
3. The RSU receives one or more V2X messages from one or more vehicles including Vehicle A's UE.
4. The RSU may or may not filter out some V2X messages received from some UEs.
5. The RSU distributes a V2X message at the cell.
6. Vehicle B's UE monitors transmission of the V2I messages and receives the V2I message at the cell.

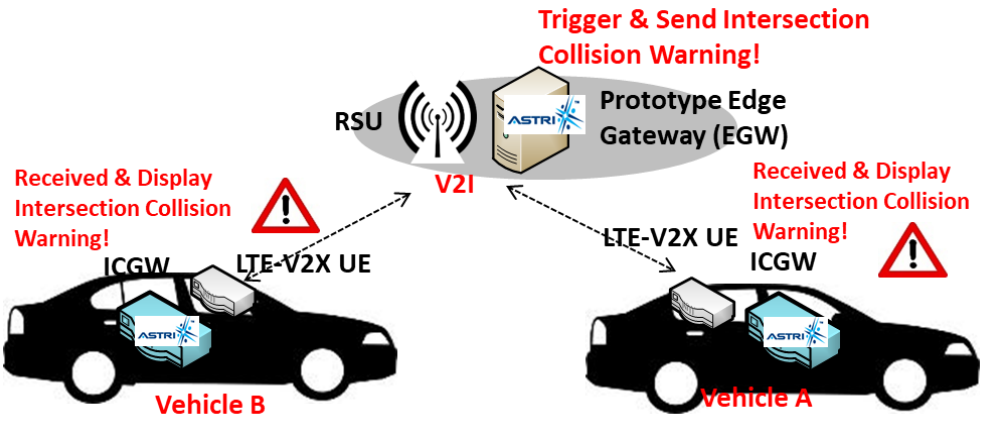


Figure 29. Service Flow for Use Case: V2I Emergency Stop Alarm.

Post-conditions

- Vehicles (which are in the vicinity of the RSU) deliver the information to the nearby RSU for further relaying the message to drivers travelling in the vicinity for taking appropriate action where necessary.

RSU & V2X UEs

- RSU supports Uu
- V2X UEs support both Uu and PC5
- V2X application for this use case

Other requirements

- User Interface & GPS at V2X UE
- In-Car Gateway (ICGW), Edge Gateway (EGW) and IoV Management System

Procedure

- Car 2 has stopped at a road intersection, and is about to cross the intersection.
- Car 3 is approaching the same road intersection, but Car 3 is not within line of sight (LOS) of the driver in Car 2.

Figure 30. Demo Location for Use Case – V2I Intersection Collision Warning.

Test Results:

- V2I Blind Intersection Warning was promptly shown on the on-board media pad to warn the driver when another vehicle is approaching the road intersection.

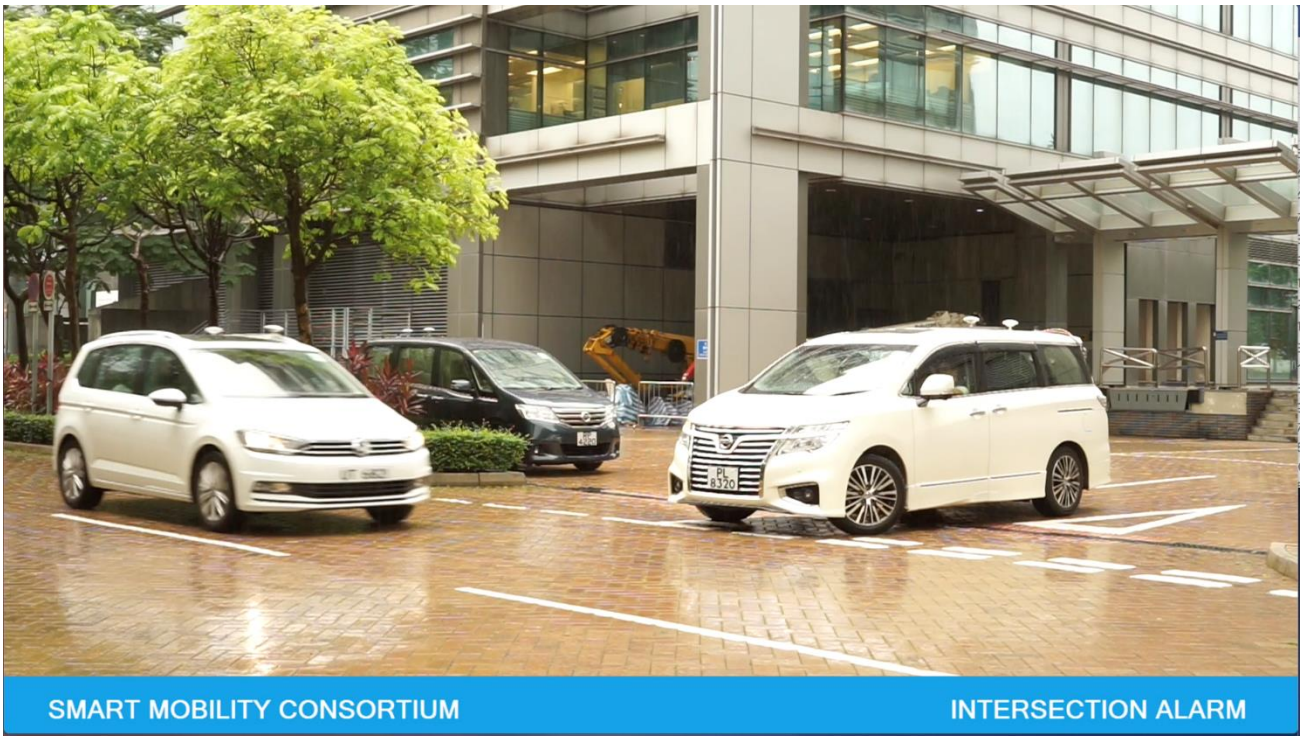


Figure 31. Trial for V2I Blind Intersection Alarm.

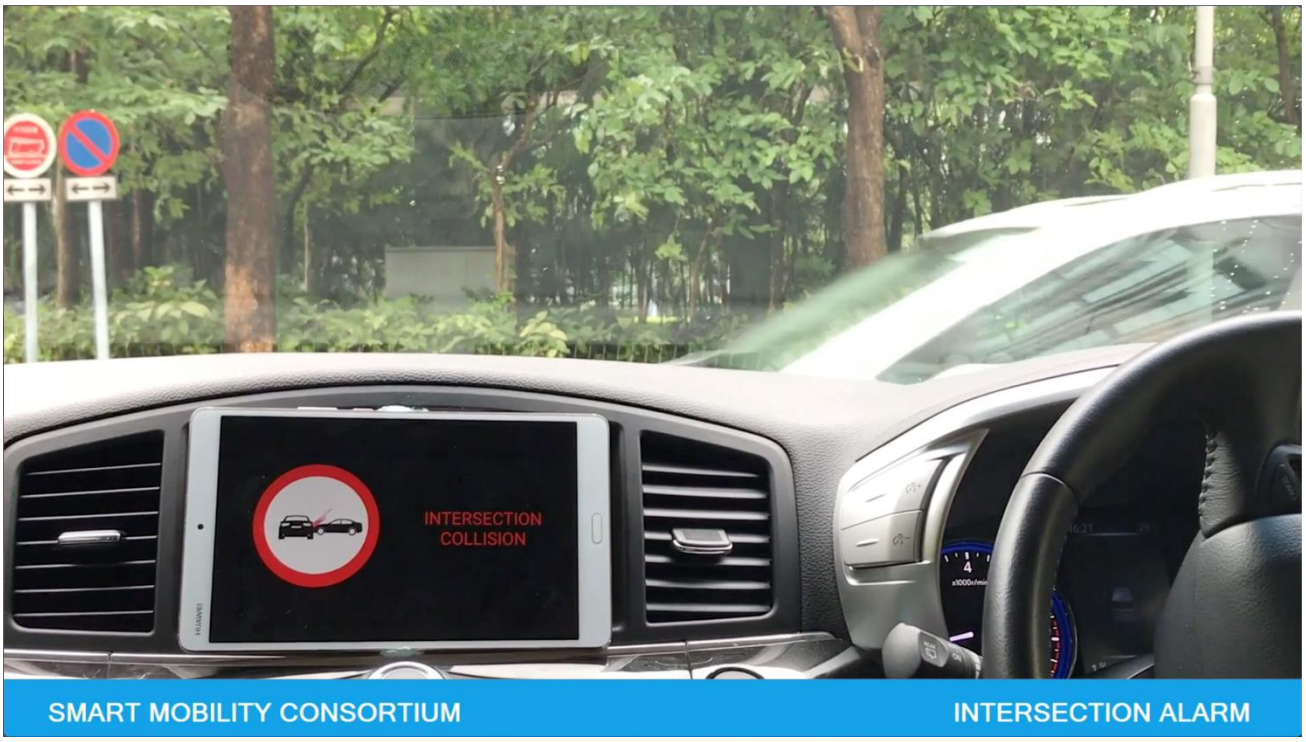


Figure 32. Trial for V2I Blind Intersection Alarm.

5 Conclusion of the Technology Trial

Throughout the 3-days trial event, SMC has successfully showcased C-V2X to the ITS & transport industry and other relevant parties for the readiness of the technology.

Appendix A – Equipment List & Testing Parameters

Equipment List

Equipment Name	Model No.	Supplier	Major Function(s)	Technical Standard (if applicable)
eNodeB Main Control Board	UMPTb4	Huawei	Main Control Function for eNodeB	3GPP Rel12
eNodeB Baseband Board	LBBPd4	Huawei	Baseband processing for eNodeB	3GPP Rel12
eNodeB Remote Radio Unit	RRU3256	Huawei	Radio Unit for eNodeB	3GPP Rel12
TUE	TUE2.0	Huawei	Prototype Terminal for PC5 and Uu communication	3GPP Rel13
GNSS-INS Navigation System	KY-ins100	BDStar	High Resolution Position\inertial Navigation	N/A
ICGW	RASPBERRYPI3-MODB-1GB	ASTRI	In Car Gateway (ICGW) for V2X applications	N/A
Server	Intel® NUC Kit NUC5i7RYH	Jumbo	Data collector and analysis for V2X management	N/A
Media Pad	Huawei Mediapad M3	Huawei	Mobile app for V2X alarm display	N/A

Notes:

TUE – Test UE

ICGW – In Car Gateway

Testing Parameters

Parameter Name	Parameter Descriptions	Parameter Values
Operating frequencies & BW- Uu	UL&DL Operating frequencies & BW- Uu	2665~2670MHz & 5MHz
Operating frequencies & BW- PC5	Operating frequencies & BW- PC5	5850~5860MHz & 10MHz
eNodeB Tx power - Uu	eNodeB Transmitter Power of PDSCH	20dBm
TUE Tx Power - Uu	Terminal Transmitter Power of PUSCH	23dBm(Max)
TUE Tx power - PC5	Terminal Transmitter Power of PC5 PSSCH	23dBm(Max)
TUE Antenna Gain	Terminal Antenna Gain of PC5	2dBi
TUE Modulation Scheme	Terminal Modulation Scheme of PSSCH	QPSK/16QAM
KY-ins100 Receiver Frequency Range	Frequency Range of GPS system, GLONASS system,Beidou system	GPS L1: 1575.42 MHz GPS L2: 1227.60 MHz GLONASS L1: 1593-1610 MHz GLONASS L2: 1237-1253 MHz BeiDou B1: 1561.098 MHz BeiDou B2: 1207.14 MHz
KY-ins100 Receive Power Range	Receiver range of GPS system, GLONASS system,Beidou system	L1: -122 to -87 (signal) dBm, -161 to -141 (noise) dBm/Hz L2: -126 to -93 (signal) dBm, -161 to -141 (noise) dBm/Hz