C-ITS Interoperability with Existing ITS Infrastructure
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Prepared By | David Green, Freek Faber and Michael Levasseur
Project Manager | Stuart Ballingall

Abstract | This report defines how emerging C-ITS will integrate with existing ITS currently being operated by Austroads member road agencies.

The report is limited to investigating what is required to achieve interoperability between 5.9 ITS (a term used to describe a subset of C-ITS which utilises 5.9 GHz communications) and the selected existing ITS infrastructure of electronic speed limit signs, traveller data collection, traffic signals and traveller information systems.

Interoperability was investigated for the four interoperability levels of technical, syntactical, semantic and organisational.

From these investigations it was found that there are changes and elements required to make 5.9 ITS interoperable with the existing ITS infrastructure investigated with many common themes identified. Some of the key common themes include to achieve:

- technical interoperability will require elements such as a 5.9 roadside ITS station and software within the unit to form a 5.9 ITS message.
- syntactical interoperability will require converting the ITS infrastructure content into the syntax required for 5.9 ITS messages.
- semantic interoperability will require forming a 5.9 ITS message that complies with the standardised content and meaning, making allowance for international terminology.
- organisational interoperability requires road agencies to integrate 5.9 ITS with existing ITS infrastructure across all interoperability levels.

While this report discusses the integration between ITS infrastructure and 5.9 ITS, it is acknowledged that some C-ITS functionality could be achieved through integrating C-ITS with existing ITS infrastructure using cellular communications.

Additional issues associated with 5.9 ITS integration and ITS infrastructure include privacy, security, certification, liability, management of ‘big data’, private–public partnerships, field operation tests/trials and location and extent of 5.9 roadside ITS station deployment.

Keywords | cellular communications, co-operative intelligent transport systems, Cooperative ITS, electronic speed limit signs, interoperability, risks, roadside ITS station, organisational interoperability, technical interoperability, traffic signals, traveller data collection, traveller information systems, semantic interoperability, syntactical interoperability and 5.9 ITS.

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Individual road agencies will determine their response to this report following consideration of their legislative or administrative arrangements, available funding, as well as local circumstances and priorities.

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Summary

The purpose of this report is to investigate how emerging Co-operative Intelligent Transport Systems (C-ITS) may integrate with existing ITS operated by road agencies, and to assist with understanding how C-ITS will be integrated with ITS at a system engineering level. The scope was limited to investigating interoperability between 5.9 ITS\(^1\) and electronic speed limit signs, traveller data collection, traffic signals and traveller information systems and in doing so investigating what is required to achieve interoperability at the technical, syntactical, semantic and organisational levels.

Technical interoperability, in the context of C-ITS integrated with ITS infrastructure, refers to the hardware/software required to enable a C-ITS equipped vehicle to communicate to a C-ITS equipped ITS infrastructure and vice versa. For this to be achieved utilising 5.9 GHz communication would require access technologies and network protocols at the field-to-field, field-to-vehicle and field-to-centre levels as outlined below:

- field-to-field (5.9 roadside ITS station integrated with roadside ITS infrastructure): this will likely require a fixed wire (e.g. optic fibre) or wireless connection using Ethernet, with an agreed networking protocol such as IPv6
- field-to-vehicle (5.9 roadside ITS station communication with 5.9 in-vehicle ITS station): this would require communication via 5.9 GHz dedicated short range communication utilising either IEEE 802.11p\(^2\) for the USA platform and ETSI standards that are based on CALM for the European platform
- field-to-centre (5.9 roadside ITS station integrated with back office systems associated with the ITS infrastructure): this would require long range communications utilising fixed wire (e.g. optic fibre) communication infrastructure and/or wide area communications such as 3G and 4G.

Syntactical interoperability, in the context of C-ITS integrated with ITS infrastructure, refers to the need for both the C-ITS equipped ITS infrastructure and the C-ITS equipped vehicle to communicate with agreed data formats so that messages can be processed and therefore know what data they both need to obtain from the vehicle (applicable to the 5.9 in-vehicle ITS station) and the ITS infrastructure (applicable to the 5.9 roadside ITS station) and therefore the syntax required for the C-ITS messages. For this to be achieved utilising 5.9 GHz communication, would require syntactical interoperability at the field-to-field, field-to-vehicle and field-to-centre levels as outlined below:

- field-to-field (5.9 roadside ITS station integrated with roadside ITS infrastructure): this would require the 5.9 roadside ITS station sourcing data from the ITS infrastructure using consistent message formats such as the Traffic Management Data Dictionary (TMDD) which refers to elements of the National Transportation Communications for ITS Protocol (NTCIP) family of standards (USA) and DATEX2 (Europe) protocols
- field-to-vehicle (5.9 roadside ITS station communication with 5.9 in-vehicle ITS station): this would require the 5.9 roadside ITS station converting the data extracted from the ITS infrastructure into an agreed C-ITS message format. The USA and Europe are developing various vehicle-to-field and field-to-vehicle messages, with attempts to harmonise messages between the regions. The various C-ITS messages are outlined in this report
- field-to-centre (5.9 roadside ITS station integrated with back office systems associated with the ITS infrastructure): similar to the field-to-field this would require the 5.9 roadside ITS station sourcing data from central based ITS infrastructure at the back office using message formats such as NTCIP (USA) and DATEX2 (Europe) protocols.

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\(^1\) 5.9 ITS is a term used to describe a subset of C-ITS which utilises 5.9 GHz communications.
\(^2\) This report refers to IEEE 802.11p as this is the component of IEEE 802.11-2012 of interest to this report.
Semantic interoperability, in the context of C-ITS integrated with ITS infrastructure, refers to the need for the C-ITS equipped ITS infrastructure and vehicle to interpret the content of the messages being communicated by defining the content of the message format (e.g. using common directories/definitions). Examples of this may be defining the content required so that the relevance of the message can be confirmed by both machines with respect to time and location, enabling both machines to correctly utilise the messages.

Organisational interoperability, in the context of C-ITS integrated with ITS infrastructure, refers to the ability of relevant organisations to exchange data across the C-ITS systems, which will require a level of consistency with business processes. Success of the outcome will also be dependent on the level of technical, syntactical and semantic interoperability. Issues to be addressed will include management and maintenance processes for ITS, device certification and compliance, security and verification processes, establishing a consistent architectural approach, and interfaces for legacy systems.

International standards are being developed by various international standard bodies. This includes the ‘Release 1’ set of standards which are considered to be the minimum set of standards required for interoperability in accordance with the European Commission Standardization Mandate M/453. Agreement and adoption of emerging international C-ITS standards will be critical to enable C-ITS interoperability with existing ITS infrastructure. This will include making a decision between the European platform and standards (ETSI and CEN standards, including CALM) and the US platform and standards (based on SAE and IEEE standards, including WAVE).

It is noted that while this report focuses on 5.9 ITS integration with the ITS infrastructure of electronic speed limit signs, traveller data collection, traffic signals and traveller information systems, some C-ITS services will be provided to road users by media other than via the 5.9 GHz band, and that the delivery of many of these services will be managed by private organisations. There will likely be a role for road agencies to enable these private organisations to have access to traffic/road data. Where possible this should be done using open data protocols/standards (e.g. for centre-to-centre), and under appropriate agreements.

Additional key findings outlined in this report include:

- The integration may increase the risk of ITS infrastructure to cyber and/or malicious attacks.
- C-ITS poses significant data management issues for road agencies.
- It is critical that C-ITS complies with the relevant privacy and surveillance legislation.
- Verification of each user’s signal is important for security and legitimacy as C-ITS has the potential to expand the issue of road agency liability.
- FOT or trials are critical to test and evaluate the level to which interoperability is achieved.
- Consideration will need to be given to proximity to power and communications to back office when locating 5.9 roadside ITS stations.
- The extent of deployment of 5.9 roadside ITS stations will be dependent on the benefit-to-cost analysis, the desire to collect of probe data and the extent to which probe data is stored in the vehicle before transmission to a 5.9 roadside ITS station.
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1. Introduction

Co-operative Intelligent Transport Systems (C-ITS) are being developed to make a substantial contribution to moving people and goods safely and efficiently (Austroads 2012a; Research and Innovative Technology Administration 2011). This will be achieved by providing connectivity between vehicles (V2V), between vehicles and roadside infrastructure (V2I) and between roadside infrastructure and vehicles (I2V) (Austroads 2012a; COMeSafety et al. 2010; Cooperative Vehicle Infrastructure Systems 2010a). These connections will enable real-time information exchange about the road environment enabling benefits to be achieved from both a road user’s and road operator’s perspective. The various benefits can be categorised into safety, productivity and environmental benefits.

Communications between vehicles (V2V) and between vehicles and infrastructure (V2I) in the C-ITS environment includes peer-to-peer communications (e.g. 5.9 GHz dedicated short range communications) and wide area communications such as cellular communications through the use of telecommunication provider services.

In addition to V2V and V2I connectivity, C-ITS also caters for the evolution of vehicle-to-business (V2B) connectivity. Examples of current V2B connectivity include telematics and traveller information services utilising wide-area communication such as:
- Transport Certification Australia’s (TCA’s) Intelligent Access Program (IAP)
- the provision of routing and congestion information to vehicles via private service operator applications delivered through navigational devices.

Substantial work has been undertaken internationally on the development of low latency, short range communications for V2V and V2I. Europe and the USA are looking at starting to deploy V2V and V2I from 2015 (Boethius 2012; Cooperative Vehicle Infrastructure Systems 2010b). Japan has already deployed vehicles and roadside infrastructure with some C-ITS functionality (Fukushima, Seto & Tsukada 2008; Honda Motor Co. 2009; ITS International 2013).

Road agencies have invested heavily in Intelligent Transport Systems (ITS) over the years. With that investment in mind, it is important that road agencies continue to leverage off and make the most of current ITS, so that C-ITS applications work with them. In order to achieve this, C-ITS and ITS infrastructure need to be interoperable as discussed in Council of the European Union (2010) and ETSI White Paper No. 3 Achieving Technical Interoperability – the ETSI Approach (van der Veer & Wiles 2008).

The evolution of C-ITS offers some particular challenges and uncertainties for road agencies worldwide as it has the potential to change the way in which information and traffic controls are communicated to drivers and the way data is collected and the methods by which road managers manage their assets. As a result, C-ITS has the potential to require significant investment by road agencies, either through investment in 5.9 roadside ITS stations or through central systems that are integrated with existing and future ITS infrastructure to enable C-ITS messages to be communicated over a wide area communications network.

1.1 Purpose

The purpose of this report is to explore how selected existing ITS that are operated by road agencies will integrate with emerging C-ITS and therefore define what needs to be done to enable interoperability. In doing so, the report will outline the benefits and risks associated with this integration.

As outlined in Section 1.3 and Section 3, the report explores only part of the story of C-ITS integration with existing ITS. As both C-ITS and ITS are broad and their potential integration extensive, there was a decision to limit the scope of the investigation to 5.9 ITS integration with the existing ITS infrastructure of electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems.

3 5.9 ITS is a term used to describe a subset of C-ITS which utilises 5.9 GHz communications. It is noted that the US uses the term DSRC 802.11p, Europe uses G5 (also G5A, G5B and G5C as subsets of G5), ISO uses CALM M5.
1.2 Report Structure

The two sections after the Introduction are:

- Section 2: Background – provides necessary background by defining what interoperability is with respect to C-ITS, outlining the need for C-ITS to be interoperable with existing ITS, defines how C-ITS is just one part of a broader ITS architecture and defines the roadside and central ITS stations.

- Section 3: Method – outlines the method used in preparing the report by defining the scope of the investigations and describes the research undertaken in preparing the report.

Following these sections, the report discusses how interoperability will be achieved between 5.9 ITS-equipped vehicles and electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems. Each section discusses how interoperability may be achieved across the four levels defined in Section 2, being technical, syntactical, semantic and organisational. Each section also discusses the benefits and risks associated with the integration. The four sections are as follows:

- Section 4: Electronic speed limit signs – defines what is needed to achieve interoperability between 5.9 ITS and electronic speed limit systems.

- Section 5: Traveller data collection – defines what is needed to achieve interoperability between 5.9 ITS and traveller data collection systems.

- Section 6: Traffic signals – defines what is needed to achieve interoperability between 5.9 ITS and traffic signals.

- Section 7: Traveller information systems – defines what is needed to achieve interoperability between 5.9 ITS and traveller information systems.

The structure of Section 4 through Section 7 is as follows:

- Introduction/background – introduces the integration between the ITS infrastructure and 5.9 ITS.

- Sub-section x.1: Technical Interoperability – discusses what is needed to achieve technical interoperability between the ITS infrastructure and 5.9 ITS.

- Sub-section x.2: Syntactical Interoperability – discusses what is needed to achieve syntactical interoperability between the ITS infrastructure and 5.9 ITS.

- Sub-section x.3: Semantic Interoperability – discusses what is needed to achieve semantic interoperability between the ITS infrastructure and 5.9 ITS.

- Sub-section x.4: Organisational Interoperability – discusses what is needed to achieve organisational interoperability between the ITS infrastructure and 5.9 ITS.

- Sub-section x.5: Benefits – discusses the benefits with the integration between the ITS infrastructure and 5.9 ITS.

- Sub-section x.6: Risks – discusses the risks with the integration between the ITS infrastructure and 5.9 ITS.

The final two sections are:

- Section 8: Discussion – provides a discussion on various elements associated with the report including:
  - outlining the need to consider the role of cellular communications in C-ITS integration with ITS
  - additional issues associated with the integration such as privacy, security, certification liability, big data, private-public partnerships, field operation tests (FOT)/trials, location and extent of 5.9 roadside ITS stations and communication coverage in rural areas.

- Section 9: Conclusions – concludes with some key findings of the report.
1.3 Context of the Report

The Policy Framework for Intelligent Transport Systems in Australia (Standing Council on Transport and Infrastructure 2012) identifies C-ITS as a priority action area and nominates Austroads as the body responsible for developing a national C-ITS strategy.

The Co-operative ITS – Strategic Plan (Austroads 2012a) sets the direction for the local deployment of C-ITS. It outlines the mission, vision, objectives and guiding principles with respect to the local deployment of a C-ITS platform with the key theme being, the need to harmonise with international standards and best practice.

A structured approach is required to establishing the C-ITS framework. The focus areas of this framework will include:

- policy and regulation
- spectrum management
- technical standards
- platform requirements
- operational framework
- trials and demonstrations.

Previous Austroads work related to different focus areas such as:

- The C-ITS 5.9 GHz Spectrum Management and Device Licencing Report – Background Document (Austroads 2012b) relates to the policy and regulation and spectrum management areas
- The Vehicle Positioning for C-ITS in Australia (Austroads 2013b) relates to the platform requirement area
- The 5.9 GHz Satellite Interference Study – Field Study (Austroads 2013c) relates to the spectrum management area
- The Emerging Digital Mapping Requirements for C-ITS (Background Document) (Austroads 2013d) relates to the platform requirement area.

This report relates to the technical, platform and operational framework areas.

Based on international developments, it is likely that 5.9 ITS equipped vehicles will be introduced to international markets from 2015 onwards. International jurisdictions are still establishing their plans for the deployment of 5.9 ITS roadside units. This report is seen as an important activity to facilitate such planning locally.

This report aims to raise the key approaches, standards, protocols etc. that are emerging internationally, and will need to be considered in order for C-ITS to be integrated with the existing ITS infrastructure of electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems. In doing so, the report recognises that some international regions (e.g. Europe, USA and Japan) are taking some different approaches and adopting different standards. This report is not intended to provide a detailed analysis regarding which standards or protocols should be recommended for Australia and New Zealand but rather provide information for the reader to ascertain how these standards and protocols fit into the broader concept of C-ITS integration with the existing ITS infrastructure of electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems.

This report also aims to assist Australian and New Zealand road agencies in making strategic decisions with respect to investing in C-ITS. This report along with existing and future reports will assist Austroads and its members in making decisions with respect to the business case for C-ITS deployment.
2. Background

C-ITS platforms are being designed to be used for real-time information exchange between vehicles and infrastructure, and possibly in the future expanded to include portable personal devices. The applications emerging internationally include:

- safety
- productivity, efficiency and the environment
- road user (including infotainment services e.g. services to enhance the driving experience but not have negative impact on the principal objectives of improving safety, productivity, efficiency and environmental outcomes) and road operator services.

This section provides some background by outlining:

- C-ITS applications – provides an overview of the C-ITS applications and the potential for interoperability with existing ITS
- interoperability – what is interoperability with respect to C-ITS
- architecture – the importance of architecture with respect to achieving interoperability
- standards – the importance of standards with respect to achieving interoperability
- C-ITS stations – provides an overview of the roadside and central ITS station
- field operation tests – provide an overview of what field operation tests are, why they are important towards achieving interoperability, and what the global approach to them are.

2.1 C-ITS Applications

Various C-ITS applications are emerging from the key C-ITS development regions of Europe, USA, Japan and South Korea.

At an international standardisation level (International Organisation for Standardisation (ISO)), seven potential ‘day 1’ C-ITS applications have been identified. The ‘day 1’ applications are those applications that are proposed to be the first C-ITS applications deployed within a few years of C-ITS standardisation having been completed.

The seven ‘day 1’ use cases were presented by Hans-Joachim Schade at the ISO/TC204 meeting in Moscow on 18 October 2012 and include:

1. in-vehicle signage (including contextual speeds)
2. floating car data and identification of traffic conditions
3. intersection safety/green wave/energy efficient intersection control traffic light optimal speed advisory
4. roadworks warning
5. traffic jam ahead warning/congestion warning
6. traffic information, strategic routing and recommended itinerary
7. hazardous location warning.

There is a wide range of C-ITS applications being developed internationally. Appendix A provides further details of some of those C-ITS applications emerging out of the key C-ITS development regions of Europe, USA, Japan and South Korea.

There are already telematics and traveller information services within the C-ITS ecosystem that have either been deployed or are about to be deployed. There may be benefit in many of these services having access to road agency data, and therefore interoperability should be considered for this also.
2.2 Interoperability

Interoperability in general terms refers to the ability of different systems to work together or interoperate in order to achieve a desired outcome. Interoperability can both refer to technical systems and social systems.

This project is interested in interoperability between C-ITS and existing ITS infrastructure. While there is not one clear definition of interoperability, it may refer to the ability of different systems to work together functionally without any impediment or restriction, regardless of the individual system’s interface, or date and place of manufacture.

The European Union Directive 2010/40/EU on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport (Council of the European Union 2010) defined interoperability in the context of C-ITS and existing ITS as:

…interoperability means the capacity of systems and the underlying business process to exchange data and to share information and knowledge.

A summarised version of the Austroads C-ITS strategic plan (Austroads 2012a) includes the key principles relating to interoperability. The national C-ITS environment will:

- be a harmonised platform – based on open, non-proprietary standards, which are aligned with international standards and best practice, and enable the deployment and operation of applications from multiple vendors
- enable interoperability – equipment, services and underlying processes must be interoperable, and enable integration of different vendor solutions
- be technically adaptable – it must be able to work with existing ITS where required, must enable new technologies to be deployed in future, and must allow forward and backward compatibility.

Within the C-ITS technical context, interoperability implies:

- the ability to communicate with each other
- the ability to understand and use the data received.

ETSI (van der Veer & Wiles 2008) categorise interoperability into the following four areas, and as shown in Figure 2.1:

1. Technical: the hardware/software of systems and platforms that enable machine-to-machine communication to take place (i.e. the technical ability to wirelessly connect).
2. Syntactical: the agreed data formats of communication so that the machine-to-machine communication can be processed and understood by each machine.
3. Semantic: refers to the meaning and interpretation of the content of the communication being exchanged. Without this interoperability messages communicated between machines may be misunderstood and therefore the machine may not be able to use the message to achieve the objective of it being sent.
4. Organisational: the ability of an organisation to exchange data across systems, which will require a level of consistency in business processes (and architecture). Success will be dependent on the level of technical, syntactical and semantic interoperability achieved.
Interoperability for existing ITS and C-ITS may also be viewed from a process-oriented perspective, as the successful integration of C-ITS with existing ITS requires the development of interfaces in order to exchange service and service calls. Process-oriented development is the analysis of functional requests and subsequent design of associated systems from the viewpoint of the underlying (business) process. This means that the flow of the process is used to determine the overall structure of the application.

### 2.2.1 The Need for C-ITS to be Interoperable with Existing ITS

In order to deliver outcomes and services across the areas of safety, productivity, efficiency and the environment, and in order to provide road user (including infotainment services) and road operator services, data is required to be delivered from both existing and future roadside ITS infrastructure to vehicles and vice versa. Such data may include information about signal phasing, traveller information, traffic control (such as lane-use management systems, speed zones) and level crossing status etc. in order to achieve the key objectives of:

- improved safety by improving traffic control compliance through better communication of traffic control information such as speed, traffic signals and level crossing status
- improved safety by providing enhanced hazard warnings such as over height, inappropriate approach speed to a curve, back of queue, weather events and roadworks
- achieving productivity, efficiency and environmental outcomes through provision of advice with respect to route guidance, congestion, road closures and traffic signal timings
- providing road user and road operator services through improved communication of traffic information.

Emerging C-ITS applications will require data from existing ITS in order to deliver optimum outcomes. Also integrating C-ITS with existing ITS is anticipated to positively influence the uptake and demand for C-ITS equipped vehicles. While integrating C-ITS with existing ITS infrastructure is likely to deliver significant benefits to road users, it is also anticipated to deliver significant benefits to road agencies by providing valuable sources of data.
C-ITS provides connectivity between road users and the roadside environment. Figure 2.2 is illustrating that C-ITS utilises a number of wireless technologies each of which will need to be interoperable with the vehicle. The uses of a variety of wireless technologies, in addition to the fact that these different wireless technologies and services may be managed by different entities (including private companies) adds an extra layer of complexity with respect to the interoperability of ITS.

Figure 2.2: Interaction between actor and ITS service domains

Source: Austroads (2010a).

2.3 Architecture

Architecture can be defined as a conceptual model that defines the structural components and relationships of a system and provides a plan from which the system can be designed, developed and deployed. Architecture is critical for C-ITS interoperability as it provides the building blocks for an interoperable C-ITS system and enables the connection between in-vehicle systems, roadside ITS infrastructure and back-end ITS infrastructure. For C-ITS, architecture can be designed to enable interoperability between components regardless of manufacturer or age and without jeopardising the safe use of the system and/or security and achievement of policy issues such as privacy.

2.3.1 System Architecture
System architecture comprises of three layers as shown in Figure 2.3 and outlined further below.
Figure 2.3: National ITS architecture layers

- **Reference architecture**: the reference architecture is the highest of the three architectures and captures the concepts of the system architecture and provides a framework in which the logical and physical architectures may be developed. It focuses on the users and user services, providing a big picture plan of current and future services and the facilities and the functional linkages between them.

- **Logical architecture**: the logical architecture is the next tier of the three architectures. It provides further detail of the components of the system, its linkages and inter-relationships, in order to undertake each service. It also indicates the nature of data and information exchange required for each function or service. Together with system requirements documented in the reference architecture, the logical architecture represents a strategic national ITS deployment scenario.

- **Physical architecture**: the physical architecture defines the physical systems to enable the services to be provided. It focuses on standardising the interfaces to enable interoperability.

### 2.3.2 Reference Architecture for Australia and New Zealand

Austroads, through project NS1696 – *National ITS architecture*, is progressing the development of the first two tiers of a national ITS architecture, being the ‘reference’ and ‘logical’ architectures. This is in order to enable road authorities and industry to develop the third tier, being the ‘physical’ architecture, as required for ITS deployment.

As part of project NS1696, international ITS architectures were reviewed and it was recommended that the European FRAME architecture be adopted for the first two tiers. The FRAME architecture was recommended as the review found that it aligned well with the local ITS requirements, and was considered less prescriptive than other architectures reviewed.
It is recommended that Austroads jurisdictions utilise and develop their ITS architecture in conformance with the FRAME architecture and given that it is a living document; maintain the architecture including any changes made to it. As stipulated by FRAME (n.d.), a key feature of the FRAME architecture:

…is that it is designed to have sub-sets created from it, and is thus unlikely to be used in its entirety. Indeed, on occasions, it contains more than one way of performing a service and the user can select the most appropriate set of functionality to deliver it in that environment. Thus the FRAME Architecture is not so much a model of integrated ITS, as a framework from which specific models of integrated ITS can be created in a systematic and common manner.

A brief description of FRAME’s reference and logical architectures are outlined below, which is consistent with the broader definition of the architectural levels outlined in Section 2.3.1:

- The FRAME reference architecture: this architecture level provides a conceptual view of ITS focussing on the users, the services, and the functional linkages.
- The FRAME logical architecture: this architecture level provides details on the components of the system, the inter-relationship between the components, and will represent a strategic, national ITS deployment scenario.

The FRAME Forum has been assisting Australia through advice on software and general cooperation and support.

New Zealand is currently developing a local consensus on ITS. This includes a draft strategic framework for ITS, which the Transport Agency has been progressing. This work will confirm ITS benefits and highlight anything that might be particular to New Zealand conditions and requirements. New Zealand aims to align where possible to approaches set by Austroads and this includes the probable adoption of a common reference architecture such as FRAME, but this will be confirmed at a later time.

2.3.3 ITS Station Architecture

In Europe, the emerging architecture standards for C-ITS stations are based on the ITS station reference architecture shown in Figure 2.4.

As outlined by Evensen (2010), the development of an ITS architecture is considered a success story as it started with ISO CALM, was validated by the European project CVIS and was later refined by the European COMeSafety project and ETSI standards. This resulted in the following outcomes of which the ITS architectures referred to are fully aligned:

- COMeSafety Architecture (COMeSafety 2010)
- ETSI EN 302 665 (European Telecommunications Standards Institute 2010c)
- ISO IS 21217 (CALM) – The Communication Access for Land Mobiles (CALM) standards are discussed in further detail in Section 2.4.

The ITS station reference architecture comprises various layers as outlined below (based on the COMeSafety Architecture (COMeSafety 2010)):

- ITS access technologies layer (‘I’ layer): the core layer upon which the rest of the system is built and includes the communication infrastructure, operating system, routers, gateways and hardware (sensors, actuators, antennas etc.). The ITS access technologies layer combines the media access control (MAC) and physical (PHY) layers of the seven layer open systems Interconnection (OSI) model.
- ITS network and transport layer (‘N’ layer): the Open Services Gateway initiative (OSGi) based execution infrastructure layer is the runtime layer upon which the applications operate.
- ITS facilities layer (‘F’ layer): the layer which provides functions to support applications for various tasks such as providing access to data inputs from other systems (e.g. vehicle and roadside sensors) including communications and providing access to information such as maps.
- ITS application layer (‘A’ layer): the layer that provides the applications or end-user services.
In addition to the horizontal layers of the reference protocol stack as shown in Figure 2.4, there are two vertical layers that span across the horizontal layers. This includes (COMeSafety 2010):

- **ITS management layer (‘M’ layer):** the layer responsible for configuration and the exchange of information between layers.
- **ITS security layer (‘S’ layer):** the layer that provides security and privacy for users.

**ITS station internal interfaces**

Interfaces are established between the various horizontal and vertical layers of the ITS reference protocol stack. The ITS station interfaces are categorised into four types being management, security, communications and application programming. As outlined in the draft *Intelligent transport systems – Communications access for land mobiles (CALM) – Architecture standard* (ISO/DIS 21217) the various interfaces categorised by these four types include:

- **ITS station management interfaces**
  - MI: enables the ITS station management (M) entity to interact with the ITS station access (I) layer.
  - MN: enables the ITS station management (M) entity to interact with the ITS station networking and transport (N) layer.
  - MF: enables the ITS station management (M) entity to interact with the ITS station facilities (F) layer.
  - MS: enables the ITS station management (M) entity to interact directly with the ITS station security (S) entity.
  - MA: enables the ITS station management (M) entity to interact directly with the ITS station application (A) entity.
• ITS station security interfaces
  – SI: enables the ITS station security (S) entity to interact with the ITS station access (I) layer.
  – SN: enables the ITS station security (S) entity to interact with the ITS station networking and transport (N) layer.
  – SF: enables the ITS station security (S) entity to interact with the ITS station facilities (F) layer.
  – SA: enables the ITS station security (S) entity to interact with the ITS station application (A) entity.

• ITS station communications interfaces
  – IN: allows the ITS station networking and transport (N) layer and the ITS station access (I) layer to interact with each other.
  – NF: allows the ITS station facilities (F) layer and the ITS station networking and transport (N) layer to interact with each other.
  – FA: allows the ITS station facilities (F) layer to interact with ITS station applications (A).

• ITS station application programming interface

The Application Programming Interface (API) is an implementation of the MA, FA and SA interfaces and connects ITS station applications to the ITS station facilities layer and the ITS station security and management entities.

USA viewpoint
The USA does not refer to an ITS station. The USA model standardises the interface. By only standardising the interface, the USA model tries to maintain flexibility and therefore encourage providers to be creative in what technology they use. The only requirement is that they need to meet the interface requirements.

2.3.4 C-ITS – One Part of a Broader ITS Architecture
C-ITS fits into the broader ITS architecture shown in Figure 2.5. With the emergence of C-ITS and the subsequent wider use of wireless communications, there is the potential to broaden the interaction between the ITS physical infrastructure of travellers, centres, field and vehicles (a description of the ITS physical entities within each group is outlined in Appendix B). In particular there are opportunities to expand beyond the current existing interactions between vehicles and field and between vehicles and centres currently being provided through in-vehicle telematics applications such as:

• Transport Certification Australia’s (TCA’s) Intelligent Access Program (IAP)
• the provision of routing and congestion information to vehicles via private service operator applications delivered through navigational devices
• electronic toll collection (ETC)
• private fleet management systems.
A description of the communication types of the ITS physical architecture as outlined in Austroads (2010a) is as follows:

- **Fixed Point to Fixed Point**: terrestrial communications system between two (or more) fixed points in the transport infrastructure. Typically provided by fibre-optic, copper and sometimes fixed wireless (such as microwave) communications links.
- **Wide Area Wireless Mobile**: typically a base station to mobile wireless communications system operating over a significant range.
- **Vehicle to Infrastructure (V2I)**: a real-time short range and short duration wireless communications system operating between a roadside station and mobile station in passing vehicles.
- **Vehicle to Vehicle (V2V)**: a real-time short range and short duration wireless communications between two (or more) vehicles which are in the vicinity.

### 2.4 Standards

A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. The primary benefit of standards is that they make industry more efficient and break down barriers to international trade by harmonising technical specifications of products and services. They also provide reassurance to consumers that a product that conforms to a standard is built to a satisfactory level of safety and efficiency as defined by the standard.
Standards are required for C-ITS in order to ensure components made by different manufacturers work together. One of the key components of C-ITS is the ability for vehicles and infrastructure to be able to talk to one another in an interoperable manner. As such, standards need to be created centrally and adopted widely.

An issue for C-ITS is that it is a complex system that is specified by a variety of standards that could be prepared by various standards bodies. This is made more complex by the fact that in order to achieve many of the envisaged applications, C-ITS will need to be interoperable with existing ITS.

Australia and New Zealand should establish a C-ITS platform that is harmonised with international standards and best practice. This should include those existing ITS that are intended to be interoperable with emerging C-ITS.

Standards are being developed by various international and regional standards bodies. These bodies are outlined below. The standards bodies generally develop standards independent of one another with consideration given to only those member countries involved in the standards organisations. As such there are differences between the standards emerging out of Europe and the USA. While there are differences there are attempts to achieve harmonisation of standards, including through the EU-US harmonisation taskforce.

Some of the key standards bodies involved in developing and publishing standards relating to C-ITS and the regions for which their standards primarily apply include but are not limited to:

- International Organisation for Standardisation (ISO) – International
- European Committee for Standardisation (CEN) – Europe
- Internet Engineering Task Force (IETF) – International
- European Telecommunications Standards Institute (ETSI) – Europe
- Institute of Electrical and Electronics Engineers (IEEE) – USA
- International Telecommunication Union (ITU) – International
- Society of Automotive Engineers (SAE) – USA.

Both ETSI and CEN/ISO have defined a set of ‘Release 1’ standards as of May 2013. The ‘Release 1’, is the minimum set of standards required for interoperability in accordance with the European Commission Standardization Mandate M/453.

As defined by ETSI, the ‘Release 1’ set of standards is focused on disseminating locally gathered information to the other participants in the C-ITS system. Following ‘Release 1’ will be ‘Release 2’. ‘Release 2’ will focus on enabling information exchange to take place between C-ITS users (European Telecommunications Standards Institute 2013). Standards from the aforementioned standard development organisations will contribute to the ‘Release 1’ set of minimum standards.

While the ETSI and CEN/ISO ‘Release 1’ standards are different, harmonisation activities are being undertaken and the CEN/ETSI progress report on Mandate M/453 (European Committee for Standardization & European Telecommunications Standards Institute 2013), lists the standards together and/or interchangeably.

The standards being developed as part of the ‘Release 1’ set of standards are categorised in alignment with the six layers of the ETSI (European) ITS station architecture. That is they are categorised under the layers of application, facilities, network and transport, access and media, management and security. In addition there is the general standards category and testing standards sub-category for some of the standards layers. Further details of standards categorised by these layers are outlined below.

If Australia and New Zealand choose to adopt the European C-ITS platform then it will likely follow the ETSI and CEN/ISO standards. If they choose to follow the USA platform, they will likely adopt the IEEE and SAE standards. The following sections include key standards from both Europe and the USA.


2.4.1 General
Standards categorised under the general layer relate to communication architecture and data dictionaries. Example standards include:

- ISO TC 17465-1: Intelligent transport systems – Terms, definitions and guidelines for Cooperative ITS standards documents – Part 1: Term, definitions and outline guidance for standards documents (under development)
  
  Provides a definition for cooperative ITS and its associated terms.

- ISO/DTS 17427: Intelligent transport systems – Cooperative ITS – Roles and responsibilities in the context of Cooperative-ITS based on architecture(s) for Cooperative-ITS (under development)
  
  Describes the roles and responsibilities required to deploy and operate Cooperative ITS.

- ISO 21217-2010: Intelligent transport systems – Communications access for land mobiles (CALM) – Architecture
  
  Specifies the architectural communications framework of ITS for the family of CALM-related International Standards.

- National Transportation Communication for ITS Protocol (NTCIP): USA protocol
  
  National Transportation Communications for ITS Protocol (NTCIP) is a family of standards that define the protocol and objects necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system. As it is a family of standards, it refers to various layers and standards such as the USA Traffic Management Data Dictionary (TMDD) standard described in Section 2.4.2. Further details are contained in Appendix C. The USA is looking at adopting NTCIP but it is also being considered by other regions.

2.4.2 Application
Standards categorised under the application layer include standards related to the actual C-ITS applications including protocols. Example standards include:

- ISO/PDTS 17426: Intelligent transport systems (ITS) – Co-operative systems – Contextual speeds (under development) – Referred to in Section 4.


  Traffic Management Data Dictionary (TMDD) – supports centre-to-centre ITS communications in order to support corridor, arterial, incident mitigation and event management, etc. TMDD provides the dialogs, message sets, data frames, and data elements to manage the shared use of these devices and the regional sharing of data and incident management responsibility (Institute of Transportation Engineers n.d.). TMDD refers to elements of the NTCIP family of standards as outlined below.

- Data Exchange (DATEX): European protocol
  
  DATEX (or its second generation development DATEX II) (Datex 2012) – standing for Data Exchange is a standard outlining traffic and travel data exchange between actors in the traffic and travel information sector. Europe (not the USA) is looking at adopting DATEX2.

  Transport Protocol Experts Group (TPEG) – produced a set of specifications addressing the transmission of language independent multi-modal traffic and travel information. The TPEG is a group of experts from the European Broadcasting Union.

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4 PDTS number not yet assigned at the time of writing.
2.4.3 Facilities
Standards categorised under the facilities layer include standards related to the data message formats and standards applicable to the facilities layers which would include standards addressing aspects such as local dynamic maps (LDM), map databases and positioning and timing data.

- Society of Automotive Engineers (SAE) SAE J2735 *Dedicated Short Range Communications (DSRC) message set dictionary* standard (Society of Automotive Engineers International 2009).
- SAE J2945 Dedicated Short Range Communication (DSRC) Minimum Performance Requirements (Society of Automotive Engineers International 2010b). This standard is not yet developed.
- European Telecommunication Standards Institute’s (ETSI) cooperative awareness message (CAM) (European Telecommunication Standards Institute 2011) and decentralised environmental notification message (DENM) (European Telecommunication Standards Institute 2010a).
- Other relevant standards applicable to the facilities layers would include standards addressing aspects such as local dynamic maps, map databases and positioning and timing data.

2.4.4 Network and Transport
Standards categorised under the network and transport layer include standards associated with the infrastructure required for the applications to operate such as the communications access for land mobiles (CALM) set of standards and the IEEE 1609 family of standards for wireless access in vehicular environments (WAVE).

The CALM set of standards is developed by ISO. It incorporates the fast networking and transport layer protocol (FNTP) and IPv6. It is part of the European ‘Release 1’ set of standards as referred to in Section 2.4. The CALM standards include:

- Communications access for land mobiles (CALM) – Non-IP networking: Part 1: Fast networking and transport layer protocol (FNTP) (ISO 29281-1-2013)
- Communications access for land mobiles (CALM) – Non-IP networking: Part 2: Legacy system support (ISO 29281-2-2013)
- Communications access for land mobiles (CALM) – IPv6 networking (ISO 21210-2012)
- Communications access for land mobiles (CALM) – IPv4-IPv6 interoperability (ISO 18380 – under development)
- Communications access for land mobiles (CALM) – ITS IPv6 networking optimisation (ISO 16789 – under development)
- Communications access for land mobiles (CALM) – IPv6 multicast (ISO 18378 – under development).

The IEEE 1609 family of standards for wireless access in vehicular environments (WAVE) is developed by IEEE. WAVE includes the wave short message protocol (WSMP), supports IPv6 and is likely to be adopted in the USA.

2.4.5 Access and Media
Standards categorised under the access and media layer include standards associated with the various communications used in C-ITS. Example standards include:

- IEEE 802.11p which addresses the data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz. IEEE 802.11-2012 incorporated amendments to 802.11-2007 including 802.11p-2010. However, as 802.11-2012 is in excess of 2000 pages, this report refers to 802.11p as this is the component of 802.11 of interest to this report.
- Access technology support (ISO 21218-2013)
- Infra-red communications (ISO 21214-2006)
- M5 communications (ISO 21215-2010)
- 2G communication (ISO 21212-2008)
• 3G communications (ISO 21213-2008)
• Broadcast (ISO 13183-2012)
• Satellite networks (ISO 29282-2011).

2.4.6 Management
Standards categorised under the management layer include standards that address cross-layer management, station management, communications management and application management. Example standards include:
• ITS station management standard: part 1: local management (ISO 24102-1-2013)
• ITS station management standard: part 3: service access points (ISO 24102-3-2013)
• ITS station management standard: part 4: station-internal management communication (IICP) (ISO 24102-4-2013)
• ITS station management standard: part 5: fast service advertisement protocol (FSAP) (ISO 24102-5-2013).

2.4.7 Security
Standards categorised under the security layer include standards that address security architecture and management, certificate management, access controls and privacy. Example standards include:
• Electronic fee collection – security framework (CEN/TS 16439-2013)
• Communication access for land mobiles (CALM) – ITS IPv6 Networking Security (ISO 16788 – under development).

These standards are an adoption of existing uses. Standards applicable to C-ITS security are yet to be developed.

2.5 Message Sets
There are several message sets that are applicable to the C-ITS applications being developed, in particular the ‘day 1’ applications as referred to in Section 2.1. The message sets include:
• CAM: cooperative awareness message
  Europe’s periodically transmitted message containing transient data on the vehicle status. The CAM message is designed primarily for communication from vehicles to vehicles and infrastructure (e.g. V2V and V2I), but may also be sent from infrastructure to vehicles (I2V). CAM is proposed by ETSI, for use on the European platform.
• DENM: decentralised environmental notification message
  Europe’s event triggered message which is generated upon detecting an event and containing information about the event. DENM messages are typically relevant for a defined geographic area. The DENM is sent from vehicles to vehicles and infrastructure (e.g. V2V and V2I), and from infrastructure to vehicles (I2V). DENM is proposed by ETSI, for use on the European platform.
• RSA: roadside alert message (as outlined in SAE J2735)
  One of three messages outlined in USA’s SAE J2735, the others being a basic safety message (BSM) and a probe vehicle message (PVM). The RSA message is used to communicate traveller information applications from roadside infrastructure. RSA is proposed by SAE and proposed for use on the USA platform.
- **BSM**: basic safety message (as outlined in SAE J2735)
  One of three messages outlined in USA’s SAE J2735, the others being the roadside alert (RSA) message (BSM) and probe vehicle message (PVM). The BSM message is used to communicate safety messages from vehicles to vehicles and infrastructure (e.g. V2V and V2I), and from infrastructure to vehicles (I2V). BSM is USA’s version of the CAM and DENM message with efforts currently in place to harmonise the BSM with the CAM and DENM message sets.

- **PVM**: probe vehicle message (as outlined in SAE J2735)
  One of three messages outlined in USA’s SAE J2735, the others being the basic safety message (BSM) and roadside alert message (RSA). The PVM message is used to communicate probe information obtained from the vehicle to roadside infrastructure. PVM is proposed by SAE and proposed for use on the USA platform.

- **PDM**: probe data management
  PDM is used to control the type of data collected and sent by the vehicle to the local 5.9 roadside ITS station. PDM is sent from the roadside ITS station to the vehicle. PDM is a message on the European platform.

- **PVD**: probe vehicle data
  PVD is used to communicate the status of a vehicle to the 5.9 roadside ITS station to allow the collection of information about vehicle movements along a segment of road. PVD is sent by the vehicle to the local 5.9 roadside ITS station. PVD is a message on the European platform.

- **Map**: geometric intersection description
  A message containing geometric details of the road such that the vehicle can cross-reference information contained in other messages sent from the roadside ITS station against the map message to determine how to apply the message (e.g. determine if the message applies to the lane the vehicle is currently in). The MAP message is sent from a 5.9 roadside ITS station integrated with a traffic signal.

- **SPaT**: signal phasing and timing
  A SPaT message contains information about the signal phasing and timing including current phase and time remaining so that it can be used by a vehicle to provide warnings about potential red light violations and/or advice on traffic light optimal speed advisory. The SPaT message is sent from a 5.9 roadside ITS station integrated with a traffic signal.

- **SRM**: signal request message
  SRM is sent by an in-vehicle 5.9 ITS unit to a 5.9 roadside ITS station at a signalised intersection (or central system). It is used for either a priority signal request or a pre-emption signal request depending on the way the message flag is set. In either case, the vehicle identifies itself, its current speed, heading and location, and makes a specific request for service as well as an anticipated time of service.

- **SSM**: signal status message
  SSM is sent by a 5.9 roadside ITS station at a signalised intersection (or central system). It is used to relate the current signal status of the signal and any collection of pending or active pre-emption or priority events acknowledged by the controller. The data contained in this message allows other users to determine their ‘ranking’ for any request they have made.

- **IVI**: in-vehicle information
  The in-vehicle information (IVI) data structures specifies the data required to be transmitted between ITS stations (I2V) in order to deliver in-vehicle signage associated with various ITS services (e.g. contextual speed, roadworks warning, vehicle restrictions, lane restrictions, road hazard warning and re-routing). The information will be specified in terms such as content/data elements and data structures. A technical standard is being developed that will specify a general data structure that is future proof, extensible and communications agnostic.
- **TPEG:** Transport Protocol Expert Group

  In addition to the actions outlined in Section 2.4.2, how TPEG can be better utilised in the C-ITS ecosystem is under discussion with the Traveller Information Service Association (TISA).

  Table 2.1 shows how many of these message sets are proposed to be utilised by the ‘day 1’ applications outlined in Section 2.1 from a European platform perspective, as opposed to a USA platform perspective.

**Table 2.1: ‘Day 1’ applications and proposed message set used**

<table>
<thead>
<tr>
<th>Application</th>
<th>Message set</th>
</tr>
</thead>
</table>
| In-vehicle signage (including contextual speeds) | • IVI  
• DENM |
| Floating car data and identification of traffic conditions | • PVD  
• PDM  
• CAM |
| Intersection safety/green wave/energy efficient intersection control traffic light optimal speed advisory | • SPaT  
• MAP  
• SRM  
• SSM |
| Roadworks warning | • IVI  
• PVD  
• DENM |
| Traffic jam ahead warning/congestion warning | • CAM  
• PVD  
• IVI |
| Traffic information, strategic routing and recommended itinerary | • IVI  
• PVD |
| Hazardous location warning | • CAM  
• DENM  
• IVI |

Source: Seeberger, Schade and Hess (2013).

### 2.6 C-ITS Stations

An ITS station is the component within the various entities (vehicle, roadside, central and personal) that enables data to be communicated between each another and for applications utilising that data to function. There are four types of ITS stations:

1. vehicle ITS station
2. roadside ITS station
3. central ITS station
4. personal ITS station.

It is noted that this report focuses on the integration between C-ITS and existing ITS infrastructure through the use of 5.9 GHz DSRC communications and roadside ITS stations. As such there is a focus on the roadside ITS station as outlined in Section 2.6.1. Although not a focus of this report cellular communications can be used for some of the integrations. Cellular communications would utilise a central ITS station as discussed in Section 2.6.3. Use of cellular communications for C-ITS interoperability with ITS infrastructure is discussed further in Section 8.1.
2.6.1 Vehicle ITS Station
The vehicle ITS station consists of the following two components:

- communication and control system (CCU in the figure below) which is responsible for the communication with other ITS devices (including other equipped vehicles and/or roadside ITS devices)
- application system which carries out the application designated for the vehicle.

The vehicle ITS station is connected into the vehicle. The connection to the vehicle is via the vehicle gateway. This enable the vehicle ITS station to obtain data from the vehicle in order to communicate it to other ITS stations and to also provide data to the vehicle for use by the vehicle. Figure 2.6 shows a conceptual layout of the vehicle ITS station in the vehicle relative to the vehicle gateway and the vehicle’s electronic control units (ECUs).

![Vehicle ITS station diagram](source)

Source: COMeSafety (2010).

2.6.2 Roadside ITS Station
The roadside ITS station consists of the following two components:

- communication and control system (CCU in the figure below) which is responsible for the communication with other ITS devices (including equipped vehicles or other roadside ITS devices)
- application system which carries out the application designated for the roadside unit.

The roadside ITS station refers to C-ITS infrastructure installed at the roadside as part of a broader ITS infrastructure network and for the purpose of communicating to equipped vehicles via C-ITS.

How the roadside ITS station interacts with the existing ITS infrastructure at a conceptual level is shown in Figure 2.7. The key interceptors in the roadside ITS station sub-system are the roadside ITS station gateway, ITS station router and the ITS station border router as discussed below. The options are in many cases complementary and not mutually exclusive.

**Roadside ITS station gateway**
The roadside gateway provides a link between the roadside ITS station and the road sensors or traffic control units (e.g. traffic lights, variable traffic signs and/or traffic controllers). This enables applications such as in-vehicle signage which can provide the information being communicated by ITS infrastructure such as variable message signs (VMS) to vehicles, as well as customising the message based on information transmitted from the vehicle.

**ITS station router**
The ITS station router enables connection between the roadside ITS stations and other ITS protocol stacks utilised in roadside ITS infrastructure (e.g. electronic tolling as shown in Figure 2.7). This connection is undertaken at the networking and transport layer.
**ITS station border router**

A border router connects the roadside ITS station to the back-haul ITS network enabling connection to both the ITS network and hosts such as the central traffic control server.

Figure 2.7: Roadside ITS station

In Queensland, many ITS infrastructures are operated on the STREAMS platform. In this scenario, STREAMS field processors are installed in the field. These field processors act as an ITS station gateway. With the development of software, this allows the transmission of information from existing ITS infrastructure (utilising STREAMS) to the ITS station.

Further to the above, and as shown in Figure 2.7, roadside ITS stations are multifunctional. That is, where required, they should be able to integrate with multiple roadside ITS infrastructure and also be able to be used to collect data for ITS station equipped vehicle (i.e. probe data).

### 2.6.3 Central ITS Station

The various ITS applications of a road agency’s network are generally managed in an ITS central station, although some may be managed remotely on site. How an ITS central station is connected to the road network or central system is shown in Figure 2.8. The physical ITS architecture and the interaction between the roadside, group, regional and central controller ITS stations are shown in Figure 2.2. The available information/data from the central system is provided to the ITS central station via a central gateway and border router.

With respect to the future evolution of C-ITS, the ITS central station, through the border router, has the potential to provide information useful for C-ITS applications to vehicles via a mobile carrier commercial cellular network (such as 3G, LTE/4G mobile wireless broadband, etc.) directly to the vehicle, or via roadside ITS stations to the ITS stations in the vehicles using 5.9 GHz, and/or by broadcast (which is typically managed by private operators in local environments). The information can then be used within the vehicle to deliver an outcome (e.g. a vehicle may receive data with respect to traffic congestion with the in-vehicle navigation system deciding how to use that data to navigate the driver around the congested area).
2.7 Field Operation Tests

Field operation tests (FOT) are trials where developers and organisations are able to trial C-ITS applications, technologies and services in real world scenarios. They are a critical step in moving from a small-scale prototype to on-the-road deployment of a large-scale system. They are valuable in identifying issues associated with the deployment, functionality and operation of new technologies and services. Knowledge gained from trials and demonstrations is also valuable in guiding planning and decision making, providing awareness of emerging applications, and in identifying issues that need to be addressed to ensure a harmonised C-ITS platform can be deployed and maintained.

With respect to interoperability, FOTs are critical as they enable an evaluation of how effectively proposed C-ITS applications are integrated with existing or proposed ITS and to identify what is required in order to achieve full interoperability across the four interoperability levels of technical, semantic, syntactical and organisational. Only with FOTs can the integration of C-ITS applications with ITS be tested and the level to which interoperability is achieved evaluated in real world conditions, or alternatively the identification of elements required to achieved full interoperability determined.

Currently there are many C-ITS trials being undertaken internationally including in Australia and New Zealand. In Europe many of the trials and FOTs are managed by projects funded by the European Commission, while in other international regions many of the trials are commissioned by road agencies or departments in partnership with industry. Findings arising from the trials are often published on FOTs website where available, or alternatively they can become available through the sponsoring road agency. There is no central management authority for the global FOTs collectively and therefore it is up to parties interested in a trial, to identify and keep informed of trials of specific interest to them. Locally, it is important that Australia and New Zealand continue to share knowledge and findings of trials being undertaken locally by different road agencies and to also share acquired knowledge of the various international trials being undertaken that are of interest to Australia and New Zealand.
3. Method

The following section outlines the method used in the preparation of this report. It outlines the scope of the report and research undertaken in preparing the following sections.

3.1 Scope

C-ITS is a complex system of interoperable systems requiring various interactions between the four components of the ITS architecture being travellers, centres, field and vehicle as shown in Figure 2.5. C-ITS focuses on the connectivity between:

- centres and travellers and vice versa (wide area communications)
- centres and vehicle and vice versa (wide area communications)
- centres and field and vice versa (wide area communication and fixed line communications) (e.g. optic fibre)
- vehicle and travellers and vice versa (peer-to-peer communications)
- field and vehicle and vice versa (peer-to-peer communications)
- field and travellers and vice versa (peer-to-peer communications).

The primary focus of this report is on connectivity, using peer-to-peer communications, between vehicles and field infrastructure operated by road agencies. This is commonly referred to as vehicle to infrastructure, or V2I; and infrastructure to vehicle, or I2V communications. While not a focus of this report it is recognised that centres have an important role in the C-ITS ecosystem. Further, it is recognised that road agencies should enable other centres (i.e. private telematics companies) to have access to certain data for use in C-ITS services delivered via private operators (this is discussed further in Section 8.1 and Section 8.2.6).

Road agencies in Australia and New Zealand operate a broad range of ITS including electronic speed limit signs and variable speed limit systems, traffic data collection systems, traffic signals and traveller information systems. Appendix D discusses some of the ITS infrastructure used in Australia and New Zealand. C-ITS offers the potential to deliver a diverse range of applications and be integrated with a wide range of existing roadside and central ITS infrastructure such as those discussed here and in Appendix D. Appendix A discusses some of the C-ITS applications emerging out of the international regions of Europe, USA, Japan and South Korea.

The potential opportunities for C-ITS integration with existing ITS infrastructure is quite broad and can include various ITS infrastructure at the central level using cellular communications and at the roadside level using 5.9 ITS communications. A decision was made to primarily focus this report on the integration with four types of existing ITS infrastructure, being electronic speed limit signs, traveller data collection, traffic signals and traveller information systems at the roadside level. The scope of works with respect to these four existing ITS infrastructures is outlined in the following tables:

- electronic speed limit signs: Table 3.1
- traveller data collection: Table 3.2
- traffic signals: Table 3.3
- traveller information systems: Table 3.4.

The principal reasoning behind limiting the scope to 5.9 ITS is that 5.9 roadside ITS stations are envisaged to be operated by road agencies and there is a need to understand how they will integrate with existing ITS infrastructure operated by them. In addition, 5.9 ITS is a large focus of C-ITS due to its ability to deliver reliable, low latency communications at no communication cost (i.e. no cost for transmitting and receiving messages). Use of 5.9 ITS for V2I may also encourage the uptake of 5.9 ITS which can also be used for V2V safety applications.
Further, for V2I applications in some scenarios (e.g. location), 5.9 ITS may be the only viable means of delivering that application. Use of other communication approaches for the integration of existing ITS infrastructure with C-ITS is discussed in Section 8.1.

Table 3.1: C-ITS interoperability with electronic speed limit signs – scope of works

| In scope | 1. To define how a 5.9 roadside ITS station could be integrated with electronic speed limit signs (including mobile/portable signs used for work zones and where speed limits are displayed on lane use management systems (LUMS) signals) to:  
| | a) communicate variable speed limit zone data to 5.9 ITS equipped vehicles  
| | b) collect anonymous data from 5.9 ITS equipped vehicles relative to the operation of the electronic speed limit sign (e.g. driver response to changes and speed limits displayed on the signs) and for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with traffic signals and for the purpose of general traveller data collection – refer to traveller data collection (Table 3.2).  
| | 2. Scope is limited to standard data messages.  
| Out of scope | 1. Communication of speed limits from non-electronic speed limit signs:  
| | a) speed limit data for non-electronic speed limit signs may be known to drivers via applications such as intelligent speed adaptation (ISA), which have the speeds inputted into a database which can be downloaded to the vehicle by other means.  
| | 2. Communication of other information displayed on the LUMS signal besides the speed limit (e.g. arrows designating the status of the lane such as closed, closing or merging signal etc.)  
| Emerging 5.9 ITS applications | 1. In-vehicle signage including the communication of regulatory/contextual speed limits:  
| | a) to be used in addition to an application such as intelligent speed advisory (ISA) to provide notifications of electronic speed limits.  
| | 2. Through the provision of road work speed signs (where electronic speed signs are used) it can also provide road work warnings.  
| | 3. Floating car data and the identification of traffic conditions through the provision of data being sent from vehicles to the roadside unit.  

Table 3.2: C-ITS interoperability with traveller data collection systems – scope of works

| In scope | 1. To define how a 5.9 roadside ITS station could be used to collect anonymous data from probe vehicles for use in road network management systems, including:  
| | a) travel time  
| | b) traffic flow management  
| | c) incident management  
| | d) identifying potential hazardous spots that may or may not have a crash history through observing travel behaviour (e.g. heavy braking).  
| | 2. Scope is limited to standard data messages.  
| Out of scope | 1. Data that would require probe vehicles to be suitably equipped with sensors and is not commonly collected through existing ITS systems such as the following environmental recognition systems:  
| | a) hazardous location  
| | b) precipitation  
| | c) road adhesion  
| | d) visibility  
| | e) wind.  
| Emerging 5.9 ITS applications | 1. Use 5.9 roadside ITS stations to collect anonymous travel time and travel flow information data from 5.9 ITS equipped vehicles:  
| | a) This may be used to deliver potential traffic information and recommended travel itinerary information.  
| | 2. Floating car data and the identification of traffic conditions through the provision of data being sent from vehicles to the roadside unit.
Table 3.3: C-ITS interoperability with traffic signals – scope of works

<table>
<thead>
<tr>
<th>In scope</th>
<th>1. To define how a 5.9 roadside ITS station could be integrated with a traffic signal controller to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) relay traffic signal phasing and timing data (SPaT) into the vehicle</td>
</tr>
<tr>
<td></td>
<td>b) collect anonymous data from 5.9 ITS equipped vehicles with respect to the operation of the traffic signals (e.g. feedback on delay) and for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with traffic signals and for the purpose of general traveller data collection – refer to traveller data collection (Table 3.2))</td>
</tr>
<tr>
<td></td>
<td>c) provide signal pre-emption and/or priority to certain vehicles.</td>
</tr>
<tr>
<td></td>
<td>2. Scope is limited to standard data messages.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Out of scope</th>
<th>1. Provision of traffic light optimal speed advisory.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Altering signal control to provide for green waves or energy efficient intersection control.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emerging 5.9 ITS applications</th>
<th>1. Signal violation warning.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Intersection safety and intersection collision warning (e.g. detect signal violations and warn opposing vehicles).</td>
</tr>
<tr>
<td></td>
<td>3. In addition, data sent from equipped vehicles has the potential:</td>
</tr>
<tr>
<td></td>
<td>a) to be used by the signal controller to provide</td>
</tr>
<tr>
<td></td>
<td>i. estimates of queue demand and delay</td>
</tr>
<tr>
<td></td>
<td>ii. emergency vehicle signal pre-emption</td>
</tr>
<tr>
<td></td>
<td>iii. green waves (1)</td>
</tr>
<tr>
<td></td>
<td>b) to be used for general traveller data collection.</td>
</tr>
</tbody>
</table>

1 Green wave is an emerging application. However investigations into how it will be delivered with adaptive traffic signals such as SCATS and STREAMS (i.e. altering signal timing to achieve green waves for C-ITS equipped vehicles) is beyond the scope of this report.

Table 3.4: C-ITS interoperability with traveller information systems – scope of works

<table>
<thead>
<tr>
<th>In scope</th>
<th>1. To define how a 5.9 roadside ITS station could be integrated with variable message signs (VMS), as part of traveller information systems, including mobile/portable signs, to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) communicate VMS messages to C-ITS equipped vehicles</td>
</tr>
<tr>
<td></td>
<td>b) collect anonymous data from C-ITS equipped vehicles relative to the operation of the VMS (e.g. if drivers respond to a VMS advice) and for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with traveller information systems and for the purpose of general traveller data collection – refer to traveller data collection (Table 3.2).</td>
</tr>
<tr>
<td></td>
<td>2. Scope is limited to standard data messages.</td>
</tr>
</tbody>
</table>

| Out of scope                                                            | 1. Internet-based route planning and real-time travel time and other traffic information (i.e. 5.9 ITS traveller information communicated to 5.9 ITS equipped vehicles via area communications from a central server). |

<table>
<thead>
<tr>
<th>Emerging 5.9 ITS applications</th>
<th>1. Information communicated to drivers from the VMS could be used to implement the following 5.9 ITS applications:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) traffic information and recommended itinerary</td>
</tr>
<tr>
<td></td>
<td>b) enhanced route guidance and navigation</td>
</tr>
<tr>
<td></td>
<td>c) limited access warning and detour notification</td>
</tr>
<tr>
<td></td>
<td>d) in-vehicle signage - this could include</td>
</tr>
<tr>
<td></td>
<td>i. dynamic over-height warning</td>
</tr>
<tr>
<td></td>
<td>ii. excessive speed on the approach to a curve</td>
</tr>
<tr>
<td></td>
<td>iii. weather alerts</td>
</tr>
<tr>
<td></td>
<td>iv. roadworks warning</td>
</tr>
<tr>
<td></td>
<td>e) congestion warning information.</td>
</tr>
<tr>
<td></td>
<td>2. In addition, data sent from vehicles could also be used for general traveller data collection.</td>
</tr>
</tbody>
</table>

1 Variable message signs (VMS) are signs which can display variable information messages to drivers. Messages can include alerting drivers of incidences on the road ahead and warning road users about weather conditions and other important information. In the context of this report they also include signs such as the RC1 and RC2 signs which are used to display messages with respect to freeway ramp signal operation such as 'ramp signal on' and 'prepare to stop'. They also include VicRoads’ RC3 signs, which are installed at the junction of the on-ramp to the freeway and the arterial road and are used to provide advice relating to the freeway condition and travel time.

As outlined in Section 1.3, this report aims to raise the key approaches, standards, protocols etc. that are emerging internationally, and will need to be considered in order for C-ITS to be integrated with the existing ITS infrastructure of electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems. In doing so, the report recognises that some international regions (e.g. Europe, USA and Japan) are taking some different approaches and adopting different standards.
3.2 Research
The research undertaken in preparing this report included investigating how existing ITS infrastructure functions and how 5.9 ITS could be integrated. This involved:

- reviewing published literature
- reviewing standards, including standards not yet published
- seeking feedback from practitioners and/or reviewing available literature from relevant FOTs and pilot projects
- consulting with practitioners – a list of which is contained in Appendix E
- reviewing material provided in personal communications.
4. Electronic Speed Limit Signs

C-ITS can be used to provide contextual (both regulatory and advisory) speed limit information in the car to the driver for action by the driver, or to provide speed information (both regulatory and advisory) to the vehicle for action by the vehicle (e.g. speed limiters). The benefits associated with providing a driver and/or vehicle with speed limit data for the section of road they are currently in stems from the road safety outcomes achieved through improved speed compliance and speed awareness.

Speed limits have different degrees of dynamics. They can be either fixed, changing depending on the date and time of the day (such as in school zones) or dynamic depending on weather or traffic conditions (such as on freeways). The dynamic speed limits are generally referred to as electronic speed limits (ESL) or variable speed limits (VSL). This report refers to them as ESL/VSL. ESL/VSL in Australia and New Zealand is used where speed limits need to be changed based on traffic conditions, road environment and/or weather conditions. Based on a review of speed limit practices (Austroads 2009a), examples in Australia and New Zealand where ESL/VSL is applied include:

- incident management
- queue management
- speed control associated with inclement weather
- roadworks (occupational health and safety)
- reversible lanes
- school speed zones
- shopping zones
- tunnels and bridges.

Figure 4.1 shows examples of where ESL/VSL is in use in Australia and New Zealand.

Figure 4.1: Examples of ESL/VSL use in Australia and New Zealand

Source: Austroads (2009a).
The degree of dynamics in the speed limit change makes a big difference to the system architecture required to communicate speed limit information to the driver and/or vehicle and for the associated interoperability issues. The more dynamic the speed limit information the more complex the system, for example:

- **At the basic level**, variable speed limits based on time of day and day of week (including days when it does not apply such as school holidays for school zones) could be communicated to the vehicle through the use of a downloadable database that is updated as required through cellular connection. The NSW intelligent speed adaptation (ISA) trial used this approach. In addition, private service providers are also emerging who can provide speed limit information at the basic level through smartphone applications or through the use of in-vehicle navigation systems. Both the NSW ISA application and smartphone applications provided by private services use a central system with updates communicated to the in-vehicle unit via wide area communication.

- **At the dynamic level**, dynamic speed limits based on environmental conditions or traffic would need to be communicated to the in-car device such that the equipped vehicle had the applicable speed for the applicable road section at the applicable time.

While many of the benefits from an ISA-type system can be realised by providing speed limit information to the vehicle at the basic level as outlined above (i.e. providing fixed and variable speed limit information), it is the communication of the speed limits at the most dynamic level (i.e. dynamic speed limits) that is the primary interest of this section of the report.

An additional complex issue applicable to NSW only is the school bus-stop zone where a 40 km/h speed applies to a defined zone (defined by static signs as shown in Figure 4.2) and only applies when the warning system of the bus is active (wig wag lights on the 40 km/h sign erected on the rear of the bus as shown in Figure 4.2). To incorporate such a speed zone application into C-ITS would require V2V communication from the bus.

**Figure 4.2: NSW school bus stop speed zone**

<table>
<thead>
<tr>
<th>Static sign</th>
<th>Warning system on bus – indicating when speed zone applies</th>
</tr>
</thead>
</table>

Source: NSW Centre for Road Safety (2011) and Road Rules 2008 (NSW).

In addition to the use of roadside ITS stations and the 5.9 GHz band, there is potential that dynamic in-car speed limit information at the dynamic speed limit level could be delivered to the vehicle directly from the back office (in a similar manner as the current live traffic website service delivered via the internet) via TPEG using either cellular communication networks or radio broadcast. A broad discussion on the use of cellular communications for C-ITS interoperability is outlined in Section 8.1.
The focus of this report is on integrating 5.9 ITS with ESL/VSL at the roadside level as opposed to through the use of cellular-based communications. Consequently the following sections discuss what is required to achieve interoperability between ESL/VSL signs and 5.9 ITS.

A typical variable speed limit system operated by road agencies may include the following key steps:

1. The back office server sends a control message to the ESL/VSL field processor, where it exists, in a format required by the field processor. The field processor may control multiple groups of ESL/VSL signs along a section of road. It is noted that some road agencies may send a control message from the back office directly to the intelligent protocol converter or group controller and not to a field processor and therefore skip step 2.

2. The ESL/VSL field processor transmits a protocol message (e.g. RTA protocol message (potentially referred to as the RMS protocol message with the name change from RTA to RMS) as adopted by many Australian road agencies) to an intelligent protocol converter, or group controller. A group controller has the critical function of coordinating VSL displays on a group of ESL/VSL signs installed at a location. This includes coordinating the operation of the LEDs.

3. The intelligent protocol converter or group controller converts the message into a proprietary message (i.e. message protocol unique to the brand of ESL/VSL) in order to control the individual ESL/VSL signs.

As this report focuses on the use of 5.9 roadside ITS stations and the use of the 5.9 GHz band for interoperability, the report is focused on the integrations between the following units:

- 5.9 roadside ITS station in order to process and generate a 5.9 ITS message (field)
- ESL/VSL (field)
- back office (centre)
- 5.9 ITS in-vehicle device (vehicle).

A schematic of the possible integrations between these units that would be required to achieve interoperability across the four levels is shown in Figure 4.3.
C-ITS Interoperability with Existing ITS Infrastructure

Figure 4.3: Possible integration between a 5.9 ITS equipped vehicle and ESL/VSL

Notes:
- This figure shows the possible integrations between the 5.9 ITS equipped vehicle and ITS infrastructure. It is noted that the actual data messages, network protocols and media protocols between vehicles, field and centres may differ from that outlined in this diagram. For example:
  - the field infrastructure may translate 5.9 ITS messages from the vehicle into DATEX2 for transmission back to the centre or translate the 5.9 ITS message directly back to the centre
  - Wave Short Message Protocol (WSMP), Fast Network and Transport Layer Protocol (FNTP) or IPv6 may be used as the network protocol for field-to-vehicle and vehicle-to-field communications
  - the media protocol for centre-to-field communication may not necessarily be Ethernet but could be other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP).
- Mapping input functionality may not be available in every vehicle.
- An integrated vehicle system may not have direct connection between the ITS-S and the HMI. The HMI would be controlled by the vehicle system. If it is a retrofit then the HMI may not be integrated and there could be several HMIs.
A discussion on the integrations required to achieve interoperability with dynamic speed limit systems across the four interoperability levels is discussed in Section 4.1 through to Section 4.4. For each level the section discusses what is required to achieve interoperability in order to both:

- communicate variable speed limit data displayed on ESL/VSL signs to C-ITS equipped vehicles
  - as part of providing ETSI use case UC018: Regulatory/contextual speed limits notification (European Telecommunications Standards Institute 2010b)
- collect anonymous data from C-ITS equipped vehicles
  - relative to the operation of the electronic speed limit sign (e.g. driver response to changes and speed limits displayed on the signs and therefore the minimum data required to be collected would include speed and acceleration) for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with ESL/VSL and for the purpose of general traveller data collection).

5.9 roadside ITS stations are multifunctional. That is, where required, they should be able to integrate with multiple roadside ITS infrastructure, including ESL/VSL as outlined in this section, and also be able to be used to collect data for ITS-station-equipped vehicles (i.e. probe data) as outlined in Section 5.

A table summarising the findings of Section 4.1 through to Section 4.6 is contained in Appendix G.

### 4.1 Technical Interoperability

Technical interoperability covers the hardware/software of systems and platforms that enable machine-to-machine communication to take place.

To achieve technical interoperability with ESL/VSL at the roadside requires integrations at the following three levels:

- field-to-field (5.9 roadside ITS station to ESL/VSL roadside infrastructure)
- field-to-vehicle (5.9 roadside ITS station to 5.9 in-vehicle ITS station)
- field-to-centre (5.9 roadside ITS station to back office).

These integrations along with the access technology and network protocols required are discussed in further detail below.

#### 4.1.1 Field-to-field

In order for 5.9 ITS roadside stations to be interoperable with ESL/VSL at a technical level the following in-field integrations will be required:

- Interface between ESL/VSL group controller or field processor and a 5.9 roadside ITS station, depending on which is more suitable (further discussion on the difference between integrating 5.9 roadside ITS stations with ESL/VSL at the roadside via the group controller or field processor is outlined in Appendix F) the 5.9 roadside ITS station would need to be mounted on hardware (preferably existing infrastructure such as a pole).

**Access technology**

The access technologies required to achieve the aforementioned integration is an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections.

**Network protocols**

Speed limit information and details of where the speed limit applies (i.e. relevance zone and awareness zone) would be communicated from the in-field ESL/VSL infrastructure to the 5.9 roadside ITS station using defined network protocols such as IPv6.
4.1.2 Field-to-vehicle
In order for 5.9 ITS equipped vehicles to be interoperable with ESL/VSL at a technical level will require the following field-to-vehicle integrations.

- 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station via the 5.9 GHz band (i.e. field-to-vehicle)
- software within the 5.9 roadside ITS station to develop a 5.9 ITS message which contains information regarding the content of the ESL/VSL sign in addition to information describing the ESL/VSL (i.e. its location and relevance zone as discussed in Section 4.3) that can be broadcast to a 5.9 ITS equipped vehicle for use in 5.9 ITS operation. Alternative scenarios include:
  - the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format
  - where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station
- 5.9 roadside ITS station in order to process data received locally and if required generate a message to be broadcast locally.

Access technology
The access technologies required to achieve the aforementioned integration are 5.9 DSRC via the media protocol of IEEE 802.11p in the USA or ITS G5 in Europe.

Network protocols
C-ITS messages between 5.9 roadside ITS stations and 5.9 in-vehicle ITS stations may utilise network protocols for the data exchange such as IPv6, Wave Short Message Protocol (WSMP) or Fast Networking and Transport Layer Protocol (FNTP). Both WSMP and FNTP are designed for ITS station application processes with severe time constraints and low latency requirements. FNTP uses MAC addresses of access technologies for identifying nodes in the network. Further to this, GeoNetworking may be required to identify geographic target areas within which ITS stations should receive a C-ITS message.

4.1.3 Field-to-centre
In order for 5.9 ITS to be interoperable with ESL/VSL at a technical level the following field-to-centre integrations will be required:

- connection to back office systems (i.e. field-to-centre) in order to communicate supplementary information regarding the speed limit (e.g. incident ahead, congestion, weather etc.) and to send data obtained from the 5.9 ITS equipped vehicle to the back office for processing (e.g. traveller data collection)
- 5.9 roadside ITS station in order to process data received locally and to send data to the back office for further processing
- it is noted that depending on the system architecture used to operate the ESL/VSL, modifications may be required to facilitate the communication of data back-up through the existing communications for processing in a back office (e.g. a modified interface may be required depending on existing systems used). If existing architecture cannot facilitate the communication of traveller data then alternative communication measures may be required (e.g. cellular).

Access technology
To achieve the aforementioned integration will require a networking media protocol standard which can provide a connection between the 5.9 roadside ITS station and the back office using communication technologies suitable for non-local communications. This may be achieved through the Ethernet or other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP). Depending on the site fixed line communications (e.g. optic fibre) or wide area communications (such as 3G and 4G) may be utilised.

Network protocols
Messages exchanged between the 5.9 roadside ITS station and the back office may utilise network protocol IPv6.
4.2 Syntactical Interoperability

Syntactical interoperability addresses the agreed data formats of communication so that machine-to-machine communication can be processed and understood by each machine.

To achieve syntactical interoperability with ESL/VSL at the roadside requires integrations at the following three levels:

- field-to-field (5.9 roadside ITS station to ESL/VSL roadside infrastructure)
- field-to-vehicle (5.9 roadside ITS station to 5.9 in-vehicle ITS station)
- field-to-centre (5.9 roadside ITS station to back office).

These integrations are discussed in further detail below.

4.2.1 Field-to-field

Current ESL/VSL signs utilise a message protocol which outlines the display on the ESL/VSL and any accompanying features to the sign (e.g. speed limit, flashing annulus, wig wags). In order to achieve syntactical interoperability between 5.9 ITS and ESL/VSL signs, software within the 5.9 roadside ITS station needs to be programmed to convert the message that is sent to the ESL/VSL to the agreed 5.9 ITS message format for broadcast via the 5.9 roadside ITS station to vehicles equipped with a 5.9 ITS in-vehicle device. Alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or the STREAMS FP is utilised with a software interface to pass information from the field processor to the 5.9 roadside ITS station.

For many Austroads jurisdictions the RTA message protocol is applied for ESL/VSL. In this case the intelligent protocol converter or group controller receives a message in the RTA protocol message format outlining what it is to display and how it is to display it. The RTA message protocol uses a predefined message frame numbering system where each frame has a specific bitmap display (e.g. message frame number 61 displays 60 km/h speed limit with a flashing annulus while message frame number 60 displays 60 km/h speed limit with a fixed annulus). As the message frame number is known, the display on the ESL/VSL is also known. Therefore the software in the 5.9 ITS device needs to read the message frame number, cross-reference this against the RTA message protocol and then convert it to the agreed 5.9 ITS message format. The same principle would apply to lane control signals (LCS), where VSL is combined with LCS as part of a lane use management system (LUMS).

However, it is noted that the Austroads (2010a and 2013a) reports recommended adopting the National Transportation Communications for ITS Protocol (NTCIP) for ITS devices in the future. Adopting NTCIP could be critical for Australia to ensure that it is consistent with other international deployments (i.e. not unique), so as to ensure scalability and interoperability with various current and future ITS. It was noted in correspondence from RMS on 13 May 2013 that the Australian Standard being developed to replace the RTA protocol (which is NTCIP-based anyway) will support backward compatibility for existing RTA protocol devices.

4.2.2 Field-to-vehicle

The agreed 5.9 ITS message format required for field-to-vehicle communications will emerge through international standards. It is noted that there are efforts to harmonise the air and communication interfaces to enable communication between ITS stations utilising the USA roadside alert message (RSA) as outlined in SAE J2735 (Research and Innovative Technology Administration 2009) and European CAM (European Telecommunications Standards Institute 2011) and DENM (European Telecommunications Standards Institute 2010b) message standards. The data message sets for the ESL/VSL C-ITS integration would vary depending on the direction of the communication as follows:

- field-to-vehicle: DENM, IVI, PDM and SAE and possibly TPEG
- vehicle-to-field: CAM, DENM, PVD and SAE.
4.2.3 Field-to-centre
Field-to-centre communications will need to be undertaken through network protocols such as NTCIP (USA) or DATEX2 (Europe). Protocols used currently by Australian and New Zealand road agencies for ESL/VSL vary but include NTCIP and RTA protocol.

For data collection purposes, the 5.9 ITS device will receive a basic safety message (also referred to as a ‘here I am’ or heartbeat message) and probe data message from the vehicle. Of interest to the operation of the ESL/VSL would be the probe data elements of speed and acceleration. This is discussed further under traveller data collection in Section 5.

4.3 Semantic Interoperability
Semantic interoperability refers to the need to interpret the messages being communicated to enable them to be understood and used appropriately.

Semantic interoperability will be assisted and guided through the adoption of the C-ITS message set as being defined by the USA’s RSA (SAE J2735) and European CAM and DENM.

Semantic interoperability needs to be achieved with respect to the 5.9 roadside ITS station message to the vehicle in addition to the 5.9 in-vehicle ITS station’s message to the roadside unit. Standards will define the 5.9 roadside ITS station message and the 5.9 in-vehicle ITS station message set. The message sets will comprise data elements which will all be defined. Some of the data elements are currently not part of the ESL/VSL, and will need to be introduced to the roadside component of the C-ITS system so it can be sent to the vehicle. An example of data elements not currently part of the ESL/VSL is the relevance zone of the speed limit.

The relevance zone of the speed limit is required as the vehicle will be able to receive a speed limit message once it is in receiving range of the roadside unit, which could be several hundred metres either side of the unit. As such, the vehicle will need to know where the speed limit it is receiving applies.

For the 5.9 roadside ITS station, most of these data elements will be fixed and generally will not vary per ESL/VSL, such as:
- location of the ESL/VSL: the location of the speed sign for which the speed of the downstream section of road applies
- relevance zone: the distance along the downstream section of road following the sign for which the speed limit applies
- the awareness zone: the distance prior to the speed limit sign (and zone) for which the driver of the vehicle should become aware of the upcoming speed limit
- vehicle types: vehicle types for which the speed limit applies if it varies between vehicles
- lanes in which the speed limit may apply: lane for which the speed limit applies if it varies between lanes.

The draft ISO standard, ISO/PDTS 17426: Intelligent transport systems (ITS) – Co-operative systems – Contextual speeds is currently establishing the requirements of the road sign message which should address the requirements of these fixed elements.

These fixed elements (i.e. location of the ESL/VSL, relevance zone, the awareness zone, vehicle types and lanes in which the speed limit may apply) may be programmed into the 5.9 roadside ITS station at the time of installation, requiring the station to only obtain the current speed limit information from the ESL/VSL system. The fixed elements may also be delivered to the 5.9 roadside ITS station from the traffic management centre.

The actual speed limit to be displayed along with any additional information, where applicable, such as the cause of the speed limit change will need to be communicated to the 5.9 roadside ITS station from the back office, or a localised speed management system where it is in place (e.g. environmental condition speed system such as wind).
The vehicle will need to operate on the same standardised time (e.g. coordinated universal time (UTC)) as the field and/or centre devices where it receives the speed limit from. It would be up to road agencies to convert from local time to UTC.

The standard speed limit can be obtained from the message received from the intelligent protocol converter or group controller. Additional information regarding the speed limit such as the cause of change (e.g. roadworks, congestion, incident etc.) may or may not be able to be communicated to the intelligent protocol converter or group controller for use by the 5.9 roadside ITS station. As the system is not originally designed for this functionality, modifications to VSL operating architecture may be required in order to facilitate this functionality where it may be desired by the responsible road agency.

As mentioned earlier, the 5.9 roadside ITS station will collect anonymous data from probe vehicles both relative to its operation and for general data collection. This is further discussed in Section 5.

### 4.4 Organisational Interoperability

Organisational interoperability refers to the ability of organisations to exchange data across systems, which will require a level of consistency with business processes (and architectural approaches). Success is also dependent on the level of technical, syntactical and semantic interoperability achieved. Some of the aspects that need to be considered in order to achieve organisational interoperability are as follows:

- **Road agencies** will need to be responsible for complying with the applicable licensing conditions overriding the use of 5.9 roadside ITS stations and certifying the devices against the required standards (the issue of certification is discussed further in Section 8.2.3). This will include registering and controlling their use, ensuring their operation is in accordance with the licence conditions, ensuring that their use is consistent with ITS architectural approaches adopted across the road agency, and ensuring that interfaces are established to enable data exchange with legacy systems.

- **Road agencies** will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations. This may require modifications to their asset management processes, as they will need to be able to detect faults and/or outages associated with the 5.9 roadside ITS station.

- **Road agencies** will need to ensure that adequate rules and systems are in place to ensure that the 5.9 roadside ITS station can fail safely in the event of a fault or outage.

- **Road agencies** will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. DENM, IVI). This may require modifications to business processes and databases.

- **Road agencies** will need to monitor international developments and standards with respect to security and ensure that processes are adopted to ensure that messages sent by either the 5.9 in-vehicle ITS station and 5.9 roadside ITS station can be identified as being authentic and therefore trusted for use. This is discussed further in Section 8.2.2.

- In some cases integrating ESL/VSL systems with 5.9 roadside ITS stations may pose contractual issues around the supply, maintenance and warranty of components. Road agencies may find it more viable to adopt a modular approach where 5.9 ITS can be retrofitted to ESL/VSL as part of a supply contract, rather than retrofitting into an existing system. Alternatively, there may be scope for ESL/VSL suppliers to incorporate 5.9 ITS units into the ESL/VSL equipment if they can overcome issues around the supply and certification of the 5.9 ITS units.

- **Road agencies** will be responsible for ensuring that vendors or supplier equipment is capable of delivering standardised messages from roadside units. Vendors or suppliers will be responsible for the supply of the message under contract with the road agency. The standardised message will be an international standard such as SAE J2735 (Society of Automotive Engineers International 2009) which will be based on internationally agreed terminology. In some cases the agreed terminology may differ from that currently used in Austroads jurisdictions.

- It is envisaged that there may be differences in the human machine interface (HMI) of various car manufacturers and that car manufacturers may offer value-added services. Road agencies should maintain an interest in how various vehicle manufacturers are using 5.9 ITS messages.
C-ITS Interoperability with Existing ITS Infrastructure

- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation. The National Transport Commission (2013) paper provides guidance on this as discussed further in Section 8.2.1.
- Road agencies may need to establish processes to enable and support data provision to private companies that will then use the data in the provision of their C-ITS services to road users, which may include interfaces to enable data exchange and establishing appropriate agreements.
- Corporate traffic information systems, including business processes and associated databases, will need to be modified in order to process and store new data. This is discussed further in Section 8.2.5.

4.5 Benefits
There are considerable road safety benefits associated with improved speed compliance as a result of drivers knowing the speed limit. This is discussed in further detail in NSW Centre for Road Safety (2010). The benefits associated with making 5.9 ITS interoperable with ESL/VSL include:

- extending the benefits associated with an advisory or limiting ISA system to roads and/or road segments with ESL/VSL
- the ability to provide additional information to the driver where ESL/VSL may exist, such as the provision of information
  - about the zone the driver is entering where the speed limit applies such as a work zone
  - about why the speed limit may have been reduced (e.g. incident ahead, congestion, weather etc.)
- the ability to utilise the 5.9 ITS unit to provide enhanced traveller information to drivers in order to aid their decision making
- the ability to utilise the 5.9 ITS unit to obtain anonymous probe data from 5.9 ITS equipped vehicles
- earlier notification of VSL speed limit ahead, which could be tailored for different vehicle types (e.g. heavy vehicles).

4.6 Risks
The risks associated with providing a vehicle with speed limit information centre around the effect on the driver of the provision of this information relative to their driving behaviour. This is discussed in further detail in the NSW Centre for Road Safety (2010) report. With respect to making 5.9 ITS interoperable with ESL/VSL, the general risks include:

- drivers becoming dependent on the technology and not understanding that the roadside sign remains the regulatory device. This could pose issues where:
  - ESL/VSL signs are not equipped with 5.9 roadside ITS stations
  - where equipped, the 5.9 roadside ITS station is not functioning
  - where equipped, the 5.9 roadside ITS station issues a conflicting message, although system design should sufficiently address this
- potential liability issues associated with the communication of ESL/VSL and whether the road agency is liable if a vehicle does not receive the ESL/VSL information or if the ESL/VSL did not communicate the information or communicated incorrect information
- speed limit information communicated to the drivers via 5.9 roadside ITS stations not being adequately integrated with speed limit information stored in the vehicle or communicated via cellular-based communications to the vehicle in order to deliver one speed limit solution for the vehicle
- emergence of other technologies that results in 5.9 ITS roadside technology becoming redundant and a legacy issue for road agencies
- the technology not being widely taken up and resulting in roadside ITS infrastructure to be maintained with the costs outweighing the benefits
• wide-scale investment in 5.9 ITS integration with ESL/VSL without due consideration for the same service being delivered either solely by or in support to cellular-based communications

• may require modifications to existing architecture in order to facilitate some functionality (e.g. communicate data collected from probe vehicles for use in back office systems)

• risks associated with how private companies may utilise C-ITS data that they are given access to

• use of temporary, but static fixed speed limit signage within a VSL zone with reduced speed limits (e.g. where a short length of road is designated as 25 km/h through the use of temporary signage, within a VSL zone that is down to 40 km/h with a 80 km/h and 60 km/h lead-in)

• the potential that integrating electronic speed limit signs with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.

The aforementioned risks will need to be considered in the context of its development, deployment and operation and appropriately mitigated.
5. Traveller Data Collection

C-ITS equipped vehicles can be a valuable source of data for road agencies. The detection of vehicles provides valuable data that allows road agencies to undertake various calculations such as traffic volumes and composition, travel time estimates, lane occupancy etc. This allows the road agencies to monitor and review the operation of the network remotely. In addition, road agencies collect data about the road environment (e.g. wind, black ice) in order to warn drivers or alter the management of the roadway to achieve safety outcomes (e.g. reduce speed).

Traveller data collected can be used in a road agency’s back office for use in road network analysis and monitoring such as:

- travel time analysis to monitor historical and real-time road conditions for traveller information and road management review
- incident management to identify potential incidents on the road network
- identifying potential hazardous spots that may or may not have a crash history through observing travel behaviour (e.g. heavy braking)
- road asset maintenance planning and identification of pavements requiring urgent repairs
- identifying environmental road conditions such as:
  - hazardous location
  - precipitation
  - road adhesion
  - visibility
  - wind.

Fixed infrastructure currently used to collect traffic data can be either intrusive (buried within the road) or non-intrusive (not buried within the road) (Austroads 2009b). Examples of intrusive and non-intrusive detection technologies available for use by Austroads jurisdictions are listed in Table 5.1.

<table>
<thead>
<tr>
<th>Intrusive</th>
<th>Non-intrusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive loop detectors (ILD)</td>
<td>Bluetooth</td>
</tr>
<tr>
<td>Wireless vehicle detection system (using a magnetometer)</td>
<td>Microwave and millimetre radar</td>
</tr>
<tr>
<td>Piezo electric</td>
<td>Infrared</td>
</tr>
<tr>
<td>Magnetic</td>
<td>Closed circuit television (CCTV) including video image processor (VIP), automatic licence plate recognition (ALPR), automatic number plate recognition (ANPR) and automatic vehicle identifier (AVI)</td>
</tr>
<tr>
<td>Weigh-in-motion (WIM)</td>
<td>Ultrasonic</td>
</tr>
</tbody>
</table>
Images of some of the technologies referred to in Table 5.1 are shown in Figure 5.1.

**Figure 5.1: Images of some vehicle detection technologies**

- Automatic vehicle identifier
- Microwave
- Video image processor
- Inductive loop detectors
- Radar

Source: Adapted from FHWA (2003) and Gibson, Mills and Klein (2007).

As outlined in Austroads (2009b) intrusive infrastructure includes inductive loop detectors (ILD) or wireless vehicle detectors (WVD). Non-intrusive infrastructure includes video incident detection (VID) or closed circuit television (CCTV).

While valuable, traditional means of data collection (such as through the use of intrusive sensors), require installations in the pavement and therefore are only collecting data at fixed locations and only when an event triggers it (e.g. for queue detection the queue length is not known, rather it is only known that the queue extends to at least the location of the detector).

Road agencies have an increasing desire to obtain more detailed traffic data. Sources may include the use of different technologies (e.g. GPS, cellular, Bluetooth, etc.) which may include sourcing data from third parties.

The potential data that could be collected from vehicles is wide ranging. The data can range from simple positioning data to vehicle sensor data that would need to be sourced from the vehicle’s controller area network bus (CAN bus) \(^5\). The probe data would be made up of elements which could be processed and analysed in order to provide various information. The SAE J2735 standard (Society of Automotive Engineers International 2010a) outlines 33 data elements that could be recorded by probe vehicles. Some data elements would be optional and would not be submitted by all probe vehicles. The 33 data elements are listed in Table 5.2.

Road agencies should become familiar with the standards defining the data elements outlined in Table 5.2, including which data elements will be mandatory and which will be optional, and develop systems and processes to collect data based on their mandatory or optional designation.

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\(^5\) A message-based protocol designed specifically for automotive applications in order to allow microcontrollers and devices to communicate with each other within a vehicle without a host computer.
Table 5.2: Probe data elements as outlined in the SAE J2735 standard

<table>
<thead>
<tr>
<th>Acceleration*</th>
<th>Heading*</th>
<th>Sun sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient air pressure</td>
<td>Latitude*</td>
<td>Time</td>
</tr>
<tr>
<td>Ambient air temperature*</td>
<td>Longitude*</td>
<td>Tire pressure*</td>
</tr>
<tr>
<td>Antilock brake status*</td>
<td>Obstacle direction*</td>
<td>Tire pressure threshold detection*</td>
</tr>
<tr>
<td>Brake applied pressure*</td>
<td>Obstacle distance*</td>
<td>Traction control state</td>
</tr>
<tr>
<td>Brake boost applied*</td>
<td>Probe segment number*</td>
<td>Vehicle type*</td>
</tr>
<tr>
<td>Coefficient of friction</td>
<td>Rain Sensor*</td>
<td>Vertical acceleration</td>
</tr>
<tr>
<td>Date</td>
<td>Speed*</td>
<td>Wiper rate*</td>
</tr>
<tr>
<td>Driving wheel angle*</td>
<td>Stability control status</td>
<td>Wiper status front*</td>
</tr>
<tr>
<td>Elevation*</td>
<td>Steering wheel angle*</td>
<td>Wiper status rear</td>
</tr>
<tr>
<td>Exterior lights*</td>
<td>Steering wheel angle rate of change*</td>
<td>Yaw rate*</td>
</tr>
</tbody>
</table>

* Designates those elements also identified, or have a similar element identified in the ETSI cooperative awareness message (CAM) and/or decentralised environmental notification message (DENM) standards.

Source: Society of Automotive Engineers International (2010a).

The use of vehicles as probes to collect data about the road environment opens up many issues around privacy and surveillance and the potential for data to be used for compliance and enforcement activities. The National Transport Commission (2013) paper documents the findings of an investigation which explored the regulatory policy issues associated with C-ITS, including investigating privacy issues in detail as discussed further in Section 8.2.1.

The information obtained from the data will depend on the systems that road agencies decide to implement or use. As C-ITS offers different data to that acquired through existing ITS systems, new systems would need to be developed that incorporate the C-ITS data in addition to data from existing sources in order to achieve the desired objectives of the road agency implementing the system. The desired objectives could vary between road agencies and would be influenced by systems already in operation for which C-ITS-based data could be utilised.

The systems developed by road agencies to utilise the data will largely be influenced by how the technology develops and how the technology is received and taken up. It will also be influenced by the opportunities that the provision of data presents, along with what business areas road agencies wish to extend into and what information road users expect road agencies to provide.

The collection of traveller data aligns with the following ETSI decentralised floating car data applications:

- UC013: Decentralised floating car data – hazardous location
- UC014: Decentralised floating car data – precipitations
- UC015: Decentralised floating car data – road adhesion
- UC016: Decentralised floating car data – visibility
- UC017: Decentralised floating car data – wind.

As with ESL/VSL, there is potential for road agencies to acquire anonymous traveller data from C-ITS equipped vehicles through both cellular-based and roadside-based communications. This is discussed further in Section 8.1.
The focus of this report is on using 5.9 roadside ITS stations to collect traveller data. The following section discusses the interoperability issues associated with traveller data collection and the interoperability issues associated with the following units:

- 5.9 roadside ITS station (field)
- back office (centre)
- 5.9 ITS in-vehicle device (vehicle).

A schematic of the possible integrations between these units that would be required to achieve interoperability across the four levels is shown in Figure 5.2.

Figure 5.2: Possible integration between 5.9 ITS roadside equipment and traveller data collection systems

Notes:

- This figure shows the possible integrations between the 5.9 ITS equipped vehicle and ITS infrastructure. It is noted that the actual data messages, network protocols and media protocols between vehicles, field and centres may differ from that outlined in this diagram. For example:
  - the field infrastructure may translate 5.9 ITS messages from the vehicle into DATEX2 for transmission back to the centre or translate the 5.9 ITS message directly back to the centre
  - Wave Short Message Protocol (WSMP), Fast Network and Transport Layer Protocol (FNTP) or IPv6 may be used as the network protocol for field-to-vehicle and vehicle-to-field communications
  - the media protocol for centre-to-field communication may not necessarily be Ethernet but could be other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP).
- Mapping input functionality may not be available in every vehicle.
A discussion on the integrations required in order to integrate C-ITS with traveller data collection systems via 5.9 roadside ITS station across the four interoperability levels is discussed in Section 5.1 through to Section 5.4.

As this section is about collecting vehicle data for use in back-end systems, the focus is more about 5.9 roadside ITS stations being interoperable with back-end systems and with vehicles, and not about these stations being interoperable with existing field devices (unlike the other sections of the report).

A table summarising the findings of Section 5.1 through to Section 5.6 is contained in Appendix G.

### 5.1 Technical Interoperability

Technical interoperability covers the hardware/software of systems and platforms that enable machine-to-machine communication to take place.

A 5.9 in-vehicle ITS station integrated in a vehicle is able to create a probe vehicle message containing relevant vehicle data. The following sections discuss the integrations required at the vehicle-to-field and vice versa and field-to-centre levels in order to achieve this.

#### 5.1.1 Vehicle-to-field and Vice Versa

Technical interoperability from a vehicle-to-field and field-to-vehicle perspective will require the following elements:

- 5.9 in-vehicle ITS station communicating probe vehicle messages to the 5.9 roadside ITS station upon request from the 5.9 roadside ITS station

  With respect to the deployment of the stations, the more that are located around the network the more frequently data can be captured and the greater the data network coverage in real time. Traveller data is likely to be collected from both dedicated 5.9 ITS roadside traveller data collection units and also 5.9 roadside ITS stations integrated with ITS infrastructure to serve other functions as discussed elsewhere in this report.

- 5.9 roadside ITS station requesting probe vehicle data from an equipped vehicle

  The vehicle will become aware of the presence of a 5.9 roadside ITS station that accepts probe data from hearing a message (e.g. wave service announcement (WSA) as referred to by the IEEE) from the station. The vehicle will be able to upload its information in response to the instructions outlined in the message from the station. In addition, the station will be able to receive a message broadcast from a vehicle that may not specifically be a probe vehicle message (e.g. standard ‘here I am’ message broadcasts from the vehicle to make other 5.9 ITS equipped vehicles and infrastructure aware of its presence).

- software within the 5.9 in-vehicle ITS station to obtain data from the vehicle (including sensors) for use in a PVD C-ITS message

- software within the 5.9 roadside ITS station to process the data and determine whether to generate a new 5.9 ITS message to vehicles in range

- road agencies have identified that they would be interested in utilising a system which could undertake localised processing and send information out to local drivers warning of hazardous situations such as wet weather etc. This would require the 5.9 roadside ITS station to process data and determine what data gets sent to the back office for processing and what data needs to be processed locally and sent out as a 5.9 ITS message to vehicles.

#### Access technology

The access technologies required to achieve the aforementioned integration are 5.9 DSRC via the media protocol of IEEE 802.11p in the USA or ITS G5 in Europe.
Network protocols

C-ITS messages between 5.9 roadside ITS stations and 5.9 in-vehicle ITS stations may utilise network protocols such as IPv6, Wave Short Message Protocol (WSMP) or Fast Networking and Transport Layer Protocol (FNTP). Both WSMP and FNTP are designed for ITS station application processes with severe time constraints and low latency requirements. FNTP uses MAC addresses of access technologies for identifying nodes in the network. Further to this GeoNetworking may be required to identify geographic target areas within which ITS stations should receive a C-ITS message.

5.1.2 Field-to-centre

In order to achieve technical interoperability from a field-to-centre and centre-to-field perspective the following elements will be required:

- Software within the 5.9 roadside ITS station to process data and determine what to send to the back office with a connection to the back office and back office systems to process the data. The 5.9 roadside ITS station would need a connection to the back office. This could be undertaken via various means such as utilising existing communication infrastructure along freeways/motorways, existing fibre networks, wide area communications such as 3G or 4G or the proposed rollout of the NBN.

- Traditionally, systems such as freeway/motorway/arterial road management systems and incident management systems rely on algorithms to calculate when certain actions should be taken. The algorithm would be based on occupancy data as a measure of density derived from the detection of vehicles by an in-pavement detector (i.e. time a vehicle is over the detector); 5.9 ITS data may offer the potential to enhance these calculations and when sufficient penetration is achieved supersede this data source. New systems will need to be developed to utilise a different data source that 5.9 ITS offers.

Not all vehicles will be able to report on all data elements as they will not be equipped with appropriate sensors and these fields will be optional.

Vehicles without appropriate sensors but equipped with 5.9 ITS may get notification of the hazard via the 5.9 roadside ITS station even though the vehicle that detected the hazard has left the area (i.e. through I2V rather than direct V2V communication of the hazard). Obviously the 5.9 roadside ITS station and/or back office may have to undertake statistical analysis to verify that probe data is reflective of actual conditions rather than a random event before broadcasting a message.

The extent to which a vehicle stores historical data (i.e. does a vehicle store all trip files since an upload, only trip files for the day, since ignition, last one hour, last five minutes etc.) is also a technical interoperability issues and will likely be influenced by

- the size of the file that can be uploaded to a 5.9 roadside ITS station when the vehicle is in range of the station
- the rules governing the collection of snapshots by equipped vehicles, with snapshots being generated either periodically, event triggered or at starts and stops
- rules governing how many snapshots can be contained in a probe vehicle message and how many messages can be stored in the vehicle and uploaded when a vehicle is in range of the 5.9 roadside ITS station
- policy issues such as privacy and surveillance
- international standards and designs adopted by the automotive industry.

Access technology

To achieve the aforementioned integration will require a networking media protocol standard which can provide a connection between the 5.9 roadside ITS station and the back office using communication technologies suitable for non-local communications. This may be achieved through the Ethernet or other media protocols such as point-to-point protocol (PPP) or point-to-multi point protocol (PMPP). Depending on the site fixed line communications (e.g. optic fibre) or wide area communications (such as 3G and 4G) may be utilised.
**Network protocols**

Messages exchanged between the 5.9 roadside ITS station and the back office may utilise network protocol IPv6 for the data exchange.

### 5.2 Syntactical Interoperability

Syntactical interoperability addresses the agreed data formats of communication so that machine-to-machine communication can be processed and understood by each machine.

To achieve syntactical interoperability with traveller data collection systems at the roadside requires integrations at the following two levels:

- **vehicle-to-field** (5.9 roadside ITS station to 5.9 in-vehicle ITS station)
- **field-to-centre** (5.9 roadside ITS station to back office).

These integrations are discussed in further detail below.

#### 5.2.1 Vehicle-to-field and Vice Versa

Standards will define the data elements of the probe data message. Work internationally has been undertaken to define such probe data messages such as the USA's PVM (SAE J2735) (Research and Innovative Technology Administration 2009) and Europe’s CAM (European Telecommunications Standards Institute 2011) and DENM (European Telecommunications Standards Institute 2010b) message set. There are efforts to harmonise the air and communication interfaces to enable communication between these message standards.

Other applicable message sets include PDM and PVD. As outlined in Section 2.5 the roadside ITS station (field) will transmit the PDM, while the vehicle ITS station (vehicle) transmits the PVD.

#### 5.2.2 Field-to-centre

Back office systems will need to be developed to utilise the data in the message format provided. Depending on the systems installed by road agencies the data format of the message may be altered at the roadside unit to suit the system in the back office or forwarded to the back office in the same format as provided by the 5.9 in-vehicle ITS station. Further, back office systems may need to be developed in order to synthesise data provided by traditional data sources. It is likely that the protocol used by road agencies for field-to-centre will be protocols such as NTCIP (USA) or DATEX2 (Europe).

### 5.3 Semantic Interoperability

Semantic interoperability refers to the need to interpret the messages being communicated, to enable them to be understood and used appropriately.

The roadside unit will transmit a message (e.g. a Wireless Access in Vehicular Environments (WAVE) service announcement (WSA) as defined in IEEE 1609) through which a vehicle becomes aware that it is approaching a roadside unit which accepts probe data. The vehicle will proceed to broadcast its probe data message when in range of the roadside unit.

Society of Automotive Engineers International (2010a) indicates that the message set will be a defined structure that will identify the message as a new message, and provide details such as an anonymous identifier, vehicle type, number of snapshots within the message and the details of the snapshots. The details of the snapshots will vary depending on the various data elements (as defined in Table 5.2).

A common approach to data definitions would be beneficial to achieving semantic interoperability, and the consistent adoption by stakeholders of recognised standards would help to facilitate this.
In addition, other semantic issues include appropriately identifying the message such that it can be located both with respect to time and location. This will require time and date identifiers in addition to a latitude and longitude identifier. Time and date identifiers will be specified in the coordinated universal time (UTC) format. Other identifiers would include segment number and heading as identified in Table 5.2.

5.4 Organisational Interoperability

Organisational interoperability refers to the ability of organisations to exchange data across systems, which will require a level of consistency with business processes (and architectural approaches). Success is also dependent on the level of technical, syntactical and semantic interoperability achieved. In order to achieve organisational interoperability, consideration needs to be given to the following:

- Road agencies will need to be responsible for complying with the applicable licensing conditions overriding the use of 5.9 roadside ITS stations and certifying the devices against the required standards (the issue of certification is discussed further in Section 8.2.3). This will include registering and controlling their use, ensuring their operation is in accordance with the licence conditions, ensuring that their use is consistent with ITS architectural approaches adopted across the road agency, and ensuring that interfaces are established to enable data exchange with legacy systems.
- Road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations. This may require modifications to their asset management processes, as they will need to be able to detect faults and/or outages associated with the 5.9 roadside ITS station.
- Road agencies will need to ensure that adequate rules and systems are in place to ensure that the 5.9 roadside ITS station can fail safely in the event of a fault or outage.
- Road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. PDM). This may require modifications to business processes and databases.
- Road agencies will need to monitor international developments and standards with respect to security and ensure that processes are adopted to ensure that messages sent by either the 5.9 in-vehicle ITS station and 5.9 roadside ITS station can be identified as being authentic and therefore trusted for use. This is discussed further in Section 8.2.2.
- There will be a need for road agencies to collect anonymous data in an internationally standardised format and keep it in that format so that it can be processed internally and externally by third parties in order to add value.
- Data will need to be amalgamated from existing sources such as intrusive detectors and 5.9 ITS systems in order to deliver new operation and road management systems.
- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation. The National Transport Commission (2013) paper provides guidance on this as discussed further in Section 8.2.1.
- Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data. This is discussed further in Section 8.2.5.

5.5 Benefits

The benefits of using 5.9 ITS for traveller data collection include:

- It provides an enhanced data source that is potentially not limited by its location (i.e. can get data from the road network surrounding the location of the 5.9 roadside ITS station and not just at the immediate location) enabling it to:
  - provide more granular data (i.e. series of data recorded and stored by the vehicle)
  - provide details of traffic conditions that would otherwise be difficult or expensive to obtain (e.g. actual queue length at a traffic signal, approaching demand).
- While subject to standards regarding the extent of data storage within the vehicle, it can provide data with respect to origins and destinations in addition to route choice, which could aid road agencies in better planning for and operating the road network.
- It can enable road agencies to collect more data with potentially less infrastructure compared to using traditional data collection infrastructure, resulting in significant cost savings (the magnitude of this benefit will be proportional to the market penetration of 5.9 ITS equipped vehicles, with increasing penetration enabling the opportunity to phase out or replace legacy data collection systems when asset renewal or upgrades are required).
- Anonymous traveller data collected by road agencies could be passed on to third parties to add value.
- Other 5.9 roadside ITS station deployments (e.g. at traffic signals, ESL/VSL, VMS) could be utilised for data collection purposes in addition to their primary purpose.

5.6 Risks
The main risks associated with 5.9 ITS integrated with traveller data collection concerns managing big data and ensuring that:
- there is sufficient bandwidth to enable data to be communicated to back-end systems
- back-end systems are adequately designed to cater for big data (including the volume, velocity, variety, and veracity of the data) and are able to synthesise 5.9 ITS data with existing data sources.

Other risks associated with 5.9 ITS integration with traveller data systems include:
- not undertaking appropriate sampling to verify a message (i.e. obtaining similar data from an appropriate number of vehicles) before determining the outcome
- not maintaining existing data sources so that roads can be adequately managed or alternatively not ensuring that new data sources (such as 5.9 ITS or C-ITS) are sufficiently established before making existing systems redundant
- using data in such a way that may violate privacy legislation
- not ensuring that data received and processed is screened in order to remove malicious or untrusted messages
- 5.9 roadside ITS infrastructure becoming redundant and a legacy issue for road agencies as a result of the emergence of other technologies and/or use of other communication media for the same outcome (e.g. cellular communications)
- the technology not being taken up and resulting in 5.9 roadside ITS infrastructure needing to be maintained with the costs outweighing the benefits and restricting the ability to collect traveller data
- investing in 5.9 ITS on a wide-scale without due consideration for the same service being delivered either solely by or in support to cellular-based communications
- the potential that integrating traveller data collection systems with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.

The aforementioned risks will need to be considered in the context of its development, deployment and operation and appropriately mitigated.
6. Traffic Signals

Several of the ‘day 1’ applications (as identified in Section 2.1) require C-ITS integration with traffic signals and the communication of traffic signal phasing and timing data (SPaT) to vehicles in order to function. The applications include:

- intersection safety (where signal phasing is communicated to the vehicle in order to aid prevention of red light running)
- green wave
- energy efficient intersection control
- traffic light optimal speed advisory.

Already there are some applications, such as a public transport priority scheme, which monitor the priority vehicle’s progression along the road network and provides input to the traffic signal control system via a top-down approach. This can be in addition to physical detection of the priority vehicle at the traffic signal. A top-down priority progression system such as Victoria’s Smart Bus can request traffic signal changes in order to further assist the progression of the bus along its route based on adherence to its schedule. Figure 6.1 shows a signalised intersection where Smart Bus is in operation, illustrating physical priority measures through a designated lane which enables the bus to queue jump, the local signal controller which controls the signal, and an overview of the Smart Bus system.

![Figure 6.1: Traffic signals with public transport priority](image)

Source: Adapted from Department of Infrastructure (2009).

The benefits of integrating C-ITS with traffic signals range from avoidance of incidents and collisions, to mobility and environmental benefits. In order to achieve many of the potential C-ITS benefits at signalised intersections, 5.9 ITS roadside units would be required to communicate the signal phasing and timing (SPaT) data to vehicles for use in the vehicle. In addition, signal operations could utilise data provided by the vehicles as part of their operation.

The SPaT data standards being developed internationally are primarily being designed for fixed time traffic signals which are commonly used internationally. However, there are some experts currently considering how to apply the SPaT standards to adaptive traffic signals. The issue for adaptive traffic control (ATC) systems is that the prediction of the amount of remaining red and green time can be poor. Jürgen Weingart of Swarco noted (in a presentation at the Joint CEN/ISO and ETSI meeting and stakeholder workshop in Berlin on 12–14 December 2012) that there is difficulty associated with providing SPaT data from ATC controllers. The presentation outlined that current thinking is moving towards the data element including minimum remaining time for the signal, maximum remaining time for the signal, likely time for the signal and confidence for the likely time.
How ATC systems comply with the SPaT standards is an issue for Austroads member road agencies in that many traffic signals within their jurisdictions, in particular those located within the metropolitan areas, are managed through adaptive traffic control (ATC) systems, meaning they adjust their signal timings in real time based on variations in traffic demand and system capacity. ATC systems used by Austroads members include the Sydney Co-ordinated Adaptive Traffic System (SCATS) in most jurisdictions and STREAMS in Queensland with the exception of the Brisbane City Council which utilises SCATS.

Traffic signals that are not connected to ATC systems generally operate under other plans which may include fixed time or vehicle actuated.

Although these ATC systems are used elsewhere around the world, other international regions do use different systems. As a result, the requirements to make traffic signal infrastructure used in Australian jurisdictions interoperable with C-ITS may differ to those required in some other international regions where it is planned to deploy C-ITS.

Both SCATS and STREAMS connect field hardware such as intersection controllers and traffic detectors back to a central server. While SCATS and STREAMS operate under different operating regimes there are some commonalities. This report does not explain the operating regimes of SCATS and STREAMS but instead outlines below some key points with respect to their operation that are deemed relevant with respect to C-ITS interoperability with traffic signals. These points have been identified based on a review of SCATS and STREAMS documentation such as Lowrie (1992), Roads and Traffic Authority (2009), Transport and Main Roads (2012), in addition to consultations with stakeholders at RMS (SCATS) and Queensland TMR.

SCATS consists of a central manager, regional controllers and local controllers as shown in Figure 6.2.

Figure 6.2: Overview of the SCATS system

The SCATS system enables traffic signals to be operated under either masterlink mode (under the control of the SCATS regional computer), flexilink mode (cable-less or synchronous linking) or isolated mode (independent vehicle actuated or fixed time operation). Key points associated with the SCATS central manager, SCATS regional controller and SCATS local controller are outlined below.

SCATS central manager:
- A central manager is used for centralised monitoring of the operation and equipment functionality. The central manager is located in the central office.
C-ITS Interoperability with Existing ITS Infrastructure

SCATS regional controller:

- Regional controllers are used to undertake strategic control of a sub-system of signalised intersections. The regional controller determines the appropriate green splits, offsets and cycle length on a cycle-by-cycle basis based on SCATS degree of saturation (SCATS DS) for each intersection. The regional controller has an ITS port in which data can be extracted for use by ITS applications without interfering with the operation. While data can be extracted, the ITS port is not set up for major input to SCATS although it can be used to trigger certain actions. Some Australian jurisdictions have experienced delays with receiving data from the ITS port which has restricted its ability to be used in real-time applications.

SCATS local controller:

- Local controllers collect flow and occupancy data from the in-pavement detectors located at the stop line and implement the signal timings determined by the regional computer. The local controller also has the intelligence to undertake tactical control, to control the intersection in the event of communication breakdown between the regional and local controllers and to manage other modes such as pedestrian movements and railway level crossing phases. The local controller is located on site.

- The specification for the current traffic signal controller is Traffic Signal Controller Specification Version 4 which is developed by the RTA and commonly referred to as TSC4. TRAFF is the controller software utilised by the TSC4 controller.

The primary difference with STREAMS compared to SCATS is that rather than determining signal timings on a cycle-by-cycle basis, STREAMS uses a measure of occupancy (to represent density in traffic), in order to implement dynamic plan selections in favour of the dominant direction of traffic (i.e. select an optimal traffic plan from a selection of plans). STREAMS occupancy is based on vehicle detections undertaken approximately 35 m in advance of the stop line (unlike SCATS which detects vehicles at the stop line).

Similarly to SCATS, STREAMS utilises the TSC4 local controller operating on TRAFF software, with the local controller able to terminate a phase based on prescribed business parameters being met.

Unlike SCATS, STREAMS has a field processor (ITS station) at every controller. When the controller is in masterlink mode it is driven by the field processor (FP) and the FP can control the time of the movements and sequences as long as minimum safety times and sequences in the controller are not violated. The FP is connected to the controller by a cable and can be kept in masterlink if the network is down. The FP in STREAMS allows for the interfacing of various field devices including controllers to STREAMS providing an established platform for the staged introduction of C-ITS capability. The use of an FP could:

- potentially reduce the need for modifications to TRAFF software as the FP already interfaces to the controllers to extract data
- allow for the conversion of controller data into a 5.9 ITS SPaT message
- allow for storage of intersection map data; provide asset management and fault monitoring through STREAMS
- provide for the ability to communicate road agency data to vehicles
- provide for the integration of vehicle priority and pre-emption
- reduce in the risk of the 5.9 Roadside ITS station becoming redundant.

The phase intervals utilised by both SCATS and STREAMS can be separated into two groups, namely running intervals and clearance intervals as shown in Figure 6.3.

In order to provide C-ITS equipped vehicles with access to real-time SPaT data from adaptive traffic signal systems, so as to enable time critical applications such as intersection safety applications to operate safely, requires the transmission of SPaT data from a roadside unit (e.g. 5.9 ITS RSU) that is directly integrated with the local traffic signal controller. This is due to the need for the data to be transmitted to vehicles with very low latency, and the significant safety risks that would be introduced if this data transmission does not meet low latency requirements.
In order to achieve the primary objective of relaying traffic signal phasing and timing (SPaT) data into the vehicle in real time for current adaptive traffic signals, the C-ITS integration with traffic signals needs to be undertaken locally through a 5.9 roadside ITS station integrated with the local traffic signal controller.

As the local controller may terminate a phase, the actual phase length (as determined by the regional controller and sent to the local controller to implement) and therefore the time remaining for a phase cannot be guaranteed, unless a specific interval is added as part of the clearance time (i.e. an interval of prescribed time at the end of the green phase). The drawback is that the signal operation will lose some of its adaptability and efficiency due to a lag time being incorporated in the clearance intervals.

Figure 6.3: Phase intervals

The other possibility is to use mathematical calculations to calculate the time remaining for a phase. However, this would need to be investigated fully. The issue of providing advance warning of signal change is discussed further in Section 6.3.

As this section of the report is focused on the integration of C-ITS with traffic signals via the 5.9 GHz band and 5.9 ITS stations, the interoperability between the following units is discussed below:

- 5.9 roadside ITS station to process and generate a 5.9 ITS message (field)
- local traffic signal controller (field)
- back office (centre)
- 5.9 ITS in-vehicle device (vehicle).

A schematic of the possible integrations between these units that would be required to achieve interoperability across the four levels is shown in Figure 6.4. Figure 6.4 and the following sections are written in the context of a 5.9 ITS device integrated with SCATS traffic signals. As STREAMS utilises a field processor at every controller it may be possible to connect the 5.9 roadside ITS station with the field processor, and modify the FP and operating system to suit.
The integrations required to achieve interoperability with traffic signals across the four interoperability levels are discussed in Section 6.1 through to Section 6.4. For each level the section discusses what is required to achieve interoperability in order to:

- relay traffic signal phasing and timing data (SPaT) and MAP data messages into the vehicle
  - as part of providing ETSI use cases UC010: Signal violation warning

- collect anonymous data from C-ITS equipped vehicles
  - with respect to the operation of the traffic signals (e.g. feedback on traffic delay at an approach to a traffic signal)
  - for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with traffic signals and for the purpose of general traveller data collection)

- provide signal pre-emption for priority vehicles.

With respect to the last two dot points anonymous data from 5.9 ITS equipped vehicles could be used for traffic signal priority measures for specific vehicle classes. Road agencies have current systems in place to cater for signal priority measures (including pre-emption) for public transport vehicles and emergency vehicles. Signal priority for these users is better implemented through a central system that tracks the priority vehicles through the network and sends messages to the appropriate traffic signals as the priority vehicle approaches. This allows the system to incorporate the priority into the overall signal operation and therefore minimise disruption to the overall system. For this reason, road agencies are implementing centrally based priority systems such as SmartBus in Victoria and emergency vehicle pre-emption in STREAMS in Queensland.
Figure 6.4: Possible integration between 5.9 ITS roadside equipment and the local traffic signal controller (TSC4)

Notes:
- This figure shows the possible integrations between the 5.9 ITS equipped vehicle and ITS infrastructure. It is noted that the actual data messages, network protocols and media protocols between vehicles, field and centres may differ from that outlined in this diagram. For example:
  - the field infrastructure may translate 5.9 ITS messages from the vehicle into DATEX2 for transmission back to the centre or translate the 5.9 ITS message directly back to the centre
  - Wave Short Message Protocol (WSMP), Fast Network and Transport Layer Protocol (FNTP) or IPv6 may be used as the network protocol for field-to-vehicle and vehicle-to-field communications
  - the media protocol for centre-to-field communication may not necessarily be Ethernet but could be other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP).
- Mapping input functionality may not be available in every vehicle.
- An integrated vehicle system may not have direct connection between the ITS-S and the HMI. The HMI would be controlled by the vehicle system. If it is a retrofit then the HMI may not be integrated and there could be several HMIs.

The following discussion focuses on the data required in order to provide signal priority to heavy vehicles; however, if desired signal priority could be applied to other vehicle classes for which road agencies wish to assign priority. This includes detection, through V2I 5.9 ITS communications, of heavy vehicles:
- approaching an intersection and therefore adjusting signal timings (traffic signal pre-emption and/or priority) under certain business rules in order to aid their progression. Such a project is proposed to be trialled as part of the Transport for NSW Cooperative ITS Initiative (CITI) project
- trying to clear an intersection and adjusting signal timings where a heavy vehicle is detected still trying to clear the intersection when the opposing phase is about to commence.
Data from 5.9 ITS could also be used for queue detection estimates and upstream detection, both of which could be utilised to monitor and influence operations. Queue estimates would need to be based on 5.9 ITS vehicle location data received in conjunction with mathematical calculations and data from upstream traffic signal detectors.

Time taken to proceed through and clear an intersection could be obtained from the 5.9 ITS data and monitored in order to identify intersections requiring a review of traffic signal timings and phasing.

In consideration of the above discussion, it is noted that the greater the penetration of 5.9 ITS equipped vehicles in the vehicle fleet, the greater the potential for the use of 5.9 ITS data in the operation of the traffic signals. Therefore, some of the concepts discussed above could not only be implemented at an influencing and review level but at a control level also. For example knowledge of queue lengths and approaching platoons through 5.9 ITS data could be used as an input in the operation of the traffic signals. Advanced knowledge of approaching vehicles through 5.9 ITS data would provide greater lead time and allow the adaptive traffic signal control system to better calculate the required remaining green time for optimal operation and therefore provide more signal phasing and timing data.

5.9 roadside ITS stations are multifunctional. That is, where required, they should be able to integrate with multiple roadside ITS infrastructure, including traffic signals as outlined in this section of the report, and also be able to be used to collect data for ITS station equipped vehicles (i.e. probe data) as outlined in Section 5 of this report.

A table summarising the findings of Section 6.1 through to Section 6.6 is contained in Appendix G.

6.1 Technical Interoperability

Technical interoperability covers the hardware/software of systems and platforms that enable machine-to-machine communication to take place. The technical integrations required from a field-to-field, field-to-vehicle (and vice versa) and field-to-centre perspective are outlined below.

6.1.1 Field-to-field

In order to achieve technical interoperability from a field-to-field perspective will require the following elements:

- Local traffic signal controller integrated with a 5.9 roadside ITS station
  - the actual connection to the signal controller as part of the broader traffic signal control can be undertaken via one of the serial ports (i.e. RS422 or RS485) available in TSC4 utilising a fibre connection
  - the 5.9 roadside ITS station would need to be mounted on existing structures or posts such as signal mast arms or pedestals.

- Software to convert the signal phasing and timing (SPaT) data extracted from the local signal controller into a format that can be sent to a 5.9 ITS equipped vehicle
  - modifications to the TRAFF software (modifications to the TRAFF software may not be required where a field processor is used such as in the case for STREAMS as outlined in Section 6) to extract the relevant data from the local traffic signal controller in order for the 5.9 roadside ITS station to convert the data into a 5.9 ITS SPaT message
  - 5.9 roadside ITS station with software to convert the TRAFF output to a 5.9 ITS message for broadcast to the vehicle and to receive anonymous data from equipped vehicles for use in signal operations (e.g. signal optimisation using queue estimation) or for general data collection
  - the 5.9 roadside ITS station would utilise a pre-programmed intersection map (which should also contain the speed limit for the approaches) in which it can assign signal state data extracted from TRAFF to lanes designated on the map.
**Access technology**  
The access technologies required to achieve the aforementioned integration are an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections.

**Network protocols**  
SPaT data would be communicated from the local traffic signal controller to the 5.9 roadside ITS station using defined network protocols such as IPv6.

### 6.1.2 Field-to-vehicle and Vice Versa
In order to achieve technical interoperability from a field-to-vehicle perspective will require the following elements:

- 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station via the 5.9 GHz band  
  - once the vehicle receives a standardised message, as governed by SAE J2735 and/or the European CAM, the vehicle will utilise the message in the vehicle as dictated by C-ITS standards being developed in addition to added features provided by the vehicle OEM

- 5.9 in-vehicle ITS station communicating with a 5.9 roadside ITS station for the purpose of data collection and input to signal operations

- ability to process data received locally and if required generate a message to be broadcast locally.

**Access technology**  
The access technologies required to achieve the aforementioned integration are 5.9 DSRC via the media protocol of IEEE 802.11p in the USA or ITS G5 in Europe.

**Network protocols**  
C-ITS messages between 5.9 roadside ITS stations and 5.9 in-vehicle ITS stations may utilise network protocols such as IPv6, Wave Short Message Protocol (WSMP) or Fast Networking and Transport Layer Protocol (FNTP) for data exchange. Both WSMP and FNTP are designed for ITS station application processes with severe time constraints and low latency requirements. FNTP uses MAC addresses of access technologies for identifying nodes in the network. Further to this GeoNetworking may be required to identify geographic targets areas within which ITS stations should receive a C-ITS message.

### 6.1.3 Field-to-centre
In order to achieve technical interoperability from a field-to-centre perspective will require the following elements:

- software within the 5.9 roadside ITS station to process data and determine what to send to the back office

- connection to back office systems in order to communicate supplementary information regarding either the signal operation or miscellaneous information and to send data obtained from the 5.9 ITS equipped vehicle to the back office for processing (e.g. traveller data collection)
  - investigations would need to be undertaken to determine if vehicle probe data could be relayed back through the signal architecture or whether probe data would need to be sent to the back office via other communications means such as 3G or 4G.

**Access technology**  
The aforementioned integration will require a networking media protocol standard which can provide a connection between the 5.9 roadside ITS station and the back office using communication technologies suitable for non-local communications. This may be achieved through the Ethernet or other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP). Depending on the site fixed line communications (e.g. optic fibre) or wide area communications (such as 3G and 4G) may be utilised.

**Network protocols**  
Messages exchanged between the 5.9 roadside ITS station and the back office may utilise network protocol IPv6.
6.2 Syntactical Interoperability

Syntactical interoperability addresses the agreed data formats of communication so that machine-to-machine communication can be processed and understood by each machine.

To achieve syntactical interoperability with traffic signals at the roadside requires integrations at the following three levels:

- field-to-field (5.9 roadside ITS station to traffic signal roadside infrastructure)
- field-to-vehicle and vice versa (5.9 roadside ITS station to 5.9 in-vehicle ITS station)
- field-to-centre (5.9 roadside ITS station to back office). These integrations are discussed in further detail below.

6.2.1 Field-to-field

To achieve syntactical interoperability between the local traffic signal controller and the 5.9 roadside ITS station will require Signal Phasing and Timing (SPaT) data to be extracted from the traffic signal controller and sent in real time at millisecond frequency. The SPaT message will comprise various data elements which will need to be obtained from the traffic signal controller. Standards will define the SPaT data elements, which ISO is in the process of drafting with preliminary versions prepared (ISO/PDTS – PDTS number not yet assigned at the time of writing). This will include signal state (e.g. green) and time remaining for the signal state. ISO is also drafting a standard outlining the performance requirements of a cooperative intersection signal information and violation warning system (ISO/CD 26684).

Further, ISO 10711-2012 (Intelligent transport systems ‒ Interface Protocol and Message Set Definition between Traffic Signal Controllers and Detectors) which defines protocols and message sets between traffic detectors and traffic signal controllers may have relevance if using C-ITS data as input into traffic signal operations.

The National Transportation Communications for ITS Protocol (NTCIP) which is a USA standard or the DATEX2 European standard may also be relevant in this regard.

Australia and New Zealand will need to monitor the development of these standards and implement the required changes to the traffic signal system such that the functionality required of these standards can be catered for in order for C-ITS integration with traffic signals to be achieved.

6.2.2 Field-to-vehicle

The agreed 5.9 ITS message format for both the signal phasing and timing (SPaT) and map data will emerge through standards such as the following draft ISO standards as identified at the time of writing:

- ISO/CD 26684: Intelligent transport systems – Cooperative Intersection signal information and violation Warning Systems (CIWS) – Performance requirements and test procedures
- ISO/PDTS (PDTS number not assigned at the time of writing): Intelligent transport systems (ITS) – Co-operative systems – Map data, Intersection topology, SPaT Signal Phase and Timing.

The USA’s RSA (SAE J2735) (Research and Innovative Technology Administration 2009) and European CAM (European Telecommunications Standards Institute 2011) and DENM (European Telecommunications Standards Institute 2010b) message standards will likely define the message standard with efforts in place to harmonise these message standards. In addition consideration may need to be given to in vehicle information (IVI) and the standards to be developed with respect to this. The IVI message set standard will aim to establish a standard message set that will provide information to vehicles that is related to their travel. As outlined in Section 2.5, an IVI standard with is proposed to be developed as part of the ‘Release 1’ standards.
The Intersection map data will be needed where SPaT information would be different for the vehicles approaching the intersection, depending on their proposed movement and/or lane allocation (e.g. right-turn lane). In these circumstances intersection map data will need to be sent to the approaching vehicle. Once the map data is sent, SPaT data can be sent 10 times per second for updating on the map. The map data elements will need to be defined. ISO is in the process of drafting a standard outlining the data elements of the map data for the intersection, with preliminary versions prepared (ISO/PDTS – PDTS number not yet assigned at the time of writing).

In addition, the SRM and SSM message sets may also be applicable. As outlined in Section 2.5 the SRM is sent by an in-vehicle 5.9 ITS unit to a 5.9 roadside ITS station at a signalised intersection (or central system). It is used for either a priority signal request or a pre-emption signal request depending on the way the message flag is set. In either case, the vehicle identifies itself, its current speed, heading and location, and makes a specific request for service as well as an anticipated time of service. The SSM on the other hand is sent by a 5.9 roadside ITS station at a signalised intersection (or central system). It is used to relate the current signal status of the signal and any collection of pending or active pre-emption or priority events acknowledged by the controller. The data contained in this message allows other users to determine their ‘ranking’ for any request they have made.

6.2.3 Field-to-centre
Field-to-centre communications will need to be undertaken through network protocols such as NTCIP (USA) or DATEX2 (European), RTA protocols or other protocols used by the road agency.

For input into traffic signal operations and general data collection purposes, the 5.9 ITS device will receive a basic safety message and probe data message from the vehicle with the standardised content.

6.3 Semantic Interoperability
Semantic interoperability refers to the need to interpret the messages being communicated, to enable them to be understood and used appropriately.

Semantic interoperability needs to be achieved with respect to the 5.9 roadside ITS station message to the vehicle in addition to the 5.9 in-vehicle ITS station’s message to the roadside. Standards will define the 5.9 roadside ITS station message and the 5.9 in-vehicle ITS station’s message set.

Bodies including the International Organisation for Standardisation (ISO) are currently working on defining a standard list of data elements for the SPaT message. This includes elements to identify the intersection; define the layout of the intersection including details of the approaches, departures, lanes and coordinates etc.; and know the overall status of the intersection including movement status and timing information. The data elements are defined across the two categories of SPaT and map data. These are discussed below along with data collection elements.

6.3.1 Signal Phase and Timing
RMS is currently exploring how to extract SPaT data from SCATS for both the purposes of the ISO working groups and for use in the Cooperative Intelligent Transport Initiative (CITI) project based in the Illawarra region of New South Wales. The CITI project is the first proposed C-ITS pilot testbed in Australia located on a 42 km route from southwest Sydney to Port Kembla in the Illawarra. The pilot will initially be focused on heavy vehicles and will involve providing signal phase and timing information. The trial will run for a minimum of four years and is closely aligned with the US DOT testbeds. Investigations by RMS have shown that both phasing and the estimated time to phase end can be extracted from SCATS and converted into the appropriate message format. Due to the adaptive nature of SCATS (i.e. the tactical control element) the actual time remaining for a phase cannot be guaranteed. However, as mentioned earlier, it is possible that this may be overcome through the use of mathematical calculations.

Transmax on behalf of Queensland TMR will need to modify the STREAMS field processor in the field and the STREAMS operating system to enable SPaT data to be sent from the field processor to the vehicle via a 5.9 roadside ITS station.
Maile et al. (2008) outlined that for traffic signals where the time to the next red phase is not known (e.g. traffic actuated signals, adaptive signals) a vehicle will not warn the driver until a reasonable level of confidence in the time remaining is achieved. Maile et al. (2008) noted that the warning deadline relative to the stop line is defined by Equation 1:

$$t_{\text{crit}} = t_{\text{react}} + \frac{v_i}{2a_{\text{lim}}}$$

where

- $t_{\text{react}}$ = reaction time
- $v_i$ = initial velocity
- $a_{\text{lim}}$ = deceleration limit

Maile et al. (2008) used a reaction time of 0.8 seconds and deceleration limit of 5.0 m/s$^2$. For initial velocity or speed limits ranging from 40 km/h to 80 km/h, this equates to a critical time of 1.9 to 3.0 seconds. This is within the minimum yellow time as specified by Austroads (2009c). Following the Austroads (2009c) guidelines, this suggests that in order to provide red signal violation warnings remaining green time might not be required but rather remaining yellow. Yellow times are prescribed and could be extracted from TRAFF.

### 6.3.2 Map Data

Maile and Delgrossi (2009) outlined that the 5.9 roadside ITS station will need to send the map to an approaching vehicle, if the vehicle does not have a map of the intersection stored. As such this could apply to each intersection where SPaT data is to be sent and map data is required in order to use the SPaT data. As such the map data message will need to be kept small so that it can be packaged within a message.

For example in the USA it is proposed to keep the map data message to 1.4 Kbytes, as specified in IEEE 802.11p, in order that it can be packaged within a wave short message packet. Of the 1.4 Kbytes, 400 bytes are assigned for security purposes, leaving 1 Kbyte for a small map. Based on this, Maile and Delgrossi (2009) outlined that the intersection map should contain the following features:

- sufficiently accurate road/lane geometry for all lanes/approach roads
- intersection identification
- stop bar locations for all lanes
- an intersection reference point
- lane widths for all the lanes
- correspondence between lane and traffic signals applying to the lane.

In order to keep the intersection map small, Maile and Delgrossi (2009) outlined that the intersection map should only incorporate the following features and exclude others:

- all the points that are used to describe the geometry are described as distance from an intersection reference point
- all roads/lanes are described as an ordered set of geometry points together with the lane width at each point
- lane geometry as described by specifying the centerline of the lane
- stop bar location for each lane as the first geometry point for the lane
- lane geometries out to a distance of 300 m from the intersection
- outgoing lanes are optional but can be included, if necessary.
The map data may be stored in the 5.9 roadside ITS station or in the signal field processor (FP) in the case of Queensland where FPs are used for STREAMS-operated signal controllers. The map data would be same unless there is change to the intersection layout. If the intersection is changed then the intersection map data as stored in the 5.9 roadside ITS station will also need to be modified, which will require a change to the management process.

6.3.3 Data Collection
The 5.9 roadside ITS station may be used to collect anonymous data from equipped vehicles for the purpose of influencing the operation of the traffic signals, for general data collection or for localised processing and broadcasting of messages. Data collection as part of traveller data collection is discussed in Section 5. However in order that data can be used for signal operations it would need to meet semantic requirements such that the signal controller can know where the vehicle is located in relation to the intersection both with respect to time and location. This is in order that the inputs may be used for signal control. This will require vehicle type identifiers in order to assign priority along with time (in UTC format) and date identifiers and latitude and longitude identifiers. Other identifiers would include segment number and heading as identified in Table 5.2.

6.4 Organisational Interoperability
Organisational interoperability refers to the ability of organisations to exchange data across systems which will require a level of consistency with business processes (and architectural approaches). Success is also dependent on the level of technical, syntactical and semantic interoperability achieved. Some of the aspects that need to be considered in order to achieve organisation interoperability are as follows:

- Road agencies will need to be responsible for complying with the applicable licensing conditions overriding the use of 5.9 roadside ITS stations and certifying the devices against the required standards (the issue of certification is discussed further in Section 8.2.3). This will include registering and controlling their use and ensuring their operation is in accordance with the licence conditions.
- Road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations. This may require modifications to their asset management processes, as they will need to be able to detect faults and/or outages associated with the 5.9 roadside ITS station.
- Road agencies will need to ensure that adequate rules and systems are in place to ensure that the 5.9 roadside ITS station can fail safely in the event of a fault or outage.
- Road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. map data). This may require modifications to business processes and databases.
- Road agencies will need to monitor international developments and standards with respect to security and ensure that processes are adopted to ensure that messages sent by either the 5.9 in-vehicle ITS station and 5.9 roadside ITS station can be identified as being authentic and therefore trusted for use. This is discussed further in Section 8.2.2.
- In some cases retrofitting existing traffic signals with 5.9 roadside ITS stations may pose issues with contracts for the supply, maintenance and warranty of components. Road agencies may find it more viable to adopt a modular approach where 5.9 ITS can be retrofitted to traffic signals as part of a supply contract, rather than retrofitting into an existing system. Alternatively, there may be scope for local traffic signal controller suppliers to incorporate 5.9 ITS units into the controller if they can overcome issues around the supply and certification of the 5.9 ITS units.
- If required, road agencies will need to ensure system architecture is able to accommodate the communication of data to a back office for processing and the communication of additional information that road agencies may wish to communicate to vehicles using the 5.9 roadside ITS station integrated with the traffic signal.
- Road agencies will be responsible for the specifications around the delivery of traffic signal information through internationally standardised messages utilising internationally agreed terminology. Vendors or suppliers will be responsible for the supply of the message under contract with the road agency.
While standards may be developed around how vehicle manufacturers will utilise 5.9 ITS messages within the vehicle, it is envisaged that there may be differences in the human machine interface of various manufacturers and that they may offer value-added services. Road agencies should maintain an interest in how various vehicle manufacturers are using 5.9 ITS messages.

Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation. The National Transport Commission (2013) paper provides guidance on this as discussed further in Section 8.2.1.

Road agencies may need to establish processes to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users.

Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data. This is discussed further in Section 8.2.5.

### 6.5 Benefits

The benefits associated with integrating 5.9 ITS with traffic signals include:

- improving traffic signal compliance and therefore improving safety through providing a vehicle with traffic signal information
- more environmentally friendly and efficient driving through providing a vehicle with traffic signal information
- enabling more productive traffic signals through providing the traffic signals and back office with data from equipped vehicles (including designated priority vehicles) which could be used in the signal operation and/or review of signal operations
- aiding better driver decisions through providing the ability to enhance information about the traffic signals along with providing broader traveller information.

Further, integrating 5.9 ITS with traffic signals in order to provide traffic signal priority measures for specialised user groups such as heavy vehicles may provide a means of realising some 5.9 ITS benefits without requiring a broad uptake of in-vehicle 5.9 ITS devices amongst the general fleet.

### 6.6 Risks

The risks associated with integrating 5.9 ITS with traffic signals include:

- provision of SPaT data from ATC systems not being feasible, or alternatively requiring limitations to some of the adaptive functionality of ATC systems in order for SPaT data to be accommodated.
- the need for road agencies to manage the issue of temporary lane closures with respect to the provision of maps of the intersections for use with the SPaT data
- misuse of phasing information (e.g. drivers speeding up on the approach to traffic signals or jumping the red as a result of the provision of signal phasing information)
- drivers becoming dependent on the technology and not understanding that the traffic signal remains the regulatory device; this could pose issues where
  - traffic signals are not equipped
  - where equipped, the 5.9 roadside ITS station is not functioning
  - where equipped, the 5.9 roadside ITS station issues a conflicting message (the implications of SPaT data transmitted to vehicles being wrong are potentially very significant with the system needing to be designed to be fail-safe, not just fault tolerant)
  - the 5.9 roadside ITS station issuing an incorrect message and/or the vehicle computer processing the message incorrectly
- it may result in required modifications to existing architecture in order to facilitate some functionality (e.g. communicate data collected from probe vehicles for use in back office systems)
- emergence of other technologies that results in 5.9 ITS roadside technology becoming redundant and a legacy issue for road agencies
- risks associated with how private companies may utilise C-ITS data that it is given access to
- the potential that integrating traffic signals with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.

The aforementioned risks will need to be considered in the context of its development, deployment and operation and appropriately mitigated.
7. Traveller Information Systems

C-ITS can be used to provide information to drivers in order to assist in their driving task. The type of information currently accessed by users includes but is not limited to:

- current traffic alerts, traffic conditions (e.g. congestion and traffic flow information) and road conditions including road closures due to weather events that may affect the road network (e.g. flooding, high winds, fires)
- information on current roadworks
- information on special events (e.g. sporting events)
- images from web cameras located on different parts of the road network
- travel information regarding other modes of transport
- travel time predictions for various routes
- route choice information and suggested routes.

Currently, traveller information is accessed by drivers through pre-drive systems, such as the internet, TV and radio, and through in-drive systems, such as variable message signs (VMS), radio and vehicle telematics applications. Examples of traveller information systems currently in use by road agencies are shown in Figure 7.1.

![Figure 7.1: Example of traveller information systems](source)

Road agencies manage various traveller information systems such as variable message signs (VMS), drive time boards, websites etc. Road agencies also provide raw data to private service providers which then manipulate the data and add value to it before providing it to the end user. The information value chain is shown in Figure 7.2.
Figure 7.2: Information value chain

<table>
<thead>
<tr>
<th>Content Segment</th>
<th>Delivery Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Info / Event</td>
<td>End User</td>
</tr>
<tr>
<td>Content detection</td>
<td>Service presentation</td>
</tr>
<tr>
<td>Content processing</td>
<td></td>
</tr>
<tr>
<td>Service provision</td>
<td></td>
</tr>
</tbody>
</table>


Figure 7.3 provides an example of an information value chain in action through highlighting the steps involved in providing road and traffic information data to a third party which can then add value to it before providing traveller information and route-choice information to a driver through their navigation device.

Figure 7.3: Example of traveller information being delivered to drivers through navigation devices

Notes:
TMC in this figure refers to traffic message channel. TMC is outlined in further detail in the text following this figure.
TMC-LT in this figure refers to TMC location table. LT is outlined in further detail in the text following this figure.
Source: Land Transport Authority (n.d.).

Where data is provided to private service providers, they are able to add value to the data and transform the raw data to valuable information that a consumer may purchase. This is reflected in Figure 7.4.
With the emergence of C-ITS, road agencies will need to determine their role in the data supply and information value chain. Road agencies will need to determine when it should be a content supplier, and when it should be a service provider to the end user. This should be done in consultation with key stakeholders in the value chain.

Data sources the private service providers may use could include:

- road agency vehicle detectors installed at traffic lights and along freeways, motorways or arterial roads
- probe vehicle data, which includes GPS-equipped vehicles, cellular-equipped vehicles and smart phone data
- road agency incident monitoring systems
- road agency traffic management centre operations including CCTV cameras, tow truck allocation systems and roadwork permit registries.

Private service providers currently supply traveller information via wide-area broadcast to navigation devices, smartphone applications or via radio news services. The format of the information may include the:

- XML-TMC service: traffic information encoded to the international traffic message channel (TMC) standard using the extensible markup language format
- RDS-TMC: traffic information encoded to the international TMC standard using the radio data service (RDS) format.

The TMC standard is used in Australia because it is low bandwidth and can be broadcast over FM frequency with good urban coverage. Internationally there is a move to adopt the Transport Protocol Expert Group (TPEG) standard because it enables more attributes, but requires higher bandwidth and thus cannot be broadcast using FM.

TPEG is commonly broadcast on digital radio in Europe. Auto manufacturers are moving towards the provision of TPEG services in Australia by 2014 through the use of broadcast and cellular (IP) communications. It is noted that Australia does not currently have wide digital radio coverage and that this is an issue that could benefit from working with both industry and government to address.
It is noted that smart dashboard applications are emerging. These applications can be characterised as specific purpose connected applications that are integrated with the vehicle dashboard systems. Under this model, the OEM/service provider ecosystem is tightly coupled using a proprietary data exchange regime, allowing flexibility and rapid adaptability. This approach will support location-aware traveller information displays integrated in the vehicle human machine interface (HMI) that can evolve to support content that can be usefully integrated.

The objectives of providing traveller information range from maximising safety, traffic efficiency and productivity of the road network, to reducing environmental impacts and providing enhanced services to road users. C-ITS has the ability to enhance the information available to road users while driving and therefore enhance the ability to achieve these objectives.

The provision of road agency issued traveller information via C-ITS aligns with the following ETSI applications:

- UC011: Roadwork warning: provides roadwork information to vehicles via roadside infrastructure
- UC020: Traffic information and recommended itinerary: provides information to vehicles of abnormal conditions and issues recommendations via roadside infrastructure
- UC022: Limited access warning and detour notification: warns the driver of limited access or restriction requirements
- UC023: In-vehicle signage: provides access to variable message sign (VMS) messages in the vehicle.

In addition, there is the ETSI use case UC021: Enhanced route guidance and navigation; however, this would likely remain the domain of the private service provider, with road agencies potentially being a source of data.

The messages addressed by these ETSI use cases are currently delivered via temporary and/or fixed VMS and/or static signage.

As with the ESL/VSL and traveller data collection systems, there is potential to provide traveller information to C-ITS equipped vehicles through cellular communications, radio broadcast and 5.9 ITS. This is discussed further in Section 8.1. However, the focus of this section of the report is on integrating 5.9 ITS with traveller information systems at the roadside level through the integration with VMS (as part of the traveller information system). This is because VMS is an existing ITS (the main focus of this report is on 5.9 ITS integration with existing ITS) with available power and communications to facilitate the installation of a 5.9 roadside ITS station.

The following sections discuss the interoperability issues associated with traveller information systems and with the following units:

- 5.9 ITS roadside unit
- back office
- variable message signs (VMS)
- 5.9 ITS in-vehicle device.

A schematic of the possible integrations between these units that would be required to achieve interoperability across the four levels is shown in Figure 7.5. It is noted that the principles for the integration with VMS for traveller information can also be applied to dynamic warning messages delivered via VMS (such as over-height warnings, roadworks, over-speed warnings etc.). The following sections will provide details on what is required to achieve interoperability with traveller information systems across the four interoperability levels of technical, syntactical, semantic and organisational.
Figure 7.5: Possible integration between 5.9 roadside ITS equipment and variable message signs, as part of the traveller information system

Notes:

- This figure shows the possible integrations between the 5.9 ITS equipped vehicle and ITS infrastructure. It is noted that the actual data messages, network protocols and media protocols between vehicles, field and centres may differ from that outlined in this diagram. For example:
  - the field infrastructure may translate 5.9 ITS messages from the vehicle into DATEX2 for transmission back to the centre or translate the 5.9 ITS message directly back to the centre
  - Wave Short Message Protocol (WSMP), Fast Network and Transport Layer Protocol (FNTP) or IPv6 may be used as the network protocol for field-to-vehicle and vehicle-to-field communications
  - the media protocol for centre-to-field communication may not necessarily be Ethernet but could be other media protocols such as point-to-point protocol (PPP) or point-to-multi-point protocol (PMPP).
- Mapping input functionality may not be available in every vehicle.
- An integrated vehicle system may not have direct connection between the ITS-S and the HMI. The HMI would be controlled by the vehicle system. If it is a retrofit then the HMI may not be integrated and there could be several HMIs.
A discussion on the integrations required to achieve interoperability with VMS across the four interoperability levels is discussed in Section 7.1 through to Section 7.4. For each level the section discusses what is required to achieve interoperability in order to:

- communicate VMS messages to C-ITS equipped vehicles
- collect anonymous data from C-ITS equipped vehicles
  - relative to the operation of the VMS (e.g. if drivers respond to a VMS advice)
  - for general data collection (utilising the 5.9 roadside ITS station both for the purpose of integrating with traveller information systems and for the purpose of general traveller data collection – refer to Section 5).

5.9 roadside ITS stations are multifunctional. That is, where required, they should be able to integrate with multiple roadside ITS infrastructure, including ESL/VSL as outlined in this section, and also be able to be used to collect data for ITS-station-equipped vehicles (i.e. probe data) as outlined in Section 5.

A table summarising the findings of Section 7.1 through to Section 7.6 is contained in Appendix G.

While the following sections focus on 5.9 roadside ITS stations being integrated with VMS at the roadside in order to deliver traveller information, consideration should also be given to the distribution of traveller information via cellular based communications and the emerging connected vehicle ecosystem.

### 7.1 Technical Interoperability

Technical interoperability covers the hardware/software of systems and platforms that enable machine-to-machine communication to take place. The technical integrations required from a field-to-field, field-to-vehicle and field-to-centre perspective are outlined below.

#### 7.1.1 Field-to-field

To achieve technical interoperability from a field-to-field perspective will require the following elements:

- 5.9 ITS installed in the field at the VMS to provide access to power communications and potential access to the a sign status reply message from the VMS sign controller if required (Note: Access to the sign status reply message would only be required in order to communicate the content of the VMS without the traffic management centre managing 5.9 ITS message content. Where the traffic management centre provides 5.9 ITS message content, systems would need to be in place to ensure contradictory messages are not communicated.)
  - a mount for the 5.9 roadside ITS station (this may be on the existing VMS or a separate mount such as a pole).

**Access technology**

The access technologies required to achieve the aforementioned integration are an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections.

**Network protocols**

Traveller information would be communicated from the in-field infrastructure to the 5.9 roadside ITS station using defined network protocols such as IPv6.
7.1.2 Field-to-vehicle
To achieve technical interoperability from a field-to-vehicle perspective will require the following elements:

- 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station via the 5.9 GHz band in order to:
  - communicate the VMS content (additional information may be communicated as outlined in the dot point below) to a 5.9 in-vehicle ITS station. This would require a connection to the sign status reply message and software used to convert the message protocol sent to the sign controller to a 5.9 ITS message that can be sent to the vehicle
  - communicate additional traveller information to a 5.9 in-vehicle ITS station. This would require a connection to an ESL/VSL field processor or similar device such that a message generated from a traffic management centre can be communicated to the 5.9 roadside ITS station

- software to convert the content of the messages received by the 5.9 roadside ITS station into a format that can be sent to a 5.9 ITS equipped vehicle for use in 5.9 ITS operation. Alternative scenarios include:
  - the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format
  - where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station

- the ability to process data received locally and if required generate a message to be broadcast locally.

Access technology
The access technologies required to achieve the aforementioned integration are 5.9 DSRC via the media protocol of IEEE 802.11p in the USA or ITS G5 in Europe.

Network protocols
C-ITS messages between 5.9 roadside ITS stations and 5.9 in-vehicle ITS stations may utilise a network protocol for the data exchange such as IPv6, Wave Short Message Protocol (WSMP) or Fast Networking and Transport Layer Protocol (FNTP). Both WSMP and FNTP are designed for ITS station application processes with severe time constraints and low latency requirements. FNTP uses MAC addresses of access technologies for identifying nodes in the network. GeoNetworking may be required to identify geographic target areas within which ITS stations should receive a C-ITS message.

7.1.3 Field-to-centre
To achieve technical interoperability from a field-to-centre perspective will require the following elements:

- connection to back office systems to communicate supplementary information regarding the response of the 5.9 ITS equipped vehicle to the message and other traveller data (e.g. driver response to a message such as a decision to take a route as a result of receiving a traveller information message with respect to the route choices provided through 5.9 ITS)

- a 5.9 roadside ITS station to process data received locally and to send data back to the back office for further processing.

Access technology
To achieve the aforementioned integration will require a networking media protocol standard which can provide a connection between the 5.9 roadside ITS station and the back office using communication technologies suitable for non-local communications. This may be achieved through the Ethernet or other media protocols such as point-to-point protocol (PPP) or point-to-multi point protocol (PMPP). Depending on the site fixed line communications (e.g. optic fibre) or wide area communications (such as 3G and 4G) may be utilised.

Network protocols
Messages exchanged between the 5.9 roadside ITS station and the back office may utilise network protocol IPv6.
7.2 Syntactical Interoperability

Syntactical interoperability addresses the agreed data formats of communication so that machine-to-machine communication can be processed and understood by each machine.

To achieve syntactical interoperability with VMS at the roadside requires integrations at the following three levels:

- field-to-field (5.9 roadside ITS station to VMS roadside infrastructure)
- field-to-vehicle (5.9 roadside ITS station to 5.9 in-vehicle ITS station)
- field-to-centre (5.9 roadside ITS station to back office).

These integrations are discussed in further detail below.

7.2.1 Field-to-field

VMS signs utilise a message protocol which outlines the display on the VMS. As the VMS can display various messages, the message sent to the sign controller is either in a text string or bitmap format. In order to communicate a VMS message to a vehicle via 5.9 ITS, software will need to be installed in the 5.9 roadside ITS station to convert the VMS bitmap or text string message to the agreed 5.9 ITS message format. Indications suggest that this will likely be in the IVI and DENM. Alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format. Where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station.

Supplementary messages will either need to be sent to the 5.9 roadside ITS station in the agreed message format, or software in the station will need to convert the message. Given that the message will be generated by alternative systems to those used for communicating messages to a VMS, it is envisaged that the preferred approach would be for messages to be prepared in the 5.9 ITS message format at the time of their creation.

7.2.2 Field-to-vehicle

The agreed 5.9 ITS message format that will be used to send 5.9 ITS messages from the 5.9 roadside ITS station to the 5.9 in-vehicle ITS station will emerge through standards such as the USA’s SAE J2735 and European CAM and DENM message standards, of which are being harmonised. There may also be C-ITS applications that receive data governed by the Transport Protocol Expert Group (TPEG) protocol or delivered via the In-Vehicle Information (IVI) message format.

Another syntactical interoperability issue is the interface between the vehicle application and the 5.9 roadside ITS station to define elements such as:

- the relevance zone: the zone along the road for the message to be valid
- driver awareness zone: the section of the road prior to the relevance zone for which appropriate messages about the road may be presented
- minimum dissemination area: the area of the road for which the message may be received by a vehicle.

The draft ISO standard, ISO/PDTS 17425: Intelligent transport systems (ITS) – Co-operative ITS – Data exchange specification for in-vehicle presentation of external road and traffic related data will likely be applicable to the integration with traveller information systems and road agencies should be familiar with its development.
Road agencies will need to transmit data in compliance with agreed international standards (e.g. IVI and DENM) and therefore not create unique data message formats. The format of the message will need to be such that a vehicle is able to use the information content in its various applications including:

- how to present the information to the driver (including making allowance for the driver to select the language in which the information is presented)
- how to prioritise messages based on
  - higher priority primary messages such as
    - immediate danger warning messages
    - regulatory messages
  - lower priority secondary messages such as
    - traffic related information messages
    - pollution messages
    - non-traffic related information messages.

With the evolution of C-ITS and the potential need for enhanced route guidance and traveller navigation information to be provided into the vehicle, there may be a need for road agencies to become more involved with other government and industry stakeholders in the provision of map data and location-table information.

7.2.3 Field-to-centre
Field-to-centre communications will need to be undertaken through network protocols such as NTCIP (USA) or DATEX2 (Europe). Current protocols for VMS and LUMS vary between road agency but include RTA protocol and NTCIP.

For general data collection purposes, the 5.9 ITS device will receive a basic safety message (also referred to as a ‘here I am’ or heartbeat message) and probe data message from the vehicle with the standardised content. This is discussed further in Section 5.

7.3 Semantic Interoperability
Semantic interoperability refers to the need to interpret the messages being communicated, to enable them to be understood and used appropriately.

Semantic interoperability can be achieved through the adoption of the C-ITS message set as being defined by the USA SAE J2735 and European CAM and DENM. For some traveller information services, the adoption of the TPEG protocol may also be beneficial. It is suspected that this will cover a data dictionary and definitions that may apply to traveller information.

Semantic interoperability needs to be achieved with respect to the 5.9 roadside ITS station’s message to the vehicle in addition to the station’s message to the roadside. Standards will define the station’s message and its message set. The message sets will consist of data elements which will all be defined. This will include information regarding the location and zone for which the traveller information applies in addition to the time frame for which it applies. The time format used will be the coordinated universal time (UTC) format.

The supplementary information sent to an ESL/VSL field processor or similar device would be a separate message to that sent to the VMS as it may not have the limitations associated with the VMS content. The actual content of the message would be dependent on the vehicle applications to be developed and how the message content would be used by the vehicle. ETSI has identified use cases that are relevant to this area. It is envisaged that standards will emerge outlining the content of messages broadcast to vehicles from the roadside.

The content of the message will likely also be limited by the packet size of the 5.9 ITS message. As per traffic signals, it is likely that content will need to be limited to 1 Kbyte.
The provision of traveller information may be split between services provided by road agencies and those provided by private service providers. The division of information will depend on the expected role of road agencies in light of the new opportunities 5.9 ITS provides, the benefit-to-cost ratios for road agencies providing traveller information versus its provision by private service providers, in addition to rules governing the use of the 5.9 GHz band.

The 5.9 roadside ITS station may collect anonymous data from probe vehicles both relative to its operation and for general data collection. This is discussed further in Section 5.

Other semantic issues include appropriately identifying the message such that it can be located both with respect to time and location. This will require time (in UTC format) and date identifier in addition to latitude and longitude identifiers. Other identifiers would include segment number and heading as identified in Table 5.2.

### 7.4 Organisational Interoperability

Organisational interoperability refers to the ability of organisations to exchange data across systems which will require a level of consistency with business processes (and architectural approaches). Success is also dependent on the level of technical, syntactical and semantic interoperability achieved. Some of the aspects that need to be considered in order to achieve organisation interoperability are as follows:

- Road agencies will need to be responsible for complying with the applicable licensing conditions overriding the use of 5.9 roadside ITS stations and certifying the devices against the required standards (the issue of certification is discussed further in Section 8.2.3). This will include registering and controlling their use, ensuring their operation is in accordance with the licence conditions, ensuring that their use is consistent with ITS architectural approaches adopted across the road agency, and ensuring that interfaces are established to enable data exchange with legacy systems.

- Road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations. This may require modifications to their asset management processes, as they will need to be able to detect faults and/or outages associated with the 5.9 roadside ITS station.

- Road agencies will need to ensure that adequate rules and systems are in place to ensure that the 5.9 roadside ITS station can fail safely in the event of a fault or outage.

- Road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. DENM, IVI). This may require modifications to business processes and databases.

- Road agencies will need to monitor international developments and standards with respect to security and ensure that processes are adopted so that messages sent by either the 5.9 in-vehicle ITS station and 5.9 roadside ITS station can be identified as being authentic and therefore trusted for use. This is discussed further in Section 8.2.2.

- Retrofitting existing VMS with 5.9 roadside ITS stations may pose contractual issues for the supply, maintenance and warranty of components. Road agencies may find it more viable to wait for the natural rollover of equipment rather than to retrofit an existing system.

- While standards may be developed on how vehicle manufacturers will utilise 5.9 ITS messages within the vehicle, it is envisaged that there may be differences in the human machine interface (HMI) of various manufacturers and they may offer value-added services. Road agencies should maintain an interest in how vehicle manufacturers are using 5.9 ITS messages.

- Road agencies need to determine their role in the supply chain of traveller information.

- Road agencies will need to determine what traveller information they provide via the 5.9 ITS technology versus what traveller information they provide via cellular-based communications and what traveller information private service providers deliver.

- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and complies with any applicable privacy and surveillance legislation. The National Transport Commission (2013) paper provides guidance on this as discussed further in Section 8.2.1.
- Road agencies may need to establish interfaces, processes and agreements to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users.
- Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data. This is discussed further in Section 8.2.5.

### 7.5 Benefits

The benefits associated with providing 5.9 ITS integration with VMS and traveller information systems include:

- the provision of enhanced traveller information for drivers (more information regarding the broader network to aid better route choices)
- the provision of enhanced delivery of information (e.g. timeliness of message and mode of message delivery (e.g. audio of VMS message))
- the ability to influence driver decisions about route choices and other driving behaviour
- the ability to provide more accurate and consistent messages.

The above benefits can aid drivers to make more informed decisions about their driving and route choices resulting in a myriad of benefits spanning across the areas of safety, productivity and efficiency, while providing environmental benefits and road user services.

### 7.6 Risks

The primary risks associated with the integration between 5.9 ITS and traveller information systems are around the provision of conflicting traveller information between sources, incorrect information, and/or no information where drivers and the transport system are reliant on it. As such some level of redundancy and/or fail safe may need to be built into the system.

Other possible risks associated with the integration include:

- vehicles potentially using information relayed to take physical action/control where the message may be intended as a warning message only
- the potential that integrating traveller information systems with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks
- risks associated with how private companies may utilise C-ITS data that it is given access to (e.g. risk that data may not be used in accordance with road agency objectives and principles)
- general risks associated with the provision of traveller information, such as the provision of information that may result in a negative impact on the road network (i.e. vehicles relocating to another route in large numbers to the detriment of that route).

The aforementioned risks will need to be considered in the context of its operation and appropriately mitigated.
8. Discussion

This section provides a discussion on various issues including:

- integration of ITS infrastructure with C-ITS via roadside (5.9 ITS) and cellular communications; while this report focusses on 5.9 ITS integration, the use of cellular communications may be a feasible option to consider for some scenarios
- additional issues associated with integration such as privacy, security, liability, big data, private-public partnerships and trials.

8.1 Interoperability Across Various Communication Media

The C-ITS platforms will use various communication media such as 3G, 4G, WiMax, digital audio broadcasting (DAB), Long Term Evolution (LTE) networks as well as 5.9 GHz DSRC (Figure 2.2).

Vehicle manufacturers are moving towards web-based connectivity in vehicles. This is in response to consumers expecting to access relevant information wherever they are, including in the vehicle. In the next few years (2014 to 2016), it is expected that consumers will consider the vehicle’s ability to access web-based information as a key criterion when purchasing an automobile (Koslowski 2013). Manufacturers will respond to this need by providing web-based connection through cellular communications. Therefore, full interoperability between C-ITS and existing ITS infrastructure using various communication mediums will need to consider the various communication protocols and channels applicable to the various communication media utilised.

5.9 ITS (or 5.9 DSRC) is particularly suited to both V2V and V2I critical safety where low latency of messages is critical. This report primarily focuses on C-ITS integration with existing ITS infrastructure through the use of roadside and in-vehicle ITS stations and the 5.9 GHz band. However it is noted that cellular communications may also be utilised for C-ITS integration with existing ITS infrastructure where low latency is not required for applications deployed in locations where there is sufficient cellular communication coverage to deliver the service adequately. On the other hand a roadside approach via 5.9 ITS has no associated communication cost between the infrastructure and the vehicle and messages from the roadside or integrated infrastructure can be delivered at low latency and with high reliability. The main constraint is that it requires significant investment in order to cater for the deployment of 5.9 ITS units at the roadside.

It is likely that road agencies may use a combination of cellular and 5.9 GHz based approaches, depending on the application, area of service and access to communication infrastructure in that area. Alternatively private telematics service providers may be better placed to deliver some C-ITS services, and road agencies may need to make data accessible to the C-ITS ecosystem. Road agencies would need to consider what content/data needs to be made available, what data protocol/format (e.g. DATEX2) will best enable interoperability with service provider systems, and what agreements might need to be established to enable and support the data access.

Table 8.1 lists perceived benefits and constraints associated with both the roadside (5.9 ITS) and cellular network approaches.
### Table 8.1: Perceived benefits and constraints associated with both the roadside (5.9 ITS) and cellular network approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>Benefits</th>
<th>Constraints</th>
</tr>
</thead>
</table>
| Roadside based communications | - 5.9 GHz communication between the roadside VSL and the equipped vehicle can be undertaken:  
  - at no variable cost (no subscription required)  
  - at low latency (e.g. information as it is currently displayed on the VSL can be communicated to a vehicle)  
  - with all 5.9 ITS equipped vehicles in the dissemination area of the roadside unit (i.e. no network coverage issues)  
  - at just targeted locations where tangible benefits can be achieved (relatively easy to implement as it only requires the integration of 5.9 ITS with individual ITS infrastructure) or where existing communications are available. | - Investments in 5.9 roadside ITS stations are required.  
- Roadside infrastructure may be damaged when needed (e.g. fire).  
- Benefits of the service will be limited to the market uptake of 5.9 ITS in-vehicle devices that are compatible with the service.  
- Coverage would be limited to those locations where 5.9 roadside ITS stations have been installed.  
- The in-vehicle unit will need to integrate information communicated via the roadside with information communicated via cellular-based communications for all ITS integrations where both roadside and cellular-based communications are used. |
| Cellular based communications | - One central system.  
- No need to deploy roadside infrastructure (assuming adequate coverage).  
- Wide-area communication coverage is available in the vast majority of the populated areas.  
- Data could be uploaded as it happens.  
- Not restricted to 5.9 ITS users and therefore wider access to the information is possible by users of existing technology (e.g. web-based mobile phones, smart phones, navigation systems, vehicles with internet connectivity etc.).  
- Vehicles can get network-wide coverage where communication to central systems is available (e.g. urban and populated areas) which could be an advantage for traveller information systems. | - Wide-area communication not available in all areas where information may be required (e.g. some rural areas). In this case satellite communication may need to be considered.  
- Communication cost (this may be incurred by the road agency or user depending on the application). If incurred by the user it could limit the uptake of the technology and therefore limit the achievement of benefits.  
- Management of data and communication costs as road agencies could potentially receive a constant stream of data from a potentially vast number of equipped vehicles via cellular communications direct from the car to the back office.  
- Latency could be an issue depending on the application, therefore restricting its suitability for use. |

From a road agency perspective, the degree to which the roadside approach is used (i.e. 5.9 ITS integrated with existing ITS) will be influenced by the following:

- the need for the particular C-ITS integration with existing ITS infrastructure to have access to the functionality that 5.9 ITS can provide (e.g. low latency communications)
- use of other communication mechanisms (such as 3G and 4G) to connect from a central server to a mobile vehicle rather than from the roadside to the mobile vehicle using 5.9 GHz (i.e. 5.9 ITS); this will be influenced by the market penetration of vehicles equipped with various communication technologies (i.e. 5.9 ITS equipped versus internet connected)
- the role of road agencies in the provision of traveller information
- provision of services by private service providers using cellular-based communication infrastructure rather than road agencies utilising roadside infrastructure
- the cost associated with integrating existing ITS infrastructure with 5.9 roadside ITS infrastructure versus the benefits it achieves
- market demand and market availability for V2I 5.9 ITS applications internationally
- the need to integrate existing ITS infrastructure with 5.9 ITS in order to provide the 5.9 ITS service, to help drive market uptake while the penetration of 5.9 ITS equipped vehicles is low.
8.2 Additional Issues

The integration of 5.9 ITS with existing infrastructure presents various issues to road agencies such as privacy, security, certification, liability, big data, private-public partnerships, field operation tests/trials and location and extent of 5.9 roadside ITS stations. These issues are discussed briefly below.

8.2.1 Privacy

As C-ITS provides the potential to monitor and track vehicle movements, it is critical that the operation of C-ITS complies with the relevant privacy and surveillance legislation.

The National Transport Commission (2013) paper documents the findings of an investigation which explored the regulatory policy issues associated with C-ITS, including investigating privacy issues in detail. The National Transport Commission (2013) paper was endorsed by SCOTI in late 2013 and has been published as a final policy paper. The two key policy findings with respect to privacy as listed in the National Transport Commission (2013) paper are as follows:

1. No changes are recommended to current privacy laws governing the private sector development of C-ITS systems and data. Companies will need to closely follow the National Privacy Principles as required, as they do for C-ITS systems that have already been developed.
2. Privacy concerns represent a potential barrier to the take-up of technology that could significantly improve road safety. Australia should aim for the highest level of privacy protection in the standards set for C-ITS safety systems. This is in keeping with emerging international standards.

Austroads is currently investigating the broader C-ITS operational framework through the development of a concept of operations. This will address privacy. In addition standards related to C-ITS that are emerging internationally, as discussed in Section 2.4, include standards covering access control and privacy. With respect to C-ITS interoperability with existing ITS infrastructure, road agencies should ensure that any integration is undertaken in accordance with any Austroads endorsed operational framework/concept of operation for C-ITS and in accordance with developed standards around privacy.

8.2.2 Security

One of the main security issues with respect to the integration of 5.9 ITS with ITS infrastructure is that the 5.9 ITS unit provides a new interface/wireless access point that could make the integrated ITS infrastructure vulnerable to cyber and/or malicious attacks. In order to mitigate this vulnerability to attack, road agencies in Australia and New Zealand will need to monitor developments internationally and implement appropriate mitigation solutions.

For 5.9 ITS integration with existing ITS, verification of each user’s signal is important for security. This is required to ensure that the 5.9 ITS signal is a legitimate one. With respect to the verification of each user’s signal the following is noted:

- This will likely need to be based on security certificates (similar in concept to those used for websites), with a central authority able to issue these certificates.
- A unique identifier, or collection of identifiers, that can potentially link a vehicle activity to a vehicle registration number needs to be created.
- The system will require some infrastructure to check the credentials of vehicles as they pass and ensure that the data they are providing to the network is correct; this potentially adds risks and hence liability issues in relation to the control and management of the system.

It is noted that there are existing offences under the Telecommunications Act that address interference and the transmission of false information that may be relevant to the security of 5.9 ITS.
Security of 5.9 ITS and C-ITS in general is an international issue and will likely be addressed internationally with Australia and New Zealand adopting harmonised standards and processes. As mentioned in Section 8.2.1, the ‘Release 1’ set of standards will include key standards covering access security. Weimerskirch (2011) outlined the current state and future of V2X security while the EU-US ITS Task Force Standards Harmonization Working Group Harmonization Task Group 1 (2012) has prepared a document outlining the status of ITS security standards.

The security issues will be dependent on the 5.9 ITS application deployed.

8.2.3 Certification

Road agencies will need to ensure that 5.9 roadside ITS stations are certified against the required standards and are licensed as a 5.9 radio communications device and registered for use prior to being integrated with ITS. Certification is important as it aids in ensuring that the unit is capable of functioning in a manner that is expected and that messages received from units can be trusted.

Certification is a broad issue that applies to C-ITS in general rather than just 5.9 roadside ITS stations integrated with the ITS infrastructure. Some of the issues to be considered with respect to certification include determining:

- What type(s) of body(s) will oversee the certification process?
- Who will provide certification services, including defining whether international certification is acceptable for new devices?
- Who will develop the certification requirements, tests and standards?
- Whether a new body is required to undertake product testing and certification or is there an existing body(s) suitable for the task?
- What devices need to be certified?
- What processes and criteria need to be followed?
- When do devices need recertification (i.e. timeframe for retesting)?
- Whether automated monitoring can be used to enable devices to self-report.

The role of certification for C-ITS devices to be deployed in Australian and New Zealand will be explored further as part of developing a Concept of Operations for C-ITS.

8.2.4 Liability

While liability of ITS systems has been an issue for road agencies in the past, C-ITS has the potential to expand the issue of road agency liability as the new system evolves. The National Transport Commission (2013) paper, referred to in Section 8.2.1, also documents the findings of investigations into the liability issues associated with C-ITS.

The National Transport Commission (2013) paper recognises that liability laws have evolved over the decades and they have generally been adequate for technology that has evolved, particularly in the transport sector. It is noted that liability has not been a significant hindrance to the development of new transport technologies in the past and that C-ITS technology does not appear to be different in this respect. As such the key policy finding with respect to liability as listed in the National Transport Commission (2013) paper is as follows:

1. No changes are recommended to current laws and approaches around liability for drivers, manufacturers and road managers in regard to the roll out of C-ITS technology.
The National Transport Commission (2013) paper does recognise that C-ITS may pose other liability related issues such as drivers becoming over-reliant on the technology, the impact of increasing vehicle automation from a liability perspective and compliance perspective, and the impact of C-ITS systems on vulnerable road users. The degree to which these issues are addressed could pose impediments for road agencies in the ability to integrate 5.9 ITS with existing ITS infrastructure. Road agencies will therefore need to ensure that the provision of information communicated via 5.9 ITS is accurate, consistent and not conflicting with existing ITS infrastructure (i.e. it is reliable).

Systems may need to be put in place to address the potential liability issues by managing external disruptions (for example by clearly indicating to the driver whether the 5.9 ITS device is correctly functioning or not) and implementing redundancy systems such as:

- planning for potential system failures (through providing redundant connections and power supplies)
- having redundancy sensors and communication systems to improve reliability.

Redundancy systems required would be dependent on the application and how the application interacts with the vehicle and driver. Road operators will need to be aware of their risks and how these change over time. This will require keeping track of 5.9 ITS developments and ensuring that policy keeps pace and is appropriate, in addition to understanding the allocation of risks.

### 8.2.5 Big Data

Big data is a term used by the information, communication and technology (ICT) industry to describe the management of large amounts of data, in specific timeframes, that is from various data sources and is accurate. As a result big data spans the four dimensions of volume, velocity, variety, and veracity (IBM nd). The issues associated with big data are being increasingly discussed in the ICT area as more people become ‘connected’ via modern-day ICT and hence exchange large amounts of data on a daily basis.

C-ITS is very similar in this regard. With potentially a large number of vehicles within a road agency’s jurisdiction being equipped with C-ITS, downloading trip data to roadside units (via 5.9 ITS) or central infrastructure (via cellular communications) the result may be the exchange of many bytes of data every day. The extent to which vehicles store data for upload to a 5.9 roadside ITS station is yet to be determined. This will have a major impact on the amount of data received by road agencies and therefore will determine the extent to which big data may be an issue.

When considering using C-ITS equipped vehicles as probe data for traveller data collection, big data becomes a new issue for road agencies to deal with. Road agencies will need to understand how to collect the data, process and distribute (communicate) it to the appropriate applications for further use.

A key factor that will determine the extent to which big data will be an issue for road agencies as a result of C-ITS will be the degree to which the private sector is involved in the value adding process of the C-ITS generated data or involved in the data inputs to the C-ITS environment.

### 8.2.6 Private-public Partnership

The private sector will have a role in C-ITS data, particularly relating to information or services to the public delivered via cellular communications.

Data used in the provision of information and services may be provided by a variety of sources, with anonymous probe data obtained through 5.9 roadside ITS stations potentially being a valuable source.

At this stage it is envisaged that 5.9 ITS roadside units will be managed by road agencies for the purpose of delivering C-ITS applications. In addition they may be used to acquire anonymous probe data that may be used to deliver various C-ITS applications and/or transport services. The C-ITS application and/or transport services may be delivered to the field and/or vehicles via 5.9 GHz and/or wide area communications such as cellular.
It may be possible that where a business case warrants it and ACMA rules governing the use of 5.9 permit it, the private sector may elect to own and operate their own 5.9 roadside ITS stations to obtain anonymous probe data for use in safety and transport productivity applications. Alternatively, road agencies may seek to roll out roadside units in a public-private partnership model in order to accelerate deployment of 5.9 roadside ITS stations in the field.

8.2.7 Field Operation Tests/Trials
As mentioned in Section 2.7, field operation tests (FOT) or trials are critical to test and evaluate the level to which interoperability is achieved. Trials of the technology and its integration with existing ITS infrastructure should be undertaken prior to any decisions regarding large-scale investment.

8.2.8 Location and Extent of 5.9 Roadside ITS Station Deployment
When locating 5.9 roadside ITS stations, considerations will need to be made for:

- potential interference issues (including coordination criteria) with other users in and near the 5.9 GHz band (e.g. fixed satellite services (FSS)) and with CEN-DSRC units (i.e. 5.8 GHz electronic tolling roadside units operating in the neighbouring 5.8 GHz band)
  - the interference issue from the perspective of FSS interference to 5.9 ITS is discussed in further detail in Austroads (2013c)
- proximity to power and communications to the back office.

Further, the extent of the road network for which road agencies wish to deploy 5.9 roadside ITS stations integrated with ITS or stand alone will be dependent on the extent to which road agencies wish to integrate 5.9 roadside ITS stations with ITS infrastructure and/or the level to which road agencies wish to use 5.9 roadside ITS stations for strategic monitoring.

The extent to which road agencies deploy 5.9 roadside ITS stations with ITS infrastructure will be largely dependent on benefit-cost analysis, the use of cellular communications (as discussed in Section 8.1), in addition to available communication coverage (including both cellular and wired communications) as discussed in Section 8.2.9.

8.2.9 Communication Coverage in Rural Areas
In some cases, particularly in some rural areas (such as regions of Northern Territory), there may be limited communication coverage (including both cellular and wired communications). In this case, if C-ITS integration with existing ITS infrastructure away from the roadside is desired then satellite communication may be required. This will have technology, infrastructure and cost implications that will need to be taken into account when considering the C-ITS application deployment in those areas.
9. Conclusions

Austroads commissioned this report in order to explore how selected existing ITS that is operated by road agencies will integrate with C-ITS and therefore define what needs to be done to enable interoperability. In addition the report aims to outline the benefits and risks associated with this integration. The report will assist road agencies in beginning to understand how C-ITS will be integrated with ITS at a system engineering level.

C-ITS is a subset of ITS. As ITS is quite broad and the potential for integration between C-ITS and existing ITS is extensive, there was a decision to limit the scope of the investigations to 5.9 ITS integration with the existing ITS infrastructure of electronic speed limit signs, traveller data collection systems, traffic signals and traveller information systems. The key conclusions are presented in the following sections.

9.1 Interoperability

Significant changes and elements need to be implemented in order to integrate 5.9 ITS with the ITS infrastructure and to achieve interoperability across the four levels of technical, syntactic, semantic and organisational.

There are many common themes associated with the integration of 5.9 ITS with the ITS infrastructure investigated across the four levels of interoperability. Appendix G contains a table of the key findings for each ITS infrastructure along with a summary table identifying the common themes.

9.1.1 Technical Interoperability

Technical interoperability addresses the hardware/software of systems and platforms that enable machine-to-machine communication to take place.

Technical interoperability would need to be achieved through:

- integrating the ITS infrastructure with 5.9 roadside ITS stations
- using software to convert ITS infrastructure content into a 5.9 ITS message
- providing a connection to back office systems (it is noted that connections from the field to the back office are available for the majority of ITS with new connections primarily needed at green field sites)
- the ability to process data locally or to send data to the back office
- where required, providing additional infrastructure such as positioning infrastructure and systems to incorporate anonymous data from 5.9 ITS vehicles in the operation of ITS infrastructure.

There are differences in what is required to achieve technical interoperability across the three levels of integrations between field-to-field, field-to-vehicle and field-to-centre. All integrations require access and network integrations; however there are some differences in how this is achieved. The differences stem from the type of integrations required.

Key points with respect to the various integrations are summarised below:

- Field-to-field
  - Field-to-field is generally associated with a short range communication.
  - The access technology required to achieve field-to-field integration is an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections.
  - Field-to-field communications may utilise network protocols such as IPv6.
Field-to-vehicle
- Field-to-vehicle is associated with a short range wireless connection.
- The access technologies required to achieve field-to-vehicle integration are 5.9 DSRC via the media protocol of IEEE 802.11p in the USA or ITS G5 in Europe.
- Field-to-vehicle communications may utilise network protocols such as IPv6.

Field-to-centre
- Field-to-centre is associated with a wide area wired or wireless communications.
- The access technology to provide a connection between the 5.9 roadside ITS station and the back office would be a communication technology suitable for non-local communications. This may vary from site to site and may include fixed wire communications (e.g. optic fibre) and wide area (non-local) communications (such as 3G and 4G).
- Field-to-centre communications may utilise network protocols such as IPv6.

9.1.2 Syntactical Interoperability
Syntactical interoperability addresses the agreed data formats of communication so that the machine-to-machine communication can be processed and understood by each machine.

Syntactical standards will define the syntax for 5.9 ITS messages. Interoperability issues expected include the need to convert the ITS infrastructure content into the syntax required for 5.9 ITS messages.

The international standards that are very likely to define or be used in the 5.9 ITS message sets are outlined below. These will utilise data protocols such as NTCIP (USA) and DATEX2 (Europe) They are categorised under field-to-vehicle and vice versa and field-to-field and field-to-centre. They include:

Vehicle-to-field
- PVM: probe vehicle message (as defined in SAE J2735 and therefore applicable to the USA platform)
- CAM: cooperative awareness message (as defined by ETSI and therefore applicable to the European platform)
- DENM: decentralised environmental notification message (as defined by ETSI and therefore applicable to the European platform)
- PVD: probe vehicle data
- SRM: signal request message.

Field-to-vehicle
- Map: geometric intersection description
- RSA: roadside alert message (as defined in SAE J2735 and therefore applicable to the USA platform)
- PDM: probe data management
- SPaT: signal phasing and timing
- SSM: signal status message
- IVI: in-vehicle information
- DENM: decentralised environmental notification message (as defined by ETSI and therefore applicable to the European platform).
• Field-to-field and field-to-centre
  – NTCIP: National Transportation Communications for ITS Protocol (adopting NTCIP could be critical for Australia to ensure it is not singled out nor has inefficient and unnecessary protocol conversions as recommended in Austroads 2010a). NTCIP is a USA standard. NTCIP refers to the USA Traffic Management Data Dictionary (TMDD) standard which provides the dialogs, message sets, data frames, and data elements to manage the shared use of these devices and the regional sharing of data and incident management responsibility.

DATEX2: a standard developed for information exchange between all actors in the traffic and travel information sector. DATEX2 is a European standard.

9.1.3 Semantic Interoperability
Semantic interoperability refers to the need to interpret the messages being communicated, to enable them to be understood and used appropriately.

Semantic standards will define the 5.9 ITS message content and meaning. Software will be required in the 5.9 ITS unit to extract and interpret the protocol used in the operation of the ITS infrastructure and convert it to a 5.9 ITS message that complies with the standardised content and meaning.

Interoperability issues include ensuring that any differences in terminology used in the ITS infrastructure with the internationally standardised 5.9 ITS message are addressed.

In addition other semantic issues include appropriately identifying the message such that it can be located both with respect to date, time and location. This will require a time and date identifier in addition to a latitude and longitude identifier. All machines will need to operate on the same date, time and location reference, which could be maintained through position, navigation and timing (PNT) data from GNSS.

9.1.4 Organisational Interoperability
Organisational interoperability refers to the ability of organisations to exchange data across systems which will require a level of consistency with business processes (and architectural approaches). Success is also dependent on the level of technical, syntactical and semantic interoperability achieved.

For road agencies, integrating 5.9 ITS with existing ITS infrastructure will have various organisational implications. Such implications include but are not limited to:

• certifying 5.9 roadside ITS stations used, and registering, controlling and operating, and ensuring their use is consistent with ITS architectural approaches adopted across the road agency, and that interfaces are established to enable data exchange with legacy systems in use
• ensuring ongoing operation of the 5.9 roadside ITS stations which may require modifications to their asset management processes
• ensuring that the 5.9 roadside ITS station can fail safely in the event of a fault or outage
• creating and managing data messages transmitted from the 5.9 roadside ITS station which may require modifications to business processes and databases
• ensuring security standards are in place so that messages can be authenticated and therefore trusted for use
• ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation
• modifying corporate traffic information systems, including business processes, in order to process and store new data
• delivering internationally standardised 5.9 ITS messages
• ensuring OEM and retrofitted in-vehicle devices can utilise the 5.9 ITS messages and deliver the service to the driver effectively and in a manner in line with the objectives of C-ITS application and the provision of the 5.9 ITS message
• establishing processes to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users

• ensuring that 5.9 ITS messages can be used with C-ITS messages delivered from a central ITS station in the vehicle.

9.2 Benefits and Risks
Each 5.9 ITS integration with the investigated ITS infrastructure offers benefits. The benefits include aiding the driver to make better driving decisions with respect to regulatory controls (i.e. speed limit, and traffic signal compliance) in addition to making better decisions regarding route choice (i.e. traveller information). Benefits to road agencies include the ability to obtain extensive probe vehicle data and the ability to operate a safer and more productive road network.

Each 5.9 ITS integration with the investigated ITS infrastructure poses risks. The risks range from managing expectations when some but not all ITS infrastructure is integrated with 5.9 ITS, misuse of information by drivers, conflicting messages between the message from the 5.9 roadside ITS station and the ITS infrastructure, use of C-ITS data by private service telematics providers, and wide scale investment in 5.9 ITS without due consideration of other architectures or the uptake of 5.9 ITS in vehicles.

9.3 5.9 ITS and Cellular Communications
While this report discusses the integration between ITS infrastructure and 5.9 ITS, it is acknowledged that C-ITS integration with ITS infrastructure could also be undertaken through the use of cellular-based communications via the central management system of the ITS infrastructure (e.g. through the variable speed limit back office management system).

The extent to which 5.9 ITS is integrated with existing ITS will be influenced by:

• the need for the particular C-ITS integration with existing ITS infrastructure to have access to the functionality that 5.9 ITS can provide (e.g. low latency communications)

• the use of other communication mechanisms (i.e. if the same service can be delivered by cellular communications via integration with the central management system of the ITS infrastructure, this will impact on the need for 5.9 ITS to be integrated with ITS infrastructure at the roadside)

• the market penetration of vehicles equipped with particular communication technologies

• provision of services by private service providers

• the benefit-cost ratios associated with integrating existing ITS infrastructure with 5.9 ITS

• market demand and market availability for V2I 5.9 ITS applications

• the need to integrate existing ITS infrastructure with 5.9 ITS in order to drive market uptake.

9.4 Additional Issues
Additional issues associated with 5.9 ITS integration with ITS infrastructure include privacy, security, certification, liability, management of big data, private–public partnerships, field operation tests/trials and location and extent of 5.9 roadside ITS station deployment. Key findings from the discussion on additional issues are as follows:

• As C-ITS provides the potential to monitor and track vehicle movements, it is critical that the operation of C-ITS complies with the relevant privacy and surveillance legislation.

• The integration of 5.9 ITS with ITS infrastructure provides a new interface/wireless access point that could make the integrated ITS infrastructure vulnerable to cyber and/or malicious attacks.

• For 5.9 ITS integration with existing ITS, verification of each user’s signal is important for security. This is required to ensure that the 5.9 ITS signal is a legitimate one.
Road agencies will need to ensure that 5.9 roadside ITS stations are certified against the required standards and are licensed as a 5.9 radio communications device and registered for use prior to being integrated with ITS.

While liability of ITS systems has been an issue for road agencies in the past, C-ITS has the potential to expand the issue of road agency liability as the new system evolves and is used by road agencies.

With potentially a large number of vehicles within a road agency’s jurisdiction being equipped with C-ITS, downloading trip data to roadside units (via 5.9 ITS) or central infrastructure (via cellular communications) may result in the exchange of many bytes of data every day. When considering using C-ITS equipped vehicles as probe data for traveller data collection, big data becomes a new issue for road agencies to deal with. Road agencies will need to understand how to collect the data, sort it and distribute (communicate) it to the appropriate applications for further processing and use.

The private sector will have a role in C-ITS data, particularly relating to information or services to the public delivered via cellular communications. Road agencies should consider making data accessible from their centre/back office to private telematics companies that will use the data to provide C-ITS services. In order to provide data, road agencies will need to determine what data protocol/format will best enable interoperability, and what agreements might need to be established to enable and support the data access.

Field operation tests (FOT) or trials are critical to test and evaluate the level to which interoperability is achieved. Trials of the technology and its integration with existing ITS infrastructure should be undertaken prior to any decisions regarding large-scale investment.

When locating 5.9 roadside ITS stations, consideration will need to be given to the potential interference issues in addition to proximity to power and communications to back office.

Consideration will need to be given to the extent of the road network for which road agencies wish to deploy 5.9 roadside ITS stations either integrated with ITS or as standalone units. This will be based on benefit-costs which would also take into consideration the use of cellular communications.

Where communication coverage (including both cellular and wired communications) is not available and C-ITS integration with existing ITS infrastructure away from the roadside is desired then satellite communication may be required. This will have technology, infrastructure and cost implications that will need to be considered when considering the C-ITS application deployment in those areas.

9.5 Additional Comments

Further to the above conclusions, it is noted that this report does not outline all possible 5.9 ITS integrations with existing ITS infrastructure. Other opportunities include but are not limited to railway level crossings and tolling infrastructure.
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C-ITS Interoperability with Existing ITS Infrastructure


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C-ITS Interoperability with Existing ITS Infrastructure


**International Organisation for Standardisation**


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ISO 21217-2010, *Intelligent transport systems: communications access for land mobiles (CALM): Architecture*


ISO 24102-5-2013, *Intelligent transport systems: communications access for land mobiles (CALM): ITS station management: part 5: fast service advertisement protocol (FSAP).*


**European Committee for Standardization**

Appendix A  Potential C-ITS Applications

This section discusses the potential C-ITS applications emerging from the key C-ITS development regions of Europe, USA, Japan and South Korea.

A.1 Europe

The European Telecommunications Standards Institute (ETSI) has a list of potential applications/use cases that are considered as deployable within the initial period after the complete standardisation of C-ITS (i.e. deployment of C-ITS platforms). The complete list of the potential use cases is presented in Table A 1. Whether the use case utilises roadside infrastructure is also identified in Table A 1, based on a review of the functional requirements as outlined in European Telecommunications Standards Institute (2010a).

This gives an indication of the number of potential C-ITS applications with a need for integration with ITS at the roadside and/or central level.

Table A 1:  ETSI use cases

<table>
<thead>
<tr>
<th>Application</th>
<th>UC no.</th>
<th>Use case</th>
<th>Utilises roadside infrastructure and/or a central ITS station (Yes/No)*</th>
<th>Central or roadside-based communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving assistance – cooperative awareness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UC001</td>
<td>Emergency vehicle warning</td>
<td>Yes</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC002</td>
<td>Slow vehicle indication</td>
<td>Yes</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC003</td>
<td>Intersection collision warning</td>
<td>Yes</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC004</td>
<td>Motorcycle approaching indication</td>
<td>Yes</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td>Driving assistance – road hazard warning</td>
<td>UC005</td>
<td>Emergency electronic brake lights</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures is taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC006</td>
<td>Wrong-way driving</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC007</td>
<td>Stationary vehicle – accident</td>
<td>Yes – An ITS station capable of detecting or estimating the event although functionality is somewhat limited compared to direct V2V communications. The data required would be time and event position with a location reference sufficient for matching to a certain road segment.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC008</td>
<td>Stationary vehicle – vehicle problem</td>
<td>Yes – An ITS station capable of detecting or estimating the event although functionality is somewhat limited compared to direct V2V communications. The data required would be time and event position with a location reference sufficient for matching to a certain road segment.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td>Application</td>
<td>UC no.</td>
<td>Use case</td>
<td>Utilises roadside infrastructure and/or a central ITS station (Yes/No)*</td>
<td>Central or roadside-based communication</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Driving assistance – road hazard warning (continued)</td>
<td>UC009</td>
<td>Traffic condition warning</td>
<td>Yes – An ITS station capable of detecting, estimating or having knowledge of the event although functionality is somewhat limited compared to direct V2V communications. The data required would be an estimate of the upstream front end of the traffic congestion with a location reference sufficient for matching to a certain road segment.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC010</td>
<td>Signal violation warning</td>
<td>Yes – An ITS station capable of detecting or estimating the event although functionality is somewhat limited compared to direct V2V communications. The data required would be the location of the violating vehicle with a location reference sufficient for matching to a certain road segment.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC011</td>
<td>Roadwork warning</td>
<td>Yes – The data required would be the location of the upstream front end of the roadwork road section.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC012</td>
<td>Collision risk warning</td>
<td>Yes – An ITS station capable of detecting or estimating the event although functionality is somewhat limited compared to direct V2V communications. The data required would be an estimate of the collision position with a location reference sufficient for matching to a certain road segment.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC013</td>
<td>Decentralised floating car data – hazardous location</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC014</td>
<td>Decentralised floating car data – precipitations</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC015</td>
<td>Decentralised floating car data – road adhesion</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC016</td>
<td>Decentralised floating car data – visibility</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC017</td>
<td>Decentralised floating car data – wind</td>
<td>Yes – Part of road hazard warning application and can provide information for traffic management purposes related to road hazards. Communication with central ITS station may be established to inform of the detected event so that the corresponding rescues or other traffic management measures are taken.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td>Application</td>
<td>UC no.</td>
<td>Use case</td>
<td>Utilises roadside infrastructure and/or a central ITS station (Yes/No)*</td>
<td>Central or roadside-based communication</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------</td>
<td>--------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Speed management</td>
<td>UC018</td>
<td>Regulatory/contextual speed limits notification</td>
<td>Yes – The data required is speed limit information, which may include regulatory, variable and advisory speeds.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC019</td>
<td>Traffic light optimal speed advisory</td>
<td>Yes – The data required is traffic light status and timing information at pre-defined transmission rates.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td>Cooperative navigation</td>
<td>UC020</td>
<td>Traffic information and recommended itinerary</td>
<td>Yes – The data required is local road traffic information. The information provided would depend on the system available.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC021</td>
<td>Enhanced route guidance and navigation</td>
<td>Yes – The data required is route guidance and navigation information. The information provided would depend on the system available (i.e. information with respect to congestion, travel time, road closures etc.).</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC022</td>
<td>Limited access warning and detour notification</td>
<td>Yes – The data required is the limited access warning and detour information. The information provided would depend on the system available (i.e. road closures etc.).</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC023</td>
<td>In-vehicle signage</td>
<td>Yes – The data required is the traffic sign information.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td>Location-based services</td>
<td>UC024</td>
<td>Point-of-interest notification</td>
<td>Yes – The data required is the point-of-interest information.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC025</td>
<td>Automatic access control and parking</td>
<td>Yes – The data required is information to support electronic transactions.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC026</td>
<td>ITS local electronic commerce</td>
<td>Yes – The data required is information to support electronic transactions.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>UC027</td>
<td>Media downloading</td>
<td>Yes – The data required is information to support the downloading of media.</td>
<td>Roadside ITS station</td>
</tr>
<tr>
<td>Communities services</td>
<td>UC028</td>
<td>Insurance and financial services</td>
<td>Yes – The data required is information with respect to the exchange of insurance and financial services details of identified vehicles.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC029</td>
<td>Fleet management</td>
<td>Yes – The data required is information with respect to the identity of the vehicle and its fleet manager.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC030</td>
<td>Loading zone management</td>
<td>Yes – The data required is information to allow identification of service users.</td>
<td>Central ITS station</td>
</tr>
<tr>
<td>ITS station life cycle management</td>
<td>UC031</td>
<td>Vehicle software/data provisioning and update</td>
<td>Yes – The data required is information to allow the exchange of vehicle software and data.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
<tr>
<td></td>
<td>UC032</td>
<td>Vehicle and RSU data calibration</td>
<td>Yes – The data required is information to allow the roadside unit calibration.</td>
<td>Roadside ITS station and/or central ITS station</td>
</tr>
</tbody>
</table>

* Based on the authors’ review of the functional requirements as outlined in European Telecommunications Standards Institute (2010a).
Source: Adapted from European Telecommunications Standards Institute (2010a).
The priority areas and actions of the European Union Directive 2010/40/EU on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport (Council of the European Union 2010) are focussed on the vehicle-infrastructure interaction as outlined below:

- **European priority areas**
  - optimal use of road, traffic and travel data
  - continuity of traffic and freight management ITS services
  - ITS road safety and security applications
  - linking the vehicle with the transport infrastructure.

- **European priority actions**
  - the provision of EU-wide multimodal travel information services
  - the provision of EU-wide real-time traffic information services
  - data and procedures for the provision, where possible, of road-safety-related minimum universal traffic information free of charge to users
  - the harmonised provision for an interoperable EU-wide eCall
  - the provision of information services for safe and secure parking places for trucks and commercial vehicles
  - the provision of reservation services for safe and secure parking places for trucks and commercial vehicles.

A.1.1 European Project Trials

There are various C-ITS projects being run across Europe, many of which are testing various C-ITS applications that utilise V2I and vehicle-to-central ITS station communications. Some of the projects and their key applications of interest are listed below:

- **Sim TD: Test Field Germany:** The applications being investigated by the Sim TD project (Sim TD n.d. a, n.d. b, n.d. c) span across the motorway, rural road and urban road scenarios and are as follows
  - identification of traffic conditions
  - optimised urban network usage based on traffic light control
  - local traffic-adapted signal control
  - identification of traffic events/incidents
  - traffic information
  - advance route guidance
  - alternative route management
  - congestion warning
  - traffic sign assistant warning
  - traffic light assistant warning
  - intersection and cross-traffic assistant
  - road weather warning
  - obstacle warning
  - roadworks information system
  - location-based services.

- **InTime:** InTime is investigating an eService in order to deliver real-time traffic and travel information to the end-user via a navigational device or smart phone.
- eCoMove is developing applications to provide fuel savings and reduce CO₂ emissions including eco pre-trip planning, eco smart driving, eco monitoring, dynamic eco driver coaching, eco tour planning, truck eco navigation, eco adaptive balancing and control, eco adaptive traveller support and eco motorway management (eCoMove nd).

### A.2 USA

The US DOT, working with the Crash Avoidance Metrics Partnership (CAMP), a research consortium of eight vehicle manufacturers, will be undertaking driver clinics and a large-scale model deployment as discussed below.

The V2V driver clinics will be undertaken as safety pilots conducted across six states. The safety pilots will look at user acceptance of the technology and the user acceptance to pay for and embrace the technology.

The V2V applications that will be tested for driver acceptance include:
- emergency electronic brake light (EEBL)
- forward collision warning (FCW)
- blind spot warning (BSW)/lane change warning (LCW)
- intersection movement assist (IMA)
- do not pass warning (DNPW).

A total of 24 original equipment manufacturer (OEM) passenger vehicles will be built for the safety pilots that are equipped with the aforementioned five V2V safety applications fully integrated into the vehicle with a commercial production finish. Clinics involving three to four fully equipped trucks will be undertaken separately.

At least 100 participants will be selected to participate in each of the six driver clinics.

The actual V2V and V2I model deployment will be undertaken on 3000 vehicles in a concentrated area, with the aim being to estimate the benefits of the connected vehicle applications. The model deployment will also include roadside infrastructure that is able to connect to the vehicle.

The 3000 vehicles will be made up of:
- fully integrated V2V and V2I OEM passenger vehicles
- fully integrated V2V and V2I OEM trucks
- vehicles equipped with aftermarket V2V and V2I devices
- vehicles equipped with devices able to broadcast their position (i.e. ‘here I am’ devices).

Further, Hill and Garrett (2011) reported that the US smart roadside initiative which is incorporated into the US V2I program includes:
- real-time traffic, weather, special event, and truck parking information shared with the driver
- vehicle sensor data collected at the roadside and shared with private vehicle maintenance providers
- unique vehicle identifier shared with the enforcement agencies
- routing clearance information shared with the driver
- vehicle size and weight shared with enforcement agencies
- origin/destination information shared to determine routing information
- construction and time restriction information shared with the driver
- real-time driver/carrier/truck information shared with enforcement agencies for inspection decisions.
roadside inspection results (violation and non-violation) shared with federal enforcement agencies
- emissions data shared with carriers and agencies to assess operating efficiencies, including those involving emissions, energy use, and carbon footprint.

In a progress report update on the ITS Strategic Research Plan, 2010–14, Pina et al. (2012) reported that the potential V2I safety applications crash scenario mitigation opportunities include:
- intersection safety
- roadway departure prevention
- speed management
- transit safety and operations
- commercial vehicle enforcement and operations
- at-grade rail crossing operations
- priority assignment for emergency vehicles.

Pina et al. (2012) also outlined that, in addition, signal phasing and timing (SPaT) data from C-ITS infrastructure interfaced with the traffic signals at an intersection and C-ITS infrastructure could be used to send a geometric intersection description of the intersection containing detailed map attributes such as pavement markings, signs and other geometric features in order to achieve various functions.

A.3 Japan

The Universal Traffic Management System Society of Japan is looking towards vehicle-infrastructure communication to address safety through its Driving Safety Support System (DSSS). The applications being tested and deployed utilise both infrared (IR) and a combination of IR and dedicated short range communications (DSRC) at 5.8 GHz as outlined below (Fukushima, Seto & Tsukada 2008):

- IR applications
  - Stop-sign violation avoidance support at intersections without traffic signals
  - information supply to a mainstream vehicle about a merging-lane vehicle at an intersection without traffic signals
  - red-light violation avoidance support at intersections with traffic lights.

- IR and DSRC applications
  - right-turn vehicle existence information supply
  - right-turn collision avoidance support

red-light violation avoidance and rear-end collision avoidance for the stopping vehicle before the red light.

In addition to the above, Japan’s Ministry of Land Infrastructure and Transport Department and the National Institute for Land and Infrastructure Management are working on the Smartway project which is interested in utilising roadside infrastructure (as conceptually shown in Figure A 1) to communicate information such as:

- warnings of a back of queue that is located around a curve and out of sight from an approaching vehicle and where the queue is detected using sensors and a message is communicated to an approaching vehicle via a 5.8 roadside ITS device
- curve speed warnings using sensors to measure the speed of the approaching vehicle and a 5.8 roadside ITS device to communicate the message to an approaching vehicle
- information to assist vehicles in carrying out merging on expressways
- traffic condition information.
As can be appreciated from the above, Japan is investing significantly in smart roadside infrastructure that is able to detect events and then broadcast the associated information to vehicles. Figure A 2 shows the concept being trialled by Honda working with the DSSS and Smartway projects (Honda Motor Co. 2009). While the figure shows collision avoidance applications with a focus on motorcycle safety, it also shows that the applications in Japan have a heavy reliance on vehicle detection cameras and optical beacons to detect vehicles on a collision course, and roadside infrastructure to calculate the potential collision and subsequently communicate the appropriate warning.

A.4 South Korea

The Ministry of Knowledge based Economy is working on the Vehicle Multi-hop Communication project for V2V and V2I communication for vehicle safety. In addition:

- The Ministry of Land, Transport and Maritime Affairs is working on the Smart Highway project for the development of the next generation intelligent highway system to provide more safe, more convenient and real-time information environments.
- The National Police Agency is working on the Urban Traffic Information Systems project for the deployment of a system to provide traffic information gathering and provisioning in urban areas.

The Korea Transport Institute has various projects, including trials in preparation for the 2018 Winter Olympics in PyeongChang.
Appendix B  ITS Physical Entities

A description of the ITS physical entities within each physical group as outlined in Austroads (2010a) is provided in Table B 1.

This appendix provides further details of the key relevant standards referred in Section 2.4.

Table B 1: Description of ITS physical entities

<table>
<thead>
<tr>
<th>ITS physical group</th>
<th>ITS physical entities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travellers</td>
<td>Personal information access</td>
<td>Supports personal access by travellers to travel information by means of personal computing devices</td>
</tr>
<tr>
<td></td>
<td>Remote traveller support</td>
<td>Supports access to traveller information through public facilities such as kiosks</td>
</tr>
<tr>
<td>Centres</td>
<td>Traffic management</td>
<td>Monitors and manages access to and usage of the transport infrastructure by vehicles and coordinates operations with other centres</td>
</tr>
<tr>
<td></td>
<td>Emergency management</td>
<td>Coordinates responses to incidents in the transport system</td>
</tr>
<tr>
<td></td>
<td>Toll administration</td>
<td>Processes and manages tolls and other payments for usage of the transport infrastructure</td>
</tr>
<tr>
<td></td>
<td>Commercial vehicle administration</td>
<td>Manages the credentials and licensing of commercial vehicles</td>
</tr>
<tr>
<td></td>
<td>Maintenance and construction management</td>
<td>Monitors and manages roadway infrastructure and coordinates the construction and maintenance activities</td>
</tr>
<tr>
<td></td>
<td>Information service provider</td>
<td>Collects, processes and disseminates information about or affecting the transport system to subscribers including travellers and traffic managers</td>
</tr>
<tr>
<td></td>
<td>Emissions management</td>
<td>Monitors and manages emissions data and provides information for traffic management</td>
</tr>
<tr>
<td></td>
<td>Public transport management</td>
<td>Monitors and coordinates the operation of transit vehicles</td>
</tr>
<tr>
<td></td>
<td>Fleet and freight management</td>
<td>Monitors and coordinates vehicle fleets including with intermodal hubs</td>
</tr>
<tr>
<td></td>
<td>Archived data management</td>
<td>Repository of operational data for legal, historical, research and process improvement purposes</td>
</tr>
<tr>
<td>Field</td>
<td>Roadway</td>
<td>Provides the transport arteries and all associated roadside devices including sensors, processors, signals and displays</td>
</tr>
<tr>
<td></td>
<td>Security monitoring</td>
<td>Includes surveillance, sensors, and access controls that provide safety and security for transport infrastructure, vehicles and travellers</td>
</tr>
<tr>
<td></td>
<td>Toll collection</td>
<td>Includes monitoring of vehicle access and usage of the transport infrastructure and generates toll and fee transactions, and noncompliance records</td>
</tr>
<tr>
<td></td>
<td>Parking management</td>
<td>Manages parking areas and collects fees for usage</td>
</tr>
<tr>
<td></td>
<td>Commercial vehicle check</td>
<td>Monitors compliance of commercial vehicles with their licence conditions, and records the results in the commercial vehicle administration systems</td>
</tr>
<tr>
<td>ITS physical group</td>
<td>ITS physical entities</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Vehicles</td>
<td>Vehicle (general)</td>
<td>The general class of vehicle that carries people and/or freight across the transport infrastructure. This will include private passenger vehicles.</td>
</tr>
<tr>
<td></td>
<td>Emergency vehicle</td>
<td>A special class of vehicle that provides emergency response services.</td>
</tr>
<tr>
<td></td>
<td>Commercial vehicle</td>
<td>A vehicle licensed to conduct commercial activities such as conveying freight or taxi services, and for which licence compliance data is kept.</td>
</tr>
<tr>
<td></td>
<td>Public transport vehicle</td>
<td>A time-tabled mass-transit passenger vehicle that interacts with traveller information systems via the Transit Management Centre.</td>
</tr>
<tr>
<td></td>
<td>Maintenance and construction vehicle</td>
<td>A vehicle purpose built to conduct maintenance and construction activities.</td>
</tr>
<tr>
<td>Communications</td>
<td>Fixed point to fixed point</td>
<td>Terrestrial communications system between two (or more) fixed points in the transport infrastructure. Typically provided by fibre optic, copper and sometimes fixed wireless (such as microwave) communication links.</td>
</tr>
<tr>
<td></td>
<td>Wide area wireless mobile</td>
<td>Typically a base station to mobile wireless communication system operating over a significant range.</td>
</tr>
<tr>
<td></td>
<td>Vehicle to infrastructure (V2I)</td>
<td>A real-time short range and short duration wireless communication system operating between a roadside station and mobile station in passing vehicles.</td>
</tr>
<tr>
<td></td>
<td>Vehicle to vehicle (V2V)</td>
<td>Real-time short range and short duration wireless communication between two (or more) vehicles which are in the vicinity.</td>
</tr>
</tbody>
</table>

Source: Austroads (2010a).
Appendix C National Transport Communications for ITS Protocol (NTCIP)

National Transportation Communications for ITS Protocol (NTCIP) is a family of standards that define the protocol and objects necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system. NTCIP is a USA standard. The equivalent in Europe is DATEX2.

NTCIP only applies to ITS communication between centres (centre-to-centre or C2C) and between centres and field (centre-to-field or C2F) devices so in that sense it is not applicable to C-ITS but is applicable to some existing C2C and C2F ITS infrastructure. Examples of C2F and C2C ITS devices to which NTCIP applies and does not apply are outlined in Table C 1.

Austroads project NS1657 *Best practice study on the use of intelligent transport system (ITS) standards in traffic management* is investigating if Australian and New Zealand C2C and C2F communications could be migrated to NTCIP.

Table C 1: Examples of C2F and C2C ITS devices to which NTCIP applies and does not apply

<table>
<thead>
<tr>
<th>C2F – Centre-to-field communications</th>
<th>C2C – Centre-to-centre communications</th>
<th>Exclusions from NTCIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable message signs (VMS)</td>
<td>Traffic management</td>
<td>Vehicle electronic tag reading (requires wireless)</td>
</tr>
<tr>
<td>Traffic signals</td>
<td>Public transport management</td>
<td>Full motion video streaming (CCTV, webcams)</td>
</tr>
<tr>
<td>Field master controllers</td>
<td>Incident management</td>
<td>Transmission of traveller information to privately owned vehicles</td>
</tr>
<tr>
<td>Data collection and monitoring devices such as traffic counters, traffic classifiers, weigh-in-motion stations</td>
<td>Emergency management</td>
<td>Financial transactions (requires security not provided by NTCIP)</td>
</tr>
<tr>
<td>Public transport on-board sensors and controllers (non-wireless)</td>
<td>Parking management</td>
<td>In-vehicle communications for vehicle control and monitoring (requires high-speed fail-safe transmissions)</td>
</tr>
<tr>
<td>Environmental sensors</td>
<td>Traveller information</td>
<td>In-cabinet communications inside a node controller (addressed in the Advanced Transportation Controller standards)</td>
</tr>
<tr>
<td>Ramp meters</td>
<td>Commercial vehicle operations management</td>
<td></td>
</tr>
<tr>
<td>Vehicle detectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed circuit television cameras (camera control only – not video signals)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video switches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road lighting control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Austroads (2010a).
Appendix D  Existing ITS infrastructure

Austroads (2010a) defines intelligent transport systems (ITS) as:

…an umbrella term for the application of a range of information and communications technologies, including computing, control, communication and electronics, to a transportation system comprising transport infrastructure and vehicles, in order to provide ITS services to enhance the manageability and safety of the transport system and to improve the traveller experience.

ITS incorporates the following four key components:
1. Vehicles: which can be identified and communicated with through ITS.
2. Road users: who utilise the information provided and communicated with through ITS.
3. Infrastructure: which is deployed in order to undertake the administrative functions of ITS.
4. Communication networks: which enable ITS messages to be communicated to the other components of ITS wirelessly.

More specifically, ITS can be used and deployed by road agencies and operators (e.g. private toll road operators) to provide a variety of services. As a result of a review of the International Standard ISO 14813 ITS/TICS Reference Architecture, Austroads (2010a) outlined that these services can be categorised into groups referred to as ITS service domains. The ITS service domains include:

- traveller information
- traffic management
- vehicle safety
- freight operations
- public transport operations
- emergency vehicle response
- electronic payment
- personal safety
- weather and environmental monitoring
- disaster response management and coordination
- national security
- ITS data management.
As outlined in Austroads (2010a), within each ITS service domain there are various service groups and for each service domain and group there are various actors that interact within an ITS system. Some of those potential actors as defined by Austroads (2010a) include:

1. User: the user actor represents all of the human roles who obtain services from an ITS.
2. Vehicle: a vehicle is any vehicle that is recognised in any way by an ITS system.
3. Service enabler: actors who interact in a privileged way with an ITS and contribute in some way to the operation of the transport system.
4. Financial: provides and manages payment by users to the transport system and its service providers.
5. Infrastructure: provides complementary services to and exchanges information with a road-based transport system so that both systems may perform their services.
6. Information provider/consumer: operates unilaterally and provides information to or derives information from an ITS.
7. Service provider: provides external services that are mediated by an ITS.
8. Conformance agency.

The interactions between the actors and the key ITS service domains as outlined in Austroads (2010a) are shown in Figure D 1.

Figure D 1: Interaction between actor and ITS service domains

Road agencies have been making significant and increasing investments in ITS through the deployment of ITS assets. Based on a review of two Austroads reports (2009d and 2009e) the ITS assets existing in Austroads member jurisdictions categorised by ITS service domain, as discussed previously, are outlined in Table D 1.
## Table D 1: ITS assets based on ITS service domain

<table>
<thead>
<tr>
<th>ITS service domain</th>
<th>ITS asset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traveller information</td>
<td>Electronic signs (i.e. variable message signs, changeable message signs and electronic information signs) which provide travel information such as travel time and traffic flow conditions.</td>
</tr>
<tr>
<td></td>
<td>Vehicle activated signs (including speed activated signs)</td>
</tr>
<tr>
<td>Traffic management</td>
<td>Traffic signals</td>
</tr>
<tr>
<td></td>
<td>Ramp metering</td>
</tr>
<tr>
<td></td>
<td>Traffic sensing loops, traffic counting loops and data stations</td>
</tr>
<tr>
<td></td>
<td>Bluetooth travel time</td>
</tr>
<tr>
<td></td>
<td>Traffic signal controllers (including SCATS/STREAMS regional computers)</td>
</tr>
<tr>
<td></td>
<td>CCTV camera equipment</td>
</tr>
<tr>
<td></td>
<td>Video incident detection cameras</td>
</tr>
<tr>
<td></td>
<td>Electronic speed limit signs (incl. variable speed limits, school zones and weather-based speed limits)</td>
</tr>
<tr>
<td></td>
<td>Overhead lane controls (incl. tidal flows)</td>
</tr>
<tr>
<td></td>
<td>Moveable medians</td>
</tr>
<tr>
<td></td>
<td>In-pavement lights</td>
</tr>
<tr>
<td></td>
<td>Red light cameras</td>
</tr>
<tr>
<td></td>
<td>Speed cameras</td>
</tr>
<tr>
<td></td>
<td>Signalised railway crossings</td>
</tr>
<tr>
<td>Vehicle safety</td>
<td>Intelligent speed assist</td>
</tr>
<tr>
<td>Freight operations</td>
<td>Height gauges</td>
</tr>
<tr>
<td></td>
<td>Weigh-in-motion</td>
</tr>
<tr>
<td></td>
<td>Truck noise cameras – enforcement of noise emissions from trucks</td>
</tr>
<tr>
<td></td>
<td>Intelligent access program (IAP) rollout</td>
</tr>
<tr>
<td>Public transport operation</td>
<td>Smart bus signs</td>
</tr>
<tr>
<td></td>
<td>Real-time bus monitoring</td>
</tr>
<tr>
<td></td>
<td>Real-time bus priority including public transport signal priority systems interfaced with traffic signal controllers</td>
</tr>
<tr>
<td></td>
<td>Bus lane cameras</td>
</tr>
<tr>
<td>Emergency vehicle response</td>
<td>Emergency vehicle signal pre-emption systems interfaced with traffic signal controllers</td>
</tr>
<tr>
<td>Electronic payment</td>
<td>Free-flow tolling equipment</td>
</tr>
<tr>
<td>Safety</td>
<td>Pedestrian detection (e.g. puffin crossing)</td>
</tr>
<tr>
<td>Weather and environment</td>
<td>Ice detection and warning stations</td>
</tr>
<tr>
<td></td>
<td>In-ground detectors to detect ground movement</td>
</tr>
<tr>
<td></td>
<td>Air quality monitoring</td>
</tr>
<tr>
<td>Disaster management and</td>
<td>No roadside ITS assets managed by road agencies</td>
</tr>
<tr>
<td>response coordination</td>
<td></td>
</tr>
<tr>
<td>National security</td>
<td>No roadside ITS assets managed by road agencies</td>
</tr>
<tr>
<td>ITS data management</td>
<td>No roadside ITS assets managed by road agencies</td>
</tr>
</tbody>
</table>

Source: Based on Austroads (2009d and 2009e).
Due to the recent and expanding use of ITS by Australian road agencies, there is a need to identify standards for ITS that can be adopted and adapted for Australia in order to promote an interoperable ITS infrastructure. This was the objective of Austroads (2010a). The Austroads (2010a) project identified that the prioritisation by Australian road agencies for the adoption and adaption of international standards to support ITS services groups are as outlined in Table D 2.

Table D 2: ITS service group priorities

<table>
<thead>
<tr>
<th>ITS service group priority</th>
<th>ITS service group</th>
<th>Associated ITS service domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Incident management</td>
<td>Traffic management</td>
</tr>
<tr>
<td>2</td>
<td>Traffic management and control</td>
<td>Traffic management</td>
</tr>
<tr>
<td>3</td>
<td>Public transport information</td>
<td>Public transport</td>
</tr>
<tr>
<td>4</td>
<td>Safety readiness</td>
<td>Vehicle</td>
</tr>
<tr>
<td>5</td>
<td>Transport planning support</td>
<td>Traffic management</td>
</tr>
<tr>
<td>6</td>
<td>Policing/enforcing traffic regulations</td>
<td>Traffic management</td>
</tr>
<tr>
<td>7</td>
<td>Collision avoidance</td>
<td>Vehicle</td>
</tr>
<tr>
<td>8</td>
<td>Emergency notification</td>
<td>Emergency</td>
</tr>
<tr>
<td>9</td>
<td>Public transport management</td>
<td>Public transport</td>
</tr>
<tr>
<td>10</td>
<td>On-trip route guidance and navigation</td>
<td>Traveller information</td>
</tr>
<tr>
<td>11</td>
<td>On-trip information</td>
<td>Traveller information</td>
</tr>
<tr>
<td>12</td>
<td>Emergency vehicle management</td>
<td>Emergency</td>
</tr>
</tbody>
</table>

Source: Austroads (2010a).
Appendix E  Consultations

Key practitioners consulted in preparing this report are listed in Table E 1.

Table E 1: Consultations

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Role</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tony Fitz</td>
<td>VicRoads</td>
<td>Manager, Traffic Systems (East) Road Operations</td>
<td>14 January 2013</td>
</tr>
<tr>
<td>Andrew Somers</td>
<td>VicRoads</td>
<td>Seconded to ARRB Group at the time</td>
<td>10 January 2013</td>
</tr>
<tr>
<td>Sohail Mohammed</td>
<td>VicRoads</td>
<td>Intelligent Transport System Manager, M80 Ring Road Upgrade</td>
<td>January 2013</td>
</tr>
<tr>
<td>Robin Marston</td>
<td>VicRoads</td>
<td>ITS Specialist, M80 Ring Road Upgrade</td>
<td>23 January 2013</td>
</tr>
<tr>
<td>Wayne Harvey</td>
<td>VicRoads</td>
<td>Principal Manager – ITS, Road Operations</td>
<td>23 January 2013</td>
</tr>
<tr>
<td>Keith Weegberg</td>
<td>VicRoads</td>
<td>Manager Traffic Management Centre</td>
<td>23 January 2013</td>
</tr>
<tr>
<td>David Stewart</td>
<td>Queensland TMR</td>
<td>Principal Engineer, Road Operations Unit</td>
<td>7 February 2013</td>
</tr>
<tr>
<td>Melissa Perkins</td>
<td>Queensland TMR</td>
<td>Team Leader, Traffic and Travel Information</td>
<td>20 February 2013</td>
</tr>
<tr>
<td>Edward Beak</td>
<td>Queensland TMR</td>
<td>Technical Project Manager, Traffic Systems and Road Use</td>
<td>20 February 2013</td>
</tr>
<tr>
<td>Geoffrey McDonald</td>
<td>Queensland TMR</td>
<td>Program Manager, Engineering &amp; Technology Branch</td>
<td>20 February 2013</td>
</tr>
<tr>
<td>Andrew Mehaffey</td>
<td>RMS NSW</td>
<td>Executive Manager, Transport Strategy &amp; Systems</td>
<td>6 February 2013</td>
</tr>
<tr>
<td>Victor Shapilsky</td>
<td>RMS NSW</td>
<td>Motorway Systems Manager, Motorway Systems Section</td>
<td>6 February 2013</td>
</tr>
<tr>
<td>Steven Shaw</td>
<td>RMS NSW</td>
<td>Traffic Systems Configuration Manager</td>
<td>6 February 2013</td>
</tr>
<tr>
<td>John Wall</td>
<td>TINSW</td>
<td>Manager Road Safety Technology</td>
<td>December 2012</td>
</tr>
<tr>
<td>Philip Blake</td>
<td>DPTI SA</td>
<td>Manager, Traffic Operations, Metropolitan Region</td>
<td>26 February 2013</td>
</tr>
<tr>
<td>Iain McAuley</td>
<td>NZTA</td>
<td>Principal Advisor, Network Optimisation Team</td>
<td>13 March 2013</td>
</tr>
<tr>
<td>David Arrowsmith</td>
<td>NZTA</td>
<td>Principal Advisor, Traffic Operations (Highways and Network Operations)</td>
<td>13 March 2013</td>
</tr>
<tr>
<td>John Venables</td>
<td>MRWA</td>
<td>Asset Manager Traffic Systems</td>
<td>1 March 2013</td>
</tr>
<tr>
<td>Paul Gray</td>
<td>Codha Wireless</td>
<td>Chief Executive Officer</td>
<td>January 2013</td>
</tr>
<tr>
<td>Paul Alexander</td>
<td>Codha Wireless</td>
<td>Chief Technical Officer</td>
<td>January 2013</td>
</tr>
<tr>
<td>Philip Lloyd</td>
<td>Transmax</td>
<td>Commercial Engineering Solutions Group Manager</td>
<td>7 February 2013</td>
</tr>
<tr>
<td>Alexander Broyda</td>
<td>QTC Traffic Solutions</td>
<td>Marketing Director</td>
<td>23 January 2013</td>
</tr>
<tr>
<td>Bob Lemon</td>
<td>Aldridge Traffic Controllers Pty Ltd</td>
<td>Technical Marketing Manager</td>
<td>11 February 2013</td>
</tr>
<tr>
<td>Adam Game</td>
<td>Intelematics</td>
<td>Chief Executive Officer</td>
<td>7 March 2013</td>
</tr>
<tr>
<td>Stuart Ballingall</td>
<td>Austroads</td>
<td>Cooperative ITS Project Director</td>
<td>April 2013</td>
</tr>
</tbody>
</table>
Appendix F  Options for connecting 5.9 roadside ITS station with ESL/VSL infrastructure in the field

This appendix discusses the options for connecting 5.9 roadside ITS stations with ESL/VSL infrastructure in the field.

There is potential for the 5.9 roadside ITS station to be integrated with ESL/VSL in the field in any one of the following ways:

1. directly from the ESL/VSL group controller or from a communications feed from the group controller to the field processor
2. from the ESL/VSL field processor
3. from the back office server directly.

The 5.9 roadside ITS station then communicates the speed limit message to the driver (field-to-vehicle).

There is unlikely to be one correct solution and the ideal solution may vary on a case-by-case basis with the choice being largely based on:

- communication range of the 5.9 roadside ITS station
- distance between VSL signs
- ability for the 5.9 roadside ITS station to be integrated into the system.

An ESL/VSL message can be in the DENM and IVI message format and delivered via 5.9 and/or the TPEG format delivered via 3G, 4G. Services delivered via 5.9 ITS and therefore message formats such as DENM and IVI are likely to be suited to options 1 and 2 (as discussed in further detail below). Services utilising TPEG via 3G, 4G are likely to be suited to option 3 where information is communicated directly from the back office (which may be operated by a private service provider with value added service) to the vehicle via wide area communications.

Option 1: Direct from the group controller or communication feed from the ESL/VSL group controller to the field processor

A communication feed from the ESL/VSL group controller to the ESL/VSL field processor was implemented in a trial undertaken on the VicRoads M80 project with Codha Wireless. In that trial the 5.9 roadside ITS station tapped into the communications feed from the ESL/VSL group controller back to the ESL/VSL field processor. The 5.9 roadside ITS station read the sign status reply message that included which frame the VSL sign was displaying (message frame formats are further discussed in Section 4.3) and converted this to a 5.9 ITS message to be broadcast from the 5.9 roadside ITS station to a 5.9 ITS in-vehicle device for use in the vehicle. This is shown in Figure F 1. The benefit of connecting to the sign status reply message is that the 5.9 roadside ITS station can be confident it is receiving the same message as received by the group controller, as the group controller is sending back a message outlining the message it received.
Figure F 1: Variable speed limit system connected to a 5.9 roadside ITS station between the field processor and group controller

Note: This figure only applies to systems where a field processor exists.
Source: Adapted from information provided in email dated 23 January 2013 from Robin Marston of VicRoads.

Option 2: Communication from the ESL/VSL field processor
Connection to the field processor is an alternative means of integrating with the in-field ESL/VSL infrastructure. The ESL/VSL field processor is considered intelligent in that it controls several groups of ESL/VSL. It may therefore offer greater potential for C-ITS integration with ESL/VSL as it may better enable the sending of data collected at the roadside back to the back office for processing.

One potential issue with the connection to the ESL/VSL field processors is that the field processor looks after a series of group controllers or groups of ESL/VSL and therefore the ESL/VSL field processors are spaced out and located away from the ESL/VSL signs that they may control, as shown in Figure F 2. While one 5.9 roadside ITS station could send out data for several ESL/VSL groups, the number of 5.9 roadside ITS stations required for a section of road where ESL/VSL are used, and managed by a group controller, is likely to depend on the length and operational parameters of the VSL section.

Figure F 2: Schematic of 5.9 ITS integrated with ESL/VSL at the ESL/VSL field processor level
Appendix G  Table of Key Findings

This report focuses on defining what is required to achieve interoperability (across the four levels of technical, syntactical, semantic and organisational) between 5.9 ITS (5.9 GHz component of C-ITS) and the selected existing ITS infrastructure of electronic speed limit signs, traveller data collection, traffic signals and traveller information systems. The key findings for each ITS infrastructure is outlined in the following tables:

- electronic speed limit signs: Table G 1
- traveller data collection: Table G 2
- traffic signals: Table G 3
- traveller information systems: Table G 4.

### Table G 1: Interoperability between 5.9 ITS and electronic speed limit signs – summary

<table>
<thead>
<tr>
<th>Technical</th>
<th>Elements required to achieve technical interoperability include:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field-to-field</td>
<td>- interface between ESL/VSL group controller or field processor and a 5.9 roadside ITS station</td>
</tr>
<tr>
<td></td>
<td>- field-to-field elements will utilise an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections. It may utilise network protocols such as IPv6.</td>
</tr>
<tr>
<td>Field-to-vehicle</td>
<td>- 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station</td>
</tr>
<tr>
<td></td>
<td>- software within the 5.9 ITS unit may be needed to convert the content of the ESL/VSL to a 5.9 ITS standardised message (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station)</td>
</tr>
<tr>
<td></td>
<td>- field-to-vehicle integration would require communication via the 5.9 GHz band, utilising the media protocol of IEEE 802.11p in the USA and ITS G5 in Europe.</td>
</tr>
<tr>
<td>Field-to-centre</td>
<td>- connection to back office systems in order to communicate supplementary information and to collect anonymous data from 5.9 ITS equipped vehicles</td>
</tr>
<tr>
<td></td>
<td>- field-to-centre elements may use fixed wire communications or wide area communications and utilise network protocols such as IPv6.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Syntactical</th>
<th>In order to achieve syntactical interoperability:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- standards will be required to define the 5.9 ITS message. Field-to-field and field-to-centre elements will require protocols such as NTCIP (USA) or DATEX2 (Europe) while field-to-vehicle elements will require message sets such as RSA (SAE J2735), CAM, DENM and IVI</td>
</tr>
<tr>
<td></td>
<td>- software within the 5.9 ITS unit may be needed to convert the content of the ESL/VSL to a 5.9 ITS standardised message (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semantic</th>
<th>In order to achieve semantic interoperability:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- standards will be required to define the 5.9 ITS message content and meaning</td>
</tr>
<tr>
<td></td>
<td>- software will be required in the 5.9 ITS unit to interpret the message sent to an ESL/VSL and convert it to a 5.9 ITS message that complies with the standardised content and meaning (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station)</td>
</tr>
<tr>
<td></td>
<td>- location and timing information will need to be provided.</td>
</tr>
</tbody>
</table>
### Organisational

Elements to be addressed in order to achieve organisational interoperability include:

- Road agencies will be responsible for registering, controlling the use and operating 5.9 ITS units.
- Road agencies will need to ensure that only certified 5.9 roadside ITS stations are used.
- Road agencies will need to ensure consistent architectural approaches are adopted across road agencies for their ITS.
- Road agencies will need to ensure that the required interfaces to enable data exchange with legacy systems are adopted.
- Road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations which may require modifications to their asset management processes.
- Road agencies will need to ensure that the 5.9 roadside ITS stations can fail safely in the event of a fault or outage.
- Road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g., DENM, IVI) which may require modifications to business processes and databases.
- Road agencies will need to ensure security standards are in place so that messages can be authenticated and therefore trusted for use.
- Retrofitting ESL/VSL with 5.9 ITS may pose contractual issues.
- Road agencies will be responsible for the specifications regarding the delivery of internationally standardised messages including making allowance for differences in international and local terminologies where appropriate.
- Road agencies should maintain an interest in how various vehicle manufacturers are using 5.9 ITS messages.
- Road agencies will need to ensure that vehicle manufacturers can combine speed limit information provided through 5.9 ITS communication with other speed limit information delivered via other communications (such as 3G and 4G etc.) to deliver the one service in the vehicle.
- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation.
- Road agencies may need to establish processes to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users.
- Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data.

### Benefits

The benefits associated with the integration of 5.9 ITS with ESL/VSL are that it aids improved speed compliance. In addition, it provides the ability:

- To provide enhanced information both about the ESL/VSL it is integrated with along with broader traveler information in order to aid better driver decisions.
- To utilise the 5.9 ITS unit to obtain anonymous probe data from 5.9 ITS equipped vehicles.
- For earlier notification of VSL speed limit ahead, which could be tailored for different vehicle types (e.g., heavy vehicles).

### Risks

The key risks associated with the integration of 5.9 ITS with ESL/VSL include:

- Management of expectations when not all ESL/VSLs are integrated with 5.9 ITS.
- Risks associated with liability, such as whether road agencies are liable if a vehicle does not receive a ESL/VSL 5.9 ITS message or if the 5.9 ITS unit does not communicate or communicates incorrect ESL/VSL information.
- Speed limit information communicated to drivers via 5.9 roadside ITS stations not being adequately integrated with speed limit information obtained from other sources.
- Wide-scale investment in 5.9 ITS integration with ESL/VSL without due consideration for the uptake of 5.9 ITS in vehicles or the use of other communication media.
- Risks associated with how private companies may utilise C-ITS data that they are given access to.
- Use of temporary, but static fixed speed limit signage within a VSL zone with reduced speed limits (e.g., where a short length of road is designated as 25 km/h through the use of temporary signage, within a VSL zone that is down to 40 km/h with a 80 km/h and 60 km/h lead-in).
- The potential that integrating electronic speed limit signs with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.
### Technical

Elements required to achieve technical interoperability include:

**Vehicle-to-field and vice versa**
- 5.9 in-vehicle ITS station communicating probe vehicle messages to the 5.9 roadside ITS station upon request from the 5.9 roadside ITS station.
- 5.9 roadside ITS station requesting probe vehicle data from an equipped vehicle.
- Software within the 5.9 in-vehicle ITS station to obtain data from the vehicle (including sensors) for use in a PVD C-ITS message.
- Software within the 5.9 roadside ITS station to process the data and determine whether to generate a new 5.9 ITS message to vehicles in range.
- Vehicle-to-field and vice versa elements would require communication via the 5.9 GHz band, utilising the media protocol of IEEE 802.11p in the USA and ITS G5 in Europe.

**Field-to-centre**
- Software within the 5.9 roadside ITS station to process data and determine what to send to the back office with a connection to the back office and back office systems to process the data.
- Field-to-centre elements may use fixed wire communications or wide area communications and utilise network protocols such as IPv6.

### Syntactical

In order to achieve syntactical interoperability:

- Standards will be required to define the 5.9 ITS message. Field-to-centre elements will require protocols such as DATEX2 while vehicle-to-field and vice versa elements will require message sets such as PVM (SAE J2735), CAM, DENM, PVD and PDM.
- Software will be required to manage data from 5.9 ITS sources with data from traditional sources in order to produce information relevant to road agencies.

### Semantic

In order to achieve semantic interoperability:

- Standards will be required to define the 5.9 ITS message content and meaning.
- Software will be required to create a 5.9 ITS message that complies with the standardised content and meaning in addition to providing information regarding its location and timing.

### Organisational

Elements to be addressed in order to achieve organisational interoperability include:

- The need for road agencies to be responsible for registering, controlling use and operation of 5.9 roadside ITS stations for the collection of anonymous data from 5.9 ITS equipped vehicles.
- Road agencies will need to ensure that only certified 5.9 roadside ITS stations are used.
- Road agencies will need to ensure consistent architectural approaches are adopted across road agencies for their ITS.
- Road agencies will need to ensure that the required interfaces to enable data exchange with legacy systems are adopted.
- Road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations which may require modifications to their asset management processes.
- Road agencies will need to ensure that the 5.9 roadside ITS stations can fail safely in the event of a fault or outage.
- Road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. PDM) which may require modifications to business processes and databases.
- Road agencies will need to ensure security standards are in place to ensure messages can be authenticated and therefore trusted for use.
- The need for road agencies to collect anonymous data in an internationally standardised format and keep it in that format so that it can be processed internally and externally by third parties in order to add value.
- Amalgamation of data from existing sources.
- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation.
- Road agencies may need to establish processes to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users.
- Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data.

### Benefits

The benefits associated with the integration of 5.9 ITS with traveller data collection systems are that it provides an enhanced data source that:

- Is not constrained by location of infrastructure.
- Is more comprehensive with respect to origins and destinations.
- Can potentially collect more data for less infrastructure cost.
- Can be passed on to third parties to add value.

In addition other ITS station deployment (e.g. at traffic signals) could be utilised for data collection purposes in addition to their primary purpose.
The key risks associated with the integration of 5.9 ITS with traveller data collection systems include:

- having insufficient capability to communicate big data to the back office and process it with existing data sources
- not getting sufficient sample sizes
- not maintaining existing data sources
- using data in such a way that may violate privacy legislation
- not ensuring that data received and processed is screened in order to remove malicious or untrusted messages
- emergence of other technologies that results in 5.9 roadside infrastructure becoming redundant and a legacy issue for road agencies
- the technology not being taken up and resulting in 5.9 roadside ITS infrastructure needing to be maintained with the costs outweighing the benefits and restricting the ability to collect traveller data
- wide-scale investment in 5.9 ITS used to collect data without due consideration of the same service being delivered either solely by or in support of cellular-based communications
- the potential that integrating traveller data collection systems with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.

### Table G 3: Interoperability between 5.9 ITS and traffic signals – summary

#### Technical

Elements required to achieve technical interoperability include:

**Field-to-field**
- a local traffic signal controller integrated with a 5.9 roadside ITS station
- software to convert the signal phasing and timing (SPaT) data extracted from the local signal controller into a format that can be sent to a 5.9 ITS equipped vehicle (modifications to the TRAFF software may not be required where a field processor is used such as in the case of STREAMS as outlined in Section 6)
- field-to-field elements will utilise an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections. It may utilise network protocols such as IPv6

**Field-to-vehicle**
- a 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station
- a 5.9 in-vehicle ITS station communicating with a 5.9 roadside ITS station for the purpose of data collection and input to signal operations
- ability to process data received locally and if required generate a message to be broadcast locally
- field-to-vehicle integration would require communication via the 5.9 GHz band, utilising the media protocol of IEEE 802.11p in the USA and ITS G5 in Europe

**Field-to-centre**
- a connection to back office systems in order to communicate supplementary information regarding either the signal operation or miscellaneous information and to send data obtained from the 5.9 ITS equipped vehicle to the back office for processing
- ability to process data received locally and generate a 5.9 ITS message for local broadcast or to send data to the back office for processing
- field-to-centre elements may use fixed wire communications or wide area communications and utilise network protocols such as IPv6.

#### Syntactical

In order to achieve syntactical interoperability:

- standards will be required to define the 5.9 ITS message. Field-to-field and field-to-centre elements will require protocols such as NTCIP (US), DATEX2 (Europe), RTA protocols or other protocols used by the road agency while field-to-vehicle elements will require message sets such as RSA (SAE J2735), CAM, DENM, IVI, SPaT and Map
- software modifications may be required to the TRAFF software to extract the relevant data and to convert the data into the format of the 5.9 ITS message (modifications to the TRAFF software may not be required where a field processor is used such as in the case of STREAMS as outlined in Section 6).

#### Semantic

In order to achieve semantic interoperability:

- standards will be required to define the 5.9 ITS message content and meaning of both the SPaT data and Map data elements
- software will be required to create a 5.9 ITS message that complies with the standardised content and meaning with respect to SPaT and map messages
- road agencies will need to define how they use anonymous data from 5.9 ITS equipped vehicles in signal systems.
<table>
<thead>
<tr>
<th><strong>Organisational</strong></th>
<th>Elements to be addressed in order to achieve organisational interoperability include:</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>- road agencies will be responsible for registering, controlling the use and operating 5.9 ITS units</td>
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<td>- road agencies will need to ensure that only certified 5.9 roadside ITS stations are used</td>
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<tr>
<td></td>
<td>- road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations (e.g. Map data) which may require modifications to their asset management processes</td>
</tr>
<tr>
<td></td>
<td>- road agencies will need to ensure that the 5.9 roadside ITS stations can fail safely in the event of a fault or outage</td>
</tr>
<tr>
<td></td>
<td>- road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station which may require modifications to business processes and databases</td>
</tr>
<tr>
<td></td>
<td>- road agencies will need to ensure security standards are in place so that messages can be authenticated and therefore trusted for use</td>
</tr>
<tr>
<td></td>
<td>- retrofitting existing traffic signals with 5.9 roadside ITS stations may pose contractual issues</td>
</tr>
<tr>
<td></td>
<td>- road agencies will need to ensure system architecture is able to accommodate the communication of supplementary information from the back office to the 5.9 ITS unit, in addition to communicating data back to the back office for processing</td>
</tr>
<tr>
<td></td>
<td>- road agencies will be responsible for the delivery of internationally standardised messages including making allowance for differences in international and local terminologies</td>
</tr>
<tr>
<td></td>
<td>- road agencies should maintain an interest in how various vehicle manufacturers are using 5.9 ITS messages</td>
</tr>
<tr>
<td></td>
<td>- road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation</td>
</tr>
<tr>
<td></td>
<td>- road agencies may need to establish processes to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users</td>
</tr>
<tr>
<td></td>
<td>- corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Benefits</strong></th>
<th>The benefits associated with the integration of 5.9 ITS with traffic signals are that it:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- aids improved traffic signal compliance and therefore safety</td>
</tr>
<tr>
<td></td>
<td>- may assist in more environmentally friendly and efficient driving</td>
</tr>
<tr>
<td></td>
<td>- may provide data that could be used for enhanced traffic signal operations</td>
</tr>
<tr>
<td></td>
<td>- provides the ability to enhance information both about the traffic signals it is integrated with, and broader traveller information in order to aid better driver decisions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Risks</strong></th>
<th>The key risks associated with the integration of 5.9 ITS with traffic signals include:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- provision of SPaT data from ATC systems not being feasible, or alternatively requiring limitations to some of the functionality of ATC systems in order for the SPaT data to be accommodated</td>
</tr>
<tr>
<td></td>
<td>- the need for road agencies to manage the issue of temporary lane closures with respect to maps of intersections for use with the SPaT data</td>
</tr>
<tr>
<td></td>
<td>- misuse of information</td>
</tr>
<tr>
<td></td>
<td>- drivers becoming dependent on the technology and not understanding that the traffic signal remains the regulatory device (this could be an issue where traffic signals are not equipped or where a 5.9 roadside ITS station issues a conflicting message)</td>
</tr>
<tr>
<td></td>
<td>- liability issues associated with whether road agencies are liable if a vehicle does not receive a 5.9 ITS message from the 5.9 ITS unit integrated with traffic signals</td>
</tr>
<tr>
<td></td>
<td>- results in required modifications to existing architecture in order to facilitate some functionality</td>
</tr>
<tr>
<td></td>
<td>- wide-scale investment in 5.9 ITS without due consideration of other architectures for the uptake of 5.9 ITS in vehicles</td>
</tr>
<tr>
<td></td>
<td>- emergence of other technologies that results in 5.9 ITS roadside technology becoming redundant and a legacy issue for road agencies</td>
</tr>
<tr>
<td></td>
<td>- risks associated with how private companies may utilise C-ITS data that they are given access to</td>
</tr>
<tr>
<td></td>
<td>- the potential that integrating traffic signals with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.</td>
</tr>
</tbody>
</table>
Table G 4: Interoperability between 5.9 ITS and traveller information systems – summary

<table>
<thead>
<tr>
<th>Technical</th>
<th>Elements required to achieve technical interoperability include:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Field-to-field</strong></td>
</tr>
<tr>
<td></td>
<td>• a 5.9 ITS installed in the field at the VMS (access to power, communications and a sign status reply message from the VMS sign controller)</td>
</tr>
<tr>
<td></td>
<td>• field-to-field elements will utilise an Ethernet networking media protocol/standard that can work on wired (e.g. optic fibre) or wireless connections. It may utilise network protocols such as IPv6.</td>
</tr>
<tr>
<td></td>
<td><strong>Field-to-vehicle</strong></td>
</tr>
<tr>
<td></td>
<td>• a 5.9 roadside ITS station communicating with a 5.9 in-vehicle ITS station</td>
</tr>
<tr>
<td></td>
<td>• software to convert the content of the messages received by the 5.9 roadside ITS station into the standardised 5.9 ITS format (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station)</td>
</tr>
<tr>
<td></td>
<td>• ability to process data received locally and to send data back to the back office for further processing</td>
</tr>
<tr>
<td></td>
<td>• field-to-vehicle integration would require communication via the 5.9 GHz band, utilising the media protocol of IEEE 802.11p in the USA and ITS G5 in Europe.</td>
</tr>
<tr>
<td></td>
<td><strong>Field-to-centre</strong></td>
</tr>
<tr>
<td></td>
<td>• a connection to back office systems in order to communicate supplementary information regarding the response of the 5.9 ITS equipped vehicle to the message and other traveller data</td>
</tr>
<tr>
<td></td>
<td>• ability to process data received locally and to send data back to the back office for further processing</td>
</tr>
<tr>
<td></td>
<td>• field-to-centre elements may use fixed wire communications or wide area communications and utilise network protocols such as IPv6.</td>
</tr>
<tr>
<td>Syntactical</td>
<td>In order to achieve syntactical interoperability:</td>
</tr>
<tr>
<td></td>
<td>• standards will be required to define the 5.9 ITS message. Field-to-field and field-to-centre elements will require protocols such as NTCIP (US) or DATEX2 (Europe) while field-to-vehicle elements will require message sets such as RSA (SAE J2735), CAM, DENM and IVI</td>
</tr>
<tr>
<td></td>
<td>• software will be required to convert VMS content and information from a traffic management centre into the 5.9 ITS message structure for use in vehicles (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station).</td>
</tr>
<tr>
<td>Semantic</td>
<td>In order to achieve semantic interoperability:</td>
</tr>
<tr>
<td></td>
<td>• standards will be required to define the 5.9 ITS message content and meaning</td>
</tr>
<tr>
<td></td>
<td>• software will be required in the 5.9 ITS unit to interpret the message sent to an VMS and convert it to a 5.9 ITS message that complies with the standardised content and meaning. In addition the software will need to process information regarding the location and timing associated with the traveller information (alternatively the centre may deliver the 5.9 ITS message to the 5.9 roadside ITS device in the 5.9 ITS standardised message format or where STREAMS is utilised the roadside ITS station gateway may be considered as a field processor, therefore only requiring a software interface to pass information from the field processor to the 5.9 roadside ITS station).</td>
</tr>
<tr>
<td>Organisational</td>
<td>Elements to be addressed in order to achieve organisational interoperability include:</td>
</tr>
<tr>
<td></td>
<td>• road agencies will be responsible for registering, controlling the use and operating 5.9 roadside ITS stations</td>
</tr>
<tr>
<td></td>
<td>• road agencies will need to ensure that only certified 5.9 roadside ITS stations are used</td>
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<tr>
<td></td>
<td>• road agencies will need to ensure consistent architectural approaches are adopted across road agencies for their ITS</td>
</tr>
<tr>
<td></td>
<td>• road agencies will need to ensure that the required interfaces to enable data exchange with legacy systems are adopted</td>
</tr>
<tr>
<td></td>
<td>• road agencies will be responsible for maintaining and ensuring ongoing operation of the 5.9 roadside ITS stations which may require modifications to their asset management processes</td>
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<td>• road agencies will need to ensure that the 5.9 roadside ITS stations can fail safely in the event of a fault or outage</td>
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<td>• road agencies will be responsible for creating and managing data messages transmitted from the 5.9 roadside ITS station (e.g. DENM, IVI) which may require modifications to business processes and databases</td>
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<td>• road agencies will need to ensure security standards are in place to ensure messages can be authenticated and therefore trusted for use</td>
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<td>• retrofitting existing VMS with 5.9 roadside ITS stations may pose contractual issues</td>
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<td></td>
<td>• road agencies will be responsible for the specifications regarding the delivery of internationally standardised messages including making allowance for differences in international and local terminologies where appropriate</td>
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<td>• road agencies should maintain an interest in how various vehicle manufacturers are using 5.9 ITS messages</td>
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<tr>
<td></td>
<td>• road agencies will need to determine what information they provide via 5.9 ITS technology versus other technologies</td>
</tr>
<tr>
<td></td>
<td>• road agencies will need to determine their role in the supply chain of traveller information</td>
</tr>
</tbody>
</table>
### Organisational (continued)
- Road agencies will be responsible for ensuring that any data that is captured and stored is anonymous and must comply with any applicable privacy and surveillance legislation.
- Road agencies may need to establish interfaces, processes and agreements to enable and support data provision to private telematics companies that will then use the data in the provision of their C-ITS services to road users.
- Corporate traffic information systems, including business processes and associated databases will need to be modified in order to process and store new data.

### Benefits
- The benefits associated with the integration of 5.9 ITS with VMS are that it provides enhanced traveller information for drivers and enhanced delivery of traveller information, both of which may aid and influence better decisions by drivers.

### Risks
- The key risks associated with the integration of 5.9 ITS with VMS include:
  - Potential for conflicting information.
  - The potential that integrating traveller information systems with 5.9 ITS provides a new interface/wireless access point that could make it vulnerable to cyber and/or malicious attacks.
  - Risks associated with how private companies may utilise C-ITS data that they are given access to.
  - Potential for negative impact on the road network (e.g. vehicles relocating from one route to another in large numbers).
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9 in-vehicle ITS station</td>
<td>In-vehicle ITS station utilising 5.9 GHz communications</td>
</tr>
<tr>
<td>5.9 ITS</td>
<td>A term used to describe a subset of C-ITS which utilises 5.9 GHz communications. The US uses the term DSRC 802.11p, Europe uses G5 (also G5A, G5B and G5C as subsets of G5), ISO uses CALM M5</td>
</tr>
<tr>
<td>5.9 roadside ITS station</td>
<td>Roadside ITS station utilising 5.9 GHz communications</td>
</tr>
<tr>
<td>ATC</td>
<td>Adaptive traffic control</td>
</tr>
<tr>
<td>BSM</td>
<td>Basic safety message</td>
</tr>
<tr>
<td>CALM</td>
<td>Communication access for land mobiles</td>
</tr>
<tr>
<td>CAM</td>
<td>Cooperative awareness message</td>
</tr>
<tr>
<td>CEN</td>
<td>European Committee for Standardisation</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardisation</td>
</tr>
<tr>
<td>C-ITS</td>
<td>Cooperative intelligent transport systems</td>
</tr>
<tr>
<td>Day 1 applications</td>
<td>Those C-ITS applications that are proposed to be the first C-ITS applications deployed within a few years of C-ITS standardisation having been completed</td>
</tr>
<tr>
<td>DENM</td>
<td>Decentralised environmental notification message</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated short range communications</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>FNTP</td>
<td>Fast networking and transport layer protocol</td>
</tr>
<tr>
<td>HMI</td>
<td>Human machine interface</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent transport systems</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>IVI</td>
<td>In-vehicle information</td>
</tr>
<tr>
<td>Map</td>
<td>Geometric intersection description</td>
</tr>
<tr>
<td>NTCIP</td>
<td>National Transportation Communications for ITS Protocol</td>
</tr>
<tr>
<td>PDM</td>
<td>Probe data management</td>
</tr>
<tr>
<td>PVD</td>
<td>Probe vehicle data</td>
</tr>
<tr>
<td>Release 1</td>
<td>Set of minimum standards required for interoperability in accordance with the European Commission Standardization Mandate M/453</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
</tr>
<tr>
<td>SPaT</td>
<td>Signal phasing and timing</td>
</tr>
<tr>
<td>SRM</td>
<td>Signal request message</td>
</tr>
<tr>
<td>SSM</td>
<td>Signal status message</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic message channel</td>
</tr>
<tr>
<td>TPEG</td>
<td>Transport Protocol Expert Group</td>
</tr>
<tr>
<td>WSMP</td>
<td>Wave short message protocol</td>
</tr>
</tbody>
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