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CITI – An update on Australia's First Pilot Deployment of CITS

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Abstract
Cooperative Intelligent Transport Systems (CITS) is a term generally used to describe a form of Intelligent Transport Systems in which information is shared amongst vehicles or between vehicles and roadside infrastructure such as traffic signals. The Cooperative Intelligent Transport Initiative (CITI) is Australia's first semi-permanent CITS field test bed site. The first stage of the CITI test bed has been deployed. It operates in an area of 917 sq. km. (91,672 hectares / 354 sq. miles) in the Illawarra Region of New South Wales (NSW), south of Sydney. Sixty vehicles (58 being heavy vehicles), 3 signalised intersections, 1 other roadside location and 2 roadside data collection locations have been equipped with DSRC units. This paper provides an update on CITI, the deployment of stage 1, and initial plans for future work, including further deployment and data analysis.

Keywords:
CITS, DSRC, Test-bed.

Introduction

Transport is facing a wave of technological change that will transform the way people travel and how they transport goods. Dedicated Short Range Communication (DSRC) and Cooperative Intelligent Transport Systems (CITS) are emerging as key technologies in the revolution. The Cooperative Intelligent Transport Initiative (CITI) is a pilot deployment project of DSRC to provide a test bed for the exploration of these technologies within an Australian context. This paper reports on the completion of stage 1 deployment of the test bed and presents initial plans for future work.

Background

The Cooperative Intelligent Transport Initiative (CITI) is a project being conducted by Transport for NSW (TfNSW) in partnership with Data61, a business unit of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the Federal Government's Heavy Vehicle Safety Productivity Program. The project is run and operated out of TfNSW. Data61 has been providing key technical expertise, initially by providing a person embedded in TfNSW to be project manager and now continuing as technical lead. The Federal Government has provided a significant funding contribution. The first stage of the project aimed to install Cooperative Intelligent Transport System (CITS) devices in up to 60 heavy vehicles, at 3 signalised intersections and at the top of Mt Ousley near Wollongong, NSW as an initial test bed for evaluation and further testing of specific Cooperative Intelligent Transport Systems (CITS) technology.

What specific "Cooperative Intelligent Transport Systems" technology is being trialled?

Intelligent Transport Systems (ITS) is a term used to describe a vast array of technologies that use computing devices associated with vehicles. The technologies range from in-vehicle navigation, electronic tolling and speed cameras to more advanced systems such as live data, parking guidance or weather information. Cooperative Intelligent Transport Systems (CITS) is the term generally used to describe a form of Intelligent Transport System in which information is communicated and shared amongst vehicles or between vehicles and roadside infrastructure such as traffic signals. An example of a common, simple CITS application is in electronic toll collection where a vehicle mounted toll tag is detected by a road operator who in turn charges the owner of the vehicle for travelling on a section of road. More recently, complex generalised CITS systems are being developed that enable vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication to occur as peers that are part of a broad network. In these networks, there are no central computers or processors controlling the network. Network participants communicate with each other as peers. These systems use radio technology known as Dedicated Short Range Communications (DSRC[1]) which work in a similar way to computer WiFi networks. Both the U.S. Department of Transport and European standards groups are refining standards that enable V2V and V2I communication. With this technology, various applications are possible, and significantly the initial applications are focusing on vehicle safety.

[1] In this paper, we use DSRC to refer specifically to V2V and V2I systems such as the Wireless Access in Vehicular Environments (WAVE) as stated in various standards including IEEE 802.11p, IEEE 1609, SAE J2735 or the equivalent European standards.

At the heart of DSRC is a communication network that is designed to be suitable for communication between vehicles and between vehicles and infrastructure. Rather than providing a solution for a specific problem like electronic tolling, this network is a platform on which applications can be built. Whilst the nature of the infrastructure lends itself to a variety of applications, the current primary motivator for deploying DSRC is road safety. Therefore, at the core is a design that has a focus on road safety. Initial applications being tested on DSRC platforms worldwide include alerts for potential collisions or other dangerous conditions such as curve speed warnings and ice on the road.

In addition to safety, it is expected that DSRC will provide a platform for applications in the areas of driver information, network management, environmental and network efficiency, routing, incident detection, vehicle management and driver assistance technology. No doubt many more applications will emerge as the technology is explored. In the future DSRC is also likely to be a technology that assists autonomous vehicles.

The CITI Project – Deployment of Stage 1

The CITI project is a test bed for DSRC technology in the Illawarra region of NSW. Stage 1 of the project is the deployment of the technology for an ongoing trial. Vehicle deployment has focused on heavy vehicles operating out of Port Kembla with a focus on safety applications. Stage 1 has been deployed with 58 heavy vehicles, 2 light vehicles, 3 signalised intersections, 1 additional roadside installations and 2 data collection units in the project area. This section provides details on that deployment.

Location

The CITI project operates in an area of 917 sq. km. (91,672 hectares / 354 sq. miles) in the Illawarra Region of NSW south of Sydney. It has a focus on a 42 kilometre length of road that connects the Hume Highway in Sydney's South West to the port of Port Kembla, situated two kilometres south of the Wollongong Central Business District. However due to the variety of routes often used by heavy vehicles using Port Kembla, the project is operating in a broader area. Figure 1 shows a map of the focus route and area.

A number of factors make the focus route and project area ideal for a DSRC test bed. The route covers a range of environments, including urban, mountains and isolated rural areas. A high concentration of heavy vehicles with regular trips and the common focus points of Port Kembla and specific coal mines give a unique opportunity to focus on heavy vehicles with a higher chance of interaction.

Having recently undergone a major expansion, Port Kembla has seen a diversification of its trade base to include general and break bulk cargoes, containers and motor vehicle imports. Mt Ousley Road is a busy road carrying an increasing number of heavy vehicles that form a significant part of the traffic using that road.

Picton Rd, connecting Mt Ousley to the Hume Highway, has recently had significant physical works completed. Roads and Maritime Services (2016) indicates that heavy vehicles are involved in the majority of fatal road crashes recorded on the focus route.

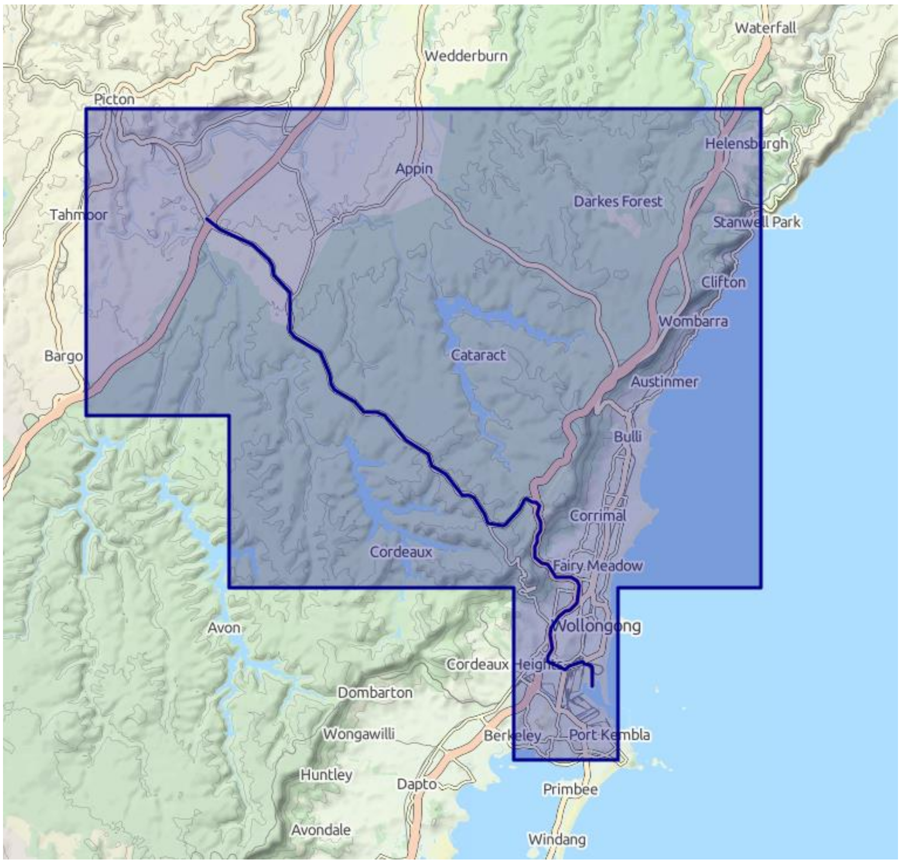

Figure 1 – CITI Area with Primary Route[2]

Equipment and System Evaluation

CITI currently utilises Cohda Wireless MK4 and MK5 DSRC units running Cohda’s software in vehicles and roadside software for infrastructure deployment. CITI is currently operating

[2] Cartography by OpenStreetMap contributors. Retrieved 1 August 2014. See http://www.openstreetmap.org/copyright

on the US standards of SAE J2735, IEEE 1609 family and with IEE 802.11p providing the underlying communication. In vehicles, the Cohda DSRC unit is running Cohda’s Aftermarket Safety Device software and is connected to a Nexus 7 tablet for audio and visual display of alerts to drivers. Alerts provided to drivers include Forward Collision Warning (FCW), Intersection Collision Warning (ICW), Electronic Brake Light Warning (EBLW), as well as two custom alerts. The custom alerts are a red light ahead warning based on Signal Phase and Timing broadcasts and a heavy vehicle speed restriction monitoring application that alerts drivers if they exceed a 40km/h restriction on a steep decent in the project area.

Before deployment, an evaluation of the alerts in test units was considered necessary due to a concern that alerts should not cause confusion or distraction. With a view to possibly redesigning alerts, CITI engaged Monash University Accident Research Centre (MUARC) to do a literature survey of Human Machine Interface (HMI) research for in-vehicle devices with interfaces similar to those of the CITI devices and to develop guidelines for developing or assessing an HMI on these types of devices. MUARC produced a comprehensive report (Young & Lenné, 2013a). CITI modified the alerts on the basis of the guidelines and MUARC was further asked to provide an independent assessment of our proposed HMI (Young & Lenné, 2013b). More information is available in Vecovski, et al. (2015) and Vecovski et al. (2016a).

Deployment in Vehicles

Stage 1 of CITI has successfully deployed 58 DSRC radio devices with displays in heavy vehicles operating out of Port Kembla. Three major transport companies have voluntarily joined the project by granting access to a range of heavy vehicles including car carriers and A-double vehicles carrying up to 85 tonne. Some vehicles are on the road 24 hours per day, 7 days a week. Additionally 2 light vehicles operated by TfNSW have each had a DSRC radio and display installed. Installation was carried out by auto electricians familiar with the fleet by mutual agreement with TfNSW.

Heavy vehicle installation proved to be more difficult than anticipated. Vehicle cabs already had significant additional installations. The initial installation configuration required one GPS antenna and two DSRC antennas, one attached to each side. Additionally the Nexus 7 tablet was mounted in each vehicle and connected to the radio by USB cable. This proved to be a difficult installation for some vehicles. More information is available in Tyler, et al. (2016)

Driver Induction

With some vehicles operating 24/7, approximately 150-200 drivers operate the 58 heavy vehicles. Driver training was conducted face to face at the transport companies' sites at the start and end of shifts. In the training, they were introduced to the basic technology and possible alerts they may experience. It was made clear to drivers that alerts could only be triggered through information from other devices and in particular that collision alerts would only occur for interactions with other equipped vehicles. Interestingly, many drivers could foresee some of possible future uses of the technology, illustrating their grasp of the basis of the technology. Overall the technology was well received. There was good understanding of the limitations of the project.

Deployment at Signalised Intersections

Three signalised intersections have been equipped with Road Side Units (RSUs) and programmed to broadcast Signal Phase and Timing (SPaT) information. Roads and Maritime Services (RMS), the developers of the SCATS adaptive traffic control system (Scats.com.au, 2016), have been integral partners in trialling the broadcast of SPaT information with SCATS. Broadcast information includes notification of impending phase changes. This information is used by vehicles' DSRC unit to present information to the driver when approaching red lights.

Deployment at a remote roadside location

To provide the functionality of the 40 km/h heavy vehicle speed restriction alert, roadside infrastructure has been deployed in a remote area near the start of that speed restriction. Operating from a solar powered trailer, the RSU broadcasts information regarding the speed zone, that it is one way only, and that it is only applicable to heavy vehicles. Software in the vehicles uses that information to determine if the vehicle is in that zone and if so, whether it needs to alert the driver for speeding.

Data collection

All DSRC units (both vehicle and infrastructure) in the project log all messages transmitted and received. This includes the Basic Safety Message (BSM) being broadcast 10 times a second by vehicles. Logging of transmissions gives the benefit of providing all BSM information for that vehicle. Logs are stored on vehicles until they are within range of one of two data collection stations. Data collection stations are themselves RSUs on solar powered trailers. Data is downloaded by vehicles to those collection stations and then physically collected to be transferred to the project data storage.

Completion of Stage 1

Stage 1 was completed at the end of September 2015. At that time, 58 heavy vehicles, 2 light vehicles, 3 signalised intersections and one road side location were equipped. In addition, 2 DSRC equipped data collection points were commissioned. Data has been collected since that point and as of the end of June 2016, over 500 million BSMs (transmitted or received) had been collected.

Planned Future Work

A number of options for future work are currently being considered. Some of the more likely options are presented here.

Initial Data Analysis

Initial data analysis has commenced and is planned to continue. Analysis planned includes:

- examining operation and data collection of all DSRC units
- examining positioning errors, especially at key areas and locations
- examining broadcast range between vehicles in various locations
- identification and examination of alert events

It is hoped this analysis will provide a better understanding of the performance of DSRC systems and the issues faced by them, especially in the Australian setting.

Driver Feedback

Work has already occurred with participating drivers about their attitudes towards the CITI DSRC device. Key areas of exploration included self-reported impact of CITS on their driving behaviour, feedback on the device and the nature of the alerts, and understanding of the project objectives and technology. The methodology for gathering driver feedback consisted of mini-group discussions with heavy vehicle drivers and interviews with fleet managers. This work is described in more detail in Vecovski et al (2016b).

Understanding Safety Impact

Due to the small sample size and nature of the project, it is not expected that it will be possible to ascertain the road safety benefits of the CITI technology using traditional measures such as reductions in crashes, fatalities and injuries or changes in offence rates. It is hoped there will be much learned from the identification of alert events and close analysis of those events. Of particular interest to the researchers is the impact of alerts on drivers.

Additionally Doecke et al. (2015) have simulated DSRC use based on real world crash data. That study indicated lower impact speed for 78% of crashes, even where a driver is slow to react to alerts and only uses moderate braking. However, those simulations assumed accurate GPS and the simulation resulted in 100% message transmission. Real world data from projects such as CITI could enable more realistic simulation of GPS positioning and DSRC communication to enhance this kind of work. Further, analysis of driver reactions in CITI might provide more accurate information on how drivers react to alerts. For example, are assumed reaction times realistic or do drivers confirm an alert before reacting, adding more time between alert and reaction?

Additional Vehicles and Roadside locations

CITI plans to deploy DSRC into up to 50 additional vehicles and several road side locations. Options are currently being canvassed to enhance the amenity of the CITI testbed with a focus on broadening the base of vehicle types while also attempting to increase the potential for interactions between participating vehicles, other vehicles and equipped roadside infrastructure.

Truck and Signalised Intersection Interaction

Deployment at the end of Stage 1 provided SPaT information to vehicle devices which in turn alerted drivers when they are approaching a red light. In conjunction with RMS, CITI is in a unique position to investigate the potential impact of adaptive traffic signals changing phases based on BSM messages and priority requests received by the signal controller. Amber and red lights can present challenges to drivers of 85 Tonne, 36.5 metre trucks. Faced with a decision to brake heavily or "run" a red light, the driver has a choice between two potentially dangerous situations. Additionally, braking heavily for a red light not only poses a safety issue, but potentially causes significant damage to road surfaces. Two approaches are being considered for this situation. The first is to provide drivers with prior warning of lights changing to red. At current equipped intersections, up to 6 seconds warning of a change to orange can be provided. Plans are also being considered to investigate how BSMs received at the controller or automatically generated priority requests might inform controller software to mitigate these kinds of risks.

GPS Positioning

CITI currently has concerns over positioning of vehicles based only on GPS. Absolute errors in GPS positioning of over 7 metres from Google earth positions are not uncommon. When two vehicles have different absolute errors, there is a possibility of false forward collision warnings and electronic brake light warnings. Initial data indicates the risk of different absolute errors appears to be more likely where two vehicles are equipped with different makes or models of devices. In CITI, false forward collision warnings have been experienced on multi-lane roads when passing another equipped vehicle. The most likely cause is different errors in the GPS position of each vehicles, overlapping the reported paths of the vehicles. CITI is also concerned that as the relative positioning between two devices of the same make (between two MK4s or between two MK5s) may be more accurate, this may be hiding a wider issue of different errors in GPS positioning between makes and models of DSRC units. Further examination is being considered of the positions reported when false alerts were generated.

BSM encoding of long vehicles

Australia has some of the longest vehicles in the world. The CITI project includes vehicles up to 36.5m long. This presents a challenge for encoding the vehicle in the BSM. Currently the project broadcasts the vehicle as a single entity of a fixed length and heading. However as some of the vehicles are articulated in up to two places, the vehicle is not in a straight line and when cornering, at any instant different parts of the vehicle have different headings. This can lead to problems with collision detection in two ways. A vehicle that is cornering may broadcast a BSM that indicates the vehicle is hanging over other lanes, including lanes in the other direction, leading to false alerts. Additionally a vehicle approaching the rear of the cornering vehicle will have a false idea of where the rear of the cornering vehicle is placed. This could result in no alerts when one ought to be issued.

While there are currently no plans to address this issue in the CITI project, it is one area that needs consideration in the future.

Conclusion

Stage one of CITI has been successfully deployed and large amounts of data are being collected. This work has resulted in a significant test bed for ongoing testing, research and development which is especially important for understanding the potential of the technology in the Australian context. Already the test bed has proved valuable in helping to identify a number of issues and areas for further work. It is planned for CITI to continue operation for a number of years and provide a platform for future work in V2V and V2I communication.

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