

Operational deployment of semi-automated vehicle (level 2) and cooperative intelligent transport system on Eastlink

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Abstract

Under the Smarter Journeys program, managed by VicRoads, the Australian Road Research Board (ARRB) in partnership with Connect East and Latrobe University, has under-taken a study of the Operational Deployment of semi-AVs and C-ITS on Eastlink. Project is divided into three phases. *Phase 1* - investigate Level 2 partially automated vehicles which were trialed along a section of Eastlink, between Springvale Rd and the Monash Freeway, including the Mullum-Mullum tunnel (South Easter Suburbs of Melbourne). *Phase 2* - investigate the connectivity using DSRC dedicated 5.9GHz and development of C-ITS and testing methodology with interference of tolling (5.8GHz). *Phase 3* - investigate the communication of Road Works Warning (RWW) to the in-vehicle HMI advising road works area and other messages using Decentralised Environmental Notification Message (DENM) over DSRC frequency.

The following is a summary of the key results from all three phases of the project:

- The driving skills required for semi-AVs are different to non-semi-AV. Therefore, it will take time for drivers to understand and feel confident in the features, while remaining engaged with the driving task (Taylor et al. 2018).
- There is a heavy reliance on-line marking for LKA, including the essential elements of luminosity and reflectivity. Furthermore, yellow line marking able to be detected but capability varies from vehicle to vehicle (Taylor et al. 2018).
- It is very noticeable that there are differences and variances in the ACC and LKA capabilities of different vehicles (Taylor et al. 2018).
- The terminology used for different technologies, with similar operations, in vehicles differs between manufacturers. Therefore, education of the public on terminology and technology features is necessary (Taylor et al. 2018).

- C-ITS units at 5.9GHz, developed as part of Phase 3, do not interfere with operations of electronic tolling collection systems (5.8GHz) currently being used on EastLink. In addition, was no data loss to tolling system during trials.
- The range of communications for RSU / OBU were 100% efficient at 1km distances. The distance for communication can vary between 900m and 2km, based on the road geometry.
- The communication performance and interference performance of DSRC devices was proven to be satisfactory. In multiple test case scenarios, all data was correctly captured. This suggests that the DSRC enabled devices can maintain accurate performance and communication for the natural movement of vehicles on EastLink.

1 Glossary

ACRONYMS	TEXT
ACMA	Australian Communications & Media Authority.
CAV	Connected and Automated Vehicles.
CEN-DSRC	An early version of DSRC (CEN-DSRC) is widely used for electronic toll collection (a Vehicle-to-Infrastructure (V2I) application) today based on EFC – CEN/TC 278
C-ITS	Cooperative Intelligent Transport System.
DENM	Decentralised Environmental Notification Message defined in ETSI TS 102 637-3. DENMs are mainly used by the cooperative Road Hazard Warning (RHW) application in order to alert road users of the detected events. The RHW application is an event-based application composed of multiple use cases.
DSRC	Dedicated Short Range Communication. A short to medium range communications service that supports both public safety and private operations engaged in roadside-to-vehicle and vehicle-to-vehicle communication environments. DSRC is meant to be a complement to cellular communications by providing very high data transfer rates in circumstances where minimising latency in the communication link and isolating relatively small communication zones are important. Typically, this refers to 5.9 GHz communication.
ETC	Electronic Toll Collection aims to eliminate the delay on toll roads, High Occupancy Vehicle (HOV) lanes, toll bridges, and toll tunnels by collecting tolls without cash and without requiring cars to stop.
ETSI	European Telecommunication Standardization Institute.
HMI	Human-Machine Interface. Normally used for displaying warnings for DSRC devices.
ITS	Intelligent Transport System.
ITS G5	ETSI defines enhancements to DSRC 802.11p required to support Intelligent Transport Systems (ITS) applications in Europe, which is the base of a European standard for vehicular communication known as ETSI ITS-G5.
MK5	The 5th generation V2X DSRC system from the Cohda Wireless Company.
MK2	The 2nd generation V2X DSRC system from the Cohda Wireless Company.
OBU	DSRC On-Board Unit deployed on moving vehicles such as cars, trains, trams, trucks, etc.
RSU	DSRC Roadside Unit deployed on roadsides to provide the necessary traffic and infrastructure information to OBUs, e.g. tolling information, traffic condition, traffic lights, intersection information.
V2V	Vehicle to Vehicle.
V2I	Vehicle to Infrastructure.
V2X	Vehicle to everything.

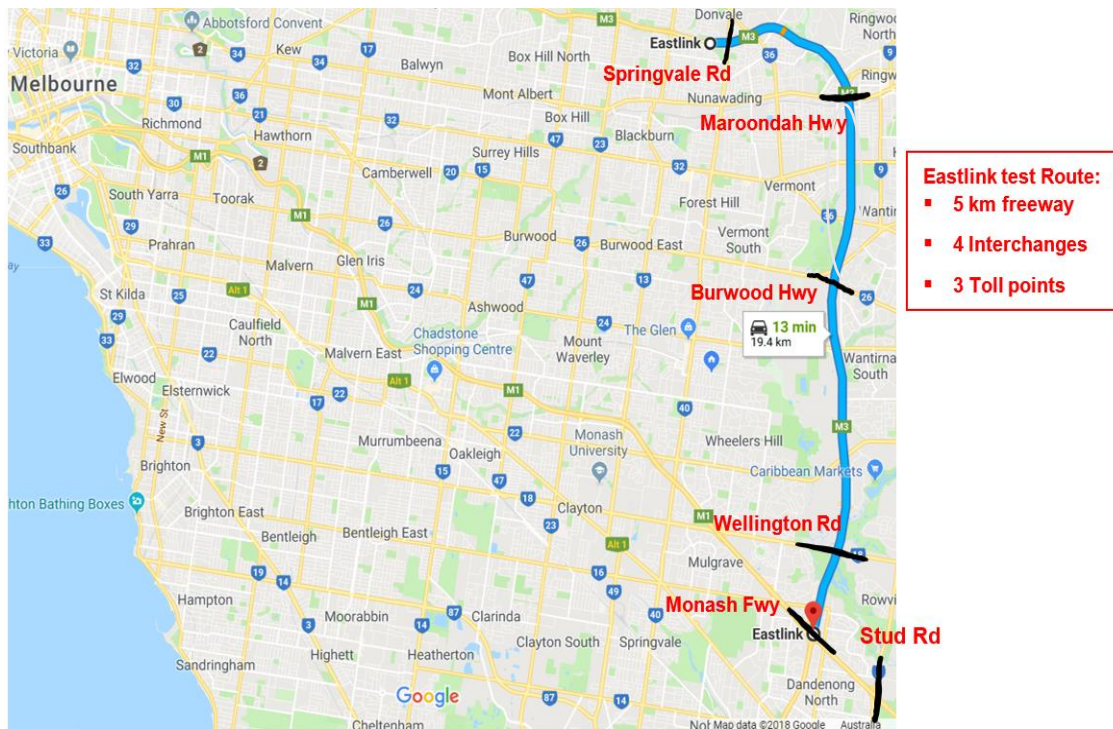
2 Introduction

As technology advances and more automated features become available, there exists a lack of real-life, practical understanding in Australia as to the requirements for and potential benefits of partial AVs (also known as advanced driver assist systems (ADAS)) in human-to-vehicle and vehicle-to-infrastructure interactions. It is also apparent that media sensationalism and incomplete knowledge of the public at large has given rise to concerns about the safety and trustworthiness of partial AVs. To help address these concerns, this project seeks to understand the capabilities and limitations of the current latest generation vehicles, and the impact road infrastructure has on a vehicle's capabilities.

This report presents findings from the first, second and third phases of the project, in which a series of currently available level 1 and 2 automated vehicles were trialled, and DSRC C-ITS units were developed, tested and installed, on Eastlink (tollway in SE Melbourne). In phase 1, trialling of vehicles was conducted between Springvale Rd and the Monash Freeway, including the Mullum-Mullum tunnel. During this phase, the driving experience and performance of each vehicle's automated/driver-assist functions (namely ACC and LKA), and their interaction with the surrounding infrastructure and traffic were noted. Meanwhile, for phase 2, the C-ITS RSU, OBU and HMI were developed and subjected to preliminary interference and range testing. This was then followed by the installation of the C-ITS RSU at toll point 2 on Eastlink in preparation for the C-ITS pilot deployment for phase 3. In the final phase, the interference between the C-ITS units and Tolling units were assessed as well as provided insight into the practicality of C-ITS messaging and the interaction between C-ITS and vehicle operators, specifically using Cohda modules, both in vehicle and at the gantry.

The map below shows the planned test route:

Figure 1: Test Route (Map)

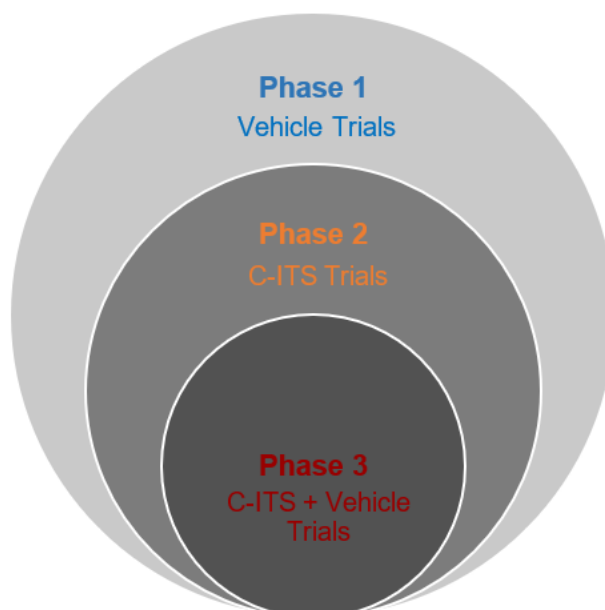


Anticipating a near-future with connected and autonomous vehicles, as part of Phase 3, the project has conducted a live ITS trial, in order to apply Dedicated Short-Range Communication (DSRC) technology to the test, delivering a concrete use case.

For that purpose, a new Intelligent Transport System based on 5.9 GHz DSRC technology to enable connectivity and safety for EastLink, including:

- An ITS DSRC application inbuilt with hazard warning algorithms
- An ITS website to manage the ITS use cases
- An On-Board-Unit (OBU) screen application to simulate the drivers' experience
- 12 OBU's to facilitate live testing
- Two Roadside Units (RSU) that were installed at two gantries
- A multi-terabyte database environment to host RSU and OBU data
- An analysis application that measures signal power and distance as well as all vehicular dynamic statistics from the RSUs to count car passes

Figure 2 Project phase outline



The report had undertaken previously published research on C-ITS and CAVs, including, but not limited to:

- *C-ITS Interoperability with Existing ITS Infrastructure – Austroads Publication No. AP-R458-14.*
- *Cooperative ITS: International Engagement – Internal Report.*
- *Cooperative ITS Strategic Plan – Austroads Publication No. AP-R413-12.*
- *Evaluation of the European C-ITS Platform including Threat, Vulnerability and Risk Analysis – Austroads Publication No. AP-R584-18.*
- *Vehicle Positioning for C-ITS in Australia (Background Document) – Austroads Publication No. AP-R431-13.*
- *5.9 GHz Satellite Interference: Field Study – Austroads Publication No. AP-R430-13.*
- *C-ITS 5.9 GHz Spectrum Management and Device Licensing Regime Report – Austroads Publication No. AP-R414-12.*
- *C-ITS Compliance Assessment Framework for Australia and New Zealand – Austroads Publication No. AP-585-18.*
- *Concept of Operations for C-ITS Core Functions – Austroads Publication No. AP-R479-15.*
- *Emerging Digital Mapping Requirements for C-ITS – Austroads Publication No. AP-R432-13.*

In addition, other recent work published includes Atkins (2016); Intelligent Transport Systems (ITS) Australia (2017); and Roads Australia (2017). These projects outline the potential benefits across transport, safety and the economy that can arise from the deployment of C-ITS connected AVs, including:

- improved traffic flow and road capacity (lowers traffic congestion and improves the efficiency of infrastructure use)
- removal of human driver error (improved road safety and reduction of cost and impacts associated with road trauma)
- reduced environmental impacts of road transport (lowers emissions/fuel use)

- heightened data collection capabilities for network operations and planning
- improved personal, public and freight transport efficiency and costing.

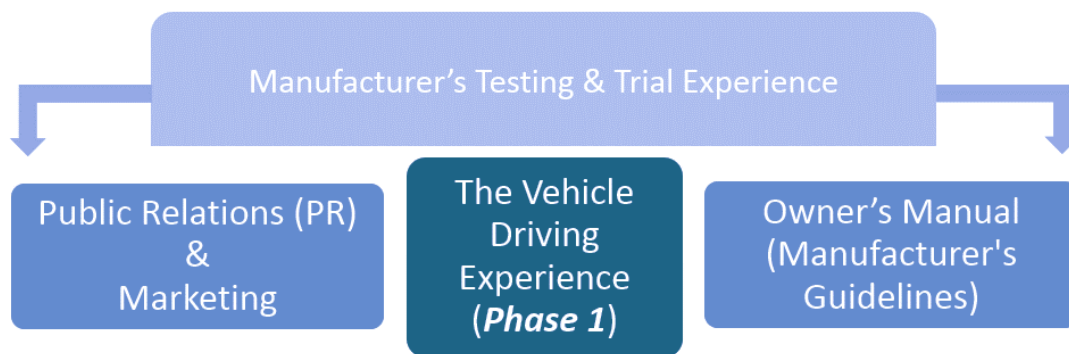
3 Phase 1

The purpose of Phase 1 was to report on:

- the operation and driving experience of production semi-AVs, and
- the interaction of semi-AVs with road infrastructure on Eastlink.

The context within which vehicle trials were undertaken can be summarised in Figure 3, which depicts the idea that vehicle manufacturers present information on their vehicles through sometimes embellished promotions (standard advertising) while accompanying owner’s manuals are legally conservative, detailed and with numerous caveats (standard legal practice), and internal R&D trial results are generally kept private (for competitive advantage). The driving perspective of the average consumer sits somewhere within these three perspectives.

Figure 3: *Various perspectives on production vehicles*



This section outlines the process in preparing and conducting trials of semi-AVs, to gain insight into the driving experience offered by these vehicles. The steps taken included:

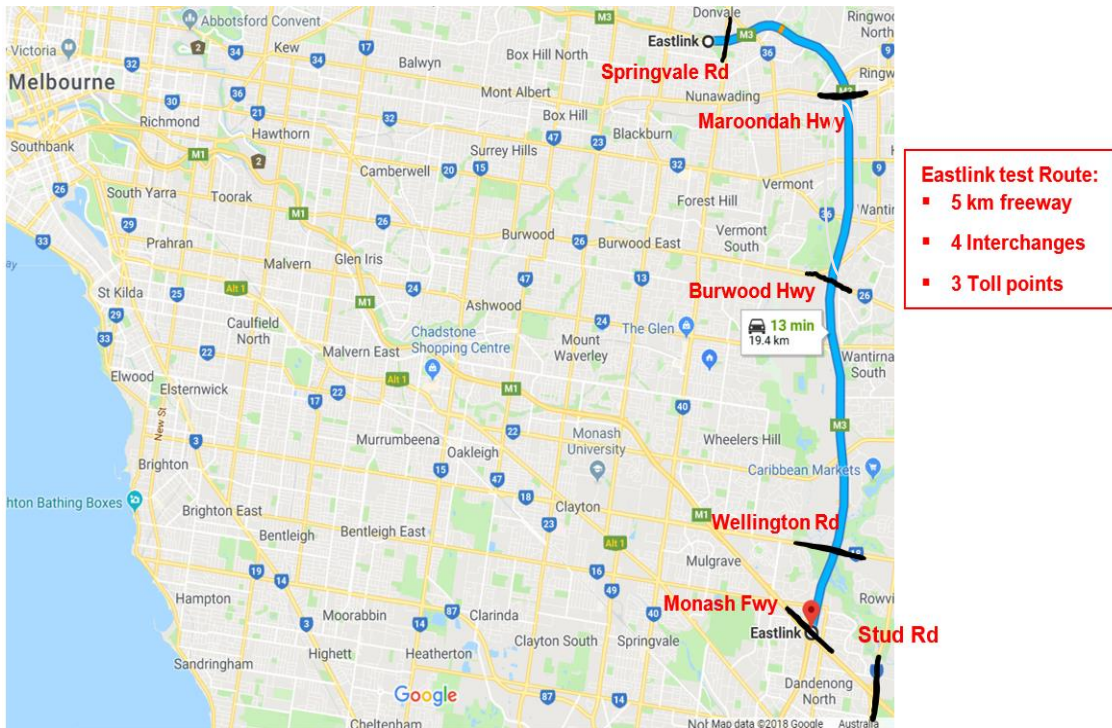
- identifying the test route
- consulting with RACV and vehicle manufacturers
- securing loan/test vehicles
- defining use cases
- assessing each vehicle’s level of automation and Operational Design Domain.

13 vehicle models were used as test vehicles. Some examples are:



Map below shows the planned test route:

Figure 1: Test Route (Map)



Phase 1 of the project reports that current level 2 AV technology has a need for high-quality lane markings with good visibility in all lighting, minimisation of ghost markings, sign technology considerations in respect of refresh rates and readability of LED signs, minimal curvature of ramps, and real-time feeding of traffic and mapping information to data providers. These findings were used in a VicRoads workshop discussion on road certification criteria and operational requirements for the safe operation of AVs on public roads. This workshop further highlighted areas of concern around widespread driver education and the potential need to change licensing processes to adapt to the change in vehicle and driver functions/roles.

It has been observed that the human experience of using ADAS highlights the human-machine interface (HMI) as a significant transition from standard driving. Standard

driving requires a mentally and physically engaged driver, whereas supervised driving (of partial AVs) requires a driver to be mentally engaged and physically ready (to be engaged). This has potential implications for driver education and deployment of level 2 vehicles, which is beyond the scope of this project but worth exploring in the future.

4 Phase 2

This phase, regarding C-ITS, aims to test a DSRC-based system that is ready to communicate with connected technology-enabled AVs on Eastlink. The process of achieving this has involved:

- development of DSRC C-ITS requirements for CAVs on public roads, including:
 - communication requirements,
 - wireless signage and safety implication requirements, and
 - functionality requirements
- interference testing between ITS-G5 5.9 GHz devices and CEN DSRC 5.8 GHz components of the electronic tolling collection system on
- verification of the Technical Requirement Specification (TRS) document through deployment of V2X (Vehicle-to-X, where X may be V for another Vehicle or “I” for Infrastructure) communications in low-level trials based on temporary installations (phase 3)
- simulating traffic flows and throughput as closely as possible to the real traffic situation, to test the reliability of the C-ITS units.

It is desired that the broadcasting of DSRC messages by the RSU will be remotely composed on a central server. Beyond this, it is proposed that an ITS-Eastlink website be developed for ease of access – to the system controls for road operators, and to travel information for road users.



Figure 4 Picture of RSU on Eastlink gantry

Phase 2 of the project, the development of both Road-side Units (RSUs) and On-Board Units (OBUs) for C-ITS deployment on Eastlink was undertaken. These units were assembled from Cohda MK2 and MK5 units, alongside a Lenovo Android Tablet (for in-vehicle human-machine interfacing use). Prior, preliminary interference testing was undertaken to ensure the C-ITS units did not interfere with Eastlink's Electronic Tolling Collection (ETC) system. Building on this initial testing in phase 2, the installation of an RSU at toll point 2 on Eastlink and further interference testing of the units were undertaken. No significant data loss occurred to the tolling system during this testing, and as such, it was deemed that the interference between the two systems was insignificant. Beyond this, the range testing of the C-ITS units was also performed. This found that the C-ITS units would be able to communicate messages from an RSU to an OBU with 100% efficiency, over a ~1 km distance. The HMI for the OBU was also developed in phase 2, and the systems were configured to display warning icons and give alert tones when a relevant Road Works Warning (RWW) or Car Accident Warning (CAW) from an RSU is received by the OBU. This HMI was developed for quick and easy viewing, and intuitive use so as to not distract the driver.

The developed RSUs, OBUs and HMIs are to be deployed in trial C-ITS pilots, for V2I communication on Eastlink, for phase 3 of the project.

5 Phase 3

Phase 3, as an extension of Phase 2, looked into the interaction of DRSC and C-ITS with vehicle operators, and tested the practicality of C-ITS messaging systems, using Cohda modules, to warn drivers of Roadworks and Collisions. As previously mentioned, Phase 2 looked at the initial testing of C-ITS systems, whereas Phase 3 undertook a live trial of these systems.

As part of Phase 3, systems were developed for the messaging and communications of DRSC and C-ITS technology with vehicle operators. This included the OBU interface and the web interface. The physical/technical design of the trial consisted mainly of the DSRC equipment.

To ensure the systems developed were practical for the trial, and for real-world applications, testing of the systems was undertaken. This included an interference test and a communications test. The interference test comprised of ensuring ACMA compliance, developing performance metrics, testing these performance metrics, and developing a mitigation plan for interference. The communications range test consisted of the development of performance metrics and testing of these performance metrics.

Two Use Cases were outlined to be investigated as part of the trial. These included a Road Works Warning (RWW) case and a Car Accident Warning (CAW) case. These Use Cases were tested to determine the real-world practice of the DRSC and C-ITS systems developed as part of this phase of the project. Figure 5 illustrates the set-up of the trial.

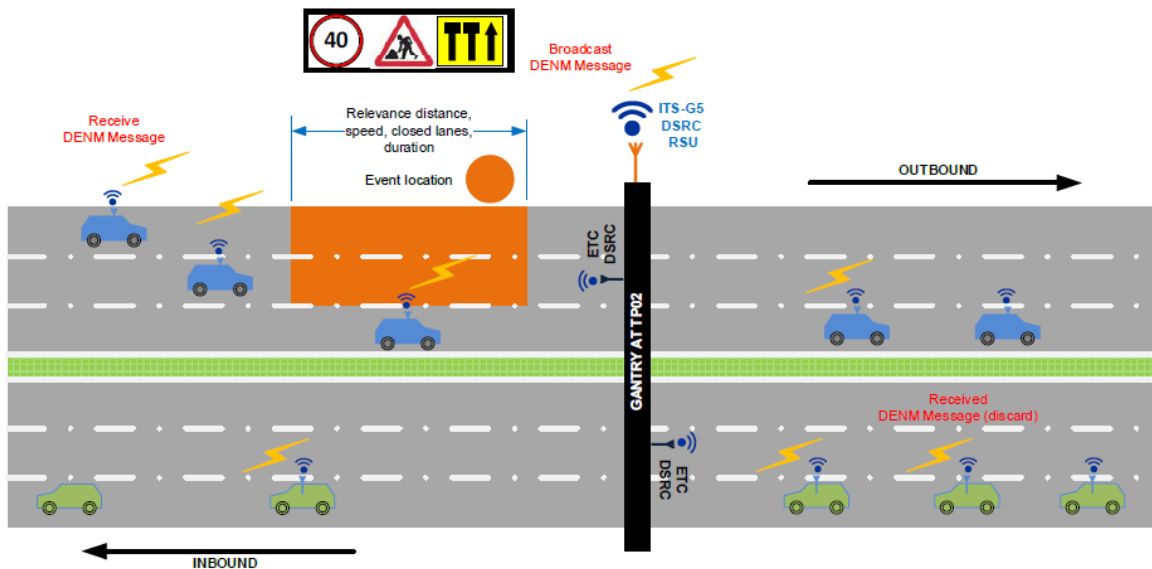


Figure 5 Event messaging on Tollway

5.1 Use Cases

Two scenarios were investigated:

- Road Works Warning (RWW): Use Case 1
- Car Accident Warning (CAW): Use Case 2

5.1.1 Use Case 1

The objective of the RWW is to reduce the risk of collision around roadwork areas (e.g. crashing into safety trailers), oncoming traffic will receive warnings and restrictions concerning the road works area and installed safety vehicle(s) such as the location of a Truck Mounted Attenuator (TMA). The broadcast frequency of DSRC message, namely Decentralised Environmental Notification Message (DENM), is 1Hz.

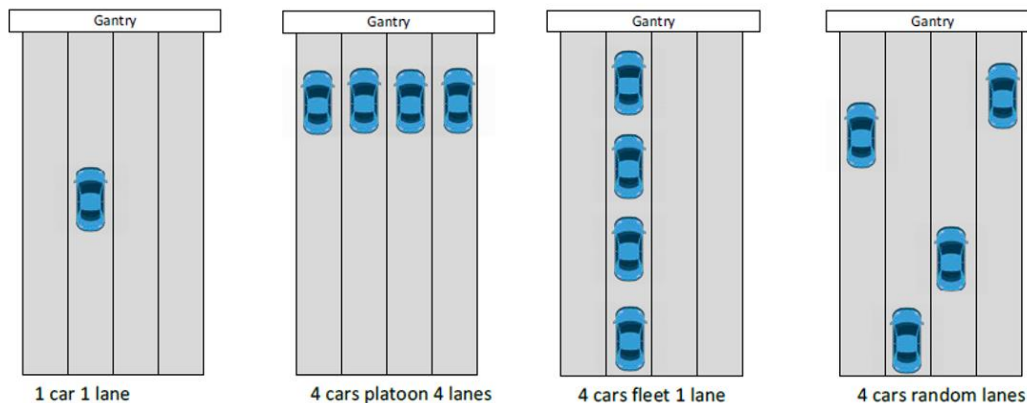
5.1.2 Use Case 2

The objective of the CAW (Use Case 2) is to notify the accident location and status to other vehicles to enhance attention level.

5.1.3 Methodology

These use cases were trialed with each group of cars followed the moving motions as shown below.

Figure 6 Test Case for consideration



The communication performance and interference were tested using different moving motions:

- 1 car and 1 lane: This is to test the communication performance of vehicle-to-infrastructure (V2I). Ideally, this will achieve excellent communication performance, as there is no interference from other DSRC devices. The performance result will be used to compare with high traffic flow and high communication load in other moving motions.
- 4 cars platoon and 4 lanes: 4 cars will move in a platoon with a fixed distance. The vehicle-to-vehicle (V2V) and the V2I communication performance was tested

against multiple lane positions and diverse distance to the RSU. This is considered a high communication load and high traffic flow scenarios. It is expected the DSRC messages from RSU will be received successfully by all vehicles communicating with each other in different positions in the platoon.

- 4 cars fleet and single lane: 4 cars move in a single lane with a certain distance towards the RSU. This is to test the delivery of RSU DSRC messages to each car in the fleet in a longer range. It is expected all vehicles will receive DSRC messages from RSU successfully without message loss that may happen due to the V2V interference.
- 4 cars and random lanes: 4 cars will move randomly in all lanes. This is to simulate the actual daily car-moving mode. The cars will maintain random distances and random positions on the highway. It is expected to achieve average communication performance as a reference for the actual car moving scenario.

6 Conclusion

The following list of key learnings has been developed, across all three Phases of this project:

- The driving skills required for semi-AVs are different from non-semi-AV. Therefore, it will take time for drivers to understand and feel confident in the features while remaining engaged with the driving task (Taylor et al. 2018).
- There is a heavy reliance on-line marking for LKA, including the essential elements of luminosity and reflectivity. Furthermore, yellow line marking able to be detected but capability varies from vehicle to vehicle (Taylor et al. 2018).
- It is very noticeable that there are differences and variances in the ACC and LKA capabilities of different vehicles (Taylor et al. 2018).
- The terminology used for different technologies, with similar operations, in vehicles differs between manufacturers. Therefore, education of the public on terminology and technology features is necessary (Taylor et al. 2018).
- C-ITS units at 5.9GHz, developed as part of Phase 3, do not interfere with operations of electronic tolling collection systems (5.8GHz) currently being used on EastLink. Also, was no data loss to the tolling system during trials.
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