TECHNICAL SPECIFICATION

ISO/TS 19091

First edition
2017-03

Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections

Systèmes intelligents de transport — Coopérative ITS — Utilisation de communications V2I et I2V pour des applications relatives aux intersections signalées

Reference number
ISO/TS 19091:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

Introduction

Cooperative-ITS (C-ITS) is a promising and remarkable advancement of intelligent transport systems (ITS). Numerous cooperative applications are specified that open up new possibilities to make traffic safer, more efficient, and smarter. Technologies are developed and improved to realize and support those new services and applications. To enable those applications, information needs to be reliably communicated between the stationary infrastructure and mobile vehicles.

This document describes the use cases for several applications that address safety, mobility, and ecological sustainability. Each use case has information needs that communication between vehicles and the infrastructure facilitate. It then identifies the information needs for the applications and the requirements to satisfy them. In turn, it maps the requirements into data frames and data elements to fulfil the requirements within the specified message set.

ISO 22951 has a relationship to this document. PRESTO addresses its user needs through the implementation of a specific system architecture similar to that described in NTCIP 1211. This architecture includes traffic signals, message signs, routing systems, human machine interfaces, and fixed detection locations. Many of PRESTO's data value details are "left undefined to allow for discretional definition by each country." The PRESTO architecture detects priority requesting vehicles by installing specific detection equipment at these locations.

This document uses a similar set of user needs to develop the message set between vehicles and the roadside equipment they interface. This document does not address the system architecture other than data needed to fulfil the user needs that will be managed elsewhere in the architecture. It details data values and structures in order to define the interface between these two devices. Routing information is supported in the architecture through other mechanisms and is not a need supported by the vehicle to roadside equipment information flows. The user needs also provide for priority by approach, a preconfigured strategy, and ingress/egress lane requests. This document is based on vehicles periodically broadcasting their location and trajectory information to other vehicles and the roadside infrastructure. This document compliments ISO 22951 as it provides for vehicle location and request information directly from connected vehicles rather than the detection of the vehicles from other fixed sensing equipment. It does not address the architecture data flows and operations that are detailed within ISO 22951. In other terms, this document provides a connected vehicle alternative for request and status communication without impacting the back office or local intersection operations of priority management.

Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections

1 Scope

This document defines the message, data structures, and data elements to support exchanges between the roadside equipment and vehicles to address applications to improve safety, mobility and environmental efficiency. In order to verify that the defined messages will satisfy these applications, a systems engineering process has been employed that traces use cases to requirements and requirements to messages and data concepts.

This document consists of a single document that contains the base specification and a series of annexes. The base specification lists the derived information requirements (labelled informative) and references to other standards for message definitions where available. Annex A contains descriptions of the use cases addressed by this document. Annex B and Annex C contain traceability matrices that relate use cases to requirements and requirements to the message definitions (i.e. data frames and data elements). The next annexes list the base message requirements and application-oriented specific requirements (requirements traceability matrix) that map to the message and data concepts to be implemented. As such, an implementation consists of the base plus an additional group of extensions within this document.

Details on information requirements, for other than SPaT, MAP, SSM, and SRM messages are provided in other International Standards. The focus of this document is to specify the details of the SPaT, MAP, SSM, and SRM supporting the use cases defined in this document. Adoption of these messages varies by region and their adoption may occur over a significant time period.

This document covers the interface between roadside equipment and vehicles. Applications, their internal algorithms, and the logical distribution of application functionality over any specific system architecture are outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22951, *Data dictionary and message sets for preemption and prioritization signal systems for emergency and public transport vehicles (PRESTO)*

ISO 26684, *Intelligent transport systems (ITS) — Cooperative intersection signal information and violation warning systems (CIWS) — Performance requirements and test procedures*

SAE J2735™:2016, *Dedicated Short Range Communications (DSRC) Message Set Dictionary*

EN 302 637-2 V1.3.2, *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service*

ARIB STD-T109, *700 MHz Band Intelligent Transport Systems*

ITS FORUM RC-010, *700 MHz Band Intelligent Transport Systems — Extended Functions Guideline, published on March 15, 2012*

ETSI/TS 102 894-2 V1.2.2, *Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer; common data dictionary*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

NOTE This document requires the understanding of the terminology used in the context of C-ITS and the various devices involved in its implementation. As a result, the following terms contain important information to set the context of the discussions which follow in the remaining sections of this document.

3.1
active manoeuvre
traveller paths (vehicles, pedestrians, bicyclists, etc.) that are allowed and have the right of way to enter and move through the path

Note 1 to entry: This term supersedes allowed movements which meant, in the context of this document, the directions of manoeuvre that are legally allowed at a specific point in time based upon the state of the intersection signals.

Note 2 to entry: Formerly known as active movement.

3.2
aftermarket safety device
ASD
connected device (3.8) in a *vehicle* (3.50) that operates while the vehicle is mobile, but which is not fully integrated into the vehicle systems (as opposed to an OEM device that is pre-installed into the vehicle systems)

3.3
allowed manoeuvre
traveller paths (vehicles, pedestrians, bicyclists, etc.) legally permitted to be performed when moving from/into a *lane* (3.21) or between lanes

3.4
application
software designed to help users perform particular tasks or handle particular types of problems, as distinct from software that controls the computer itself

Note 1 to entry: In the context of this document, it is a software program that provides functionality to realize safety, mobility, and environmental benefits.

[SOURCE: ISO/IEC 26514:2008, 4.5, modified.]

3.5
Barnes dance
signal phase that stops vehicular manoeuvres and allows pedestrian manoeuvres to exclusively occur across the *intersection* (3.17) including diagonally moving between corners

Note 1 to entry: Also referred to as a scramble, or "X" crossing. The term refers to Henry Barnes, a deceased traffic engineer.

3.6
commercial motor vehicle
self-propelled or towed motor *vehicle* (3.50) used on a highway in interstate commerce to transport passengers or property when the vehicle

a) has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4 536 kg (10 001 pounds) or more, whichever is greater,

b) is designed or used to transport more than 8 passengers (including the driver) for compensation,

c) is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation, or

d) is used in transporting material found by the Secretary of Transportation to be hazardous under 49 USC 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C

[SOURCE: 49 USC 31132]

3.7
commercial motor vehicle on-board equipment
OBE (3.29) or *ASD* (3.2) mounted or in a *vehicle* (3.50) moving goods, heavy equipment, or people

Note 1 to entry: Vehicles include tractor-trailer combinations, panel trucks, and motor coaches.

3.8
connected device
device used to transmit to or receive messages from another device

Note 1 to entry: A connected device can be sub-categorized as an *OBE* (3.29), *ASD* (3.2), or *RSE* (3.39).

Note 2 to entry: In many cases, the connected device will be a *DSRC* (3.10) device, but other types of communications could be supported.

3.9
connected vehicle
vehicle that contains a *connected device* (3.8)

3.10
dedicated short range communications
DSRC
technology for the transmission of information between multiple *vehicles* (3.50) (V2V) and between vehicles and the transportation infrastructure (V2I and I2V) using wireless technologies

Note 1 to entry: It is characterized as having a limited distance (approximately 300 m) but is assumed to be low latency to establish a connection and exchange information.

Note 2 to entry: Alternative definition - means of effecting (short-range) transactions between fixed equipment and OBE(s) using an "air interface" comprising inductive or propagated signals between the fixed equipment and OBE(s)

[SOURCE: ISO 17687:2007, 3.10 and ISO 17261:2012, 3.15]

3.11
eco-driving
practice of driving in such a way as to minimize fuel consumption and emissions

3.12
eco-lane
dedicated *lane(s)* (3.21) optimized for *eco-driving* (3.11) similar to high-occupancy vehicle lanes

Note 1 to entry: However, these lanes are optimized for the environment using connected vehicle data.

Note 2 to entry: These lanes would be targeted toward low-emission, high-occupancy freight, public transport, and alternative-fuel vehicles (AFV).

Note 3 to entry: Drivers would be able to opt-in to these dedicated eco-lanes to take advantage of eco-friendly applications such as eco-speed limits, eco-cooperative adaptive cruise control, and connected eco-driving applications.

3.13
electronic on-board recorders
device on-board a commercial *vehicle* (3.50) used to record driver information such as hours of service

3.14
inactive manoeuvre
traveller paths (vehicles, pedestrians, bicyclists, etc.) that are allowed and do not have the right of way to enter and move through the path

3.15
intelligent transportation systems
ITS
transport system in which advanced information, communication, sensor, and control technologies, including the Internet, are applied to increase safety, sustainability, efficiency, and comfort

Note 1 to entry: Another appropriate meaning of the ITS acronym is integrated transportation systems, which stresses that ITS systems will often integrate components and users from many domains, both public and private.

[SOURCE: ISO/TR 17465-1:2014, 2.3]

3.16
interoperability
ability of two or more systems or components to exchange information and to use the information that has been exchanged

[SOURCE: IEEE 610.12-1990]

3.17
intersection
nexus where two or more approaches (*links*) (3.26) meet and *vehicles* (3.50) and other type of users may travel between the connecting links

Note 1 to entry: Typically, this is a signalized intersection when considered by this document, and as such, the modes of allowed manoeuvre are reflected in the signal phases, the geometry of the intersection, and the local regulatory environment.

Note 2 to entry: The messages of J2735™ convey some of this intersection information to the travelling public. Specifically, the *MAP message* (3.28) conveys the relevant road geometry, while the *SPaT* (3.44) message conveys the current allowed manoeuvres and timing which control movements within the intersection.

Note 3 to entry: Alternative definition - GDF level 2 representation of a crossing which bounds a road or a ferry as a complex feature composed of one or more GDF level 1 junctions, road elements and enclosed traffic areas

[SOURCE: ISO/TS 20452:2007, 3.14]

3.18
interval
part of a traffic signal cycle during which, *signal indications* (3.43) are stable and do not change

Note 1 to entry: In the *SPaT* (3.44) message, the current timing value for the remaining interval time estimate, as well as the anticipated interval for yellow change (clearance) interval, is provided for each lane.

Note 2 to entry: Because signal interval times commonly change based on triggering events in many types of signalling systems, the value provided in the SPaT message may represent a minimal value that is extended and updated as the message is re-transmitted in real time.

3.19
interval sequence
order of appearance of *signal indications* (3.43) during successive periods of a traffic signal cycle

3.20
international traveller information system
ITIS
standard for incident phrases developed by the SAE ATIS Committee in conjunction with ITE TMDD and other standards

Note 1 to entry: The ITIS documentation contains a wide variety of standard phrases to describe incidents and is expected to be used throughout the *ITS* (3.15) industry. The codes found there can be used for sorting and classifying types of incident events, as well as creating uniform human readable phrases. In the capacity of classifying incident types, ITIS phrases are used in many areas. ITIS phrases can also be freely mixed with text and used to describe many incidents.

3.21
lane
portion of the transportation network (typically a section of roadway geometry) which is being described (its paths and various attributes about it) or referred to

Note 1 to entry: In the DSRC message set, the lane object is widely used. Lanes consist not only of sections of drivable roadway traversed by motor vehicles, but other types of lanes including pedestrian and bicycle walkways, trains and public transport lanes, and certain types of dividers and barriers.

Note 2 to entry: When used in describing an intersection, a lane is defined for each possible path into and out of the intersection (in the MAP message). The current allowed manoeuvres applicable to the lane or its approach are provided in the *SPaT* (3.44) message.

3.22
lane-use control signal
signal face displaying *signal indications* (3.43) to permit or prohibit the use of specific *lanes* (3.21) of a roadway or to indicate the impending prohibition of such use

Note 1 to entry: Typically, these are arrow displays of varying colours.

Note 2 to entry: This document does not attempt to use signal colours/indications to reflect the allowed vehicle operation, rather, the permitted movements are indicated and the state of the movement as explained later herein. Each region has unique mechanisms for using the display signals to indicate the movement(s) allowed.

3.23
latency
<system> time interval between the instant at which an instruction control unit issues a call for data and the instant at which the transfer of data is started

Note 1 to entry: The reader is advised to select the appropriate definition based on the context.

[SOURCE: ISO/IEC/IEEE 24765:2010, 3.1565]

3.24
latency
<communication> time delay between sending a signal from one device and receiving it by another device

Note 1 to entry: The reader is advised to select the appropriate definition based on the context.

[SOURCE: ISO/IEEE 11073-10201:2004, 3.31]

3.25
link
<radio frequency> communications channel being used in support of application data transfer needs

3.26
link
<traffic> segment of a road network

Note 1 to entry: While highway links are generally separated by one data collection node (such as an RSE or a vehicle detector station), local road links tend to be limited by intersections with cross streets.

Note 2 to entry: Other common usages of the word "link," such as those used in telecommunications, may also appear in this document.

3.27
low-emissions zone
geographically defined area that seeks to restrict or deter access by specific categories of high-polluting *vehicles* (3.50) to improve the air quality within the geographic area

Note 1 to entry: The low-emissions zone can be dynamic, allowing the operating entity to change the location, boundaries, or time of the low-emissions zone.

3.28
MAP data message
MAP
data elements and frames comprising a message, the contents of which describe the geometry of a roadway *intersection* (3.17)

Note 1 to entry: In the context of USDOT J2735™ SE Candidate, the MAP message provides the road geometry at an intersection.

Note 2 to entry: It is broadcast from the infrastructure to the vehicle.

Note 3 to entry: The MAP message contains geographic intersection description (GID) data.

3.29
on-board equipment
OBE
compliment of equipment located in the *vehicle* (3.50) for the purpose of supporting the vehicle side of the C-ITS applications

Note 1 to entry: It is likely to include the DSRC radios, other radio equipment, message processing, driver interface, and other applications to support the use cases described herein.

Note 2 to entry: It is also referred to as the vehicle ITS station.

Note 3 to entry: Alternative definition - device on board or attached to the vehicle/equipment to perform the functionality of AVI/AEI

[SOURCE: ISO 17687:2007]

3.30
prohibited manoeuvre
traveller paths (vehicles, pedestrians, bicyclists, etc.) legally disallowed from being performed when moving from/into a *lane* (3.21) or between lanes

3.31
traffic signal phase
set of manoeuvres being allowed by the roadside traffic signal controller

Note 1 to entry: This term is commonly used in North America to refer to a specific manoeuvre that is allowed (e.g. main street left turn to a side street, main street north bound through manoeuvre, side street pedestrian walk.)

3.32
platoon
collection of vehicles travelling together, coordinating their operation (e.g. speed, headway) using V2V communications

Note 1 to entry: Platoons may consist of a mixture of *vehicle types* (3.51) or in special circumstances, a single vehicle type such as freight vehicles (e.g. lorries), public safety vehicles, or *public transport vehicles* (3.35).

3.33
precondition
condition that must exist or be established before something can occur or be considered

3.34
public safety on-board equipment
PSOBE
OBE (3.29) or *ASD* (3.2) mounted or in an authorized public safety *vehicle* (3.50)

Note 1 to entry: It may be designed to transmit at a higher power to allow its messages to be received from a greater distance to provide more time to complete appropriate clearance intervals at signalized intersections.

3.35
public transport vehicle
PTV
vehicle (3.50) specifically designed to carry multiple passengers such as a bus

Note 1 to entry: Does not refer to taxis or similar vehicles.

3.36
queue jump
operation where *public transport vehicles* (3.35) are provided an advantage over adjacent *vehicles* (3.50) through signal operations that allow the public transport vehicle to enter an *intersection* (3.17) in advance of the adjacent vehicles

3.37
road surface condition
environmental measures of a pavement's running surface including temperature and moisture condition

EXAMPLE Dry, wet, snowy, icy, chemical concentration, oil, etc.

Note 1 to entry: This information may also include information regarding surface conditions that could be used to compute stopping distances for selected use cases.

3.38
road sign
physical traffic control device intended to communicate specific information to road users through a word, symbol, and/or arrow legend

Note 1 to entry: Road signs do not include highway traffic signals, pavement markings, delineators, or channelization devices.

3.39
roadside equipment
RSE
compliment of equipment located at the roadside that prepares and transmits messages to *vehicles* (3.50) and receives messages from vehicles for the purpose of supporting the V2I and I2V applications

Note 1 to entry: This is intended to include the DSRC radio, traffic signal controller, where appropriate, interface to the backhaul communications network necessary to support the applications, and support such functions as data security, encryption, buffering, and message processing.

Note 2 to entry: It may also be referred to as the roadside ITS station.

3.40
roadway segment
section of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, or that portion of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, but exclusive of the sidewalk, berm, or shoulder even though such sidewalk, berm, or shoulder is used by persons riding bicycles or other human-powered *vehicles* (3.50)

[SOURCE: MUTCD, 2009, Section 1A.13]

3.41
signal control zone
geo-physical area of an *intersection* (3.17) used for an approaching *vehicle* (3.50) to request a pre-empt or priority request of a traffic signal

3.42
signal group
set of traffic signals providing a *signal indication* (3.43) that governs the vehicle/pedestrian/bicycle manoeuvres possible for a set of one or more *lanes* (3.21)

3.43
signal indication
illumination of a signal lens or equivalent device

Note 1 to entry: The signal face of a signal indication is an assembly of one or more signal sections that is provided for controlling one or more traffic manoeuvres on a single approach.

[SOURCE: MUTCD, 2009, Section 1A.13]

3.44
signal phase and timing
SPaT
SAE J2735™ message from the infrastructure to the C-ITS device that describes the current state of a traffic signal system (at one or more intersections) and its phases and relates this to the specific *lanes* (3.21) (and therefore to manoeuvre and approaches) in the *intersection* (3.17)

Note 1 to entry: It is used along with the *MAP message* (3.28) to allow describing an intersection and its current allowed manoeuvres and timing of same.

3.45
signal request message
SRM
SAE J2735™ message from a C-ITS device to the infrastructure by which the *vehicle* (3.50) asks for priority treatment by an intersection's traffic signal controller

3.46
signal status message
SSM
SAE J2735™ message from the infrastructure to the C-ITS device that contains the infrastructure's response details to a *signal request message* (SRM) (3.45) for requesting priority from an intersection's traffic signal controller

Note 1 to entry: This is a broadcast message in this document; this is not a unicast message.

3.47
speed
rate of progress, or change in position, usually without regard to direction

Note 1 to entry: The distance travelled divided by time (if speed is constant). A scalar quantity which refers to how fast an object is moving.

3.48
traffic signal phase overload
proceed manoeuvre that has been terminated while demand for the manoeuvre continues

Note 1 to entry: Repeated phase overloads indicate that the signal phase timing is not adequate to satisfy the demand.

3.49
public transport vehicle on-board equipment
PTVOBE
OBE (3.29) or *ASD* (3.2) mounted or within a *public transport vehicle* (3.35)

3.50
vehicle
self-propelled transport device, along with any attachments (e.g. trailers), that is a legal user of the transportation network

Note 1 to entry: Alternative definition — Object subject to being navigated or tracked

Note 2 to entry: Alternative definition — Machine for the transportation of goods and people on land

[SOURCE: ISO 11783-1:2007, 3.70]

3.51
vehicle type
classification scheme used to identify *vehicles* (3.50) for appropriate services by various crosscutting C-ITS applications

Note 1 to entry: Observe that this definition differs from the (multiple other) vehicle types defined elsewhere in other International Standards used in *ITS* (3.15). The specific vehicle type (i.e. classification) used for an application may not satisfy the needs of other applications.

Note 2 to entry: Alternative definition - type (i.e. classification) of vehicle based on the nature of its construction or intended purpose

Note 3 to entry: See SAE J1100.

[SOURCE: ISO 12353-1:2002]

3.52
work zone
area of a highway with construction, maintenance, or utility work activities

Note 1 to entry: A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles.

Note 2 to entry: A work zone extends from the first warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle to the END ROAD WORK sign or the last Temporary Traffic Control device.

[SOURCE: MUTCD 2009, Section 6C.02]

4 Abbreviated terms

AEI	Automatic Equipment Identification
AERIS	Applications for the Environment: Real-Time Information Synthesis
ASD	Aftermarket Safety Device
ATIS	Advanced Traveller Information System
AVI	Automatic Vehicle Identification
BOPC	Back Office Processing Centre (also known as Traffic Management Centre)
BSM	Basic Safety Message (J2735™)
CAM	Cooperative Awareness Message (ETSI)
CEN	Comité Européen de Normalization (European Committee for Standardization)
CV	Connected Vehicle

DSRC	Dedicated Short Range Communications
ETSI	European Telecommunications Standards Institute
EVP	Emergency Vehicle Pre-emption
FrVOBE	Freight Transport Vehicle On-Board Equipment
FSP	Freight Signal Priority
GHG	Green House Gas
GID	Geographic Intersection Description
GNSS	Global Navigation Satellite System
GPS	Geographic Positioning System (by use of GNSS)
HDOP	Horizontal Dilution of Precision
HOV	High Occupancy Vehicle
I2V	Infrastructure to Vehicle
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITIS	International Traveller Information System
ITS	Intelligent Transport Systems
MMITSS	Multi-Modal Intelligent Traffic Signal System (a project within the US)
MPR	Minimum Performance Requirements
MUTCD	Manual on Uniform Traffic Control Devices (a US Department of Transportation technical document)
NMEA	National Marine Electronics Association
OBE	On-Board Equipment
PRESTO	Data Dictionary and Message Sets for Pre-emption and Prioritization Signal System for Emergency and Public Transport Vehicles
PSOBE	Public Safety On-Board Equipment
PTV	Public Transport Vehicle
RF	Radio Frequency
RSE	Roadside Equipment
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers International
SPaT	Signal Phase and Timing (J2735™)

SRM	Signal Request Message (J2735™)
SSM	Signal Status Message (J2735™)
TMC	Traffic Management Centre (also known as Back Office Processing Centre)
TMDD	Traffic Management Data Dictionary
PTVOBE	Public Transport Vehicle On-Board Equipment
TSC	Traffic Signal Controller
TSP	Public transport Signal Priority
USC	United States Code
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VRU	Vulnerable Road User (typically, a pedestrian may include bicycle rider)

5 General description (informative)

5.1 Overview

This clause describes the actors, needs, and models requiring the services provided by the message set. It describes how the connected vehicle (CV) obtains the data needed from the infrastructure to perform its on-board processing and decision making within the context of the use cases.

It also describes the assumptions and operational issues associated with delivering the services.

The use cases are organized into three areas: safety, mobility/sustainability, and priority/pre-emption for specific vehicle types (public safety, public transport, freight, etc.) and are shown in Annex A. Each area is identified using an alpha-numeric identification consisting of a use case category and a number. The use case categories are PR for priority/pre-emption, SA for safety, and MS for mobility/sustainability. Table A.1 lists the use cases by their identification and name.

Each use case comprises 16 descriptive characteristics ranging from simple identification information through data/process flow sequences and outstanding issues. These are presented in tabular form with each use case beginning on a new page. An illustration is included with each use case to provide a visual reference when discussing the operation.

Three types of travellers are supported by this document: general motorized vehicles, non-motorized (e.g. pedestrians, bicyclists), and specialized motor vehicles. Vehicular lanes are lanes for motorized vehicles, pedestrian lanes (cross walks) are for pedestrians, including non-motorized vehicles such as bicycles, while special lanes are for lanes for a specific type of motorized vehicle such as trains or public transport vehicles.

5.2 Functional model

5.2.1 Description

The use cases described in this document utilize the following functional working model, which describes at a high level the relevant vehicle equipment, roadside infrastructure, and traffic management functionality to support the use cases. While the focus is on the communications between the vehicle and roadside infrastructure, selected use cases involve interaction with traffic/fleet management functions beyond the roadside. The precise details of these interactions are not defined herein, but rather are described in general terms. While DSRC communications media has been assumed for message exchanges, the focus of this document is to identify the specific data elements needed for the exchanges over the V2I/I2V link to meet the needs of the use cases described herein. The message content is intended to be media-independent. However, it is likely that performance requirements for certain applications will dictate the type of media capable of supporting the intended functionality.

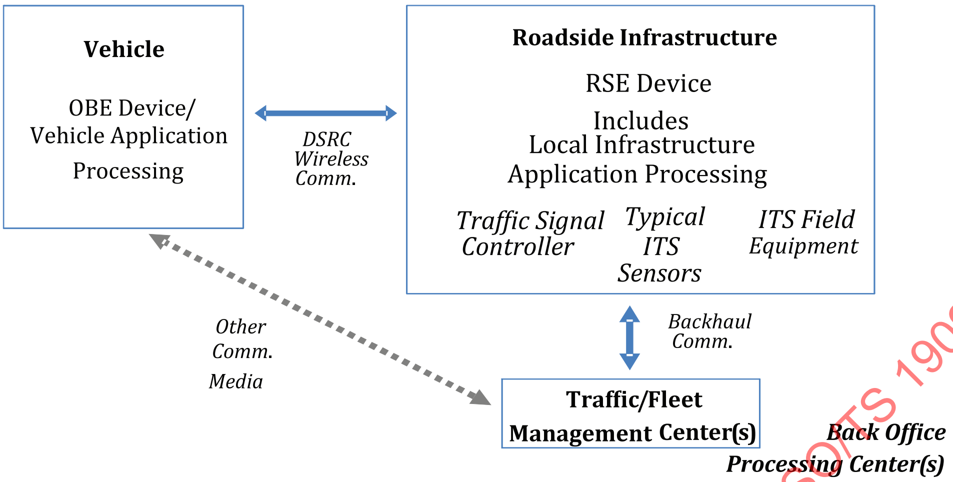


Figure 1 — Working model for use cases (functional)

Vehicle role. The connected vehicle includes the basic functionality needed to implement transmission of basic safety messages (BSM) [or cooperative awareness messages (CAM)], and signal request messages (SRM), where applicable, as well as receiving and processing incoming signal phase and timing (SPaT) messages, MAP messages, signal status messages (SSM), and other infrastructure-to-vehicle messages. The following assumptions apply.

— An OBE device provides for DSRC communications with the field infrastructure.

— Vehicle application processing may be provided by the OBE device and/or separately.

— Other communications may exist to communicate with the traffic/fleet management center.

— Vehicles are assumed to make all safety-related decisions and determine what, if any, advisory, alert, or warning to provide to the driver.

The vehicle transmits to the infrastructure (V2I) and receives from the infrastructure (I2V). These transmissions are also received by other vehicles (V2V) since they are broadcast messages. While the data flows between vehicles could be utilized within the use cases identified herein, they exist only to indicate data availability and these data flows are outside the scope of this document.

Roadside infrastructure role. The roadside infrastructure incorporates the communications and processing functionality to send, receive, and process messages to and from the vehicle and, as applicable, provides for traffic signal control, sensing/detection using traditional ITS devices, and other field-related functions. It also includes backhaul communications capability to support management functions such as traffic management. The following assumptions apply.

— RSE devices provide for DSRC communications with vehicles.

— Local infrastructure application processing may be provided by the RSE device and/or separately (in combination, the RSE may be referred to as roadside equipment).

— RSE device, traffic signal controller, and other ITS field equipment are connected via backhaul network to one or more back office processing centres (BOPC).

— Traffic signal controller and other ITS field equipment are typically connected to the RSE device via local wireline communication.

— Roadside equipment can provide limited control and performance management over a specific geographic area, i.e. at an intersection and its approaches.

— The use cases typically identify or separate functions within the roadside infrastructure as the RSE and the TSC to be separate devices. Hence, selected processing is assigned to the RSE while other processing is assigned to the traffic signal controller. This is an arbitrary separation; the reader should assume that the functions specified at the roadside can be performed by any of the roadside devices, thus all processing could take place within the traffic signal controller if it has sufficient processing power and memory, or such processing could be assigned to other devices within the cabinet. This document only addresses the message content exchanged between the vehicle and the roadside.

Traffic management center (TMC) role. The traffic management centre, also known as the back office processing centre (BOPC), provides for management of field ITS equipment including traffic signal controllers, RSE devices and associated processing capabilities, as well as managing information such as policies and rules, the geometric database, regional (section, arterial) signal timing data, and performance management. The following assumptions apply.

— Traffic management center (TMC) manages traffic signal controllers and ITS field equipment.

— TMC incorporates other back-office functions.

— Backhaul communication exists between field infrastructure components and TMC.

— Other communications may exist to communicate with vehicles and other centres.

— Traffic management is assumed to provide for higher-level control and coordination for area-wide (network) and corridor-level functions and performance. This includes arterial progression, adaptive control, and timing pattern/plan selection.

— Multiple facilities could be represented by the single centre shown in the diagram.

5.2.2 Architecture

The conceptual architecture for the use cases is shown below. This generalizes the overall distribution of equipment. The roadside equipment (RSE) will contain a DSRC radio transceiver that hears the broadcasts from the vehicles (BSM/CAM) and uses this information to provide the applications to support use cases. The RSE includes the traffic signal controller responsible for controlling the traffic signals, and it uses the infrastructure-based sensors along with the information provided from the BSM to regulate the right of way at the signalized intersection.

NOTE The term BSM and CAM are used in this document to refer to the basic safety message and cooperative awareness message which is broadcast by the vehicles to provide data regarding the position, trajectory, and other data for each vehicle within range of the signal.

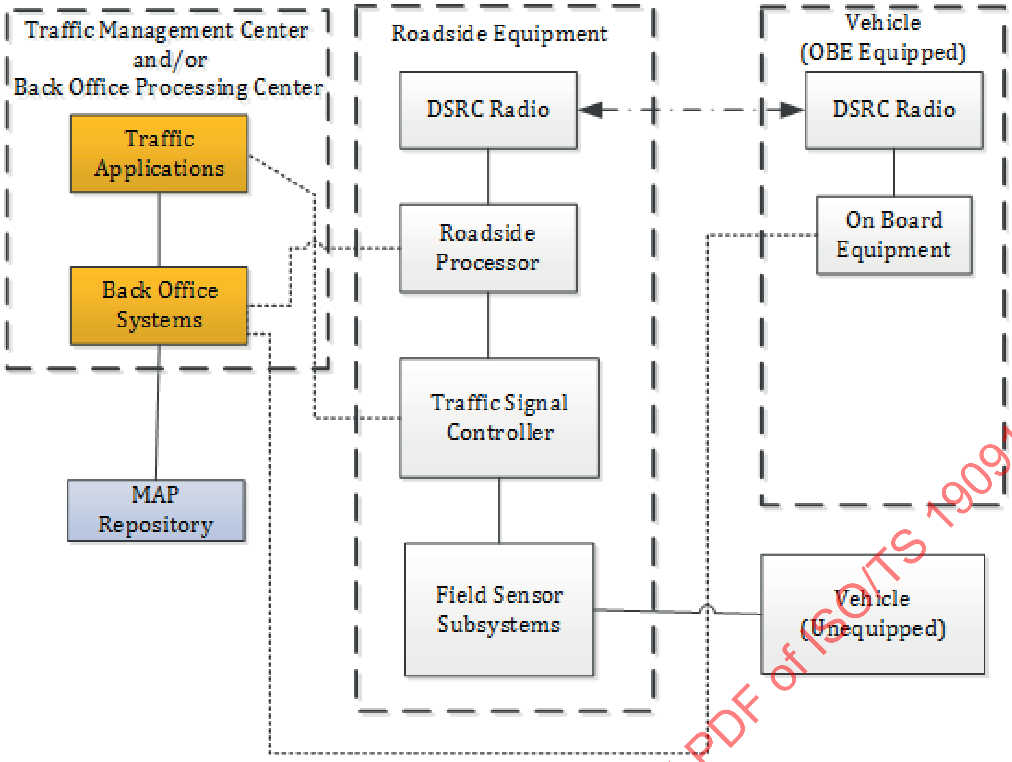


Figure 2 — General architecture for V2I/I2V communications

Some of the key concepts are the connection to the back-office systems where the RSE will obtain its local configuration information, which will include the security certificates, GNSS augmentation information, and the detailed static geometric information for the intersection (MAP). The connection to the BOPC (in this specific case, the traffic management centre) is used for the management of the traffic controller database which includes timing patterns, schedules, etc. The BOPC is also involved in the selection of timing plans and adaptive signal timing to accommodate special timing plans, platoon management, etc.

There is a connection shown from the vehicle to the BOPC which is recognition that some of the information may be exchanged directly with the BOPC if there is a wide area network available. This connection may also include the back-office systems and could be used for such tasks as the distribution of the MAP information, regional status, and route pre-emption (green wave). While a single TMC/BOPC is logically shown in the figure, it represents one or more physical locations where various processes/functions may be resident, such as traffic, public transport, and/or emergency services operations.

Note that the exchanges between the RSE and the OBE may also be used to directly impact the signal timing and will be used to provide the approaching connected vehicle with the real-time information regarding the currently permitted manoeuvres and timing such as the remaining "green" time and the remaining "red" time. Note that signal colours have been used; it is the intent of these use cases that the RSE provides information to the OBE that indicates the permitted manoeuvres for the specific location of the vehicle. In some cases, this may be lane by lane, while in other cases, it may be by approach only. Since different countries/regions use different displays to indicate the permitted manoeuvres and the time point of their change, they will be dealt with as information concepts termed movement states rather than specific displays.

This document focuses on the messages exchanged over the interface between the vehicles and the roadside equipment. Since these are message specifications, using broadcast messages, the role of the ITS station is not addressed. It is assumed that the roadside equipment (RSE) and the on-board equipment (OBE) could be constructed in any manner using any architecture including the ITS station as described in other standards, or other hardware and software constructs of a proprietary nature. It is important that the messages adhere to the structure, dialogues, and content specified herein and this content identified for the specific regions in the subsequent additional annexes (e.g. Annex E for North America). This approach allows an intermix of proprietary and open devices to be used to implement the various elements of the C-ITS infrastructure and remain interoperable with equipment constructed by a variety of vendors.

As noted below, security issues (e.g. authentication, encryption, privacy protection, misbehaviour detection, etc.) are assumed to be addressed in the implementation of the message exchanges as required but are outside the scope of this document. The use cases assume that the communications among all parties is secure.

5.2.3 Message interactions

The messages which support the use cases described herein are based on the concept of "broadcast" messages where the appropriate device (OBE or RSE) broadcasts the message content to all entities (e.g. vehicles and infrastructure) within range of the DSRC radio signals. The messages to support these use cases are not based on the concept of an interactive information exchange between two or more specific entities.

Given the nature of the DSRC communications, the applications described herein (safety, mobility/sustainability, priority/pre-emption) rely on the replication of messages and the probability that the target entity will receive the message in time to take appropriate action, such as warning the driver of an impending intersection violation or that a specific vehicle is requesting priority treatment. Each entity in turn cannot assume that its request(s) have been received and honoured unless it confirms such a situation based on a broadcast message from the target entity. Even in such cases, conditions can change instantaneously; for example, a priority treatment can be immediately terminated to accommodate an emergency vehicle of higher priority pre-emption. Thus, the entity should continuously monitor the messages received and act accordingly whether it is to modify signal timing or provide driver warnings.

Where the application described uses wide area communications (e.g. 3G/4G/LTE), then the exchanges may be point to point exchanges using other protocols such as TCP/IP, where a specific unit to unit interaction is required.

5.2.4 Common operational assumptions

The use cases described herein are based on the following general assumptions.

a) It is assumed that all OBE equipped vehicles are broadcasting the basic safety message (BSM) or cooperative awareness message (CAM) message continuously at some repetition rate which has yet to be determined and may vary depending on the saturation of active vehicles. The commonly assumed rate is 10 times per second; however, the exact latency necessary for such use cases has not been determined at this time. It is likely that the rate of less than 10 Hz will be adequate for these applications.

b) The use cases described below are based on the assumption that the vehicles within range of the intersection will all be broadcasting the BSM or CAM, which includes information regarding the vehicle's location, speed, heading, and directional signals as a minimum. This information will be used by the applications supporting these use cases as described herein.

c) These use cases are also based on the use of DSRC communications from the vehicle to the RSE with a range of approximately 300 m under "normal" conditions. While different conditions and locations may extend this, the applications should only be designed to work with this range in mind. It is likewise possible that infrastructure (buildings) and weather conditions restrict the range to significantly less than 300 m.

d) The RSE at the traffic signal controller (TSC) is continuously broadcasting the signal phase and timing (SPaT) message to indicate the current (and future) signal state information to vehicles in the vicinity. Vehicles approaching the intersection become aware of the traffic signal when they "hear" this message.

e) The RSE at the traffic signal controller (TSC) is periodically broadcasting information that describes the geometrics of the intersection, which defines the approach lanes, the departure lanes, and the permitted manoeuvres (the MAP message). A set of performance requirements are included to establish a framework for the periodic broadcast of the MAP message. At this time, these performance requirements are subject to additional analysis as the repetition rate will be determined in part by the RF propagation characteristics and the speed of the approaching vehicles. Note that it is assumed that the vehicle "knows" its position and can judge the relevant intersection it is approaching. Since it may be possible for the OBE to "hear" multiple RSE's at any point in time, the responsibility of determining which intersection ID it is approaching and hence how to react to the messages.

f) It is assumed that the priority requesting vehicles and other OBE equipped vehicles have some sort of on-board map database that they can use for identifying a route through the street network. The map database will contain information regarding the identification of the intersections along the route such that the vehicle "knows" its current location and "knows" what type of signal priority request (scenario) to make at a given intersection it is approaching. It will also be able to determine when it will arrive at the intersection and when the required priority manoeuvre is needed.

g) The MAP information will include base geometric information and other related information (e.g. manoeuvres permitted). Generally, MAP information is static in nature. There are times when the MAP information changes (e.g. when access to a side road or a turn is not permitted). Therefore, the MAP information shall contain both the base geometry and changes to the other MAP information. A vehicle receiving the MAP information message need only process the changes unless the base geometric information has changed (e.g. the version for the base geometric is different from what is currently stored in the vehicle). If the base geometric information has changed, the vehicle shall process the base geometric information. If the vehicle does not contain a base geometric for the intersection in question, then the vehicle process the base geometric information and other changes contained in the MAP.

h) Vehicles will be assigned a type that will be used by the intersection control logic to determine the nature of the priority request that may be supported for that vehicle. This shall identify such vehicle types as public transport vehicles, freight vehicles (lorry), emergency vehicles, etc.

i) Where route pre-emption or platoon support is desired over multiple intersections (for example, along an arterial), interaction with a central system or interaction between traffic controllers will be necessary to manage signal timing along a route (arterial) and route priority or pre-emption rather than an isolated intersection interaction.

j) Security is a global requirement for all SPaT/MAP, SRM and SSM transmissions found in these use cases. The use cases assume that security will be in place and is therefore not mentioned in the respective use cases.

k) While the message sets are intended to be media-independent, their application should address the chosen media's bandwidth limitations and propagation latencies for a successful implementation.

5.3 Safety use cases

5.3.1 Intent

The safety related use cases for V2I/I2V are intended to provide vehicles with information regarding the current condition of the traffic signal it is approaching (permitted manoeuvre) and the time point for the manoeuvre to change. Using this type of information, the approaching vehicle should be able to determine the appropriate actions to avoid violating the right of way and a subsequent crash.

It is also possible for the traffic controller to use the information regarding impending violations of the stop-bar to alter the signal timing to reduce the probability of a crash under such circumstances.

The safety use cases are related to the concept of using the connected vehicle (CV) message exchanges (V2I, I2V) for the purpose of modifying the traffic signal operation and/or providing warning information to OBE equipped vehicles. These use cases are based on the use of DSRC communications, although some of them could be supported with other media that meet the appropriate performance characteristics such as latency, reliability, and range. It is important to keep in mind that the SPaT and MAP are intended to be media-independent such that they could be handled with alternatives to DSRC.

The details of the safety use cases are provided in Annex A.

5.3.2 Additional assumptions

There are not any safety specific assumptions contained within these use cases.

5.3.3 Architecture implications

The conceptual architecture for the use cases for general safety applications is shown in Figure 2. This generalizes the overall distribution of equipment. The roadside equipment (RSE) will contain a DSRC radio transceiver that hears the broadcasts from the vehicles (BSM/CAM) and uses this information to provide the applications to support use cases. The RSE includes the traffic signal controller responsible for controlling the traffic signals, and it uses the infrastructure-based sensors along with the information provided from the BSM to regulate the right of way at the signalized intersection.

One of the key concepts is the connection to the back-office systems where the RSE will obtain its local configuration information which will include the security certificates, GNSS augmentation information, and the detailed static geometric information for the intersection (MAP). The connection to the BOPC (in this specific case, the traffic management centre) is used for the management of the traffic controller database which includes timing patterns, schedules, etc. The BOPC is also involved in the selection of timing plans and adaptive signal timing to accommodate special timing plans, platoon management, etc.

Note that the exchanges between the RSE and the OBE may also be used to directly impact the signal timing and will be used to provide the approaching connected vehicle with the real-time information regarding the currently permitted manoeuvres and timing such as the remaining “green” time and the remaining “red” time. Note that signal colours have been used here; it is the intent of these use cases that the RSE provides information to the OBE that indicates the permitted manoeuvres for the specific location of the vehicle and not the specific signal display. In some cases, this information may be on a lane-by-lane basis, while in other cases, it may be provided by approach only. Since different countries/regions use different displays to indicate the permitted manoeuvres and the time points when they will change, the information will be dealt with in this document as movement states rather than specific displays.

Several use cases involve non-signalized intersections. These use cases assume that one of two situations exist. Either the non-signalized intersection has an RSE located at the intersection or a near-by RSE equipped intersection provides the MAP data for the non-signalized intersection. This means that the vehicle has sufficient information to navigate the intersection’s geometrics. The remaining issue is whether there is a SPaT message to indicate the allowable manoeuvres or whether the allowable manoeuvres are completely described within the MAP message. If the manoeuvres are static, then there is no need for a SPaT transmission from the non-signalized intersection. If the manoeuvres change due to circumstances or time-of-day, then it is assumed that the updates will be distributed through an updated MAP message and will be available to all vehicles approaching the intersection.

5.4 Mobility/sustainability use cases

5.4.1 Intent

The mobility/sustainability use cases are related to the concept of using the connected vehicle (CV) message exchanges (V2I, I2V) for the purpose of modifying vehicular operations to improve travel and reduce environmental impacts within a roadway network. These use cases are based on the use of DSRC communications, although some of them could be supported with other media that meet the appropriate performance characteristics such as latency, reliability, and range. It is important to keep in mind that the SPaT and MAP are intended to be media-independent such that they could be handled with alternatives to DSRC.

The overall operation and architecture is identical to that described in 5.3 for the safety applications. While 5.3 dealt primarily with the use cases and requirements to support intersection safety, the use cases in this subclause deal with the additional information needed to promote more efficient use of the roadway network and, more specifically, improved efficiency of the individual intersections. For example, for ECO driving, knowing how much green remains or when the green will appear allows the vehicle/driver to better modulate the vehicle's speed to minimize the production of green house gases (GHG) and allow more efficient driving. It is also possible for the intersection to track the location of all approaching vehicles and to improve the efficiency of the overall system operation through optimal intersection and arterial timing to accommodate platoons.

The information needed is virtually identical. The vehicles need to know what manoeuvre is currently permitted for their specific lane (approach) and how long it will remain active. If their desired manoeuvre is not currently permitted, the vehicle needs to know when it will be permitted such that it can make efficient use of the time before "green" for such applications as vehicle charging and engine shutdown and startup. This information can also be used in conjunction with other on-board sensors to modulate the vehicle speed through the intersection or roadway network to minimize the hard breaking or startup costs. A modulated speed can create a safer environment and minimize pollution and fuel consumption, as well as reduce congestion.

The details of the mobility/sustainability use cases are provided in Annex A.

5.4.2 Additional assumptions

It should be noted that the mobility/sustainability use cases include applying these operational concepts to vehicular platoons in addition to single vehicles. The definition and operations involving platoons have yet to be established for these applications. The uses cases do not address these ongoing needs and therefore requirements for platoon operations will be addressed in a future version of this document.

The inductive charging use case assumes that any financial transaction involving the use of the facility is provided outside the scope of this document. The location of the facility and the time available for the operation are the only aspects of the use case that are within the scope of this document.

5.4.3 Architecture implications

The mobility use cases exist within the architecture outlined in 5.2.2. Otherwise, there are not any additional architecture implications.

5.5 Priority/pre-emption use cases

5.5.1 Intent

The priority/pre-emption use cases are related to the concept of using the connected vehicle (CV) message exchanges (V2I, I2V) for the purpose of modifying the traffic signal operation, for one or more intersections, to better serve the needs of public transport, freight, and emergency service vehicles. These use cases are based on the use of DSRC communications, although some of them could be supported with other media that meet the appropriate performance characteristics such as latency, reliability, and range. It is important to keep in mind that the SRM and SSM are intended to be media-independent such that they could be handled with alternatives to DSRC.

The details of the priority/pre-emption use cases are provided in Annex A.

This is a vehicle to infrastructure message set, typically sent from an emergency vehicle, public transport vehicle, or freight transport vehicle to request priority treatment at a signalized intersection. The priority vehicle message set consists of two distinct messages, as outlined below.

— Signal request message (SRM) is used to request a pre-emption or priority signal state (preferential treatment) from a signalized intersection. This message is broadcast from the vehicle to the infrastructure.

— Signal status message (SSM) is used to relate the current pre-emption or priority signal state(s) that a signalized intersection may be in. This message is broadcast from the infrastructure to the vehicle.

These two messages are used to request and acknowledge priority "service" at a signalized intersection during emergency or priority response operations. The first message is transmitted by an approaching vehicle and is used by the traffic controller of a signalized intersection. The second message is transmitted by the local RSE (with content created by the signal controller) if a pre-emption or priority request is granted, causing a change to the signal state status data of the SPaT message stream being sent. This message provides emergency vehicles and priority public transport/freight vehicles information regarding the internal state of the controller and may include specific information with respect to servicing the request.

The scenarios are built on the assumption that such communications will be directly between the vehicle(s) and the RSE and intersection equipment, but these messages are broadcast in nature with no specific vehicle interaction with the intersection/RSE.

Restating the sequence of operations in greater detail is as follows.

a) When the vehicle "knows" that it is in the vicinity of the intersection for which priority treatment is desired, the OBE equipped vehicle transmits a signal request message (SRM) to the RSE at the identified intersection which then passes the request to the TSC equipment. This message is sent after the vehicle has received and processed the intersection MAP message.

   NOTE This presupposes a specific approach to identifying the actions desired by the approaching vehicle. This will be examined later when the detailed requirements are established for each message.

b) The alternative to requesting a predetermined (and configured) scenario at the intersection the vehicle is approaching is for the vehicle to use the MAP information and to request priority treatment to support a specific manoeuvre. In this situation, the vehicle could identify its intended approach (and lane) and request a specific manoeuvre along with the expected time of arrival or other relevant information. In this situation, the RSE and traffic controller would need to evaluate all such requests, prioritize these requests and establish the optimal sequence and timing to accommodate the approaching vehicle(s). It is anticipated that both techniques for priority requests should be supported by the RSE/TCS. Different requirements are needed for each mechanism.

c) The RSE will transmit a signal status message (SSM) if there is one or more active or pending pre-emption or priority events to report. This message is transmitted by the local intersection RSE in a broadcast style. The RSE should include sufficient information such that the vehicles approaching the intersection can determine if their specific request is being serviced. However, the SPaT message will always indicate the state of the signal and thus the approaching vehicle can determine if and when the movements required will be available.

d) There is a potential that multiple local vehicles will be simultaneously sending signal request messages as they approach the intersection and receive the RSE/TSC generated signal status message in this time interval. The required logic to decode the "winner" in such a conflict is outside the scope of this of document and resides in the combination of the RSE and TSC. The outcome of that process is reflected in the SSM. These two messages (along with the SPaT and MAP message discussed elsewhere) are considered part of the intersection control message set.

5.5.2 Additional assumptions

The priority/pre-emption use cases described herein are based on the following additional assumptions that are specific to this set of use cases.

a) Vehicles will be assigned a priority that will be used by the intersection to determine the priority of this vehicle relative to the priority structure for all vehicle types and the operation to be supported. For both vehicle type and priority, these attributes shall be developed for each region as it is likely that the rules of engagement may vary by region and the actions to be taken by the intersection control algorithms are likely to vary as well.

b) In general, use cases associated with a single intersection are not based on real-time interaction with a central traffic management system to support priority treatment at the specific intersection.

c) Public transport vehicles, freight vehicles, and emergency vehicles are assumed to have consistent, non-changing IDs for the duration of all interactions described for pre-emption and priority as described herein. That is, the randomization present for light vehicles to maintain anonymity does not apply to this class of vehicle for these applications.

d) The use cases herein do not reflect the user needs or use cases that are intended to optimize traffic signal operation based on receipt of BSM/CAM messages from all vehicles approaching the intersection. The assumption is that priority/pre-emption is of greater importance than operation of other vehicles. It is also assumed that the traffic management centre (TMC) is responsible for configuring the RSE and TSC and for enabling and disabling priority operation at the intersection. Hence, the link to the TMC is critical, although its active role is limited to a few of the scenarios that deal with signal priority along an arterial or string of intersections.

5.5.3 Architecture implications

When an emergency vehicle and other surrounding vehicles are equipped with an OBE, the vehicles can establish communication when they are within range of each other and share information relative to their location and direction. A special application (PSOBE) may be used in emergency vehicles and is not available to standard OBEs. This PSOBE limits ID changes and may be implemented as a high-powered application to extend the range. It is expected that the surrounding private vehicle OBEs will receive BSM and SRM messages from the high-powered PSOBE well before they begin to receive the normal BSM/CAM transmission from the same vehicle. From calculations resulting from this information, the private vehicle can first notify its driver of the situation, after which it may offer suggestions to avoid path interference. While it is difficult to make this function robust and precise, enough information can be made available to the driver that improvements over a non-equipped system can be significant.

NOTE This presumes that the DSRC 5,9 GHz license allows certain emergency vehicle applications to transmit at a power higher than that of the normal OBE and RSU, thus extending the range.

The message content for the V2V use case will not be developed here since this concept is completely within the V2V domain and not the V2I and I2V domain space.

The basic architecture for the connected vehicle system for the discussion of priority and pre-emption is illustrated in Figure 2. The major components are the roadside equipment (RSE) and the vehicle systems. To simplify the interface discussion in this document, the vehicle systems will be called the on-board equipment (OBE). Traffic management and fleet management systems are designated as back office processing centres (BOPC). This basic physical architecture will be used for the discussion of the use cases.

These use cases focus on the message exchanges between the connected vehicle and the intersection traffic controller with the intent to modify the operation of the traffic controller and the vehicle to support the operational scenarios described. Although DSRC is assumed, the message content could be routed through a public transport centre, fleet management centre, and a traffic management centre which may also affect its operation. Examples might include the need to suspend priority operation due to special events or road construction or to change priority strategy based on environmental conditions.

While a separate roadside processor is shown in Figure 1, this could be a function included in the traffic signal controller depending on the age and capabilities of that device. Many of today's traffic controllers include encryption processors and processor speeds that are more than adequate to handle the functions described herein. Likewise, the use cases describe interactions between the RSE and the TSC that imply that there is a layered decision-making process. Again, these may be combined into a single processor unit such that the only external element is the DSRC radio and all algorithms and interactions take place within the TSC.

5.5.4 Public transport signal priority application

There are several use cases associated with public transport and while they are shown as separate here, they are similar in operation. They have the common characteristic of requiring specific actions by the traffic controller to facilitate the progression through the intersection.

However, there are different needs associated with each; therefore, they will be represented separately as follows:

a) providing preferential "through" manoeuvre to allow a public transport vehicle (PTV) to proceed through the intersection by truncating conflicting manoeuvres and returning to the required manoeuvre "early" or by extending the required manoeuvre to allow the public transport vehicle more time to get through the intersection;

b) preferential "turning" manoeuvre at the intersection, for example, a protected left (or right) that may normally be prohibited or a permissive turn. In this instance, the traffic controller shall determine the need for advancing the green phase to clear the queue in front of the public transport vehicle to allow the vehicle to enter the left-turn pocket, and manages coordinated priority timing between the through and left-turn manoeuvres;

c) "clearing a queue" to enable a vehicle to get to a near side passenger stop. This could be combined with additional actions as described below;

d) providing a leading public transport vehicle "green" (queue jump) to allow the public transport vehicle to "jump" out into traffic after the completion of passenger pickup/discharge at a near side public transport stop.

Operational constraints

The desired "action" from the TSC is embodied in the configuration of the scenario at the intersection and is requested in the SRM. The action taken by the TSC will depend on the priority manoeuvre requirements and current conditions and the rules for signal operation within the roadway and region.

There are two mechanisms that could be used by the public transport vehicle to identify the preferential treatment needed.

— The intersection is "pre-configured" to support specific actions (scenarios) requested by the vehicle. In this case, the vehicle would indicate the required "scenario" (based on their route) and the traffic controller would respond accordingly based on current conditions and conflicting requests. This approach requires that the vehicle be programmed to know which scenario is required based on its "route" and the intersection ID.

  If the public transport vehicle is required to deviate from its route due to such situations as roadway construction, a crash, a special event, or other blockage, then scenarios should be developed for those possibilities and intersections as well.

— The vehicle is "pre-configured" to request that the traffic controller provides preferential treatment for its approach in a specific lane and exit in a specific lane, i.e. "I am arriving in lane X and departing in lane Y". This requires that the vehicle "know" the intersection geometrics (MAP) and is able to translate its route information into the "X" and "Y" parameters indicated above. The use cases indicated below are based on the concept of "pre-configured" intersection scenarios.

5.5.5 Freight vehicle signal priority application

This subclause describes the use cases for heavy vehicles (assumed to be carrying freight) with characteristics that include a slower start-up and greater stopping distance/time than light vehicles. The term freight vehicle, truck, and lorry (EU) are used synonymously. The freight signal priority use cases are similar in nature and support the following concepts:

a) priority treatment for an individual truck at a signalized intersection;

b) priority treatment for a fleet (platoon) of trucks at a signalized intersection;

c) priority treatment for a fleet (platoon) of trucks travelling along an arterial of signalized intersections.

There are advantages to keeping the platoon moving where possible to avoid unnecessary stops. This makes trucks different from public transport vehicles which must stop to pick up and discharge passengers.

One of the issues with attempting to move a platoon through an arterial or even an isolated intersection is the identification of the existence of such a platoon with the limited range of the DSRC communications. It would be important if the platoon could identify itself with a lead and end such that the TSC and BOPC could adjust the complete arterial to pass a limited number of vehicles. Knowing the length and speed of the platoon, the TSC can determine how to best accommodate the platoon through the arterial or intersection. If the platoon is to be identified as an entity, then there needs to be V2V propagated communications where the vehicles identify if there is another vehicle “behind” them and how many vehicles are behind them. It would also be useful to know the overall length of the platoon.

For these use cases, it will be assumed that the RSE/TSC will continuously monitor the BSM/CAM for the identified truck(s) and monitor their locations through the intersection(s).

Figure 3 demonstrates the normal FSP interaction where a group of vehicles is involved.

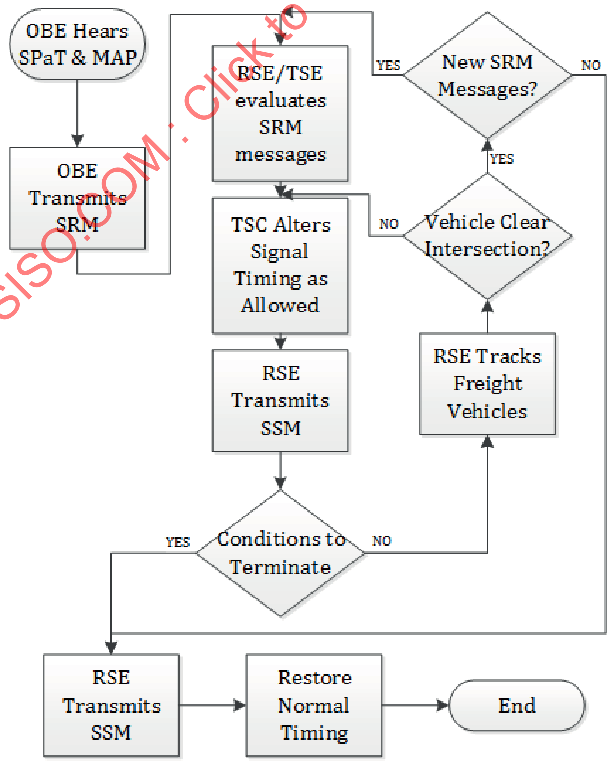


Figure 3 — FSP flow for a platoon of vehicles

The FSP operation is largely intended to improve the efficiency of freight transport through a signalized intersection, arterial, and ultimately, a corridor with the benefit of improved safety, travel time reliability, reduced fuel consumption, and reduced GHG production. One concept is to develop a "green band" for connected freight vehicles that requires that the platoon be constructed and limited, and that members of the platoon be tracked and notified when the green period is about to close and they will need to stop and wait until the next "green wave" of freight vehicles. The platoon cannot be infinite in length; therefore, some criteria need to be invoked to determine when a platoon must stop for the next green band.

Many of the use cases described above are similar in nature and it is likely that they can be combined during the development of the requirements and the design of the dialogues and message content to support these applications. It will be up to the developers of the detailed requirements to determine which of these use cases can be combined.

Ultimately, it will be the responsibility of the TSC to make the priority decision as to which manoeuvres are serviced next, the duration of manoeuvre(s), and how the intersection responds to specific and competing priority requests. Some priority requests such as FSP and TSP are not "mission critical", whereas emergency vehicle pre-emption is considered critical such that it will take over the normal operation of the intersection. However, the exact operation of the intersection will depend on the geometrics and specifics of the request including the vehicle type and priority.

The rules that must be enforced are likely to vary by region; hence, the detailed requirements need to be open and consider that different regions may establish different priorities for each type of vehicle.

5.5.6 Emergency (public safety) vehicle pre-emption application

Emergency vehicle pre-emption (EVP) is different from priority treatment in that it is expected that the intersection will react and immediately take steps to terminate all conflicting manoeuvres and grant a "green" that will both clear vehicles that may be "in the way", as well as facilitate the emergency vehicle path through the intersection(s). However, most of the exchanges with the RSE/TSC devices are similar to that for TSP and FSP. The use case is presented separately, but ultimately, the messaging is anticipated to be identical to the TSP or FSP with changes only to the vehicle type and priority. The TSC equipment, however, will take much more dramatic and immediate action for this type of priority.

Two different pre-emption use cases are presented in Annex A. The first, PR4, assumes a standard OBE and is based on the concept that the emergency vehicle should first "hear" the intersection RSE before reacting and initiating an EVP request. Under these circumstances, there is a provision for the intersection to "tell" the vehicle what type of pre-emption is supported and the full geometrics for the intersection such that the vehicle can either make a specific request or indicate entry and exit.

The second use case, PR5, depends on the implementation of a "high-powered" OBE radio that is presumed to have a much greater range than a standard OBE, and hence, it can provide information regarding its location, heading, speed, lane, type, etc. long before it can actually receive data from the intersection. It is uncertain at this time as to which approach will be supported so both are covered here.

These two use cases cover "on-the-fly" pre-emption at intersections as encountered by a public safety vehicle. Another pre-emption scenario involves a "green wave" or route pre-emption concept such that pre-emption is requested at a series of intersections in sequence in anticipation of the public safety vehicle(s) arrival. This third possibility allows a platoon of PSOBE-equipped vehicles to travel through closely spaced signalized intersections and provides time for the traffic signals to clear traffic in advance of the platoon. The mechanism for implementing the green wave varies as it may involve operations at the TMC/BOPC or be triggered by the first PSOBE-equipped vehicle as it requests priority at the first intersection of a pre-defined emergency route. In such a case, the request can be transmitted from RSE to RSE along a route based on the content of the SRM. This scenario is discussed in the above use cases under the issues topic as route pre-emption.

6 Function description (informative)

This clause is informative as it documents a portion of the system engineering process used in the development of this document. It identifies requirements based on the information flows that move data from sources to destinations as needed to implement solutions on geographically fixed and mobile devices. They address the interface between the infrastructure's roadside equipment (RSE) and the vehicle's on-board equipment (OBE). It also identifies system implementation requirements for deployment under various communication solutions reflecting various bandwidth and media constraints.

Each use case assumes that there is at least a single connected vehicle broadcasting its basic vehicle information using the basic safety message (BSM), cooperative awareness message (CAM), or decentralized environmental notification message (DENM). These messages are beyond the scope of this document; therefore, they are only referenced in the requirements where utilized by special vehicles.

All of the use cases include the collection of "performance measures" with the intent to provide a tool for analysis to improve operations; however, these are not necessary for the operation of the use cases. The exact details of the data to be collected are not identified in the requirements contained herein. It is expected that future revisions will provide these details and will be related to the specific needs of a project or technology.

The requirements are organized into sections based on the device or message to which they apply. Information as to whether the requirement is mandatory or optional and details regarding the type of information required are provided in the requirements traceability matrix in Annex C or as defined in the selected annex for additional group requirements. Note that selecting an optional requirement for a given project means that selected requirement shall be implemented for the project to conform to this document.

6.1 Public safety vehicle

In addition to the generic vehicle requirements in SAE J3067™:2014, 3.5.1, there are several safety-related requirements specific to public safety vehicles. For example, while travelling to the scene of an incident, public safety connected vehicles need to make other road users aware of their presence and also may need to request preferential priority at signalized intersections.

The detailed requirements for a properly authorized public safety connected vehicle to respond to an incident and broadcast incident response and emergency alert messages are listed below.

6.1.1 Broadcast public safety vehicle information

Each public safety vehicle shall broadcast information about its location to other connected devices.

6.1.2 Broadcast emergency response indication

A public safety connected vehicle needs to identify itself as an authorized public safety vehicle travelling to or at the scene of a service call. This identification is included as part of vehicle information broadcast to connected devices (see SAE J3067™:2014, 3.5.1.1.4.6.19).

6.2 Signal pre-emption

While travelling to the location of an incident, a public safety connected vehicle needs to request preferential treatment when approaching a signalized intersection.

The detailed requirements for a properly authorized public safety connected vehicle to request preferential treatment at a signalized intersection are listed below. Note that the requirements support priority requests using the operational concepts discussed in the previous section for normal or high-power transmissions.

6.2.1 Signal pre-empt request (normal power)

An authorized public safety vehicle shall begin transmitting SRM to an intersection using a normal power OBE transmission when the following conditions are met.

a) The authorized vehicle is on the intersection's approach or moving toward the intersection.

b) The vehicle has the intersection's roadway geometric information available or has received one or more MAP message(s) from the intersection.

c) The authorized vehicle has a need for priority services.

d) The vehicle has received one or more SPaT message(s) from the intersection.

6.2.2 Signal pre-empt request (high power)

An authorized public safety vehicle shall begin transmitting SRM to an intersection using a high-power OBE transmission when the following conditions are met.

a) The vehicle is on the intersection's approach or moving toward the intersection.

b) The vehicle has sufficient intersection roadway geometric data available to identify its approach in the request.

c) The authorized vehicle has a need for priority services.

6.2.3 Request signal pre-empt — Message identifier

A public safety connected vehicle shall include a request identifier for each signal request message transmitted to an RSE. The message (request) identifier is used to identify a sequence number within a stream of messages (of the same message type) from a connected vehicle. The message identifier increments by one whenever the contents of the message has changed. This identifier is used by the RSE to distinguish between requests from the same connected vehicle.

Each signal request message shall also include a unique identifier for the specific request and use that same identifier for all subsequent changes necessary related to that same request. For example, if the expected arrival time were to change, then the vehicle could transmit a new arrival time (in a subsequent SRM) using the same request identifier. Further, the intersection shall assume the request remains active until the RSE receives a clear request from the same vehicle or the request "times out" based on a "time to live" transmitted by the vehicle as part of the signal request message.

6.2.4 Request signal pre-empt — Intersection identifier

A public safety connected vehicle shall include the unique identifier of the intersection that is the target of the signal request broadcast.

Each intersection shall have a unique identifier which is used for all requests and navigation functions. The intersection identifier shall be included in the roadway geometric message broadcast by the RCU located at or near the intersection.

6.2.5 Request signal pre-empt — Approach lane

A public safety connected vehicle shall include the identifier of the lane, approach, or connection to be used to approach the intersection as part of the signal request message transmitted to an RSE. The lane numbering is identified as part of a roadway geometrics message broadcast by the RSE at the signalized intersection.

6.2.6 Request signal pre-empt — Egress lane

In addition to identifying the approach lane, a public safety connected vehicle shall include the lane number to be used to exit the intersection as part of the signal request message transmitted to an RSE. The lane number is assigned as part of the roadway geometrics information broadcast by the RSE at the signalized intersection. The egress lane information is needed to determine which pre-emption strategy may be appropriate for the public safety connected vehicle.

6.2.7 Request signal pre-empt — Vehicle class

A public safety connected vehicle shall include its vehicle type and request level as part of the signal request message transmitted to an RSE. Signalized intersections can use the vehicle type and request level to determine which vehicle receives priority in the event multiple conflicting requests are received by the same signalized intersection. Examples of vehicle types are public safety vehicle, public transport vehicles, military vehicles, commercial motor vehicles carrying freight, and private vehicles. A signal request from a higher vehicle class type may take priority over another signal request from a lower vehicle class type. In addition, within each vehicle class type, a vehicle may also be assigned a vehicle class level. For example, with a public safety vehicle class type, an emergency services vehicle may have a higher vehicle class level than a law enforcement vehicle. A signal request with a higher vehicle class level will take priority over another signal request from a lower vehicle class level. The order of precedence for the signal request priority is by signal priority vehicle class type and then class level. How these are assigned and how the intersection traffic control equipment reacts may vary by jurisdiction and is not standardized here.

6.2.8 Request signal pre-empt — Time of service

A public safety connected vehicle shall include the time when the signal pre-empt is requested to start as part of the signal request message transmitted to an RSE. This is the estimated time (point), in minutes and seconds past midnight that the connected vehicle expects to arrive at the intersection's stopping point (e.g. stop bar). The time is assumed to be a future time and is based on the current local time.

6.2.9 Request signal pre-empt — Vehicle identity

A connected public safety vehicle shall include its vehicle identifier as part of the signal request message transmitted to an RSE. The vehicle identifier may be a permanent identifier assigned by the public safety agency and used to track the service performance for that vehicle, or it may be a random number to ensure the overall anonymity of the connected device. The vehicle identifier is used to allow the RSE to distinguish requests from different connected vehicles and to distinguish different requests from the same connected vehicle. Where the pre-empt request is for one or a sequence of intersections (e.g. an arterial), then the vehicle ID shall remain constant throughout the navigation of the intersection/arterial such that the traffic management systems can track the progress of the vehicle and manage the coordination between intersections where appropriate.

6.2.10 Request signal pre-empt — Vehicle location and speed

A public safety connected vehicle shall include its current location, speed, and heading as part of the signal request message transmitted to an RSE. This information may be used by the traffic signal controller to determine what operational strategy it will perform (service) in the event there are more than one conflicting request for preferential treatment from different connected vehicles.

6.2.11 Request signal pre-empt — Cancellation

A public safety connected vehicle shall transmit to an RSE a signal request message to cancel (clear) a previously transmitted signal request. The combination of the vehicle identifier and the message identifier for the initial signal request message are used to identify the signal request to be cancelled.

6.2.12 Request signal pre-empt — Transaction identifier

Each signal request message shall also include a unique identifier for the specific request and use that same identifier for all subsequent changes related to that same request. For example, if the expected arrival time were to change, then the vehicle could transmit a new arrival time (in the SRM) using that same request identifier. Further, the intersection shall assume the request remains active until the RSE receives a clear request from the same vehicle or the request "times out" based on a "time to live" transmitted by the vehicle as part of the signal request message.

6.2.13 Request signal pre-empt — Duration

Each signal request message shall include a "duration" value as calculated by the requesting vehicle. The duration value shall be the time as seconds that the request may remain active after the time of service (see 6.2.8) occurs.

6.3 Public transport and commercial vehicle

In addition to the generic vehicle requirements in SAE J3067™:2014, 3.5.1, there are several requirements specific to public transport vehicles (PTV) and commercial freight transport vehicles. These requirements include providing preferential treatment to PTVs to improve the throughput of travellers through the transportation network.

The detailed requirements for a connected PTV or freight vehicle to exchange priority request and status information are listed below.

6.3.1 Broadcast priority requesting vehicle information

Each public transport or commercial vehicle shall broadcast information about its location to other connected devices.

6.4 Signal priority requirements

A connected public transport vehicle (PTV) or commercial vehicle approaching a signalized intersection may wish to send a priority request to stay on schedule. For example, a public transport connected vehicle with a passenger load in revenue service and behind schedule may send a signal priority request to maintain its schedule.

The detailed requirements for a connected PTV or commercial vehicle to transmit requests for signal priority at an intersection are listed below.

6.4.1 Signal priority request

An authorized PTV or commercial vehicle shall begin transmitting SRM to an intersection using a normal power OBE transmission when the following conditions are met.

a) The authorized vehicle is on the intersection's approach or moving toward the intersection.

b) The authorized vehicle has received one or more SPaT message(s) from the intersection.

c) The authorized vehicle has the intersection's MAP content available or has received one or more MAP message(s) from the intersection.

d) The authorized vehicle has a need for priority services.

6.4.2 Request signal priority — Message identifier

A connected PTV or commercial vehicle shall include a request identifier for each signal request message transmitted to an RSE. The message (request) identifier is used to identify a sequence number within a stream of messages (of the same message type) from the connected PTV or commercial vehicle. The message identifier increments by one whenever the contents of the message has changed. This identifier is used by the RSE to distinguish between requests from different connected devices and to distinguish different requests from the same connected vehicle.

6.4.3 Request signal priority — Intersection identifier

A connected PTV or commercial vehicle shall include the unique identifier of the intersection that is the target of the signal request message transmitted to an RSE. The intersection identifier is assigned as part of a roadway geometric message broadcast by an RSE at or near the intersection.

6.4.4 Request signal priority — Approach lane

A connected PTV or commercial vehicle shall include the lane, approach, or connection number to be used to approach the intersection on as part of the signal request message transmitted to an RSE. The lane numbers and lane information are assigned by the RSE at the signalized intersection as part of the roadway geometrics information broadcast by the RSE.

6.4.5 Request signal priority — Egress lane

In addition to identifying the approach lane, a connected PTV or commercial vehicle shall include the lane number to be used to exit the intersection as part of the signal request message transmitted to an RSE. The lane numbers and lane information may be provided by the RSE at the signalized intersection as part of the roadway geometrics information broadcast by the RSE. The egress lane information is needed to determine which priority strategy or signal timing pattern may be the most appropriate to provide the requested service.

6.4.6 Request signal priority — Vehicle class

A connected PTV or commercial vehicle shall include its vehicle type and request level as part of the signal request message transmitted to an RSE. Signalized intersections may use the vehicle type and request level to determine which vehicle receives priority in the event multiple requests are received by the same signalized intersection. Examples of vehicle types may be public safety vehicle, public transport vehicles, or commercial motor vehicles carrying freight.

A signal request message from a higher vehicle class type may take priority over another signal request from a lower vehicle class type. In addition, within each vehicle class type, a vehicle may also be assigned a vehicle class level. For example, in public transport vehicle class type, a bus rapid public transport vehicle may have a higher vehicle class level than a local public transport vehicle. A signal request message with a higher vehicle class level may take priority over another signal request from a lower vehicle class level. The order of precedence for the signal request priority is by signal priority vehicle class type and then class level. However, the operation of the local intersection is left to the local agency.

6.4.7 Request signal priority — Time of service

A connected PTV or commercial vehicle shall include the time when the signal service is requested to start as part of the signal request message transmitted to an RSE. This is the estimated time point representing minutes and seconds that the connected vehicle arrives at the intersection's stopping point (e.g. stop bar). The time is assumed to be a future time and is based on the current local time.

6.4.8 Request signal priority — Vehicle identity

A connected PTV or commercial vehicle shall include its vehicle identifier as part of the signal request message transmitted to an RSE. The vehicle identifier may be a permanent identifier assigned by the owning public transport agency or commercial organization and used to track the service performance for that vehicle or it may be a random number to ensure the overall anonymity of the connected device. The vehicle identifier is used to allow the RSE to distinguish requests from different connected vehicles and to distinguish different requests from the same connected vehicle. Where the priority request is for one or a sequence of intersections (e.g. an arterial), then the vehicle ID shall remain constant throughout the navigation of the intersection/arterial such that the traffic management systems can track the progress of the vehicle and manage the coordination between intersections where appropriate.

6.4.9 Request signal priority — Vehicle location and speed

A connected PTV or commercial vehicle shall include its current location, speed, and heading as part of the signal request message transmitted to an RSE. This information may be used by the traffic signal controller to determine what operational strategy it will perform (service) in the event there are more than one request for preferential treatment from different connected vehicles. It may also be used to optimize the signal timing to accommodate the vehicle for an ad hoc request.

6.4.10 Request signal priority — Service information

A connected PTV shall include its public transport service status as part of the signal request message transmitted to an RSE. Such status information may include the passenger load of the PTV, if the PTV is stopped, if the PTV vehicle door is open, and if the PTV is in the process of loading a mobility device (e.g. wheelchair) or bicycle (device that needs to be racked). The passenger load information may be used by the traffic signal controller to determine what operational strategy to service in the event there are more than one conflicting request for preferential treatment from different connected vehicles. The other status information may be used to help the traffic signal controller to determine when to provide preferential treatment if a public transport vehicle is stopped to load/unload before reaching the intersection.

6.4.11 Request signal priority cancellation

A connected PTV or commercial vehicle shall transmit to an RSE a message to cancel a previously transmitted signal request message. The priority request ID combined with the vehicle ID shall be sufficient to cancel the request. See 6.4.2.

6.4.12 Request signal priority — Priority request level

A connected PTV or commercial vehicle shall include a priority request level as part of the signal request message transmitted to an RSE. The priority request level shall be configurable with 1 being lowest and 10 being highest. The default request shall be set to 5.

6.4.13 Request signal priority — Transaction identifier

Each signal request message shall also include a unique identifier for the specific request and use that same identifier for all subsequent changes related to that same request. For example, if the expected arrival time were to change, then the vehicle could transmit a new arrival time (in the SRM) using that same request identifier. Further, the intersection shall assume the request remains active until the RSE receives a clear request from the same vehicle or the request “times out” based on a “time to live” transmitted by the vehicle as part of the signal request message.

6.4.14 Request signal priority — Duration

Each signal request message shall include a “duration” value as calculated by the requesting vehicle. The duration value shall be the time as seconds that the request may remain active after the time of service (see 6.4.7) occurs.

6.4.15 Request signal priority — Transit schedule

When PTV transmit a signal priority request, the signal request message shall include the time difference between the PTV’s current location and its scheduled location with a positive value indicating that the PTV is in advance of its schedule and a negative value indicating that the PTV is behind its schedule with the value in minutes.

6.5 Broadcast area's geometrics

An area's geometric information is used to provide connected devices with information about the roadway geometry, including intersection descriptions, speed curve outlines, and roadway segment information. For example, roadway geometric data can be used by a connected vehicle to support warnings to drivers for accident prevention.

The detailed requirements for providing roadway geometric information from the infrastructure to connected devices are as follows herein. Note that this information is broadcast to all devices within range. There is not any point to point or individual communications directed to specific vehicles implied.

6.5.1 Broadcast roadway geometrics

An RSE shall broadcast a message with information about the roadway geometrics to connected devices. The following sub-requirements identify the types of information needed to support the use cases described herein with respect to roadway geometrics.

6.5.2 Broadcast roadway geometrics — Message identifier

An RSE shall include a message identifier as part of the roadway geometrics information broadcast. The message identifier is used to identify a message within a stream of messages (of the same message type) from the RSE. The message identifier increments by one whenever the contents of the message has changed. This requirement allows a receiving connected device to ignore (not process) messages from an RSE when the content has not changed. This is required to support the concept of updating the roadway geometric information related to construction activities or other permanent or transient (semi-static) situations.

6.5.3 Broadcast intersection — Identifier

An RSE shall include the unique identifier of the intersection as part of the geometric information broadcast. This identifier is used to uniquely define an intersection within a country or region.

6.5.4 Broadcast intersection — Reference point

An RSE shall include the geographic location (latitude, longitude, elevation) of a reference point for the intersection as part of the geometric information. This reference point will be used to determine the offset for other data points. The latitude and longitude are measured in units of 1 cm. The elevation represents the intersection's geographic position above or below the reference ellipsoid (WGS-84) in units of 1 cm.

6.5.5 Broadcast intersection — Lane/approach default width

An RSE shall include the default lane/approach width for the intersection as part of geometric information broadcast. The default lane/approach width, measured in one centimeter units, is used such that a lane/approach width does not have to be transmitted for each lane/approach at the intersection. For each lane/approach at an intersection, the intersection's default lane/approach width is used unless the lane/approach width is specified or adjusted at points along the specific lane/approach.

6.5.6 Broadcast intersection — Egress lanes/approach

An RSE shall include all the vehicular lanes/approach that are leaving the intersection as part of the geometric information broadcast. These lanes/approach, known as egress lanes/approach, allow vehicles that have entered into the intersection to exit out of the same intersection.

6.5.7 Broadcast intersection — Ingress lanes/approach

An RSE shall include all the vehicular lanes/approach that are approaching the intersection as part of the geometric information broadcast. These lanes/approach, known as ingress lanes/approach, allow vehicles to enter into an intersection.

6.5.8 Broadcast intersection — Lane/approach number

For each lane/approach at an intersection, the RSE shall include a lane/approach number as part of the geometric information. Each lane/approach number shall be unique for that intersection.

A number convention should be established for consistency of the lane numbering but is not requried for the use cases described herein.

6.5.9 Broadcast intersection — Lane/approach centerline coordinates

For a lane/approach at an intersection, an RSE shall include a sequence of node locations that together describe the path of the lane's/approach centre line, as part of the geometric broadcast information. Each node location (based on the WGS-84 coordinate system and its reference ellipsoid) shall be referenced from the previous node's location with an accuracy of ±1 cm. The number (and location) of nodes needed to represent the path of a lane shall be selected such that the perpendicular distance between the lane centre line and the straight line connecting the two consecutive nodes is less than 1 m. For example, two nodes may be sufficient to represent a straight lane, while for a curved roadway segment, more nodes will be needed. The first node location should be the node that is closest to the geometric centre of the intersection, and is typically at the stop line of the lane, and the values should be the offset from the intersection's reference point (see 6.5.4).

NOTE The specific choice for the accuracy specified herein is based on previous versions of the SAE J2735™ data dictionary standard and may be subject to change as more research is performed.

6.5.10 Broadcast intersection — Vehicle lane/approach manoeuvres

For each vehicular lane at an intersection, an RSE shall include the allowed (valid) manoeuvres from the lane as part of the geometric information broadcast. The allowed manoeuvres indicate the types of manoeuvre(s) permitted through the intersection and the type(s) of vehicles that are allowed to perform those manoeuvres. Valid manoeuvre types are as follows:

— no data available;

— straight;

— left;

— right;

— U-turn;

— turn on red after stop;

— shared opposing turns.

Valid vehicle types are as follows:

a) general vehicles;

b) HOV;

c) commercial vehicles;

d) emergency vehicles (public safety);

e) bus (public transport vehicles);

f) taxi;

g) tracked vehicle;

h) undefined.

The shared lane represents a lane, generally in the centre of the roadway, that can be used as a turn lane for both directions of traffic to cross opposing through traffic. Shared lanes can be represented as a single lane or multiple uni-directional lanes that overlay one another with each lane supporting left turns.

A lane may allow more than one valid manoeuvre value, for example, a lane may have straight, left, right, and U-turn as valid manoeuvre types.

A lane may allow more than one valid vehicle type.

6.5.11 Broadcast intersection — Pedestrian crossing lane/approach manoeuvres

For each pedestrian lane at an intersection, an RSE shall include the allowed (valid) manoeuvres from the lane as part of the geometric information. The allowed manoeuvres for a pedestrian lane are related to the type of crosswalk, bicycle-crossing, or non-motorized lane and, as a minimum, shall include no data available, straight, and proceed after stopping. Valid user types for these lanes are pedestrians, bicycles, other.

6.5.12 Broadcast intersection — Special lane/approach manoeuvres

For each special lane at an intersection, an RSE shall include the allowed (valid) manoeuvres from the lane as part of the geometric information broadcast to connected devices. The allowed manoeuvres indicate the allowed navigational manoeuvres through the intersection and any other restrictions. Valid manoeuvre values for special lanes are no data available, straight, and proceed after stopping. Valid traffic types for special lanes are no data available, heavy rail, commuter rail, light rail trains, buses, HOV. Each special lane may have more than one manoeuvre and more than one vehicle type.

6.5.13 Broadcast intersection — Version identifier

An RSE shall include a version identifier as part of the geometrics information broadcast. This version identifier is used to identify the version of the roadway geometrics currently being broadcast from the RSE. A map version identifier should be assigned whenever the roadway geometrics change. For example, an intersection may have an approach with two reversible lanes, which are used as egress lanes in the morning, and allows vehicles to enter the intersection at all other times. This intersection may have a version identifier of “2” during the weekday morning peak hours and a version identifier of “3” all other times. If the intersection geometrics were to change, for example, a new lane was added to the approach, it would be assigned a new version identifier.

This requirement allows a receiving connected device to ignore (not process) the intersection’s geometric information if the geometric information has not changed. A connected device may also have the capability to store the intersection’s geometric information in its memory - if that connected device already has that version of the geometric information stored, the device may ignore the remainder of the geometric information being transmitted, if the version identifier has not changed.

6.5.14 Broadcast intersection — Crossings

An RSE shall include lane information about all the crossings in the intersection as part of the geometric information broadcast. Crossings can generally be considered bi-directional and do not have approaches or egresses. The users of crossings are typically not vehicles but include pedestrians, bicyclists, or railroad cars (including light rail).

6.5.15 Broadcast intersection — Lane/approach width

For each lane/approach at an intersection, an RSE shall include its lane/approach width as part of the geometric information broadcast. This is the lane width, in one centimeter units, at each offset value defining the path of the lane. A non-zero value will take precedence over the default lane/approach width for the intersection; otherwise, the default lane/approach width for the intersection (see 6.5.5) should be used. To support regional interests, the lane can be defined as an approach or parts of an approach.

6.5.16 Broadcast intersection — Node lane/approach width

For a lane/approach at an intersection, an RSE shall establish its lane/approach width at each point location describing the path of the lane/approach as part of the geometric information broadcast. This requirement allows an RSE to establish the width of the lane/approach at each node for lanes/approach when the width of the lane/approach varies. An absolute lane width value or a delta lane width from previous values are acceptable approaches to establishing the lane/approach width. A non-zero value will take precedence over the default lane/approach width for the intersection (see 6.5.5) and any lane/approach width defined for length of the lane/approach (see 6.5.15). It is expected that if the lane/approach width at each node is broadcast, a lane/approach width for the length of the lane/approach will not be broadcast.

6.5.17 Broadcast intersection — Egress connection

For each lane/approach entering an intersection, an RSE shall identify the lanes/approaches that the subject lane/approach connects to, called the egress lanes/approach, as part of the geometric information broadcast. The egress lane/approach information is needed to help identify potential pedestrian/cyclist/special vehicle crossing conflicts that affect the turning manoeuvre times for that vehicle.

The egress connection also needs to identify the vehicle manoeuvre needed to turn into the egress lane. Valid manoeuvre information are unknown (or not applicable), uTurn, leftTurn, rightTurn, straightAhead, and lane change.

6.5.18 Broadcast intersection — Traffic control

An RSE shall broadcast intersection geometric and manoeuvre information for intersections controlled by signs, beacons, crossing gates, pedestrian hybrid beacon (e.g. HAWK), rectangular rapid flashing beacons (RRFB), or ramp signals. This requirement enables connected vehicles to navigate intersections controlled by other types of traffic control devices. An RSE will utilize a “psuedo-signal” to broadcast the movement phase states that are consistent with the intersection’s traffic control devices and their states.

6.5.19 Broadcast intersection — Traffic control by lane/approach

An RSE shall broadcast intersection geometric and manoeuvre information for each lane/approach at intersections controlled by signs, beacons, crossing gates, pedestrian hybrid beacon (e.g. HAWK), rectangular rapid flashing beacons (RRFB), ramp signals. This requirment enables connected vehicles to navigate intersection lanes/approaches controlled by other types of traffic control devices. An RSE will utilize a “psuedo-signal” to broadcast each lanes/approaches manoeuvres and the movement phase states that are consistent with the intersection’s traffic control devices and the device’s states.

6.5.20 Broadcast road conditions

The RSE shall broadcast environmental information to connected devices regarding pavement conditions. This information enables OBEs to calculate stopping distances based on the current conditions in order to properly predict the stopping distance and time.

6.5.21 Broadcast intersection — Signal group

An RSE shall broadcast the signal group identifier, the lanes/approaches associated with the signal group, and the lanes/approaches' allowable manoeuvres. This association enables connected devices to associate broadcast signal phase and timing information with the lanes/approaches in which it is travelling.

6.6 Broadcast GNSS augmentation details

Connected devices need information to improve its positional accuracy estimate. These differential GPS corrections allow a mobile GPS receiver, such as a GPS system in a connected vehicle, to achieve a greater absolute positional accuracy, compensating for errors that exist in satellite positioning. GPS receivers use the differential GPS corrections to improve the accuracy of their positioning by comparing its position with the RSE's location, which is known.

The detailed requirements for transmitting differential GPS corrections are as follows.

6.6.1 Broadcast GNSS augmentations

An RSE shall broadcast GNSS augmentation details using one of the following GNSS augmentation messages.

6.6.2 Broadcast GNSS augmentation detail — NMEA

The RSE shall broadcast Marine Electronics Association (NMEA) 0183 differential GPS correction messages. NMEA 0183 is a standard that defines the interface between two different devices, generally marine devices. NMEA 0183 includes support for a GPS receiver to provide its real-time position information, such as position, velocity and time as computed by the GPS receiver.

6.6.3 Broadcast GNSS augmentation detail — RTCM

The RSE shall broadcast Radio Technical Commission for Maritime Services (RTCM) 10402.3 and RTCM 10403.1 messages to connected devices. These standards support very high accuracy navigation and positioning through a broadcast to mobile global navigation satellite system (GNSS) receivers, which allows the receivers to compensate for errors that exist in satellite positioning without augmentation. RTCM 10403.1 is a later edition of RTCM 10402.3 and more efficient.

6.7 Signalized intersection requirements

Signal phase and timing information is used to provide connected vehicles with information to safely and efficiently pass through the intersection. For example, signal phase and timing information can be used by the connected vehicles to determine imminent signal changes, and hence alert the driver in the event it appears that the vehicle will enter the intersection when such movements are not allowed.

It is assumed that the signal phase and timing (SPaT) information is periodically broadcast to all devices within range of the RF signal in a timely manner such that the information can be used by the vehicle to avoid violating the permitted manoeuvres that might cause a crash or to manage its operation to more efficiently navigate an arterial network, thus reducing fuel consumption.

6.7.1 Broadcast signal phase and timing information

An RSE shall broadcast a message with signal phase and timing information. Signal phase and timing information may be used to provide connected devices with the current status of a signalized intersection. Together with the intersection geometric information, connected vehicles can determine what manoeuvres are currently permitted by lane/approach,and when their permitted manoeuvre may end.

6.7.2 Broadcast signal phase and timing — Message identifier

An RSE shall include a message identifier as part of the signal phase and timing message broadcast. A change in the message identifier indicates a change in the message content. This requirement allows a connected device to ignore (not process) messages from an RSE when the content has not changed.

6.7.3 Broadcast signal phase and timing — Intersection identifier

An RSE shall include the unique identifier for the intersection as part of the signal phase and timing message broadcast. The intersection identifier is provided as part of a roadway geometric message broadcast by an RSE at or near the intersection.

Note that it is assumed that the vehicle will use information about its current position and the interesection geometrics (MAP message) to determine its relative position with respect to the lanes, intersection stop lines, etc. and the SPaT information to determine the manoeuvres permitted and the time at which such manoeuvres will no longer be allowed in order to improve the efficiency and safety of its navigation through the roadway network.

6.7.4 Broadcast signal phase and timing — Intersection status

An RSE shall include the operational status of the intersection's traffic signal controller as part of the signal phase and timing message broadcast. Valid operational status includes operating normally (i.e. fixed time, traffic dependent as in actuated or semi-actuated, standby), intersection is in conflict flash mode, pre-empt is active, priority is active, manual control is enabled, and stop time is activated and all counting/timing has stopped.

6.7.5 Broadcast signal phase and timing — Timestamp

An RSE shall include a timestamp as part of the signal phase and timing message broadcast. The timestamp indicates when the message was generated. This time, indication allows detection and correction of different rates and offsets between the clocks and latency of message transmission.

6.7.6 Broadcast manoeuvre — Signal group

For each active manoeuvre at a signalized intersection, an RSE shall include the signal group at the intersection for which this manoeuvre is permitted as part of the signal phase and timing message broadcast. The signal group is assigned as part of a roadway geometrics message broadcast by the RSE at the signalized intersection for each lane and its manoeuvres.

6.7.7 Broadcast manoeuvre — Manoeuvre state

For each active manoeuvre at a signalized intersection, an RSE shall indicate the state and signal indications pertaining to that manoeuvre.

6.7.8 Broadcast manoeuvre — Vehicular state

For each vehicular manoeuvre at a signalized intersection, an RSE shall include the current movement's state pertaining to that manoeuvre as part of the signal phase and timing message broadcast. The valid movement phase states are unavailable, stop then proceed, stop and remain, permissive movement allowed, protected movement allowed, permissive clearance, protected clearance, and caution conflicting traffic.

6.7.9 Broadcast manoeuvre — Pedestrian state

For each pedestrian manoeuvre at a signalized intersection, an RSE shall include the movement state of the manoeuvre as part of the signal phase and timing message broadcast. The valid states for pedestrian movements are unavailable, stop then proceed, stop and remain (i.e. don't walk), permissive movement allowed (i.e. walk), protected movement allowed (i.e. exclusive walk), permissive clearance (i.e. flashing don't walk), protected clearance (i.e. exclusive flashing don't walk), and caution conflicting traffic.

6.7.10 Broadcast manoeuvre — Special state

For each manoeuvre for specialized vehicles at a signalized intersection, an RSE shall include the movement state of that manoeuvre as part of the signal phase and timing message broadcast. Special signal states are needed for traffic in non-vehicular (special) lanes, such as fixed guideways for trains. The allowable states for the special movement states are unknown, the special lane/approach is empty (no traveller) or not in use (closed), the special lane/approach is about to be occupied, the special lane/approach is occupied, and the special lane/approach is about to be empty.

NOTE This information is intended to notify the vehicles in the area about the condition of the special lane(s)/approach(es) and is not intended to provide instructions to the vehicles that use the special lane/approach.

6.7.11 Broadcast manoeuvre — Time of change — Minimum

For each manoeuvre at a signalized intersection, an RSE shall include the earliest time point when the manoeuvre state is predicted to change as part of the signal phase and timing message broadcast. This is the earliest time that the manoeuvre's signal indication will change. For example, with this information, connected devices can calculate if it has sufficient time to safely pass through the intersection before the manoeuvre state changes.

For actuated traffic signal controllers, since the actuation on a side street can occur at any time, this earliest time will be equal to the time that the minimum green or pedestrian times have been satisfied, whichever is later. The same earliest time value will continue to be transmitted by the RSE even after the minimum green and pedestrian time have been satisfied. Note that the earliest time is subject to and could be overridden by pedestrian manoeuvre actuations depending on the local intersection control algorithms. It is essential that the traffic controller always indicates the soonest the movement can terminate such that any vehicle approaching the stop line can make an appropriate descision.

For traffic signal controllers operating fixed time, where the time of change is known, the earliest time of change will be equal to the latest time of change (see requirement in 6.7.12).

6.7.12 Broadcast manoeuvre — Time of change — Maximum

For each manoeuvre at a signalized intersection, an RSE shall include the latest time for when the manoeuvre state is predicted to change as part of the signal phase and timing message broadcast. This is the latest time that the manoeuvre's signal indication will change. For example, with this information, connected vehicles can calculate if it has sufficient time to safely pass through the intersection before the manoeuvre state changes.

For actuated traffic signal controllers, since the actuation on a side street can occur at any time, this latest time will be equal to the time that the manoeuvre state will reach the maximum allowable green or pedestrian duration, whichever is later. Once this time is reached, the manoeuvre state will change. Note that the latest time is subject to and could be overridden by pedestrian actuations and signal pre-emption or priority activity.

For traffic signal controllers operating fixed time, where the time of change is known, the latest time of change will be equal to the earliest time of change (see requirement in 6.7.11).

6.7.13 Broadcast manoeuvre — Succeeding signal indications

For each manoeuvre at a signalized intersection, an RSE shall include the next expected movement states pertaining to that manoeuvre (the succeeding manoeuvre) as part of the signal phase and timing message broadcast. The movement states after an allowed vehicle manoeuvre is usually a clearance state, such as a yellow or red state. Local regulations determine permitted actions during clearance conditions. Typically, vehicles are allowed to enter during the "yellow" clearance state but not on a "red" state and typically, an intersection may include a red clearance time before the conflicting manoeuvres are permitted (receive a “green”). Valid movement states for vehicle and pedestrian manoeuvres are identical to those required in 6.7.8 and 6.7.9.

The SPaT message shall indicate the currently permitted movement(s) for the subject lane(s)/approaches and the time points when each movement will terminate (assumed with a clearance interval).

For each manoeuvre which is not currently permitted, the SPaT message shall indicate the time point when the manoeuvre will next be permitted.

Rationale: the former is to support the intersection violation warning and the latter is to support the ECO driving applications. This is based on the following premise. The OBE will take steps to either notify the driver or other automated means to keep the vehicle from entering the intersection (violating the stop line for the movement for the lane).

For example, if the current movement state for a vehicle manoeuvre is a proceed (protected) and a protected left turn, the next expected movement state for the manoeuvre may be a proceed (permissive) and a left turn clearance. This indicates to connected vehicles continuing straight through the intersection that the next clearance state does not apply to them, while connected vehicles intending to make a left turn at the intersection are now aware when a clear or stop left turn signal indication is expected so the vehicle should approach the intersection with caution.

6.7.14 Broadcast manoeuvre — Succeeding signal indication time of change

For each manoeuvre at a signalized intersection, an RSE shall include the time point for when the succeeding manoeuvre state is predicted to change as part of the SPaT message broadcast. The succeeding manoeuvre state is generally a clearance state, such as a yellow indication. Thus, this time generally defines the time the clearance state will end. With this information, travellers with connected devices can calculate if it has sufficient time to clear an intersection before the clearance manoeuvre state changes.

6.7.15 Broadcast manoeuvre pending manoeuvre start time

An RSE shall transmit the start time for each pending (i.e. currently stopped) manoeuvre at a signalized intersection. The time shall be broadcast as a time point and is subject to change based on pedestrian actuations, priority treatment, pre-emption, vehicle actuations for opposing manoeuvres, and adaptive signal timing algorithms. Intersections running a pretimed timing pattern can provide the exact time subject to priority and pre-emption actions.

6.7.16 Broadcast manoeuvre — Pedestrian detect

As part of the signal phase and timing message broadcast, for each manoeuvre at a signalized intersection, an RSE shall indicate if one or more pedestrians have been detected in the pedestrian crossing. Valid types are pedestrians detected (one or more) or no pedestrians detected. This requirement can be used to warn turning vehicles at an intersection, e.g. public transport vehicles, that a pedestrian may be in its blind spot. The message content is considered to represent the condition at the time of transmission.

6.7.17 Broadcast manoeuvre — Pedestrian call

As part of the signal phase and timing message broadcast to connected devices, for each manoeuvre at a signalized intersection, an RSE shall transmit an indication if a pedestrian call (request) has been detected in the pedestrian crossing. Valid types are no call detected, pedestrian call detected, and unavailable. This requirement can be used to warn turning vehicles at an intersection, e.g. public transport vehicles, that a pedestrian may be present in the pedestrian crosswalk. Note that the presence of a pedestrian call is only valid if the “walk” signal is not being displayed. The presence of a “call” indicates that a pedestrian has requested pedestrian service that has not or is not being serviced by a “walk” signal.

6.7.18 Broadcast manoeuvre — Optimal speed information

An RSE shall transmit information about the optimal speed for vehicles on each lane.

6.7.19 Broadcast manoeuvre — Signal progression information

An RSE shall transmit information about the signal timing progression speed along the roadway. This speed may be the signal progression's "green wave" speed or speed associated with another progression algorithm.

6.7.20 Broadcast manoeuvre — Egress lane queue

An RSE shall transmit the length of the queue on each egress lane. The queue length shall be limited to the range from 0 to the length of the egress lane's roadway segment.

This information is useful where there are regulations regarding blocking the intersection ("do not block the box") due to down stream queue lengths.

6.7.21 Broadcast manoeuvre — Egress lane storage availability

An RSE shall transmit the length of available vehicular storage on each egress lane. The available storage length shall be limited to the range from 0 to the lower of the length of the egress lane's roadway segment or 500 m.

6.7.22 Broadcast manoeuvre — Wait indication

An RSE shall determine whether there is available storage on an egress lane. When the available storage length is greater or equal to than the length of a vehicle at the stop line, the RSE shall indicate that the vehicle can proceed into the intersection. Otherwise, the RSE shall indicate that vehicles shall wait at the stop line and not proceed into the intersection.

6.8 Broadcast cross traffic sensor information

An RSE shall broadcast a message with cross traffic sensor information to connected devices. Cross traffic sensor information is used to provide connected devices with the current (see 6.18) status of vehicles (position, speed, and direction) that have the potential for a collision in a non-signalized intersection. Together with the intersection geometric information, connected vehicles can determine when their intended manoeuvres may conflict with other vehicles approaching or in the intersection.

6.9 Broadcast vulnerable road user sensor information

An RSE shall broadcast a message with vulnerable road user sensor information to connected devices. Vulnerable road user sensor information consists of potential presence (for signalized and non-signalized intesections). Together with the intersection geometric information, connected vehicles can determine when their intended manoeuvres may be in conflict with other non-vehicle users of the intersection.

6.10 Broadcast dilemma zone violation warning

An RSE shall broadcast a message that indicates that a vehicle is violating the intersection by entering after the termination of the clearance indication.

6.11 Broadcast signal preferential treatment status

Preferential treatment at signalized intersections, generally in the form of signal pre-emption for emergency vehicles and signal priority for public transport vehicles, provides improved safety and operational efficiencies at the intersection. After a connected vehicle approaching a signalized intersection transmits a signal pre-emption request or a signal priority request, it is helpful for the connected vehicle to determine if their preferential treatment request is currently being serviced by the signal controller.

Note that the repetition rate for the transmission of the SSM is unclear, but it is assumed that the RSE will broadcast the SSM information periodically as long as the signal is attempting to adjust its operation to accommodate the request.

The detailed requirements for an RSE broadcast signal status message to connected devices are listed below.

6.11.1 Broadcast preferential treatment — Signal status message

If a request for signal preferential treatment is received, an RSE shall broadcast a signal status message (SSM) indicating what preferential treatment, if any, a signal controller is processing.

6.11.2 Broadcast preferential treatment — Message identifier

If a request for signal preferential treatment is active, an RSE shall include a message identifier for each signal status message broadcast to connected devices. The message identifier is used to identify a sequence number within a stream of messages from the RSE. The message identifier increments by one whenever the contents of the signal status message has changed. This requirement allows a connected device receiving the signal status message to ignore (not process) the message from the RSE when the contents has not changed.

6.11.3 Broadcast preferential treatment — Intersection identifier

If a request for signal preferential treatment is received, RSE shall include the unique identifier of the intersection for which the signal status is broadcast to connected devices. The intersection identifier is the same identifier included in the roadway geometrics message broadcast by an RSE near or at the signalized intersection.

6.11.4 Broadcast preferential treatment — Intersection status

An RSE shall include the operational status of the traffic signal controller as part of the signal status message broadcast to connected devices. Valid operational status includes intersection is normal (i.e. fixed time, traffic dependent as in actuated or semi-actuated, standby), conflict mode (controller is in conflict flash state), pre-empt active (pre-empt is active), priority active (priority is active), stoptime (stop time is activated and all counting/timing has stopped), and manual control (manual control is enabled).

6.11.5 Broadcast preferential treatment — Prioritization request status

An RSE shall include the status of pre-empt and priority requests as part of the signal status message broadcast to connected devices. The prioritization request status provides information on the infrastructure's processing of the request. The states are defined as unknown, requested, processing, granted, rejected, watch for other traffic, and maximum presence time exceeded.

6.11.6 Broadcast preferential treatment — Vehicle source

An RSE shall include the identifier of the vehicle that is the source of the signal request currently being serviced by the signal controller as part of the signal status message broadcast to connected devices.

This is the mechanism by which the requesting vehicle can determine that its request is being serviced; likewise, other vehicles requesting service will know that they are not being serviced.

6.11.7 Broadcast preferential treatment — Transaction identifier

An RSE shall include the transaction identifier (see 6.2.12 and 6.4.13) of the preferential treatment request as part of the signal status message broadcast to connected devices.

6.12 Message identifier

A connected vehicle shall change the message identifier transmitted to another connected device when its device identifier (see SAE J3067™:2014, 3.6.1.2) has changed. This is done to protect the overall anonymity of the connected vehicle.

Where a priority/pre-emption request is made for one or a sequence of intersections (e.g. an arterial), then the vehicle ID shall remain constant throughout the navigation of the intersection/arterial such that the traffic management systems can track the progress of the vehicle and manage the coordination between intersections where appropriate.

6.13 System performance requirements

The following requirements address implementation needs within the various communications environments that will support these applications. They are based on the general requirement to minimize the bandwidth required for the transmission of the data content. These requirements are not inherent in the use cases and hence are included separately.

6.13.1 Broadcast intersection — Computed lane/approach

For a lane/approach at an intersection, an RSE shall include an offset value from another defined lane/approach at the intersection, to indicate its path relative to the referenced lane/approach as part of the geometric information broadcast. The offset value indicates the distance, in centimeters, and angle between the centerline of the referenced lane/approach and the centerline of the subject (computed) lane/approach. This offset value also includes the lane number of the referenced (referenced) lane/approach. This requirement reduces the bandwidth needed to define similar lanes/approaches at an intersection. Instead of transmitting a new sequence of offset values for each lane, only an offset value and lane/approach number information of a referenced lane/approach is transmitted.

6.14 Transmission rates — Signal preferential treatment

The detailed transmission rate requirements for an authorized connected vehicle to transmit a preferential treatment request to an RSE are as follows.

6.14.1 Maximum transmission rate — Request signal preferential treatment

An authorized connected vehicle shall transmit requests to an RSE for preferential treatment at a signalized intersection no more than once every 500 ms.

6.14.2 Maximum response time — Request signal preferential treatment

An RSE shall process all signal preferential treatment requests from authorized connected vehicles within the maximum response time. The response time is measured as the time between the receiving of the last byte of the request and the transmission of the first byte of the response. If the specification does not indicate the response time, the default maximum response time shall be 2 s.

6.14.3 Minimum transmission rate — Signal status message

The RSE shall broadcast the signal status message in response to a signal request message at a minimum of once every 500 ms.

6.14.4 Minimum transmission period — Signal status message

The RSE shall broadcast the signal status message from the maximum response time-request signal preferential treatment until the authorized connected vehicle clears the intersection.

6.15 Transmission rate requirements — Broadcast roadway geometrics information

RSE(s) broadcasting roadway geometrics information has different transmission requirements than a generic RSE because of its safety aspects. For example, connected vehicles approaching or within an intersection needs to be aware of the roadway geometrics. Wireless communications are not 100 % reliable, thus if a vehicle only has the opportunity to receive one transmission, there is a reasonable potential it will miss it. Thus, for RSEs broadcasting roadway geometric information, which may be considered safety critical, the transmission rates should be different to increase the opportunities for a connected device to receive the messages.

6.15.1 Minimum transmission rate — Broadcast roadway geometrics information

An RSE shall broadcast roadway geometrics information to connected devices no less than once per 2 s.

6.15.2 Maximum transmission rate — Broadcast roadway geometrics information

An RSE shall broadcast roadway geometrics information to connected devices no more than once per 500 ms.

6.15.3 Default transmission rate — Broadcast roadway geometrics information

If the specification does not indicate a default transmission rate, the suggested default transmission rate for an RSE to broadcast roadway geometrics information to a connected device shall be once per second.

6.16 Transmission rate requirements — GNSS augmentations detail broadcasts

The detailed transmission rate requirements for an RSE to broadcast GNSS augmentation details information to connected vehicles are as follows.

6.16.1 Minimum transmission rate — GNSS augmentation details broadcasts

An RSE shall broadcast the GNSS augmentation details message to connected devices at least once per second (1 Hz) for the GNSS augmentation messages. Broadcasting GNSS augmentation detail messages any slower than once per second has a significant effect on the integrity of the GNSS augmentation information.

6.16.2 Default transmission rate — GNSS augmentation details broadcasts

If the specification does not indicate a default transmission rate, an RSE shall broadcast the GNSS augmentation details message to connected devices at a constant 1 Hz for the GNSS augmentation messages and at least once every 15 s for other auxiliary messages.

6.17 Transmission rate requirements — Broadcast signal phase and timing information

Broadcasting signal phase and timing information has different requirements because of its safety aspects. Connected vehicles approaching a signalized intersection needs to be aware of the signal timing information. Wireless communications are not 100 % reliable, thus if a vehicle only has the opportunity to receive one transmission, there is a reasonable potential it will miss it. Thus, for RSE(s) broadcasting signal phase and timing information, which may be considered safety critical, the transmission rates should be different to increase the opportunities for a connected vehicle to receive the messages.

6.17.1 Minimum transmission rate — Broadcast signal phase and timing information

An RSE shall broadcast signal phase and timing information to connected vehicles no less than once every 2 s.

6.17.2 Maximum transmission rate — Broadcast signal phase and timing information

An RSE shall broadcast signal phase and timing information to connected vehicles no more than once every 100 ms.

6.17.3 Default transmission rate — Broadcast signal phase and timing information

If the specification does not indicate a default transmission rate, the default transmission rate for an RSE to broadcast signal phase and timing information to a connected vehicle shall be once per 150 ms.

6.18 Transmission rate requirements — Broadcast cross traffic sensor information

Broadcasting cross traffic sensor information has different requirements because of its safety aspects. Connected vehicles approaching a non-signalized intersection needs to be aware of the presence of vehicles that maybe approaching the intersection in a conflicting angle. Wireless communications are not 100 % reliable, thus if a vehicle only has the opportunity to receive one transmission, there is a reasonable potential it will miss it. Thus, for RSEs broadcasting cross traffic sensor information, which may be considered safety critical, the transmission rates should be different to increase the opportunities for a connected vehicle to receive the messages.

6.18.1 Minimum transmission rate — Broadcast cross traffic sensor information

An RSE shall broadcast cross traffic sensor information to connected vehicles no less than once every 2 s.

6.18.2 Maximum transmission rate — Broadcast cross traffic sensor information

An RSE shall broadcast cross traffic sensor information to connected vehicles no more than once every 100 ms.

6.18.3 Default transmission rate — Broadcast cross traffic sensor information

If the specification does not indicate a default transmission rate, the default transmission rate for an RSE to broadcast cross traffic sensor information to a connected vehicle shall be once per 150 ms (TBR).

6.19 Transmission rate requirements — Broadcast vulnerable road user sensor information

Broadcasting vulnerable road user sensor information has different requirements because of its safety aspects. Connected vehicles approaching an intersection (signalized and non-signalized) needs to be aware of the presence of vulnerable road users that may be in a crossing. Wireless communications are not 100 % reliable, thus if a vehicle only has the opportunity to receive one transmission, there is a reasonable potential it will miss it. Thus, for RSE(s) broadcasting vulnerable road user sensor information, which may be considered safety critical, the transmission rates should be different to increase the opportunities for a connected vehicle to receive the messages.

6.19.1 Transmission rate — Broadcast vulnerable road user sensor information

An RSE shall broadcast vulnerable road user sensor information to connected vehicles no less than once every 2 s.

6.19.2 Maximum transmission rate — Broadcast vulnerable road user sensor information

An RSE shall broadcast vulnerable road user sensor information to connected vehicles no more than once every 100 ms.

6.19.3 Default transmission rate — Broadcast vulnerable road user sensor information

If the specification does not indicate a default transmission rate, the default transmission rate for an RSE to broadcast vulnerable road user sensor information to a connected vehicle shall be once per 150 ms.

7 Messages

This document specifies the data dictionary to be used internationally for the deployment of the following messages:

a) map data (MAP);

b) signal phase and timing (SPaT);

c) signal request message (SRM);

d) signal status message (SSM).

The structure of these messages is defined by selection of an annex and the message requirements therein. The annexes with message structure requirements are as follows:

— Annex E Profile A for J2735™;

— Annex F Profile B for J2735™;

— Annex G Profile C for J2735™.

8 Conformance

An implementation is conformant with this document when all of the following conditions are met.

a) The implementation's data content shall satisfy the mandatory and selected optional requirements as identified in the requirements traceability matrix (see Annex C) or as defined in the selected annexes.

b) The implementation's message structure satisfies the requirements of the selected annex.

c) To conform to a requirement in this document, a system or device interface shall implement all data elements traced from that requirement (and in the order specified in this document). To be consistent with a requirement, a system or device interface shall be able to fulfil the requirement using only messages, data frames, and data elements that a conforming system or device interface is required to support.

Annex A
(informative)

Use cases

Table A.1 — Identified use cases

ID	Title
PR1	A.2 — PR1: Localized public transport signal priority (TSP)
PR1-a	A.3 — PR1-a: Localized public transport signal priority — Near side stop
PR2	A.4 — PR2: Public transport signal priority along an arterial (group of intersections)
PR3	A.5 — PR3: Localized freight signal priority
PR3-a	A.6 — PR3-a: Localized freight signal priority with a platoon
PR3-b	A.7 — PR3-b: Arterial freight signal priority for a platoon
PR4	A.8 — PR4: Emergency vehicle single or multiple vehicles (normal power PSOBE)
PR5	A.9 — PR5: Emergency vehicle single or multiple vehicles (high-power PSOBE)
PR6	A.10 — PR6: Mixed emergency vehicle and other priority eligible vehicles
SA1	A.11 — SA1: Dilemma zone protection
SA2	A.12 — SA2: Red light violation warning
SA3	A.13 — SA3: Stop sign violation warning
SA4	A.14 — SA4: Turning assistant — Oncoming traffic
SA5	A.15 — SA5: Turning assistant — Vulnerable road user avoidance
SA6	A.16 — SA6: Non-signalized crossing traffic warning
SA7	A.17 — SA7: Crossing vulnerable road user advisory (non-signalized)
MS1	A.18 — MS1: Basic local traffic signal actuation
MS2	A.19 — MS2: Platoon detection for coordinated signals
MS3	A.20 — MS3: Congested intersection adjustment
MS4	A.21 — MS4: Traffic signal optimal speed advisory
MS5	A.22 — MS5: Signalized corridor eco-driving speed guidance
MS6	A.23 — MS6: Idling stop support
MS7	A.24 — MS7: Start delay prevention
MS8	**(Deleted) Travel lane advice**
MS9	A.25 — MS9: Inductive charging at signals
MS10	A.26 — MS10: Don’t block the box

Table A.2 — PR1: Localized public transport signal priority (TSP)

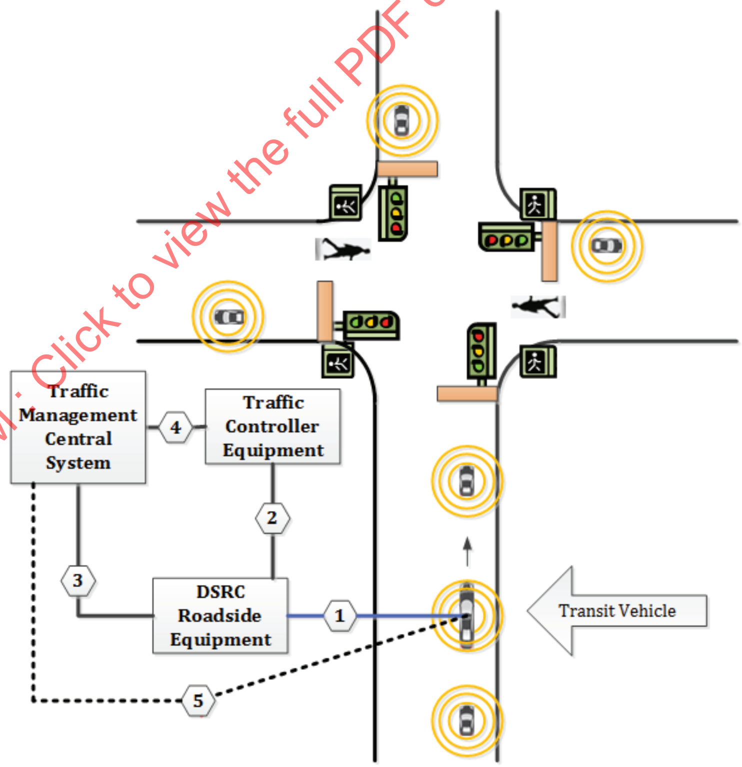
Use case name	Basic TSP scenario — Single public transport vehicle at one signalized intersection
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for connected public transport vehicles.
Goal	Improved public transport efficiency and reliability
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the public transport vehicle to indicate its TSP request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation)
Geographic scope	Localized to a specific intersection
Actors	Public transport vehicle equipped with on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)
Illustration	
Preconditions	1) The transportation agency(ies) has established a policy for priority control (called N-level priority) and the fleet management (public transport) system is prepared to provide priority service for vehicles on routes. 2) The traffic signal controller is programmed with a variety of priority control schemes, such as early green, green extension, phase rotation, phase skipping, etc. The traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow	Vehicle to TSC — Direct 1) The use case begins when an equipped public transport vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE (public transport vehicle) receives MAP and SPaT messages from the RSE.

Table A.2 *(continued)*

	3) The OBE sends basic safety messages (BSM) or cooperative awareness message (CAM). 4) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed. The scenario requested may include a straight through manoeuvre, a right or left turn (permissive or protected), or a queue jump. 5) The RSE receives and monitors the vehicle position using the BSM/CAM. 6) The RSE receives the SRM from the OBE. 7) The RSE manages and prioritizes requests (SRM) from multiple public transport vehicles on the same or conflicting manoeuvres with the consideration of the prevailing traffic conditions and the requested level of priority (as determined by the vehicle and the established policy). 8) The RSE determines the best signal timing plan to accommodate the active priority request and executes plan (if it can be accommodated). NOTE Depending on the current timing, time in cycle, and phase sequence, it is more likely that the TSC will need to evaluate all priority requests received to determine how to best service the approaching vehicles. This will depend on such information as the vehicle location, speed, projected arrival time, current traffic queues, etc. 9) The RSE broadcasts the signal status message (SSM) to any connected vehicle (CV) approaching the intersection. 10) The OBE receives the SSM and determines if and when the request will become active at the intersection. 11) The OBE determines that the public transport vehicle has cleared the intersection and sends a new SRM to cancel the priority request. (Alternative 11a: The RSE determines that the time to live for the request has expired and terminates the priority action. Alternative 11b: The RSE determines that the vehicle has cleared the intersection based on receipt of the BSM/CAM and terminates the priority action.) 12) The RSE receives the cancel SRM (or timeout) and terminates the priority action. 13) The RSE initiates the configured recovery procedures to normal signal timing operation. 14) The case ends.
Alternate flow(s)	1) (7) The public transport vehicle changes speed and the RSE updates its priority timing based on travel time estimates. 2) (8) The public transport vehicle will not arrive during green max window and vehicle has to stop at red signal. 3) (insert between steps 12 to 13) The RSE updates the public transport vehicle served performance measures.
	Vehicle to Intersection — Indirect through BOPC 4) OBE monitors its vehicle position using an on-board map and location algorithms. Hence, the vehicle determines which intersection(s) it is approaching and the likely time of arrival. Precondition: the vehicle should have on-board map information sufficient to make priority requests at the appropriate time. 5) The OBE transmits its SRM to the BOPC via a non-DSRC media such that the traffic control management systems are aware of the location and impending need for TSP treatment. 6) The BOPC alerts the TSC of the approaching vehicle with the need for TSP treatment and the likely time of arrival along with the current location of the vehicle, adjusting for traffic conditions. 7) The TSC prepares to adjust its signal operation based on the approaching vehicle and alerts the BOPC of its operation. 8) Once the OBE begins to “hear” the SPaT message from the intersection, it updates its SRM to the RSE and the scenario described above continues.

Table A.2 *(continued)*

Post-conditions	The TSC initiates recovery operations to restore normal timing operation, which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvre(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and Pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, (time to apply) (Optional: entry lane, exit lane) SSM Priority scenario being serviced, vehicle ID(s) being serviced, time to reach desired display, vehicle type being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) This use case assumes that the scenarios needed for the public transport vehicle are pre-determined and loaded into TSC. 2) It also presumes that the public transport vehicle knows which of the scenarios that the controller can support should be invoked to meet its specific needs although these might be included in the SSM. Note that this also assumes that the vehicle knows its route and hence knows what exit lane (or manoeuvre) to request. 3) It is also possible for the public transport vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the TSC will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC.
Source docs/ references	MMITSS, CEN, USDOT J2735™ SE Candidate

Table A.3 — PR1-a: Localized public transport signal priority — Near side stop

Use case name	Basic TSP scenario — Single public transport vehicle at one signalized intersection for near side stop
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for connected public transport vehicles for near side stops
Goal	Improved public transport efficiency and reliability

Table A.3 *(continued)*

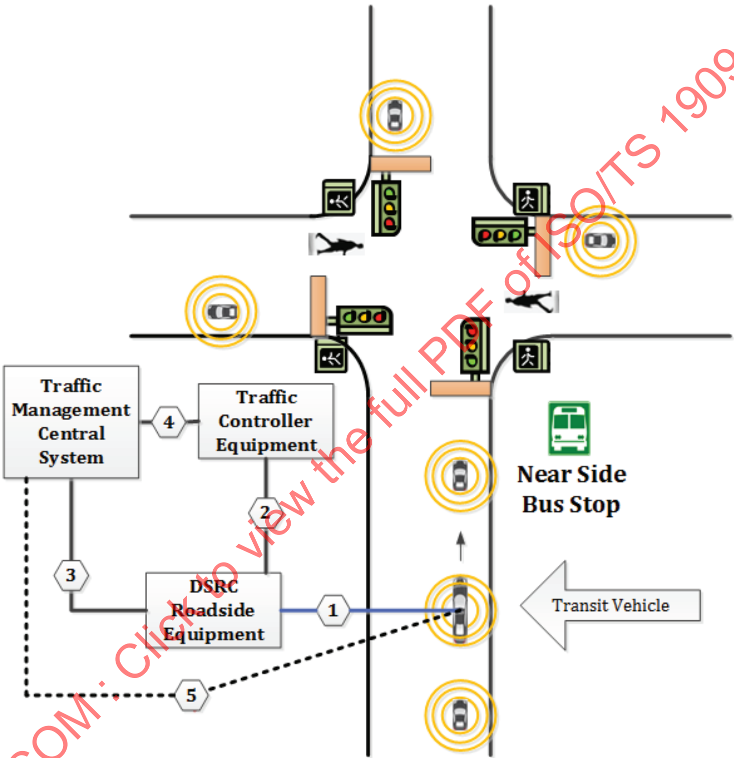
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the public transport vehicle to indicate its TSP request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation)
Geographic scope	Localized to a specific intersection
Actors	Public transport vehicle equipped with on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)
Illustration	
Preconditions	1) The transportation agency(ies) has established a policy for priority control (called N-level priority) and the fleet management (public transport) system is prepared to provide priority service for vehicles on routes. 2) The traffic signal controller is programmed with a variety of priority control schemes, such as early green, green extension, phase rotation, phase skipping, etc. The traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow	Vehicle to TSC — Direct 1) The use case begins when an equipped public transport vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE receives MAP and SPaT messages from the RSE. 3) The OBE sends basic safety messages (BSM) or cooperative awareness message (CAM). 4) The RSE receives and monitors the vehicle position using the BSM/CAM. 5) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed. The scenario requested may include a straight through manoeuvre, a right or left turn (permissive or protected), or a queue jump. 6) The RSE receives SRM.

Table A.3 *(continued)*

	7) The RSE manages and prioritizes requests (SRM) from multiple public transport vehicles on the same or conflicting manoeuvres with the consideration of the prevailing traffic conditions and the requested level of priority (as determined by the vehicle and the established policy). 8) The RSE determines the best signal timing plan to accommodate the active priority. NOTE Depending on the current timing, time in cycle, and phase sequence, it is more likely that the TSC will need to evaluate all priority requests received to determine how to best service the approaching vehicles. This will depend on such information as the vehicle location, speed, projected arrival time, current traffic queues, etc. 9) The RSE broadcasts an updated signal status message (SSM) to any connected vehicle (CV) approaching the intersection. 10) The OBE receives the SSM and determines if and when the request will become active at the intersection. 11) The OBE determines that the public transport vehicle has either cleared the intersection or has stopped at the near side stop and sends a new SRM to cancel the priority request. (Alternative 11a: the RSE determines that the time to live for the request has expired and terminates the priority action. Alternative 11b: The RSE determines that the vehicle has cleared the intersection based on receipt of the BSM/CAM and terminates the priority action.) 12) The RSE receives the cancel SRM (or timeout). 13) The RSE initiates the configured recovery procedures to normal signal timing operation. 14) The case ends. 15) The bus will start the sequence over from the near side stop when ready to depart if the signal does not allow it to depart. Otherwise, no further action is required. Note that recovery does not complete before accepting the queue jump request.
Alternate flow(s)	1) (7) The public transport vehicle changes speed and the RSE updates its priority timing based on travel time estimates. 2) (8) The public transport vehicle will not arrive during green max window and vehicle has to stop at red signal. 3) (insert between steps 12 to 13) The RSE updates the public transport vehicle served performance measures.
	Vehicle to intersection — Indirect through BOPC (replaces steps 5 to 9 of main flow) 5) OBE monitors its vehicle position using an on-board map and location algorithms. Hence, the vehicle determines which intersection(s) it is approaching and the likely time of arrival. Precondition: the vehicle should have on-board map information sufficient to make priority requests at the appropriate time. 6) The OBE transmits its SRM to the BOPC via a non-DSRC media such that the traffic control management systems are aware of the location and impending need for TSP treatment. 7) The BOPC alerts the RSE of the approaching vehicle with the need for TSP treatment and the likely time of arrival along with the current location of the vehicle, adjusting for traffic conditions. 8) The RSE prepares to adjust its signal operation based on the approaching vehicle and alerts the BOPC of its operation. 9) Once the OBE begins to "hear" the SPaT message from the intersection, it updates its SRM to the RSE/BOPC and the scenario described above continues.
Post-conditions	The RSE initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.

Table A.3 *(continued)*

Information requirements	SpaT Current manoeuvre(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than MAP base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, vehicle ID(s) being serviced, time to reach desired display, vehicle type being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) This use case assumes that the scenarios needed for the public transport vehicle are pre-determined and loaded into the TSC. 2) It also presumes that the public transport vehicle knows which of the scenarios that the controller can support should be invoked to meet its specific needs although these might be included in the SSM. Note that this also assumes that the vehicle knows its route and hence knows what exit lane (or manoeuvre) to request. 3) It is also possible for the public transport vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the TSC will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC.
Source docs/ references	MMITSS, CEN, SAE USDOT J2735™ SE Candidate

Table A.4 — PR2: Public transport signal priority along an arterial (group of intersections)

Use case name	Public transport signal priority along an arterial (group of intersections)
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for a connected public transport vehicle travelling through a section of signalized intersections.
Goal	Improved public transport efficiency and reliability
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the public transport vehicle to indicate its TSP request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation)
Geographic scope	Localized to a specific intersection. However, while the vehicle will deal with a single intersection at a time (or multiple if they are tightly located), the BOPC may attempt to modify the timing pattern at a number of intersections along an arterial to provide optimal signal timing considering the location of the bus stops, vehicle speed, etc.

Table A.4 *(continued)*

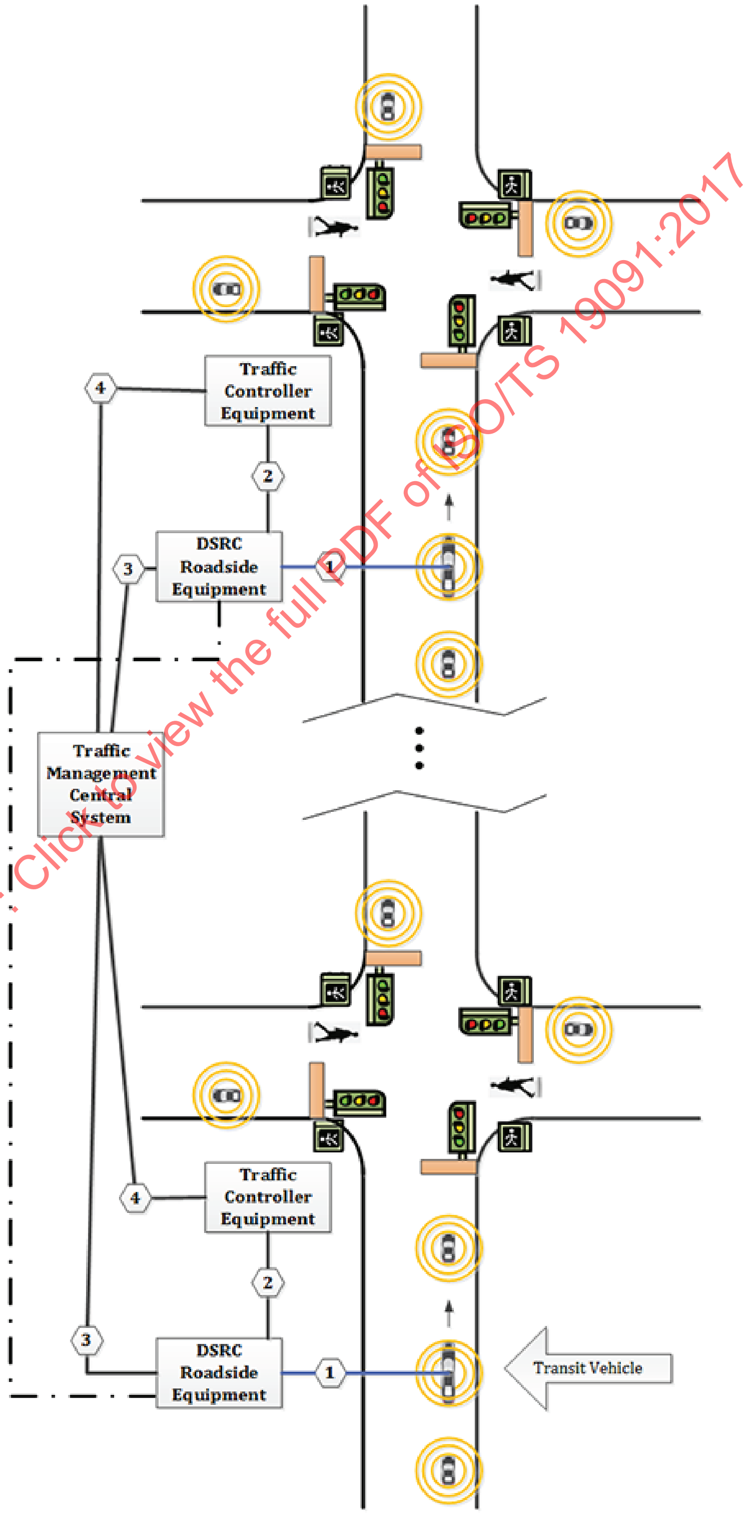
Actors	Public transport vehicle equipped with on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)
Illustration	
Preconditions	1) Multiple signalized intersections are equipped with RSE(s) and have RSE-to-RSE communication enabled. Alternatively, RSE and/or traffic controllers communicate with the BOPC and the BOPC is responsible for coordinating the intersection to intersection offset relationship and priority treatment to support the priority request.

Table A.4 *(continued)*

	2) The RSE(s) store public transport route MAP data or this data is available from the public transport management system. 3) The traffic signal controllers in the section are programmed with a variety of priority control schemes, such as early green, green extension, phase rotation, phase skipping, etc. or the traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow	1) The use case begins when an equipped public transport vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE receives MAP and SPaT messages from the RSE. 3) The OBE send basic safety messages (BSM) or cooperative awareness message (CAM) 4) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed. 5) The RSE receives and monitors the vehicle position using the BSM/CAM. 6) The RSE receives SRM and forwards to the BOPC. 7) The BOPC manages and prioritizes requests (SRM) from the public transport vehicles to issue priority based on prevailing traffic conditions at a section of signalized intersections and the requested level of priority (as determined by the vehicle and the established policy). 8) The BOPC determines the best coordinated signal timing strategy along the section of signalized intersections to accommodate the active priority request. 9) The BOPC sends priority timing to the traffic signal controllers (via RSE-to-RSE communication or directly to the RSE for each intersection in the "section") for further processing and execution. 10) The TSC sends updated SSM to the RSE and the RSE broadcasts the SSM to any connected vehicle (CV) approaching the intersection. 11) The OBE receives the SSM and determines if and when the request will become active at the intersection. 12) The OBE determines that the public transport vehicle has cleared the intersection and sends a new SRM to cancel the priority request. (Alternative 12a: the RSE determines that the time to live for the request has expired and terminates the priority action. Alternative 12b: the RSE determines that the vehicle has cleared the intersection based on receipt of the BSM/CAM and terminates the priority action.) 13) The RSE receives the cancel SRM (or timeout) and sends it to the TSC. 14) The RSE initiates the configured recovery procedures to normal signal timing operation. 15) The case ends.
Alternate flow(s)	1) (12) The public transport vehicle changes speed and the RSE updates its priority timing based on travel time estimates. This shall also include the BOPC since it is managing the arterial. 2) (12) The public transport vehicle will not arrive during green max window and vehicle has to stop at red signal. 3) (insert between steps 13 to 14) The RSE updates the Public Transport vehicle served performance measures. 4) The RSE continues to assist the vehicle based on its configuration information on subsequent cycles until the vehicle clears the intersection. 5) The BOPC may further adjust the timing to reflect difficulties at the subject intersection.
	Vehicle to intersection — Indirect through BOPC (replaces steps 4 to 8 of the main flow): 4) The OBE monitors its vehicle position using an on-board map and location algorithms. Hence, the vehicle determines which intersection(s) it is approaching and the likely time of arrival. Precondition: the vehicle should have on-board map information sufficient to make priority requests at the appropriate time.

Table A.4 *(continued)*

	5) The OBE transmits its SRM to the BOPC via a non-DSRC media such that the traffic control management systems are aware of the location and impending need for TSP treatment. 6) The BOPC alerts the RSE of the approaching vehicle with the need for TSP treatment and the likely time of arrival along with the current location of the vehicle, adjusting for traffic conditions. 7) The RSE prepares to adjust its signal operation based on the approaching vehicle and alerts the BOPC of its operation. 8) Once the OBE begins to "hear" the SPaT message from the intersection, it updates its SRM to the RSE and the scenario described above continues.
Post-conditions	The RSE initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other that MAP base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, time to reach desired display, vehicle type being serviced, vehicle ID(s) being serviced, entry lane (approach roadway), exit lane (exit roadway), progression speed for green band
Issues	1) This use case assumes that the scenarios needed for the public transport vehicle are pre-determined and loaded into the RSE. 2) It also presumes that the public transport vehicle knows which of the scenarios that the controller can support should be invoked to meet its specific needs although these might be included in the SSM. 3) It is also possible for the public transport vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the traffic signal will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC. 5) For this use case, there is a shared responsibility between the BOPC and the RSE as to how to best service the vehicle and how to react if the vehicle is unable to make the green within the parameters allowed. This is a more complex use case and requires that timing of the arterial be dynamic for the vehicle as it travels along the route.
Source docs/ references	MMITSS 11.2.3

Table A.5 — PR3: Localized freight signal priority

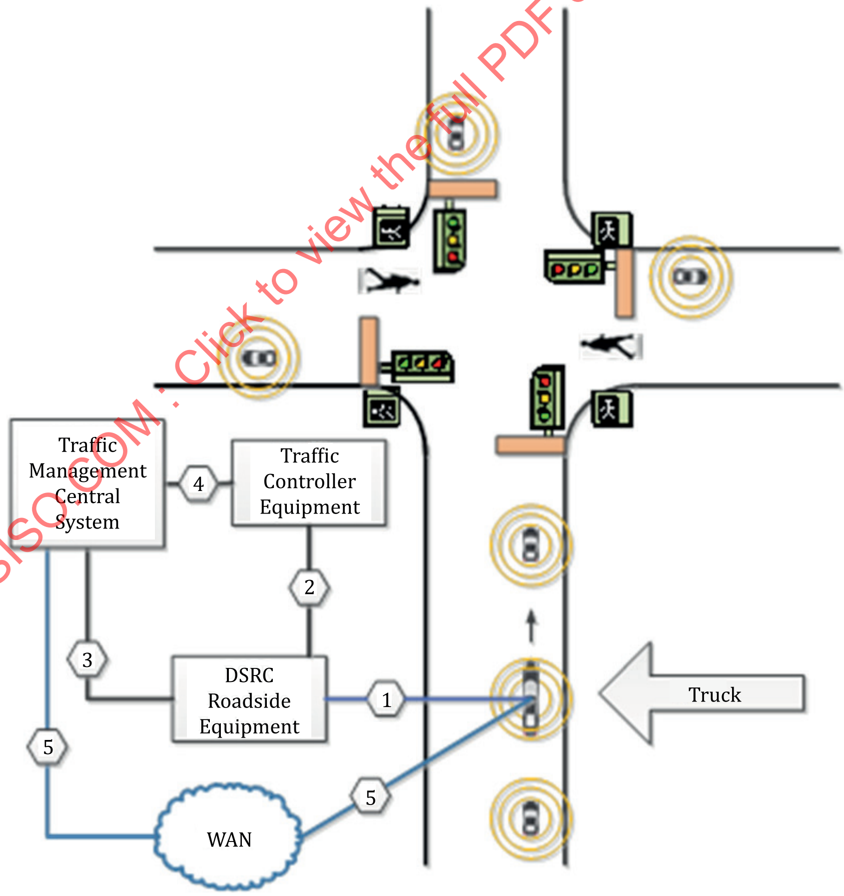
Use case name	Basic FSP scenario — Single freight vehicle (truck, lorry) at one signalized intersection
Category	Mobility, sustainability (ECO)
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for connected heavy vehicles.
Goal	Improved freight movement efficiency and reliability
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the freight vehicle to indicate its FSP request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation)
Geographic scope	Localized to a specific intersection
Actors	Freight vehicle equipped with on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)
Illustration	
Preconditions	1) The transportation agency(ies) has established a policy for priority control (called N-level priority) and the fleet management (trucks) system is prepared to provide priority levels for vehicles on routes. 2) The traffic signal controller is programmed with a variety of priority control schemes such as early green, green extension, phase rotation, phase skipping, and etc. or the traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.

Table A.5 *(continued)*

Main flow	1) The use case begins when an equipped vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE receives MAP and SPaT messages from the RSE. 3) The OBE sends basic safety messages (BSM) or cooperative awareness message (CAM) 4) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed. The SRM includes the level of requested priority which can differentiate the case that the truck can or cannot make a safe stop before the stop bar. 5) The RSE receives and monitors the vehicle position using the BSM/CAM. 6) The RSE receives an SRM. 7) The RSE manages and prioritizes requests (SRM) from multiple vehicles on the same or conflicting manoeuvres with the consideration of the prevailing traffic conditions and the requested level of priority (as determined by the vehicle and the established policy). 8) The RSE determines the best signal timing plan to accommodate the active priority request. 9) The RSE broadcasts the updated SSM to any connected vehicle approaching the intersection. 10) The OBE receives the SSM and determines if and when the request will become active at the intersection. 11) The OBE receives and monitors the SPaT message to determine when the signals are likely to change state, i.e. whether a stop is required. 12) The OBE determines that the freight vehicle has cleared the intersection and sends a new SRM to cancel the priority request. (Alternative 12a: the RSE determines that the time to live for the request has expired and terminates the priority action. Alternative 12b: the RSE determines that the vehicle has cleared the intersection based on receipt of the BSM/CAM and terminates the priority action.) 13) The RSE receives the cancel SRM and sends it to the TSC. 14) The RSE initiates the configured recovery procedures to normal signal timing operation. 15) The case ends.
Alternate flow(s)	1) (10) The truck changes speed and the RSE updates its priority timing based on revised travel time estimates. 2) (14) The RSE updates the delay and stop performance measures. 3) (Insert between steps 13 to 14) The RSE updates the freight vehicle served performance measures.
	Vehicle to intersection — Indirect through BOPC (replaces steps 4 to 8 of main flow): 4) The OBE monitors its vehicle position using an on-board map and location algorithms. Hence, the vehicle determines which intersection(s) it is approaching and the likely time of arrival. Precondition: the vehicle should have on-board map information sufficient to make priority requests at the appropriate time. 5) The OBE transmits its SRM to the BOPC via a non-DSRC media such that the traffic control management systems are aware of the location and impending need for FSP treatment. 6) The BOPC alerts the RSE of the approaching vehicle with the need for FSP treatment and the likely time of arrival along with the current location of the vehicle, adjusting for traffic conditions. 7) The RSE prepares to adjust its signal operation based on the approaching vehicle and alerts the BOPC of its operation. 8) Once the OBE begins to “hear” the SPaT message from the intersection, it updates its SRM to the RSE and the scenario described above continues at step 9.

Table A.5 *(continued)*

Post-conditions	The TSC initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvre(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than MAP base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type
	SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, vehicle characteristics (acceleration time, deceleration time/distance), [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, time to reach desired display, vehicle type being serviced, vehicle ID(s) being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) This use case assumes that the scenarios needed for the truck are pre-determined and loaded into the traffic signal controller. 2) It also presumes that the truck knows which of the scenarios that the controller can support and should be invoked to meet its specific needs. 3) It is also possible for the vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the traffic signal will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC.
Source docs/ references	MMITSS

Table A.6 — PR3-a: Localized freight signal priority with a platoon

Use case name	Basic FSP scenario — Platoon of freight vehicles (truck, lorry) at one signalized intersection
Category	Mobility, sustainability (ECO)
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for a connected heavy vehicle platoon.
Goal	Improved freight transport efficiency and reliability

Table A.6 *(continued)*

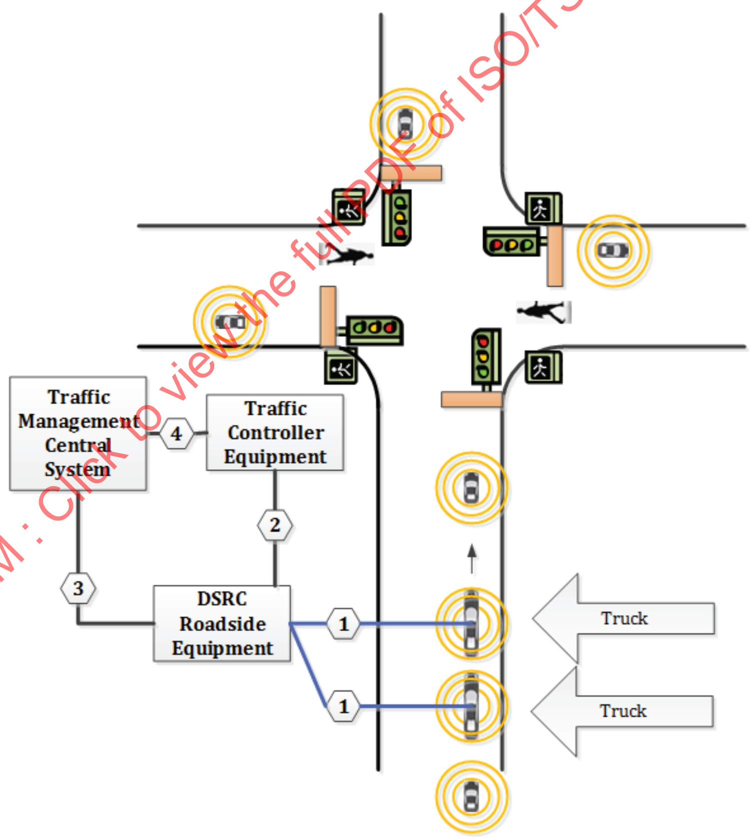
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the freight vehicle to indicate its TSP request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation). Since an infinite platoon cannot be accommodated, the intersection should continuously monitor the BSM/CAM messages received for the trucks and decide when to "cut off" the platoon and signal the vehicles approaching in some manner that they will no longer be accommodated and that the signal will be stopping the movement's traffic at a specific time.
Geographic scope	Localized to a specific intersection
Actors	Freight transport vehicle equipped with on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)
Illustration	
Preconditions	1) The transportation agency(ies) has established a policy for priority control (called N-level priority) and the fleet management (trucks) system is prepared to provide priority levels for vehicles on routes. 2) The traffic signal controller is programmed with a variety of priority control schemes, such as early green, green extension, phase rotation, phase skipping, etc. or the traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow	1) The use case begins when an equipped vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE receives MAP and SPaT messages from the RSE. 3) The OBE send basic safety messages (BSM) or cooperative awareness message (CAM).

Table A.6 *(continued)*

	4) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed. The SRM includes the level of requested priority which can differentiate the case that the truck can or cannot make a safe stop before the stop bar. 5) The RSE receives and monitors the vehicle position using the BSM/CAM. 6) The RSE receives an SRM. 7) The RSE manages and prioritizes requests (SRM) from multiple vehicles on the same or conflicting manoeuvres with the consideration of the prevailing traffic conditions and the requested level of priority (as determined by the vehicle and the established policy). 8) The RSE determines the best signal timing plan to accommodate the active priority request. 9) The RSE broadcasts the updated SSM to any connected vehicle approaching the intersection. 10) The OBE receives the SSM and determines if and when the request will become active at the intersection. 11) The OBE receives and monitors the SPaT message to determine when the signals are likely to change state, i.e. whether a stop is required. 12) The OBE determines that the freight vehicle has cleared the intersection and sends a new SRM to cancel the priority request. (Alternative 12a: the RSE determines that the time to live for the request has expired and terminates the priority action. Alternative 12b: the RSE determines that the vehicle has cleared the intersection based on receipt of the BSM/CAM and terminates the priority action.) 13) The RSE receives the cancel SRM and sends it to the TSC. 14) The RSE initiates the configured recovery procedures to normal signal timing operation. 15) The case ends. NOTE The platoon may be making a turn and exiting the intersection in a direction other than the through manoeuvre.
Alternate flow(s)	1) (10) The truck changes speed and the RSE updates its priority timing based on revised travel time estimates. 2) (insert between steps 14 and 15) The RSE updates the freight vehicle served performance measures or the RSE updates the delay and stop performance measures. An additional alternate flow is that the RSE determines that the platoon is too long and hence should be broken into sections for the progression through the intersection and/or arterial. In this case, the RSE/TSC needs to know the length of the platoon, which raises the issue of communications among the vehicles to form a platoon. In this alternate flow, the RSE will need to notify a specific vehicle that it will not be granted right of way and should stop at the intersection while the preceding vehicle will be tracked through the intersection.
Post-conditions	The RSE initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request. NOTE If it was necessary to split a platoon, then local timing priorities will determine whether a new platoon will be “formed” by counting vehicles and tracking the formation and then separating if there are too many as described above.
Information requirements	SPaT Current manoeuvre(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base

Table A.6 *(continued)*

	BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, vehicle characteristics (acceleration time, deceleration time/distance), [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, time to reach desired display, vehicle type being serviced, vehicle ID(s) being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) This use case assumes that the scenarios needed for the truck are pre-determined and loaded into the traffic signal controller. 2) It also presumes that the truck knows which of the scenarios that the controller can support and should be invoked to meet its specific needs. 3) It is also possible for the vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the traffic signal will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC. 5) Platoon operation's research is ongoing and therefore platoon requirements will be addressed in a future version of this document.
Source docs/ references	MMITSS

This use case is identical to the PR3 except that the intersection should be tracking a group of trucks through the intersection. Since an infinite platoon cannot be accommodated, the intersection should continuously monitor the BSM/CAM messages received for the trucks and decide when to "cut off" the platoon and signal the vehicles approaching in some manner that they will no longer be accommodated and that the signal will be stopping the movement's traffic at a specific time.

Table A.7 — PR3-b: Arterial freight signal priority for a platoon

Use case name	Arterial freight signal priority for a platoon
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic priority control for a connected freight platoon travelling through a section of signalized intersections.
Goal	Improved freight transport efficiency and reliability
Constraints	Use of DSRC or other medium that will meet the performance requirements for this use case (the RSE and OBE include radio devices that operate in the medium used) Alternate: wide area broadband communications is available for the public transport vehicle to indicate its priority request via an alternate media than DSRC through back office processing centre (BOPC). (Data flow #5 supports that situation)
Geographic scope	Localized to a specific intersection
Actors	Freight vehicles equipped with on-board equipment (OBE) forming a platoon Roadside equipment (RSE) and traffic signal controller (TSC) Alternate: traffic management central system (BOPC)

Table A.7 *(continued)*

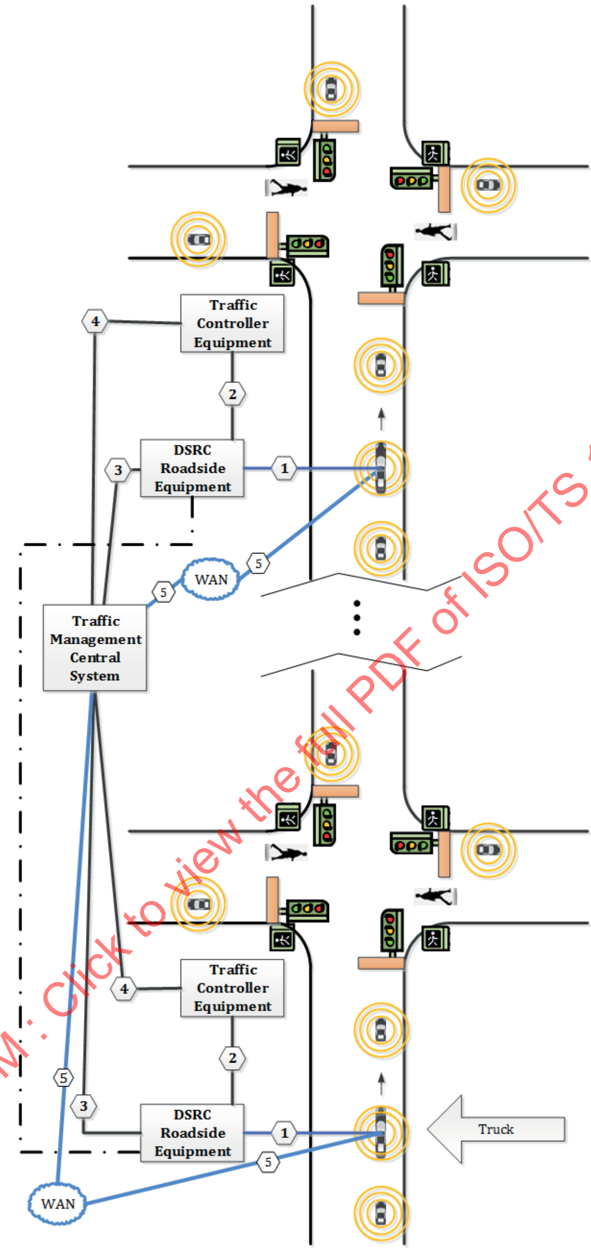
Illustration	
Preconditions	1) Multiple signalized intersections are equipped with RSE(s) and have RSE-to-RSE communication enabled. Alternatively, RSE and/or traffic controllers communicate with the BOPC and the BOPC is responsible for coordinating the intersection to intersection offset relationship and priority treatment to support the priority request. 2) The RSE(s) stores freight route MAP data or this data is available from the traffic management system. 3) The traffic signal controllers in the section are programmed with a variety of priority control schemes, such as early green, green extension, phase rotation, phase skipping, etc. or the traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow	1) The use case begins when an equipped freight vehicle enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The OBE receives MAP and SPaT messages from the RSE. 3) The OBE sends basic safety messages (BSM) or cooperative awareness message (CAM). 4) The OBE determines the eligibility for priority and sends a signal request message (SRM) if needed.

Table A.7 *(continued)*

	5) The RSE receives and monitors the vehicle position using the BSM/CAM. 6) The RSE receives SRM and forwards to the BOPC. 7) The BOPC manages and prioritizes requests (SRM) from the freight vehicles to issue priority based on prevailing traffic conditions at a section of signalized intersections and the requested level of priority (as determined by the vehicle and the established policy). The BOPC also determines the size of the platoon for a given intersection or group of signalized intersections. 8) The BOPC determines the best coordinated signal timing strategy along the section of signalized intersections to accommodate the active priority request. 9) The BOPC sends priority timing to the traffic signal controllers (via RSE-to-RSE communication or directly to the TSC for each intersection in the "section") for further processing and execution. 10) The TSC sends updated SSM to the RSE and the RSE broadcasts the SSM to any connected vehicle (CV) approaching the intersection. 11) The OBE receives the SSM and determines if and when the request will become active at the intersection. 12) The OBE determines that the freight vehicles (forming a platoon) has cleared the intersection and sends a new SRM to cancel the priority request. Arterial freight signal priority for a platoon. The RSE determines when all vehicles have cleared the intersection. (Alternative: the RSE determines that the time to live for the request has expired and terminates the priority action.) The RSE may split a platoon for signal coordination and to support the needs of an emergency vehicle. 13) The RSE receives the cancel SRM, determines that a timeout condition exists or an emergency vehicle is present and requesting pre-emption, and sends the cleared status to the TSC. 14) The TSC initiates the configured recovery procedures to normal signal timing operation. 15) The case ends.
Alternate flow(s)	1) (12) The freight vehicles change speed and the RSE updates its priority timing based on travel time estimates. This should also include the BOPC since it is managing the arterial. 2) (12) The freight vehicles will not arrive during green max window and the freight vehicles have to stop at red signal. 3) (insert between steps 13 to 14) The RSE updates the freight vehicles served performance measures.
Post-conditions	The TSC initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane)

Table A.7 *(continued)*

	SSM Priority scenario being serviced, time to reach desired display, vehicle type being serviced, vehicle ID(s) being serviced, entry lane (approach roadway), exit lane (exit roadway), progression speed for green band
Issues	1) This use case assumes that the scenarios needed for the public transport vehicle are pre-determined and loaded into the traffic signal controller. 2) It also presumes that the public transport vehicle knows which of the scenarios that the controller can support should be invoked to meet its specific needs although these might be included in the SSM. 3) It is also possible for the public transport vehicle to identify its entry lane (BSM/CAM locates the vehicle) and then the vehicle identifies its exit lane based on the MAP information. In this case, the traffic signal will be reviewing all timing requests and priority requests and selecting the optimal sequence of phases and signal timing to meet the priority requests. 4) The recovery rate, re-service time, and techniques to be used are configured at the intersection and shall be part of the algorithm and configuration data exchanged with the BOPC. 5) For this use case, there is a shared responsibility between the BOPC and the TSC as to how to best service the vehicle and how to react if the vehicle is unable to make the green within the parameters allowed. This is a more complex use case and requires that timing of the arterial be dynamic for the vehicle as it travels along the route. 6) Platoon operation's research is ongoing and therefore platoon requirements will be addressed in a future version of this document.
Source docs/ references	MMITSS 11.2.3

This is similar to the TSP use case where the BOPC should also be involved to communicate the appropriate timing pattern to all of the intersections that will be involved along the arterial. The SSM message to the freight vehicles needs to include information necessary for the individual vehicles to determine the speed they should maintain and when the signal will turn "red" so that they can take appropriate breaking actions.

This use case will also include the BOPC as an actor since it will be directing the selection of a compatible timing plan and manage signal timing along the arterial to support the platoon.

Table A.8 — PR4: Emergency vehicle single or multiple vehicles (normal power PSOBE)

Use case name	Emergency vehicle single or multiple vehicles (normal power PSOBE)
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes the basic emergency vehicle pre-emption control for connected emergency response vehicles (police, fire, ambulance, etc.). The nature of those vehicles permitted to make such requests will depend on the region and local laws.
Goal	Improved emergency response efficiency and reliability
Constraints	DSRC Normal power PSOBE on vehicle, therefore, the pre-empt request is issued within the normal limits of DSRC communications
Geographic scope	Localized to a specific intersection
Actors	Emergency vehicle equipped with normal power on-board equipment (OBE) Roadside equipment (RSE) and traffic signal controller (TSC) (BOPC if route pre-emption is provided.)

Table A.8 *(continued)*

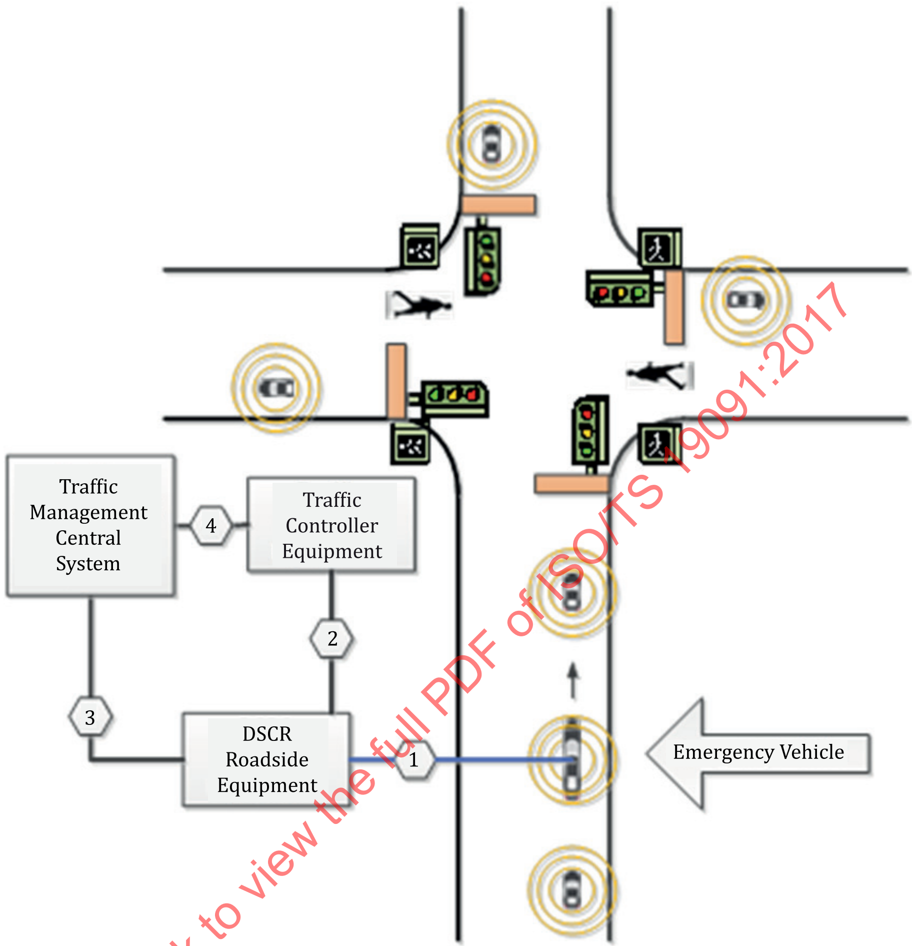
Illustration	
Preconditions	1) Emergency vehicle is in active response mode. 2) The transportation agency(ies) has established a policy for pre-emption control (called N-level priority) and the emergency service agency is prepared to provide priority levels for vehicles on routes. 3) The traffic signal controllers are programmed with a variety of pre-emption control schema, such as early green and green extension, or the traffic signal controller has an intelligent algorithm for providing pre-emption signal timing for priority requests. NOTE The term pre-emption is distinct and considered different from priority treatment. A pre-emption operation can significantly alter the operation of the signalized intersection and hold phase displays for prolonged periods or run different sequence of displays (railroad pre-emption blocking one of the egresses), whereas the concept of priority treatment assumes that the traffic signal will attempt to accommodate the request, but only within limited parameters in an attempt to recover and still permit cross street traffic. Priority treatment typically adds a phase (e.g. protected left/right turn), extends the current phase, or accelerates service to the requested phase, without totally disrupting the overall local timing and arterial coordination. In addition, the servicing of the emergency vehicle requests can be handled significantly different from priority requests as often the signal will simply get to and stay in green facing all lanes in the direction of travel while presenting red to all other manoeuvres, thereby facilitating the vehicle entry to the intersection and blocking possible opposing manoeuvres or making it possible to go into the oncoming lane to get through the intersection.
Main flow (example)	1) The use case begins when any one of the equipped emergency vehicles enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The following steps occur for each emergency vehicles that approaches the intersection:

Table A.8 *(continued)*

	a) The OBE receives MAP and SPaT messages from the RSE. b) The RSE receives basic safety messages (BSM/CAM) from the OBE. c) The OBE computes the estimated arrival time (min, max) and desired manoeuvre (entry lane, exit lane) as available. d) The OBE determines the eligibility for priority and establishes the proper level of priority. e) The OBE sends a signal request message (SRM) to the RSE. f) The RSE determines the appropriate traffic signal phase to serve the vehicle (translates SRM data into a phase request). g) The RSE determines which SRMs (from multiple vehicles) can be served. h) The RSE notifies the traffic signal controller (or logic) of the active requests including desired phase and service time. i) The RSE transmits a status message (SSM) with information about which requests will be served (feedback to the vehicle). j) Emergency vehicles OBE notifies RSE it has cleared the intersection, or if the vehicle has cleared the intersection (as tracked by the RSE using the BSM/CAM) or if a request cancelation is not received, the RSE clears the requested service after a locally set time. 3) Traffic signal initiates recovery procedure from effects of EVP on timing and coordination. 4) The use case ends.
Alternate flow(s)	1) (2c) The OBE updates the SRM with new arrival information based on a change of speed or route change. 2) (2d) If the OBE determines that the vehicle is not eligible for priority, the use case ends and the emergency vehicle operates as any normal vehicle. 3) (insert between steps 3 to 4) The RSE updates the vehicles served performance measures.
Post-conditions	The TSC initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvres(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, vehicle ID(s) being serviced, time to reach desired display, vehicle type being serviced, entry lane (approach roadway), exit lane (exit roadway)

Table A.8 *(continued)*

Issues	1) Route pre-emption, i.e. vehicle priority along a route, requires that the BOPC receive information from the emergency vehicle identifying its current location, the intended destination, and the route to be followed. Then, the traffic controllers along the route should be tracking the vehicle and updating the BOPC so that it can take steps to “clear the way” and attempt to provide a “green wave” or similar effect to support the more rapid movement of the emergency vehicle through the network. 2) In addition to the above, the BOPC could be tracking multiple vehicles through the roadway network and may need to alter the route or handle conflicting requests for emergency vehicle routing by communicating these circumstances to the emergency vehicle via either the RSE along the route or some other wide-area wireless service/media.
Source docs/ references	CEN#n pp. xx; MMITSS p. x ID xx

Table A.9 — PR5: Emergency vehicle single or multiple vehicles (high-power PSOBE)

Use case name	Emergency vehicle single or multiple vehicles (high-power PSOBE)
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case differs from the previous use case because it is based on the concept of a one-way broadcast to the intersection, such that the intersection is likely to “hear” the SRM before the vehicle (OBE) can hear the intersection SPaT message. It is anticipated that if the high-power PSOBE is supported for such vehicles (police, fire, ambulance, etc.), the intersection can receive advance warning of the approaching vehicle and take the appropriate steps to facilitate movement through the intersection based on a specific scenario(s). The nature of those vehicles permitted to make such requests will depend on the region and local laws. Note that this use case does not deal with the vehicle based applications that warn the driver to take appropriate action to avoid the approaching public safety vehicle (rear, front, side).
Goal	Improved emergency vehicle efficiency and reliability
Constraints	DSRC
Geographic scope	Localized to a specific intersection
Actors	Emergency vehicle equipped with a high-power public safety on-board equipment with extended broadcasting range Roadside equipment (RSE) and traffic signal controller (TSC) (BOPC if route pre-emption is provided.)

Table A.9 *(continued)*

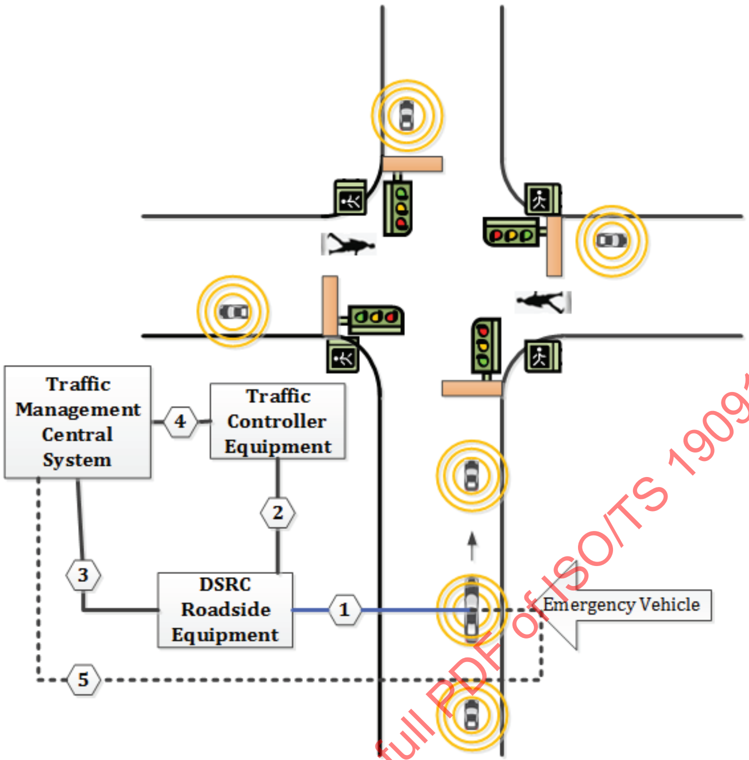
Illustration	
Preconditions	1) Emergency vehicle is in active response mode 2) The transportation agency(ies) has established a policy for pre-emption control (called N-level priority) for emergency response vehicles. 3) The traffic signal controllers are programmed with a variety of pre-emption control schema for emergency vehicle pre-emption or the traffic signal controller has an intelligent algorithm for providing priority signal timing for priority requests.
Main flow (example)	1) The use case begins when the PSOBE equipped emergency vehicle reaches a specific area where it has been configured to initiate an SRM to the intersection(s) it is approaching. 2) For each vehicle approaching the intersection, the following steps will occur: a) The OBE determines the eligibility for priority and establishes the proper level of priority. b) The PSOBE transmits the SRM indicating the specific scenario desired. NOTE Because it does not have the MAP at this point, it is assumed that the vehicle is likely to simply request the scenario desired based on where it is and the approach and exit. c) The RSE determines which SRMs (from multiple vehicles) can be served (priority ranking? or maximum number). d) The RSE determines the appropriate traffic signal phase to serve the vehicle. e) The RSE notifies the TSC (or logic) of the active requests including desired phase and service time. f) The RSE transmits a status message (SSM) with information about which requests will be served (feedback to the vehicles). g) As the vehicle approaches the intersection, the vehicle begins to “hear” the RSE broadcast of the SSM, SPaT, and MAP. At this point, the vehicle can either continue with Step 2h or jump to Step 3 (thereby switching to a more interactive request for pre-emption service).

Table A.9 *(continued)*

	h) Emergency vehicles OBE notifies RSE it has cleared the intersection, or if the vehicle has cleared the intersection (as tracked by the RSE using the BSM/CAM), or if a request cancelation is not received, the RSE clears the requested service after a locally set time. i) Transition to step 4 below. 3) The following steps occur for each emergency vehicles that approaches the intersection (note that this is the same as PR4 since the distance factor has been fully compensated for above): a) The OBE receives MAP and SPaT messages from the RSE. b) The RSE receives basic safety messages (BSM/CAM) from the OBE. c) The OBE computes the estimated arrival time (min, max) and desired manoeuvre (entry lane, exit lane) as available. d) The OBE determines the eligibility for priority and establishes the proper level of priority. e) The OBE sends a signal request message (SRM) to the RSE. f) The RSE determines the appropriate traffic signal phase to serve the vehicle (translates SRM data into a phase request). g) The RSE determines which SRMs (from multiple vehicles) can be served (priority ranking? or maximum number). h) The RSE notifies the traffic signal controller (or logic) of the active requests including desired phase and service time. i) The RSE transmits a status message (SSM) with information about which requests will be served (feedback to the vehicle). j) Emergency vehicles OBE notifies RSE it has cleared the intersection, or if the vehicle has cleared the intersection (as tracked by the RSE using the BSM/CAM) or if a request cancelation is not received, the RSE clears the requested service after a locally set time. 4) Traffic signal initiates recovery procedure from effects of EVP on timing and coordination. 5) The use case ends.
Alternate flow(s)	1) (3c) The OBE updates the SRM with new arrival information based on a change of speed or route change. 2) (3d) If the OBE determines that the vehicle is not eligible for priority, the use case ends and the emergency vehicle operates as any normal vehicle. 3) (insert between steps 4 and 5) The RSE updates the vehicles served performance measures.
Post-conditions	The TSC initiates recovery operations to restore normal timing operation which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type

Table A.9 *(continued)*

	SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, vehicle ID(s) being serviced, time to reach desired display, vehicle type being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) For route pre-emption (i.e. for vehicle priority along a route), this requires that the BOPC receive information from the emergency vehicle identifying its current location, the intended destination, and the route to be followed. Then, the traffic controllers along the route should be tracking the vehicle and updating the BOPC so that it can take steps to "clear the way" and attempt to provide a "green wave" or similar effect to support the more rapid movement of the emergency vehicle through the network. NOTE This could be accomplished by expecting the PSOBE to be transmitting route information of some sort to either the BOPC or the RSE and the first RSE would pass this information along to the BOPC for route pre-emption consideration. 2) In addition to the above, the BOPC could be tracking multiple vehicles through the roadway network and may need to alter the route or handle conflicting request for emergency vehicle routing by communicating these circumstances to the emergency vehicle via either the RSE along the route or some other wide-area wireless service/media. 3) Use of the high-powered OBE DSRC transmitter means that the intersection can hear the requests long before the vehicle can hear the intersection details (SPaT and MAP and SSM); hence, there is an issue with multiple overlapping or conflicting SRM messages from the PSOBE. It is estimated that the other approaching vehicles will be able to "hear" the SSM and understand what vehicle has been granted pre-emption to avoid intersection conflict.
Source docs/ references	MMITSS

Table A.10 — PR6: Mixed emergency vehicle and other priority eligible vehicles

Use case name	Mixed emergency vehicle and other priority eligible vehicles
Category	Mobility
Infrastructure role	Data receiver, traffic signal control, data transmitter
Short description	This use case describes multiple priority requesting vehicles including an emergency vehicle and a platoon of public transport vehicles. The nature of those vehicles permitted to make such requests will depend on the region and local laws.
Goal	Improved priority granting efficiency and reliability
Constraints	DSRC All priority requesting vehicles have normal power OBE on vehicle; therefore, the priority requests are issued within the normal limits of DSRC communications
Geographic scope	Localized to a specific intersection
Actors	Emergency vehicle equipped with normal power on-board equipment (OBE) Platoon of public transport vehicles each equipped with normal power OBE Roadside equipment (RSE) and traffic signal controller (TSC)

Table A.10 *(continued)*

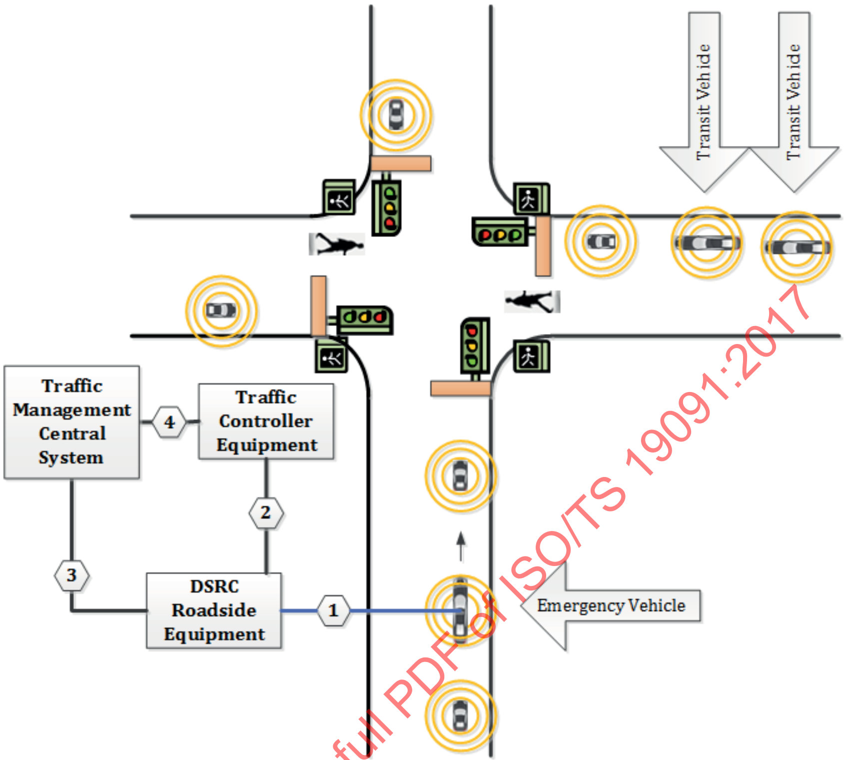
Illustration	
Preconditions	1) Emergency vehicle is in active response mode. 2) The transportation agency(ies) has established a policy for pre-emption control (called N-level priority). 3) The traffic signal controllers are programmed with a variety of pre-emption control schema, such as early green and green extension, or the traffic signal controller has an intelligent algorithm for providing pre-emption signal timing for priority requests. NOTE The term pre-emption is distinct and considered different from priority treatment. A pre-emption operation can significantly alter the operation of the signalized intersection and hold phase displays for prolonged periods or run different sequence of displays (railroad pre-emption blocking one of the egresses), whereas the concept of priority treatment assumes that the traffic signal will attempt to accommodate the request but only within limited parameters in an attempt to recover and still permit cross street traffic. Priority treatment typically adds a phase (e.g. protected left/right turn), or extends the current phase, or accelerates service to the requested phase, without totally disrupting the overall local timing and arterial coordination. In addition, the servicing of the emergency vehicle requests can be handled significantly different from priority requests as often the signal will simply get to and stay in green facing all lanes in the direction of travel while presenting red to all other manoeuvres, thereby facilitating the vehicle entry to the intersection and blocking possible opposing manoeuvres or making it possible to go into the oncoming lane to get through the intersection.
Main flow (example)	1) The use case begins when a platoon of public transport vehicles enters the radio range of an RSE (note that if another medium is used, the same assumption applies). 2) The following steps occur as each public transport vehicle approaches the intersection: a) The OBE receives MAP and SPaT messages from the RSE. b) The RSE receives basic safety messages (BSM/CAM) from the OBE. c) The OBE computes the estimated arrival time (min, max) and desired manoeuvre (entry lane, exit lane) as available. d) The OBE determines the eligibility for priority and establishes the proper level of priority. e) The OBE sends a signal request message (SRM) to the RSE.

Table A.10 *(continued)*

	f) The RSE determines the appropriate traffic signal phase to serve the vehicle (translates SRM data into a phase request). g) The RSE determines which SRMs (from multiple vehicles) can be served (Priority ranking? Or maximum number). h) The RSE notifies the traffic signal controller (or logic) of the active requests including desired phase and service time. i) The RSE transmits a status message (SSM) with information about which requests will be served (feedback to the vehicle) and which requests are pending. j) The RSE issues updated SPaT messages with revised signal timing information. 3) An equipped emergency vehicle enters the radio range of the RSE (note that if another medium is used, the same assumption applies). 4) The following steps occur for each emergency vehicles that approaches the intersection. a) The OBE receives MAP and SPaT messages from the RSE. b) The RSE receives basic safety messages (BSM/CAM) from the OBE. c) The OBE computes the estimated arrival time (min, max) and desired manoeuvre (entry lane, exit lane) as available. d) The OBE determines the eligibility for priority and establishes the proper level of priority. e) The OBE sends a signal request message (SRM) to the RSE. f) The RSE determines the appropriate traffic signal phase to serve the vehicle (translates SRM data into a phase request). g) The RSE determines which SRMs (from multiple vehicles) can be served (priority ranking? or maximum number). h) The RSE notifies the traffic signal controller (or logic) of the active requests including desired phase and service time. i) The RSE transmits a status message (SSM) with information about which requests will be served (feedback to the vehicle) with the status of multiple priority requests. j) The RSE issues updated SPaT messages with revised signal timing information. k) Emergency vehicle traverses the intersection. l) The public transport vehicles continue to issue signal request messages. m) Either one of the following will occur: 1) emergency vehicles OBE notifies RSE it has cleared the intersection, 2) if the vehicle has cleared the intersection (as tracked by the RSE using the BSM/CAM), 3) if a request cancelation is not received, the RSE clears the requested service after a locally set time, 4) an external system notifies that the need has expired. n) The RSE updates the list of priority requests and identifies the next priority request to be serviced. The RSE transmits a status message (SSM) with the updated request information. o) The traffic signal controller initiates signal timing changes for the current priority request. p) The RSE transmits updated SPaT messages with revised signal timing information. q) Steps 5 to 10 repeat until the priority requests are either cancelled or satisfied. 5) Traffic signal initiates recovery procedure from effects of granting priority on timing and coordination. 6) The use case ends.
Alternate flow(s)	1) (2c) The OBE updates the SRM with new arrival information based on a change of speed or route change. 2) (2d) If the OBE determines that the vehicle is not eligible for priority, the use case ends and the emergency vehicle operates as any normal vehicle.

Table A.10 *(continued)*

	3) (insert between steps 9 to 10) The RSE updates the vehicles served performance measures.
Post-conditions	The TSC initiates recovery operations to restore normal timing operation, which might include appropriate coordination. Some recovery may include split time compensation to clear queues which might have formed on the phases that were adversely affected by the priority request.
Information requirements	SPaT Current manoeuvres(s) permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue length or end of queue information, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type SRM Vehicle type, priority request scenario, vehicle priority, time to arrive, cancel request, [Time to apply] (Optional: entry lane, exit lane) SSM Priority scenario being serviced, vehicle ID(s) being serviced, time to reach desired display, vehicle type being serviced, entry lane (approach roadway), exit lane (exit roadway)
Issues	1) Route pre-emption, i.e. vehicle priority along a route, requires that the BOPC receives information from the emergency vehicle identifying its current location, the intended destination, and the route to be followed. Then, the traffic controllers along the route should be tracking the vehicle and updating the BOPC so that it can take steps to “clear the way” and attempt to provide a “green wave” or similar effect to support the more rapid movement of the emergency vehicle through the network. 2) In addition to the above, the BOPC could be tracking multiple vehicles through the roadway network and may need to alter the route or handle conflicting requests for emergency vehicle routing by communicating these circumstances to the emergency vehicle via either the RSE along the route or some other wide-area wireless service/media.
Source docs/ references	CEN#n pp. xx; MMITSS p. x ID xx

Table A.11 — SA1: Dilemma zone protection

Use case name	Dilemma zone protection
Category	Safety
Infrastructure role	Data receiver
Short description	This use case describes detection of equipped vehicles approaching a traffic signal that, upon onset of yellow, may find it challenging to either stop before the stop bar or continue through the intersection before the signal turns red. Vehicles in this situation are termed dilemma zone vehicles though their actual location may vary.
Goal	Detect potential dilemma zone vehicles and pass information to signal controller to minimize occurrences

Table A.11 *(continued)*

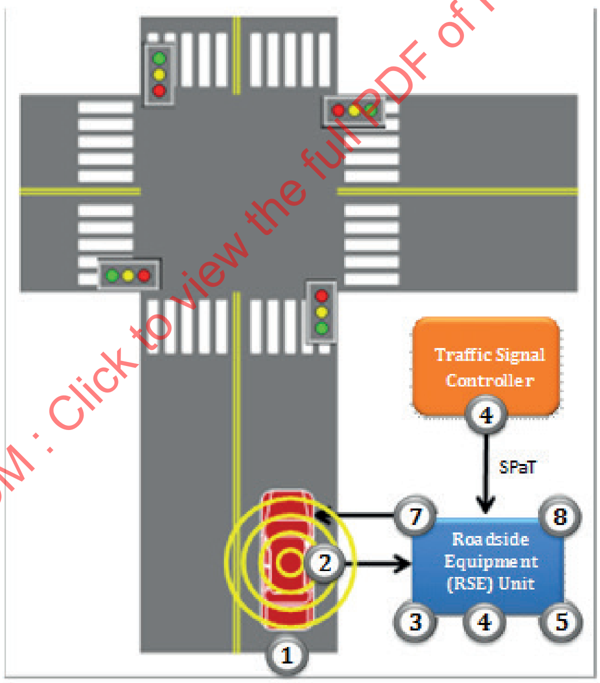
Constraints	Channel plan in place to allow RSE to receive BSM/CAMs. Vehicles' DSRC transmit performance under high-speed approach conditions adequate for timely RSE reception. OBE BSM/CAM meets minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates segments governed by other traffic control device (signal/stop/yield) This use case will only deal with data exchanges between the connected vehicle and the infrastructure (RSE), while other local intersection sensors could be used to augment the information available to the intersection controller. Such information is considered out of scope for this use case. The traffic signal controller operation is configured to accept input from the RSE and has been configured to allow clearance extension to enable vehicles to pass based on BSM/CAM and anticipated vehicle trajectory.
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles RSE connected to local traffic signal controller
Illustration (example)	
Preconditions	Local traffic signal controller not in pre-empt/special mode Local traffic signal controller operating in [pretimed, semi-actuated/actuated] mode
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE transmit/RSE receive) of RSE (note that if another medium is used, the same assumption applies). 2) OBE transmits BSM/CAM. 3) RSE receives BSM/CAM. 4) RSE parses BSM/CAM to identify vehicle temporary ID, position, speed, heading, type, turn signal status. 5) (in parallel with steps 1 to 4) RSE receives SPaT information from traffic signal controller. 6) (in parallel with steps 1 to 4) RSE receives road condition information. 7) RSE updates state map of vehicles on each intersection approach. 8) If RSE estimates that a vehicle will not reach the stop bar before the red onset, RSE notifies the traffic signal controller.

Table A.11 *(continued)*

	9) The traffic controller adjusts the signal timing to extend the clearance before displaying conflicting movements.
Alternate flow(s)	1) (insert after step 9) RSE updates vehicles served performance measures One or more of these alternative flows may be added in a later revision of this document. Alternative A: 8a) RSE also uses vehicle type in calculating stopping distance Alternative B: 8a) RSE transmits advisory message aimed at vehicles on other approaches
Post-conditions	Vehicle crosses stop bar before red onset or stops on red before entering intersection.
Information requirements	SPaT (for RSE use only) Current manoeuvre permitted, time points for manoeuvre terminations yellow clearance time, red clearance time, next manoeuvres to begin To support the alternate flows B: Advisory to other vehicles MAP (for RSE use only) Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type, turn signal status
Issues	1) Vehicle may change speed abruptly (driver brakes, or changes mind). 2) Timing/stopping distance for heavy vehicles 3) Advance warning information/advisory to other vehicles 4) Coupling with enforcement NOTE This use case is only intended to address actions taken by the intersection equipment and is intended to augment the appropriate stand alone in-vehicle warnings of stop line violations based on the SPaT and MAP information. 5) May be subject to abuse by drivers (learned behaviour) 6) Source and nature of road condition information is undetermined; it is intended to reflect the friction for stopping distance calculations.
Source docs/ references	MMITSS p. 6 ID 11.1.4

Table A.12 — SA2: Red light violation warning

Use case name	Red light violation warning
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes provision of signal timing information to approaching vehicles to help prevent red light violations.
Goal	Roadside equipment sends MAP and SPaT in real-time to approaching vehicles, which utilize the information to notify the driver of the need to stop to avoid potential red light violation.
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception. Security management system in place to allow OBE to check RSE messages

Table A.12 *(continued)*

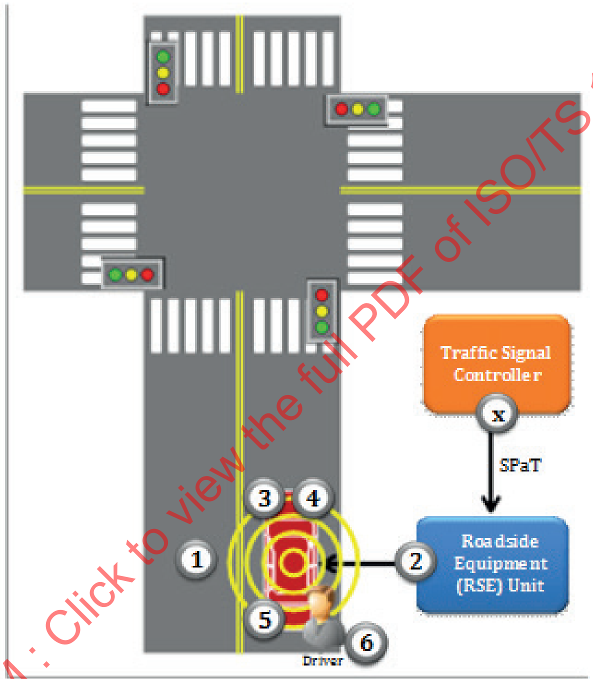
	RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles with red light violation warning application RSE connected to local traffic signal controller
Illustration (example)	
Preconditions	MAP message reflects current intersection geometry.
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP and SPaT information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane and associated signal phase. 5) OBE determines if vehicle is expected to violate red indication based on vehicle trajectory and other information. 6) If violation is expected, OBE provides information to the driver to stop at the appropriate time (in time to stop).
Alternate flow(s)	4) OBE also utilizes turn signal information and/or other vehicle parameters to match with signal phase. 5) OBE also considers vehicle stopping parameters (e.g. size/weight). 6a) OBE utilizes other information (e.g. image processing of traffic light, etc.) as a backup to determine whether the information to stop should be provided to the driver. 6b) OBE initiates action directly with vehicle if violation is expected.
Post-conditions	Vehicle crosses stop bar before red onset or stops on red before entering intersection.

Table A.12 *(continued)*

Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced MAP Intersection geometry, permitted manoeuvres
Issues	1) Determining turn lane prior to approach 2) Violation based on current signal phase vs. future 3) MPR/acceptability of current RSE messages
Source docs/ references	CEN#1 p. 3; USDOT J2735™SE Candidate Use Case #1, p. 4

Table A.13 — SA3: Stop sign violation warning

Use case name	Stop sign violation warning
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes provision of stop sign location information to approaching vehicles to help prevent stop sign violations (running).
Goal	Roadside equipment sends MAP and SPaT to vehicles, which utilize the information to notify the driver of the need to stop to avoid running on stop sign.
Constraints	RSE coverage adequate for providing MAP to vehicles approaching stop signs Security management system in place to allow OBE to check RSE messages RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by stop sign and segments governed by other traffic control devices Positioning performance adequate to match vehicle with lane-specific stop controls, if applicable OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Individual stop-controlled intersections and approaching roadway segments
Actors	OBE-equipped vehicles with stop sign violation warning application RSE with MAP and SPaT information

Table A.13 *(continued)*

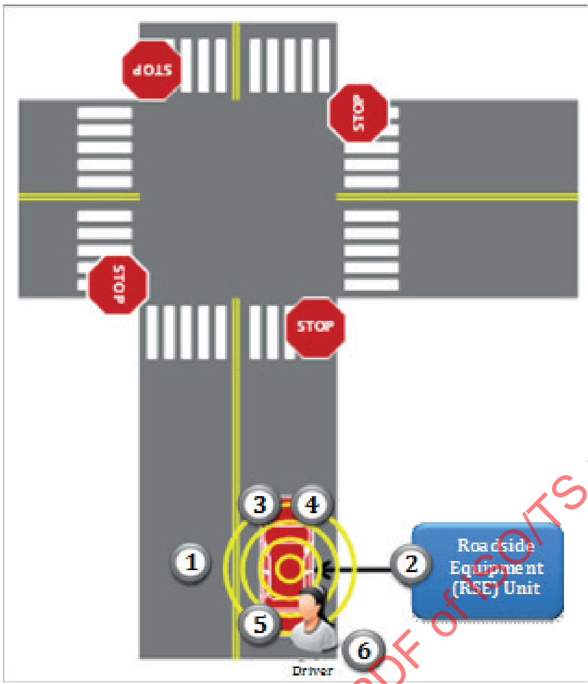
Illustration (example)	
Preconditions	MAP message reflects current intersection geometry, SPaT message reflects stop sign configuration
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP information 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR) 4) OBE matches vehicle location to intersection geometry/lane and SPaT associated stop sign(s) 5) OBE determines if vehicle is expected to violate (run) stop sign based on vehicle trajectory and other information 6) If violation is expected, OBE provides information to driver to stop at appropriate time (in time to stop)
Alternate flow(s)	2a) RSE also transmits MAP information for other intersections. The following flow steps address yield controlled approaches (replace steps 4 to 6 of the main flow). 4) OBE matches vehicle location to intersection geometry/lane and SPaT associated yield sign(s). 5) OBE determines whether a crossing vehicle is expected to violate (run) its stop sign based on the crossing vehicle's BSM, the other vehicle's trajectory, OBE vehicle trajectory, and other information. 6) If the crossing vehicle is expected to violate the stop sign, the OBE provides information to the driver to stop at the appropriate time (in time to stop).
Post-conditions	Vehicle stops at stop sign.

Table A.13 *(continued)*

Information requirements	MAP Intersection geometry, permitted manoeuvres (governed by stop signs) SPaT Manoeuvre information related to intersection's sign controlled lanes/approaches
Issues	1) Is stop sign information in MAP message or separate message? 2) Threshold for definition of stop speed
Source docs/ references	CEN#2 p. 4; USDOT J2735™SE Candidate ID 2.5.3.1.1 p. 8

Table A.14 — SA4: Turning assistant — Oncoming traffic

Use case name	Turning assistant — Oncoming traffic
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes the provision of information on approaching oncoming traffic to vehicle(s) waiting to turn at a signalized intersection.
Goal	Roadside equipment sends MAP, SPaT, and Sensor information to a vehicle waiting to turn across oncoming traffic to warn its driver of potential conflicts
Constraints	RSE transmit performance adequate for vehicles' timely DSRC reception Security management system in place to allow OBE to check RSE messages RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiate lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable Sensor information adequately covers details of opposing traffic in a timely fashion OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles with turning assistant warning application RSE connected to local traffic signal controller and sensor(s)

Table A.14 *(continued)*

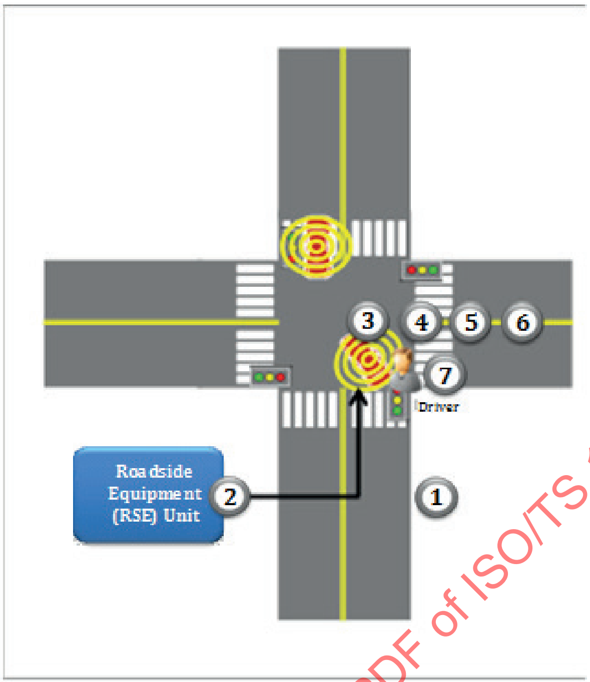
Illustration (example)	
Preconditions	MAP message reflects current intersection geometry Sensor senses vehicle(s), if any, in opposing zone Equipped vehicle waiting to turn across traffic at intersection
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP, SPaT, and sensor information. 3) RSE transmits infrastructure-sensed vehicle information in a BSM as a proxy for the vehicle. 4) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 5) OBE matches own vehicle location to intersection geometry/lane and associated signal phase. 6) OBE uses received sensor information to estimate opposing vehicle trajectory. 7) OBE determines if infrastructure-sensed vehicle is expected to conflict with turn manoeuvre, based on vehicle trajectory and other information. 8) If conflict is expected, and OBE-equipped vehicle senses initiation of turning, OBE provides information to the driver to stop turning at the appropriate time (in time to avoid conflict).
Alternate flow(s)	None
Post-conditions	Equipped vehicle proceeds through turn without conflict.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced MAP Intersection geometry including approaches, permitted manoeuvres Sensor information: coverage, traffic location/heading/speed/acceleration
Issues	1) Adequacy of opposing traffic zone coverage 2) Details of sensor information: which message, location, and definition
Source docs/ references	CEN#3 pp. 5

Table A.15 — SA5: Turning assistant — Vulnerable road user avoidance

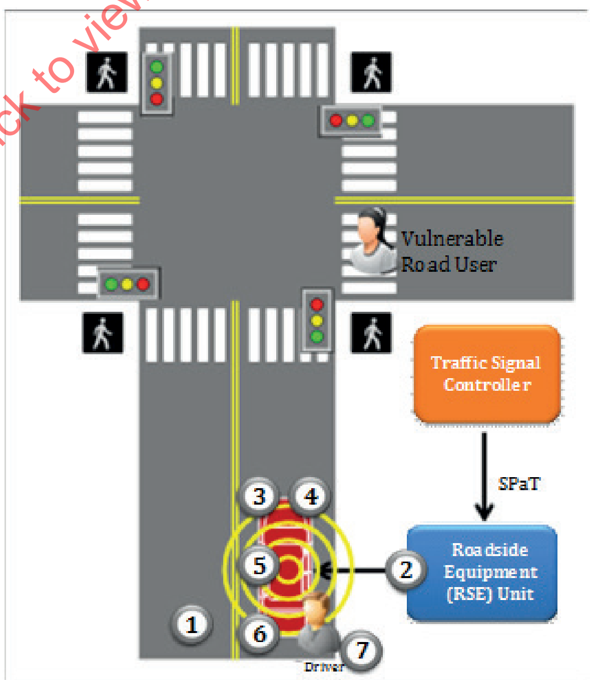
Use case name	Turning assistant — Vulnerable road user avoidance
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes provision of information on vulnerable road users (e.g. cyclists, pedestrians) to turning traffic at a signalized intersection.
Goal	Roadside equipment sends MAP, SPaT, and sensor information to a vehicle about to turn to warn its driver of potential conflicts with vulnerable road users.
Constraints	RSE transmit performance adequate for vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiate lanes governed by each signal phase. Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable Sensor information adequately covers position and movement details of vulnerable road users in a timely fashion OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Local signalized intersection and connected roadway segments
Actors	OBE-equipped vehicles with turning assistant warning application RSE connected to local traffic signal controller and sensor(s)
Illustration (example)	 **SA5 Illustration**
Preconditions	MAP message reflects current intersection geometry Sensor senses vulnerable road user(s), if any, in alongside zone and far turning zone. Equipped vehicle approaching or stopped at intersection

Table A.15 *(continued)*

Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP, SPaT, and sensor information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches own vehicle location to intersection geometry/lane from MAP and associated signal phase. 5) OBE uses received sensor information in conjunction with MAP to estimate location and trajectory of vulnerable road users. 6) OBE determines if vulnerable road users are expected to conflict with potential turn manoeuvres, based on vehicle trajectory and other information. 7) If conflict is expected, and OBE-equipped vehicle senses initiation of turning, OBE provides information to the driver to stop turning at the appropriate time (in time to avoid conflict).
Alternate flow(s)	None
Post-conditions	Equipped vehicle proceeds through intersection without conflict with vulnerable road users.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, pedestrian sensor/call information, cyclist sensor information MAP Intersection geometry (MAP base), permitted manoeuvres, changes to MAP other than base geometry, pedestrian crossings, and sensor areas
Issues	1) Adequacy of vulnerable road user sensor coverage 2) Details of sensor information: which message, location, and definition
Source docs/ references	CEN#4 pp. 6–7

Table A.16 — SA6: Non-signalized crossing traffic warning

Use case name	Non-signalized crossing traffic warning
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes provision of information on cross traffic at a non-signalized intersection
Goal	Roadside equipment sends MAP and sensor information (position, movement from OBE-equipped vehicles or roadside sensors) to vehicle. The information provided includes trajectory of crossing traffic to prevent potential crossing path crashes.
Constraints	RSE transmit performance adequate for vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy Vehicle positioning performance adequate to match vehicle with roadway segment Sensor information adequately covers position and movement details of cross traffic in a timely fashion OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Local non-signalized intersection and roadway approaches

Table A.16 *(continued)*

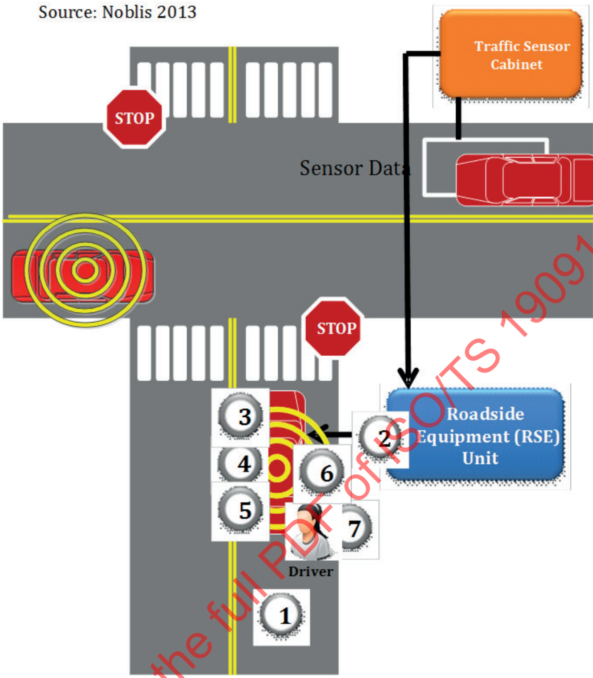
Actors	OBE-equipped vehicles with crossing traffic warning application Non-OBE-equipped vehicles detected by sensors RSE connected to local vehicle lane/approach sensor(s)
Illustration (example)	 NOTE This figure is just an example. The use case description applies to any non-signalized intersection with a stop sign.
Preconditions	MAP message reflects current intersection geometry. Sensor senses vehicle(s), if any, in crossing traffic zone approaching intersection Equipped vehicle approaching intersection Alternate: vulnerable user mobile device signals RSE of their presence. NOTE Communications between vehicles is a different use case and out of scope for this document.
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2a) RSE broadcasts MAP information and GNSS augmentation information to vehicle OBE 2b) RSE broadcasts sensor information relating the location of cross traffic vehicle(s). 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR) 4) OBE matches own vehicle location to intersection geometry/lane from MAP 5) OBE uses received sensor information in conjunction with MAP to estimate location and trajectory of crossing traffic (either oncoming such as in a cross traffic turn or crossing traffic due to an intersecting road). 6) OBE determines if crossing traffic is expected to conflict with continued trajectory (or startup movement if stopped) 7) If conflict is expected, and OBE-equipped vehicle is moving in conflicting direction, OBE either provides information to driver or starts control actions on vehicle to stop (or not allow a start-up) at appropriate time (in time to avoid conflict)
Alternate flow(s)	MAP information may be omitted from the local RSE message if it is provided in a regional manner, i.e. if the vehicle receives MAP information from an RSE as it enters the general region or via broadband wide area network media.
Post-conditions	Vehicle proceeds through intersection without conflict from cross traffic.

Table A.16 *(continued)*

Information requirements	MAP Intersection geometry (MAP base) including approaches, permitted manoeuvres (governed by stop signs), and changes to MAP other than base geometry (e.g. time-of-day restrictions, construction restrictions). Sensor information (crossing traffic location/heading/speed)
Issues	1) Adequacy of cross traffic sensor coverage 2) Details of sensor information: which message, location, and definition
Source docs/ references	CEN#15, p. 24

Table A.17 — SA7: Crossing vulnerable road user advisory (non-signalized)

Use case name	Crossing vulnerable road user advisory (non-signalized)
Category	Safety
Infrastructure role	Data provider
Short description	This use case describes provision of information on vulnerable road users (e.g. cyclists, pedestrians) to traffic at a non-signalized intersection.
Goal	Roadside equipment sends MAP, SPaT, and sensor information to a vehicle that is approaching a pedestrian/vulnerable road user crossing, at a non-signalized intersection, in order to warn the driver of potential conflicts with pedestrian/vulnerable road users.
Constraints	RSE transmit performance adequate for vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates area governed by sensor(s) Vehicle positioning performance adequate to match vehicle with lane/approach-specific crossing areas, if applicable Sensor information adequately covers presence and location details of vulnerable road users and if available, the trajectory and speed, in a timely fashion. OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Local non-signalized intersection and connected roadway approaches
Actors	OBE-equipped vehicle with crossing vulnerable road user advisory application RSE connected to sensor(s) Alternate: RSE equipped to accept transmissions from vulnerable users to identify their location (which may include trajectory, and speed)

Table A.17 *(continued)*

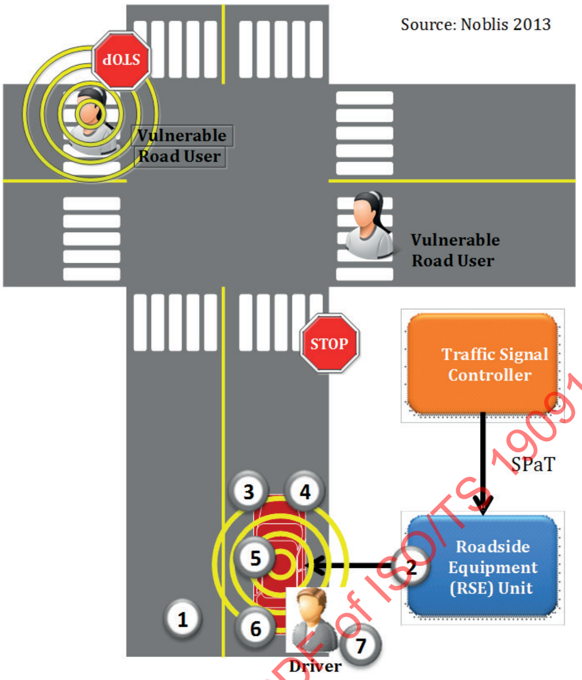
Illustration (example)	 NOTE This figure is just an example. The use case description applies to any non-signalized intersection with a stop sign.
Preconditions	MAP Message reflects current intersection geometry. SPaT Pedestrian detection and manoeuvre information for the intersection Roadside sensor senses vulnerable road user(s), if any, in approach zone and turning zones. Alternate: vulnerable user mobile device signals RSE of their presence NOTE Communications between a pedestrian mobile device and the vehicle is a different use case and out of scope for this document. Equipped vehicle approaching or stopped at intersection
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2a) RSE broadcasts MAP information and GNSS augmentation information to vehicle OBE. 2b) RSE broadcasts information relating to the presence of vulnerable road users. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches own vehicle location to intersection geometry/lane/approach from MAP and associated crossing area(s). 5) OBE uses received vulnerable user location information in conjunction with the MAP information to estimate location and trajectory of vulnerable road users. 6) OBE determines if vulnerable road users are expected to conflict with potential manoeuvres, based on vehicle trajectory and other information. 7) If conflict is expected, and OBE-equipped vehicle senses initiation of turning, OBE provides information to driver or starts control actions on vehicle to stop at the appropriate time (in time to avoid conflict). If vulnerable user is in the approach roadway, OBE provides information to the driver or starts control actions on vehicle to stop at the appropriate time (to avoid conflict).
Alternate flow(s)	MAP information may be omitted from the local RSE message if it is provided in a regional manner, i.e. if the vehicle receives MAP information from an RSE as it enters the general region or via broadband wide area network media.

Table A.17 *(continued)*

Post-conditions	Equipped vehicle proceeds through intersection without conflict with vulnerable road users.
Information requirements	MAP Intersection geometry (MAP base) including approaches, permitted manoeuvres (governed by stop signs) and changes to MAP other than base geometry (e.g. time-of-day restrictions, construction restrictions) SPaT SPaT message indicates the Vulnerable Road User's presence). A future version of this document may optionally provide the VRU's detailed location, heading, and speed.
Issues	1) Adequacy of vulnerable road user sensor coverage 2) Details of sensor information: which message, location, and definition 3) Support for vulnerable user to RSE communications 4) While the use case currently supports vulnerable road users' presence, trajectory, speed, and heading information for vulnerable users, only presence will be supported by this document.
Source docs/ references	CEN #16, p. 25

Table A.18 — MS1: Basic local traffic signal actuation

Use case name	Basic local traffic signal actuation
Category	Mobility, sustainability
Infrastructure role	Data receiver
Short description	This use case describes basic real-time traffic signal actuation by connected vehicles in the vicinity of a single intersection.
Goal	Roadside equipment utilizes real-time information on the motion and specific characteristics of approaching vehicles to provide more precise demand information to the local traffic signal controller, thereby increasing efficiency and reducing emissions for the intersection.
Constraints	Channel plan in place to allow RSE to receive BSM/CAMs Approaching vehicles' DSRC transmit performance adequate for timely RSE reception OBE BSM/CAM meets minimum performance requirements (e.g. SAE J2945). Intersection approach roadway segments mapped to sufficient accuracy and differentiates segments governed by other traffic control device (signal/stop/yield) RSE algorithm established to determine what input to provide to traffic signal controller based on vehicle, SPaT information
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles RSE (includes the local traffic signal controller) BOPC/signal operations back office

Table A.18 *(continued)*

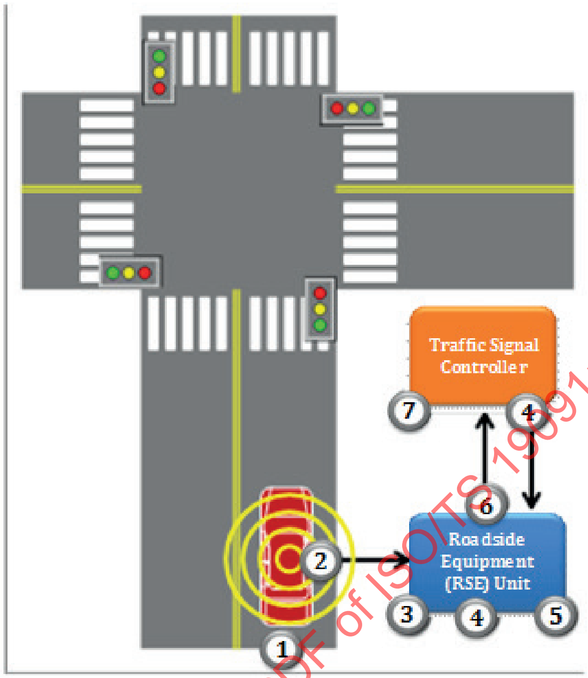
Illustration (example)	
Preconditions	Local traffic signal controller not in pre-empt/special mode Local traffic signal controller operating in [semi-actuated/actuated] mode
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE transmit/RSE receive) of RSE (note that if another medium is used, the same assumption applies). 2) OBE transmits BSM/CAM. 3) RSE receives BSM/CAM. 4) RSE parses BSM/CAM to identify vehicle temporary ID, position, speed, heading, type, and turn signal status. 5) RSE updates state map (i.e. tracks individual trajectories) of vehicles on each intersection approach. 6) RSE determines what type of calls to place or remove based on projected trajectory and signal phase. 7) RSE places or removes call on applicable detector input(s) based on algorithm and timing.
Alternate flow(s)	5a) RSE also identifies/tracks vehicles formerly on/not on an intersection approach [e.g. messages from vehicles that have already passed through the intersection, or on a nearby street not associated with this intersection, or entering land parcels adjacent to the intersection (e.g. re-fuelling station, parking facility)]. 8) (insert after step 7) RSE updates performance measure data 8a) RSE also sends performance measure data to BOPC
Post-conditions	Vehicles able to pass through intersection without stopping when local efficiency is increased (alt.) BOPC/signal operations receives performance measure input data
Information requirements	SPaT (used internally by the RSE only) Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, call placed BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type, turn signal status

Table A.18 *(continued)*

	MAP (used internally by the RSE only) Intersection geometry, permitted manoeuvres
Issues	1) OBE transmit range may be dynamic (e.g. Tx power based on congestion control) 2) RSE needs to account for periodic changes to OBE ID 3) Optimization at corridor/network level may constrain local intersection
Source docs/ references	CEN#13 pp. 20–21; MMITSS p. 3 ID 11.1.1.3

Table A.19 — MS2: Platoon detection for coordinated signals

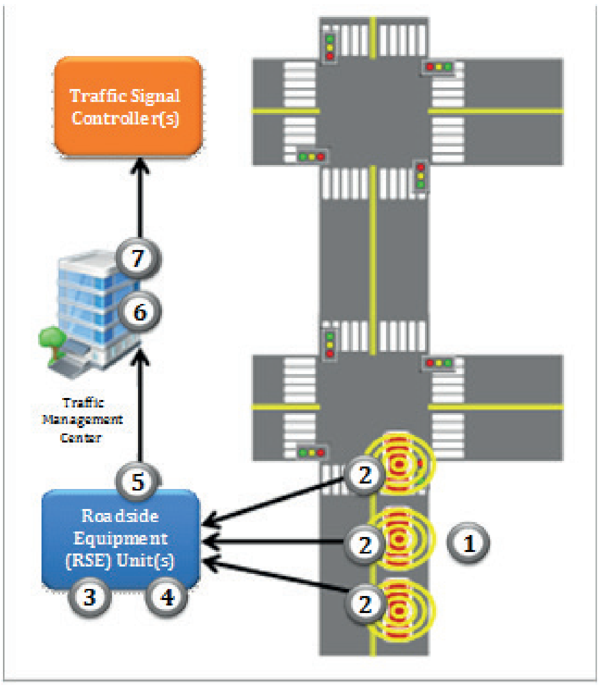
Use case name	Platoon detection for coordinated signals
Category	Mobility, sustainability
Infrastructure role	Data receiver
Short description	This use case describes provision of vehicle platoon characteristics to facilitate real-time arterial-level traffic signal timing adjustments. This case only targets timing optimization (i.e. does not send directions to drivers).
Goal	Roadside equipment relays vehicle platoon information to BOPC which uses information to dynamically adjust signal timing offsets
Constraints	Channel plan in place to allow RSE to receive BSM/CAMs Platoon vehicles' DSRC transmit performance adequate for timely RSE reception Security management system in place to allow RSE to check BSM/CAM OBE BSM/CAM meets minimum performance requirements (e.g. SAE J2945) Coordinated corridor of traffic signals connected to TMC/BOPC
Geographic scope	Roadway section with coordinated traffic signals
Actors	OBE-equipped vehicles RSE(s) connected to local traffic signal controllers TMC/BOPC/signal operations back office
Illustration (example)	

Table A.19 *(continued)*

Preconditions	Local traffic signal controller not in pre-empt/special mode Platoon of vehicles is travelling in direction of coordination plan
Main flow (example)	1) OBE-equipped vehicles in platoon enter DSRC range (i.e. for OBE transmit/RSE receive) of RSE (note that if another medium is used, the same assumption applies). 2) Each OBE transmits BSM/CAM. 3) RSE(s) receives BSM/CAM(s). 4) RSE parses BSM/CAMs to identify vehicle temporary ID, position, speed, heading, type. 5) Each RSE sends estimated platoon status information based on received BSM/CAMs (speed, time, location of head and tail of platoon) to BOPC. 6) BOPC processes information on platoons to optimize offsets at each intersection in the platoon direction including time periods for application and transitions. 7) BOPC sends newly adjusted offsets/time period of application (and transition information) to each traffic signal controller.
Alternate flow(s)	5a) RSE sends platoon vehicles' individual status information to BOPC. 5b) RSE sends platoon vehicles' information in conjunction with loop/conventional detector information to BOPC. 6a) BOPC processes information on platoons to optimize offsets at each intersection incorporating a trade-off function with both directions.
Post-conditions	Traffic signal timing reflects dynamically optimized offsets for vehicle flow in corridor. Time period of application passes and signal controller executes transition.
Information requirements	SPaT (for RSE only) Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, vehicle type, turn signal status MAP (for RSE only) Intersection geometry, permitted manoeuvres
Issues	1) Definition of platoon/detection information. 2) Accurate identification of front and back of platoon challenging without high fleet penetration. 3) Platoon enters DSRC range of RSE over period of time. 4) Optimization at corridor level may conflict with network and/or local intersection optimization. 5) Platoon operation's research is ongoing and therefore platoon requirements will be addressed in a future version of this document.
Source docs/ references	CEN#13 pp. 20–21; MMITSS p. 4 ID 11.1.2

Table A.20 — MS3: Congested intersection adjustment

Use case name	Congested intersection Adjustment
Category	Mobility, sustainability
Infrastructure role	Data receiver

Table A.20 *(continued)*

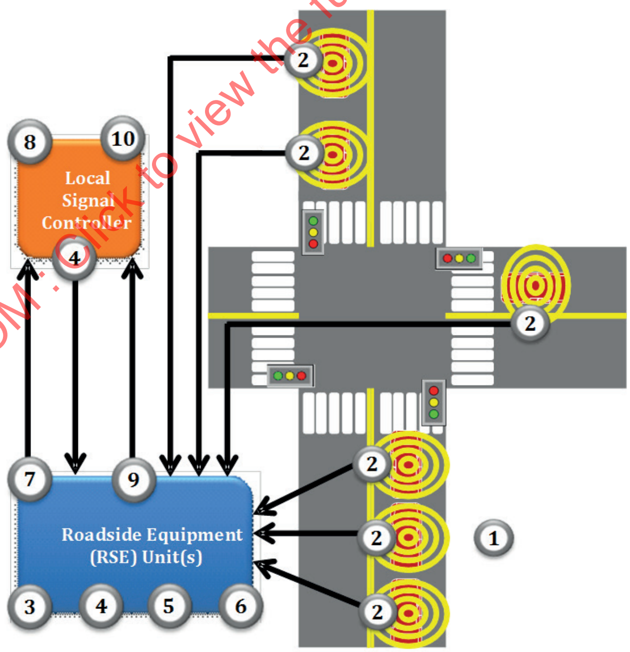
Short description	This use case describes the detection of persistent traffic signal phase overloads on one or more manoeuvres and executing mitigating adjustments to traffic signal plans at the intersection(s). Multi-intersection adjustments involve a BOPC.
Goal	Reduce impacts of phase overloads at a congested intersection by utilizing adjustments to traffic signal timing based on mitigation strategies.
Constraints	Channel plan in place to allow RSE to receive BSM/CAMs Vehicles' DSRC transmit performance under congested conditions adequate for timely RSE reception OBE BSM/CAM meets minimum performance requirements (e.g. SAE J2945) Intersection approach roadway segments mapped to sufficient accuracy and differentiates segments governed by other traffic control device (signal/stop/yield) RSE algorithm established to determine what input to provide to traffic signal controller and/or BOPC based on vehicle information indicating phase overloads (e.g. vehicle present in queue at the beginning of the phase did not pass through the intersection prior to the termination of the phase) Intersection has sufficient detection to identify phase overloads, e.g. stop bar detection.
Geographic scope	Local signalized intersection and potentially nearby intersections
Actors	OBE-equipped vehicles RSE connected to local traffic signal controller BOPC/signal operations back office
Illustration (example)	 Source: Noblis 2013
Preconditions	Sufficient number of equipped vehicles on approach segment to accurately identify true phase overloads
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE transmit/RSE receive) of RSE (note that if another medium is used, the same assumption applies). 2) OBE transmits BSM/CAM 3) RSE receives BSM/CAM 4) RSE parses BSM/CAM to identify vehicle temporary ID, position, speed, heading, type, turn signal status (Steps 5 to 7 are occurring in parallel with steps 2 to 4.)

Table A.20 *(continued)*

	5) RSE updates state map of vehicles on each intersection approach using SPaT and MAP information. 6) RSE identifies phase overload based on equipped vehicle not being serviced for (configurable number) cycles. 7) RSE sends phase overload information to local signal controller. 8) Local signal controller implements strategy (free operation, split adjustment/dynamic split assignment, cycle length modification, queue management) to eliminate phase overloads. 9) If phase overloads not detected for (configurable number) cycles, RSE sends message to local signal controller. 10) Local signal controller adjusts to strategy absent phase overloads.
Alternate flow(s)	7a) RSE sends phase overload information to BOPC which determines the action. 8a) BOPC implements strategy adjusting timing of other intersection(s). 9a) RSE sends lack of phase overload detection to BOPC which determines the action. 10a) BOPC implements normal operation/recovery transition at intersection(s) based on absence of phase overload.
Post-conditions	Conditions on congested manoeuvre at the intersection improved to eliminate phase overload
Information requirements	SPaT Current manoeuvre permitted, time points for manoeuvres including yellow clearance, red clearance, and next manoeuvre to begin BSM/CAM Vehicle ID (for tracking), vehicle location, vehicle heading, vehicle speed, turn signal status MAP (for RSE only) Intersection geometry, permitted manoeuvres
Issues	1) RSE needs to account for periodic changes to OBE ID 2) Optimization at corridor/network level may conflict with adjustments at local intersection level, and similarly, local optimizations may conflict with corridor/network level strategies. 3) SPaT information (as described in the requirements of 6.7.1x series) does not contain phase overload indicators. 4) Communication of phase overloads from the RSE to the intersection controller
Source docs/ references	CEN#13 pp. 20–21; MMITSS p. 5 ID 11.1.3; NCHRP 3–79

Table A.21 — MS4: Traffic signal optimal speed advisory

Use case name	Traffic signal optimal speed advisory
Category	Mobility, sustainability
Infrastructure role	Data provider
Short description	This use case describes provision of traffic signal information to approaching vehicles to enable speed adjustment, and lane switching, to optimize vehicle trajectory for smooth operation of the vehicle.
Goal	Roadside equipment sends MAP and SPaT in real time to approaching vehicles, which utilize the information to notify the driver of optimal speed to smoothly stop or traverse the intersection.
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception

Table A.21 *(continued)*

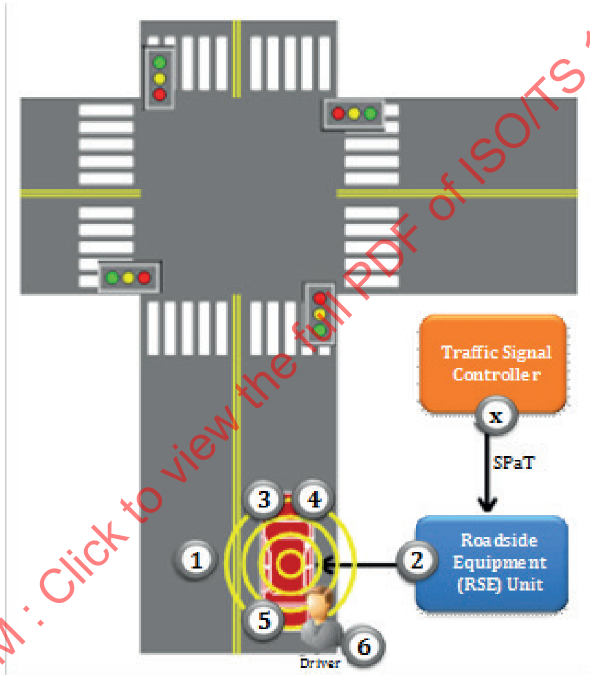
	RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiate lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate timing/inputs established OBE acceleration/deceleration profiles established for possible trajectory and timing input
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles with optimal speed application RSE connected to local traffic signal controller
Illustration (example)	
Preconditions	MAP message reflects current intersection geometry.
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP and SPaT information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane, associated signal phase, intersection speed limit, vehicle routing, turn signal status, vehicle type, and queue length (by lane) information. 5) OBE determines if vehicle is expected to arrive at intersection during red interval (based on vehicle trajectory and other information) or if the queue length is excessive by lane. 6) If arrival at/near red interval is expected, the OBE determines optimal deceleration profile to stop at intersection, or acceptable acceleration profile, and provides information to the driver. If the queue length is excessive, the OBE alerts the driver of the situation and recommends a change in speed or a change in lanes. Note that stop lines effectively move upstream due to the presence of queues.
Alternate flow(s)	6a) OBE provides optimal profile as input for vehicle control system
Post-conditions	Vehicle stops smoothly at intersection or continues through without stopping in environmentally optimal fashion.

Table A.21 *(continued)*

Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, predicted future timing, queue length, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base
Issues	1) Acceptability of speed guidance 2) Speed range (speed limit) information: message location, details 3) Determining turn lane prior to approach 4) Impacts on optimal speed due to dynamic environment (predicted signal timing, other vehicles, accuracy on the location of the queue length) 5) Matching vehicle location to intersection geometry and signal phase requires vehicle routing information to associate the vehicle with the proper lane and signal phase. (What lane is an 18-wheeler in when it straddles the lane marking so that it can make a right-turn without the trailer hitting the curb?) 6) Traffic signal controllers vary as to when the next phase is identified. 7) Decisions will impact platoons.
Source docs/ references	CEN#5 p. 8

Table A.22 — MS5: Signalized corridor eco-driving speed guidance

Use case name	Signalized corridor eco-driving speed guidance
Category	Mobility and sustainability
Infrastructure role	Data provider
Short description	This use case describes the provision of traffic signal information to approaching vehicles to enable speed and lane adjustments to optimize vehicle trajectory for improved fuel efficiency in a corridor.
Goal	Roadside equipment sends MAP and SPaT in real time to approaching vehicles, which utilize the information to notify vehicle of optimal speed and lane use to smoothly stop or traverse the intersection using less fuel
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiate lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate timing/inputs established OBE acceleration/deceleration and engine management profiles established for possible trajectory and timing input
Geographic scope	Roadway section with traffic signals
Actors	OBE-equipped vehicles with eco-driving application RSE(s) connected to local traffic signal controllers and BOPC BOPC/signal operations back office

Table A.22 *(continued)*

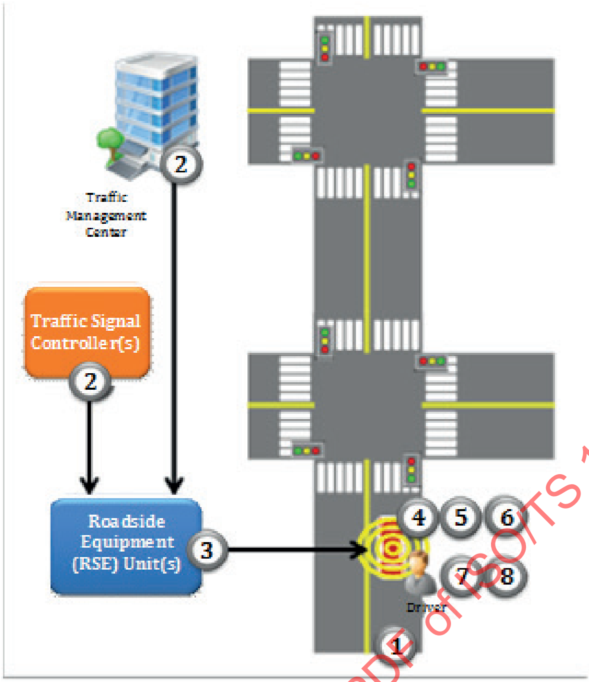
Illustration (example)	
Preconditions	MAP message reflects current intersection geometry Vehicle travelling in direction of coordination plan
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2a) RSE receives SPaT from signal controller and corridor progression information from BOPC. 2b) RSE transmits MAP and SPaT information, corridor progression information 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane and associated signal phase. 5) OBE determines if vehicle is expected to arrive at intersection during red interval, based on vehicle trajectory and other information or if the current queue length for the lane the vehicle is travelling is excessive. 6) If arrival at/near red interval is expected, OBE determines optimal deceleration profile to stop at intersection, or acceptable acceleration profile, or if the vehicle should switch lanes based on SPaT and corridor progression information, and provides information to driver. 7) If arrival during green interval is expected, OBE determines optimal speed, or if the vehicle should change lanes profile based on SPaT and corridor progression information, and provides information to driver
Alternate flow(s)	6a) Optimal deceleration profile information provided to vehicle control system from RSE or from BOPC. 7a) Optimal speed profile information provided to vehicle control system from RSE or from BOPC.
Post-conditions	Vehicle traverses corridor with increased efficiency.

Table A.22 *(continued)*

Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, predicted future timing, and pedestrian warning MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base Corridor progression information
Issues	1) Definition, message location of corridor progression information 2) Platoon operations through a corridor (it is unclear how the vehicle would even use the preference information to make its trajectory calculations) 3) Acceptability of speed guidance 4) Speed range (speed limit) information: message location, details 5) Determining turn lane prior to approach 6) Impacts on optimal speed due to dynamic environment (predicted signal timing, other vehicles)
Source docs/ references	CEN#6 p. 10; USDOT J2735™SE Candidate Use Case#2 p. 5

Table A.23 — MS6: Idling stop support

Use case name	Idling stop support
Category	Mobility and sustainability
Infrastructure role	Data provider
Short description	This use case describes provision of traffic signal timing information to vehicles stopped at a signal to enable engine shutoff.
Goal	Roadside equipment sends MAP and SPaT in real time to vehicles stopped at the intersection to enable drivers/vehicles to turn off engines while idling (stopped).
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate idling/startup timing/inputs established
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles with idling stop support application RSE connected to local traffic signal controller

Table A.23 *(continued)*

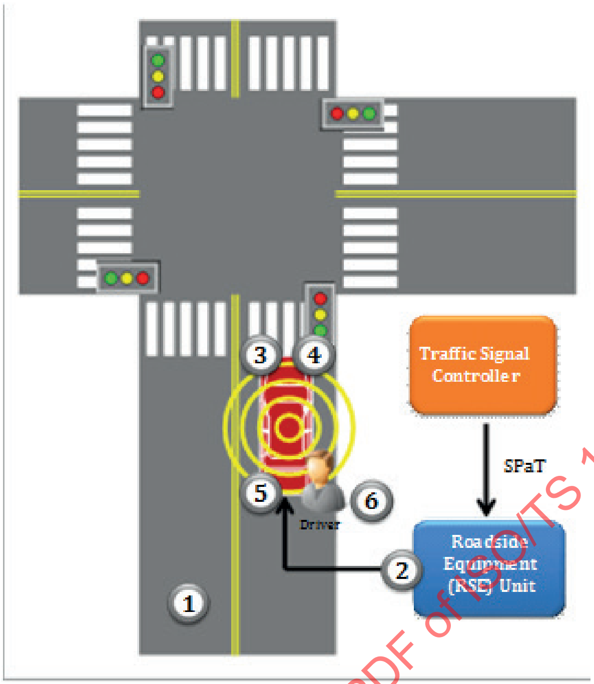
Illustration (example)	
Preconditions	OBE-equipped vehicle stopped at red signal (does not include vehicles stopped at a convenience store or fueling station driveway trying to enter the roadway)
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP and SPaT information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane, manoeuvres, and associated signal phase. 5) OBE determines if vehicle is stopped and governed by red indication using SPaT. 6) If vehicle is expected to remain stopped, based on duration of the applicable predicted manoeuvre change time, OBE determines optimal engine shutdown profile based on the time remaining in intervals and queue lengths prior to the time for the vehicle to go, and provides information to the driver on shutdown/startup.
Alternate flow(s)	6a) Information on shutdown/startup provided to vehicle engine control system
Post-conditions	Vehicle leaves intersection after the end of red interval, assuming that the egress lanes are clear of traffic.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base
Issues	Determination of permissible/optimal shutdown and startup parameters under manual/automatic control of the vehicle
Source docs/ references	CEN#7 pp. 11–12; USDOT J2735™SE Candidate Use Case #2, p. 5

Table A.24 — MS7: Start delay prevention

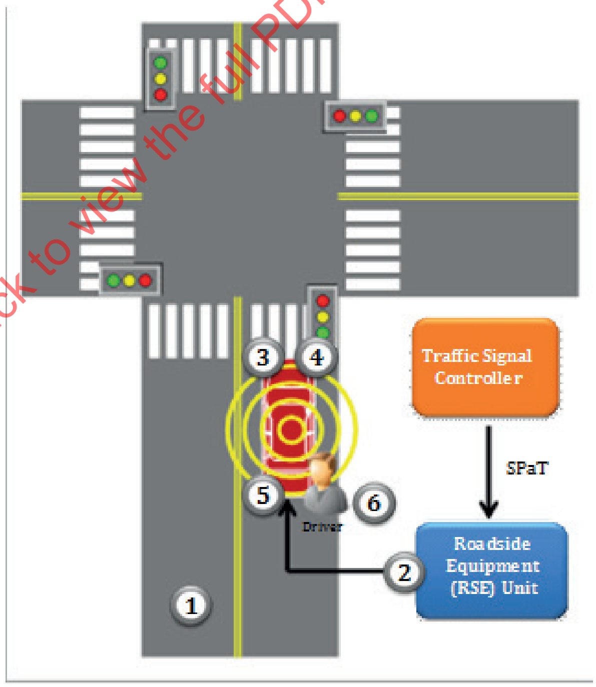
Use case name	Start delay prevention
Category	Mobility, sustainability
Infrastructure role	Data provider
Short description	This use case describes a provision of traffic signal timing information to vehicles stopped at a signal to enable efficient resumption of flow.
Goal	Roadside equipment sends MAP and SPaT in real time to vehicles stopped at the intersection to enable drivers/vehicles to prepare for startup efficiently.
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate startup timing/inputs established
Geographic scope	Local signalized intersection and approaching roadway segments
Actors	OBE-equipped vehicles with start delay prevention application RSE connected to local traffic signal controller
Illustration (example)	
Preconditions	Equipped vehicle stopped at red signal
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP and SPaT information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane and associated signal phase. 5) OBE determines if vehicle is stopped and governed by red indication using SPaT. 6) If vehicle is stopped but expected to receive green indication within a specified time, based on SPaT information, OBE determines the optimal time and nature of message to provide to the driver to prepare for startup.
Alternate flow(s)	None

Table A.24 *(continued)*

Post-conditions	Vehicle proceeds through intersection once green indication given
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base
Issues	Human factors: confidence/timing of startup information, false startup
Source docs/ references	CEN#8 p. 13

MS8: (Deleted) Travel lane advice

This page intentionally left blank.

Table A.25 — MS9: Inductive charging at signals

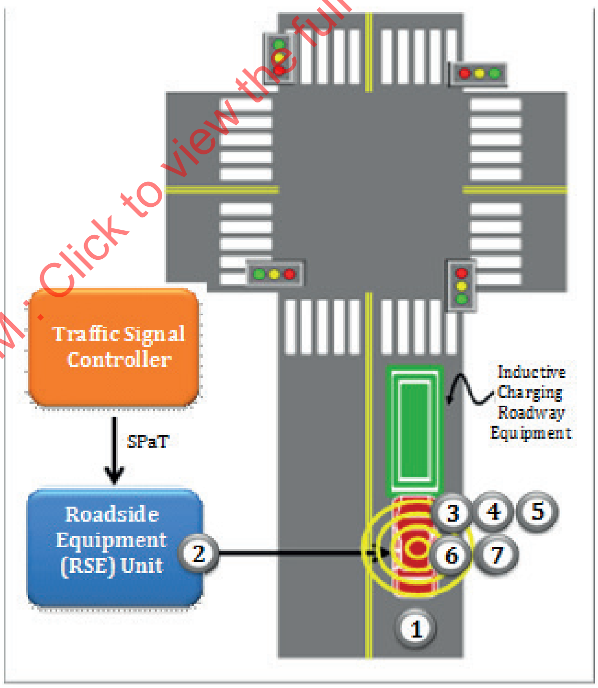
Use case name	Inductive charging at signals
Category	Sustainability
Infrastructure role	Data provider
Short description	This use case describes provision of inductive charging information to vehicle stopped at a signal. Actual charging transaction and technology is outside scope.
Goal	Roadside equipment sends MAP and SPaT in real time to vehicles stopped at the intersection to enable vehicles to establish temporary charging.
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable, and inductive charging location OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Approach of equipped intersection
Actors	OBE-equipped vehicles equipped with inductive charging application RSE connected to local traffic signal controller
Illustration (example)	
Preconditions	Equipped vehicle stopped at red signal above inductive charging location
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) RSE transmits MAP and SPaT information. 3) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR). 4) OBE matches vehicle location to intersection geometry/lane and associated signal phase. 5) OBE determines if vehicle is stopped above charging station using SPaT and MAP or TIM for station location. 6) If vehicle is stopped and is not expected to receive a go indication within a specified time, OBE determines timing to initiate and terminate charging connection.

Table A.25 *(continued)*

	7) OBE conducts charging request transaction. 8) OBE completes charging transaction.
Alternate flow(s)	None
Post-conditions	Vehicle continues through intersection after charging.
Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base MAP or TIM Inductive charging location(s)
Issues	1) Inductive charging location(s) on MAP or through TIM messages as addressed in a future edition of this document. 2) Charging transaction and related attributes 3) Assumes that the charging transaction is between the OBE and the inductive charging station and is independent of the RSE
Source docs/ references	CEN#14 pp. 22–23

Table A.26 — MS10: Don't block the box

Use case name	Don't block the box (also known as manoeuvre assist)
Category	Mobility
Infrastructure role	Data provider
Short description	This use case describes OBE vehicles determining whether they can enter and clear an intersection or stopping until they can enter and clear.
Goal	Roadside equipment sends MAP and SPaT in real time to vehicles approaching the intersection to enable vehicles to determine whether to enter the intersection or to wait.
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception RSE messages meet minimum performance requirements. Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable, and inductive charging location OBE driver interface/algorithm with appropriate timing/inputs established
Geographic scope	Approaches and egress lanes at the intersection
Actors	OBE-equipped vehicle equipped with the manoeuvre assist application RSE connected to local traffic signal controller

Table A.26 *(continued)*

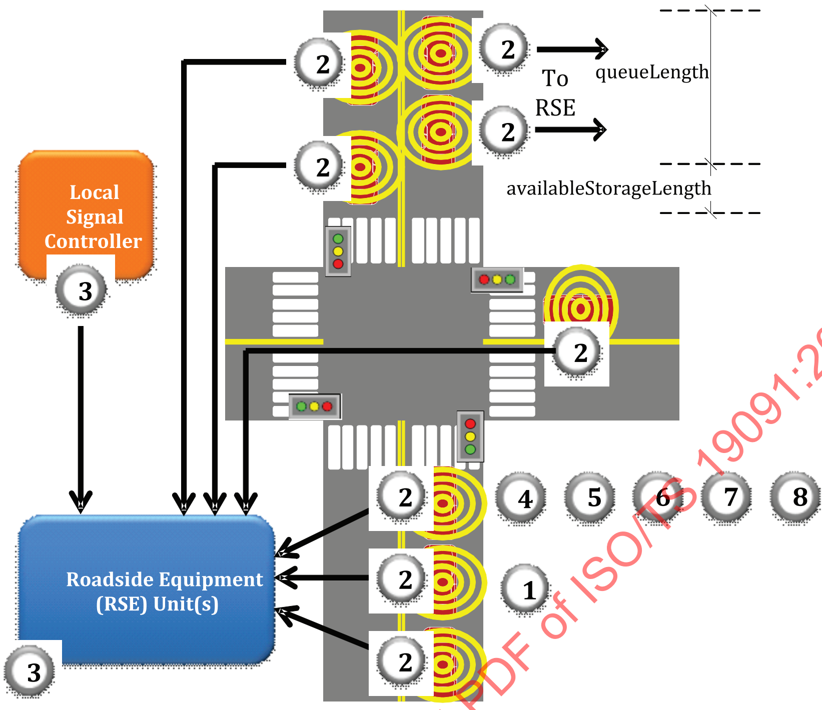
Illustration (example)	
Preconditions	Equipped vehicle in an approach lane about to enter the intersection
Main flow (example)	1) OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2) OBE transmits BSM to RSE and other vehicle's OBE 3) RSE transmits MAP and SPaT information 4) OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR) 5) OBE matches vehicle location to intersection geometry/lane and associated signal phase 6) OBE checks routing information and identifies its egress lane. 7) OBE determines whether egress lane entrance contains a vehicle or has storage space available for it to move into 8) OBE notifies driver whether the vehicle can enter the intersection and move into the egress lane or the vehicle needs to remain in its current location.
Alternate flow(s)	2a) RSE updates queueLength and availableStorageLength based on all available data. 2b) RSE calculates whether vehicles approaching the stop line may proceed due to available storage or stop until storage space is available. 2c) RSE updates SPaT with current queueLength, availableStorageLength, and a wait (i.e. stop or proceed) indication.
Post-conditions	Vehicle continues through the intersection into the clear egress lane or the vehicle stops and waits for the egress lane to have space for the vehicle to clear into.

Table A.26 *(continued)*

Information requirements	SPaT Current manoeuvre permitted, remaining time for manoeuvre, yellow clearance time, red clearance time, next manoeuvre to be serviced, queue and available storage lengths, wait indicator. MAP Intersection geometry (MAP base), permitted manoeuvres, and changes to MAP other than base, inductive charging location(s)
Issues	1) Identification of egress lane storage space by sensing/mapping of vehicles in egress lane 2) Assumes that the egress lane situation is known and assessed by the approaching vehicle.
Source docs/ references	Manoeuvre assist e-mail documents

Annex B
(informative)

Use case to requirements traceability

B.1 General

Table B.1 to Table B.6 provide traceability from the use cases to the requirements. The tables identify information requirements associated with each use case. Three tables, Table B.3 to Table B.6, are provided, each organized by use case operational type (priority/pre-emption, safety, and mobility).

B.2 Symbols indicating requirement status

Table B.1 indicates the how individual requirements apply to the use cases. The symbols are used in the tables to the logic of how the requirement shall be addressed in context of the use case.

Table B.1 — Symbols indicating requirement status

Abbreviated term	Description
M	Mandatory
M.#	Support of every item of the group labelled by the same numeral # is required, but only one is active at a time
O	Optional
O.# (range)	Part of an option group. Support of the number of items indicated by the "(range)" is required from all options labelled with the same numeral #
C	Conditional
N/A	Not applicable (i.e. logically impossible)
REG:	Regional selection
X	Excluded or prohibited
Ix	Internal RSE<->TSC use only with "x" replaced by the status symbols listed above

The O.# (range) notation is used to show a set of selectable options, e.g. O.2 (1..*) would indicate that one or more of the option group 2 options is required to be implemented. Two character combinations are used for dynamic requirements. In this case, the first character refers to the static (implementation) status and the second refers to the dynamic (use); thus, "MO" means "mandatory to be implemented, optional to be used."

B.3 Conditional status notation

The predicate notations in Table B.2 may be used.

Table B.2 — Predicate notations

Notation	Description
<predicate>:	This notation introduces a single item that is conditional on the <predicate>.
<predicate>::	This notation introduces a table or a group of tables, all of which are conditional on the <predicate>.
(predicate)	This notation introduces the first occurrence of the predicate. The feature associated with this notation is the base feature for all options that have this predicate in their conformance column.

The <predicate>: notation means that the status following it applies only when the use case to requirements tables state that the feature or features identified by the predicate are supported. In the simplest case, <predicate> is the identifying tag of a single use case to requirements table item. The <predicate>:: notation may precede a table or group of tables in a section or subsection. When the group predicate is true, then the associated section shall be completed. The symbol <predicate> also may be a Boolean expression composed of several indices. "AND", "OR", and "NOT" shall be used to indicate the Boolean logical operations.

The predicates used in use case to requirements tables are as follows.

Table B.3 — Predicate mapping to this document's subclauses

Predicate	Subclause
Location	6.6.1
Safe1 Safe2	6.1

B.4 Prioritization and pre-emption use case to requirements table

Table B.4 — Prioritization and pre-emption related use case to requirements matrix

Requirements		Prioritization and pre-emption use cases								
ID	Title	PR1	PR1-a	PR2	PR3	PR3-a	PR3-b	PR4	PR5	PR6
6.1.1	Broadcast public safety vehicle information	M	M	M	M	M	M	M	M	M
6.1.2	Broadcast emergency response indication	X	X	X	X	X	X	M	M	M
6.2.1	Transmit pre-empt request	O	O	O	O	O	O	M	M	M
6.2.2	Request signal pre-empt — Message identifier	O	O	O	O	O	O	M	M	M
6.2.4	Request signal pre-empt — Intersection identifier	O	O	O	O	O	O	M	M	M
6.2.5	Request signal pre-empt — Approach lane	O	O	O	O	O	O	M.2	M.2	M.2
6.2.6	Request signal pre-empt — Egress lane	O	O	O	O	O	O	M.2	M.2	M.2
6.2.7	Request signal pre-empt — Vehicle class	O	O	O	O	O	O	O	O	O
6.2.8	Request signal pre-empt — Time of service	O	O	O	O	O	O	O	O	O
6.2.9	Request signal pre-empt — Vehicle identity	O	O	O	O	O	O	O	M	M
6.2.10	Request signal pre-empt — Vehicle location and speed	O	O	O	O	O	O	O	O	O
6.2.11	Request signal pre-empt — Cancellation	O	O	O	O	O	O	M	M	M
6.2.12	Request signal pre-empt — Transaction identifier	O	O	O	O	O	O	M	M	M
6.2.13	Request signal pre-empt — Duration	O	O	O	O	O	O	M	M	M
6.3.1	Broadcast priority requesting vehicle information	M	M	M	M	M	M	M	M	M
6.4.1	Transmit priority request	M	M	M	M	M	M	O	O	M
6.4.2	Transmit priority request — Message identifier	M	M	M	M	M	M	O	O	M
6.4.3	Transmit priority request — Intersection identifier	M	M	M	M	M	M	O	O	M
6.4.4	Transmit priority request — Approach lane	M.2	M.2	M.2	M.2	M.2	M.2	O	O	M.2
6.4.5	Transmit priority request — Egress lane	M.2	M.2	M.2	M.2	M.2	M.2	O	O	M.2
6.4.6	Transmit priority request — Vehicle class	O	O	O	O	O	O	O	O	O
6.4.7	Transmit priority request — Time of service	O	O	O	O	O	O	O	O	O
6.4.8	Transmit priority request — Vehicle identity	O	O	O	O	O	O	O	O	O
6.4.9	Transmit priority request — Vehicle location and speed	O	O	O	O	O	O	O	O	O
6.4.10	Transmit priority request — Service information	O	O	O	O	O	O	O	O	O
6.4.11	Transmit priority request cancellation	M	M	M	M	M	M	O	O	M
6.4.12	Transmit priority request — Priority request level	X	X	X	M	M	M	O	O	M

Table B.4 *(continued)*

Requirements		Prioritization and pre-emption use cases								
ID	**Title**	**PR1**	**PR1-a**	**PR2**	**PR3**	**PR3-a**	**PR3-b**	**PR4**	**PR5**	**PR6**
6.4.13	Request signal priority — Transaction identifier	M	M	M	M	M	M	M	M	M
6.4.14	Request signal priority — Duration	M	M	M	M	M	M	M	M	M
6.4.15	Request signal priority — Transit schedule	O	O	O	X	X	X	X	X	O
6.5.1	Broadcast area geometrics	M	M	M	M	M	M	M	M	M
6.5.2	Broadcast roadway geometrics — Message identifier	M	M	M	M	M	M	M	M	M
6.5.3	Broadcast intersection — Identifier	M	M	M	M	M	M	M	M	M
6.5.4	Broadcast intersection — Reference point	M	M	M	M	M	M	M	M	M
6.5.5	Broadcast intersection — Lane default width	M	M	M	M	M	M	M	M	M
6.5.6	Broadcast intersection — Egress lanes	O	O	O	O	O	O	O	O	O
6.5.7	Broadcast intersection — Approach lanes	M	M	M	M	M	M	M	M	M
6.5.8	Broadcast intersection — Lane number	M	M	M	M	M	M	M	M	M
6.5.9	Broadcast intersection — Lane centerline coordinates	M	M	M	M	M	M	M	M	M
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	M	M	M	M	M	M	M	M	M
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	O	O	O	O	O	O	O	O	O
6.5.12	Broadcast intersection — Special lane manoeuvres	O	O	O	O	O	O	O	O	O
6.5.13	Broadcast intersection — Version identifier	M	M	M	M	M	M	M	M	M
6.5.14	Broadcast intersection — Crossings	O	O	O	O	O	O	O	O	O
6.5.15	Broadcast intersection — Lane width	O	O	O	O	O	O	O	O	O
6.5.16	Broadcast intersection — Node lane width	O	O	O	O	O	O	O	O	O
6.5.17	Broadcast intersection — Egress connection	O	O	O	O	O	O	O	O	M
6.5.18	Broadcast intersection — Traffic control	M	M	M	M	M	M	M	M	M
6.5.19	Broadcast intersection — Traffic control by lane/approach	M	M	M	M	M	M	M	M	M
6.5.20	Broadcast road conditions	O	O	O	O	O	O	O	O	O
6.5.21	Broadcast intersection — Signal group	M	M	M	M	M	M	M	M	M
6.6.1	Broadcast GNSS augmentations (**Location**)	M	M	M	M	M	M	M	M	M

Table B.4 *(continued)*

Requirements		Prioritization and pre-emption use cases								
ID	**Title**	**PR1**	**PR1-a**	**PR2**	**PR3**	**PR3-a**	**PR3-b**	**PR4**	**PR5**	**PR6**
6.6.2	Broadcast GNSS augmentations detail — NMEA **<Location>**	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)
6.6.3	Broadcast GNSS augmentations detail — RTCM **<Location>**	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)	0.1(1)
6.7.1	Broadcast signal phase and timing information	M	M	M	M	M	M	M	M	M
6.7.2	Broadcast signal phase and timing — Message identifier	M	M	M	M	M	M	M	M	M
6.7.3	Broadcast signal phase and timing — Intersection identifier	M	M	M	M	M	M	M	M	M
6.7.4	Broadcast signal phase and timing — Intersection Status	M	M	M	M	M	M	M	M	M
6.7.5	Broadcast signal phase and timing — Timestamp	M	M	M	M	M	M	M	M	M
6.7.6	Broadcast manoeuvre — Lane data	M	M	M	M	M	M	M	M	M
6.7.7	Broadcast manoeuvre — Manoeuvre state	M	M	M	M	M	M	M	M	M
6.7.8	Broadcast manoeuvre — Vehicular state	M	M	M	M	M	M	M	M	M
6.7.9	Broadcast manoeuvre — Pedestrian state	O	O	O	O	O	O	O	O	O
6.7.10	Broadcast manoeuvre — Special state	O	O	O	O	O	O	O	O	O
6.7.11	Broadcast manoeuvre — Time of change — Minimum	M	M	M	M	M	M	M	M	M
6.7.12	Broadcast manoeuvre — Time of change — Maximum	M	M	M	M	M	M	M	M	M
6.7.13	Broadcast manoeuvre — Succeeding signal indications	O	O	O	O	O	O	O	O	O
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	O	O	O	O	O	O	O	O	O
6.7.15	Broadcast manoeuvre pending manoeuvre start time	O	O	O	O	O	O	O	O	O
6.7.16	Broadcast manoeuvre — Pedestrian detect	O	O	O	O	O	O	O	O	O
6.7.17	Broadcast manoeuvre — Pedestrian call	O	O	O	O	O	O	O	O	O
6.7.18	Broadcast manoeuvre — Optimal speed information	O	O	O	O	O	O	O	O	O

Table B.4 *(continued)*

Requirements		Prioritization and pre-emption use cases								
ID	**Title**	**PR1**	**PR1-a**	**PR2**	**PR3**	**PR3-a**	**PR3-b**	**PR4**	**PR5**	**PR6**
6.7.19	Broadcast manoeuvre — Signal progression information	O	O	O	O	O	O	O	O	O
6.7.20	Broadcast manoeuvre — Egress lane queue	X	X	X	X	X	X	X	X	X
6.7.21	Broadcast manoeuvre — Egress lane storage availability	X	X	X	X	X	X	X	X	X
6.7.22	Broadcast manoeuvre — Wait indication	X	X	X	X	X	X	X	X	X
6.11.1	Broadcast preferential treatment — Signal status message	M	M	M	M	M	M	M	M	M
6.11.2	Broadcast preferential treatment — Message identifier	M	M	M	M	M	M	M	M	M
6.11.3	Broadcast preferential treatment — Intersection identifier	M	M	M	M	M	M	M	M	M
6.11.4	Broadcast preferential treatment — Intersection status	M	M	M	M	M	M	M	M	M
6.11.5	Broadcast preferential treatment — Prioritization request status	M	M	M	M	M	M	M	M	M
6.11.6	Broadcast preferential treatment — Vehicle source	M	M	M	M	M	M	M	M	M
6.11.7	Broadcast preferential treatment — Transaction identifier	M	M	M	M	M	M	M	M	M
6.12	Message identifier	M	M	M	M	M	M	M	M	M
6.13.1	Broadcast intersection — Computed lane	O	O	O	O	O	O	O	O	O
6.14.1	Maximum transmission rate — Request signal preferential treatment	M	M	M	M	M	M	M	M	M
6.14.2	Maximum response time — Request signal preferential treatment	M	M	M	M	M	M	M	M	M
6.14.3	Minimum transmission rate — Signal status message	M	M	M	M	M	M	M	M	M
6.14.4	Minimum transmission period — Signal status message	M	M	M	M	M	M	M	M	M
6.15.1	Minimum transmission rate — Broadcast roadway geometrics information	M	M	M	M	M	M	M	M	M

Table B.4 *(continued)*

Requirements		Prioritization and pre-emption use cases								
ID	**Title**	**PR1**	**PR1-a**	**PR2**	**PR3**	**PR3-a**	**PR3-b**	**PR4**	**PR5**	**PR6**
6.15.2	Maximum transmission rate — Broadcast roadway geometrics information	M	M	M	M	M	M	M	M	M
6.15.3	Default transmission rate — Broadcast roadway geometrics information	M	M	M	M	M	M	M	M	M
6.16.1	Minimum transmission rate — GNSS augmentation details broadcasts	M	M	M	M	M	M	M	M	M
6.16.2	Default transmission rate — GNSS augmentation details broadcasts	M	M	M	M	M	M	M	M	M
6.17.1	Minimum transmission rate — Broadcast signal phase and timing information	M	M	M	M	M	M	M	M	M
6.17.2	Maximum transmission rate — Broadcast signal phase and timing information	M	M	M	M	M	M	M	M	M
6.17.3	Default transmission rate — Broadcast signal phase and timing information	M	M	M	M	M	M	M	M	M

B.5 Safety related use case to requirements matrix

Table B.5 — Safety related use case to requirements matrix

Requirements		Safety related use cases						
ID	**Title**	**SA1**	**SA2**	**SA3**	**SA4**	**SA5**	**SA6**	**SA7**
6.5.1	Broadcast Area Geometrics	IM	M	M	M	M	M	M
6.5.2	Broadcast Roadway Geometrics — Message Identifier	IM	M	M	M	M	M	M
6.5.3	Broadcast Intersection — Identifier	IM	M	M	M	M	M	M
6.5.4	Broadcast Intersection — Reference Point	IM	M	M	M	M	M	M
6.5.5	Broadcast Intersection — Lane/Approach Default Width	IM	M	M	M	M	M	M
6.5.6	Broadcast Intersection — Egress Lanes	IX	X	X	REG:M	M	REG:M	REG:M
6.5.7	Broadcast Intersection — Approach Lanes	IM	M	M	M	M	M	M
6.5.8	Broadcast Intersection — Lane/Approach Number	IM	M	M	M	M	M	M
6.5.9	Broadcast Intersection — Lane/Approach Centerline Coordinates	IM	M	M	M	M	M	M
6.5.10	Broadcast Intersection — Vehicle Lane/Approach Manoeuvres	IM	M	M	M	M	M	M
6.5.11	Broadcast Intersection — Pedestrian Lane/Approach Manoeuvres	IX	X	X	O	M	M	M
6.5.12	Broadcast Intersection — Special Lane/Approach Manoeuvres	IX	X	X	O	X	O	O
6.5.13	Broadcast Intersection — Version Identifier	IO	O	X	O	O	O	M
6.5.14	Broadcast Intersection — Crossings	IX	X	X	O	M	M	M
6.5.15	Broadcast Intersection — Lane/Approach Width	IO	O	O	O	O	O	O
6.5.16	Broadcast Intersection — Node Lane/Approach Width	IO	O	O	O	O	O	O
6.5.17	Broadcast Intersection — Egress Connection	IX	X	X	REG:O	M	REG:M	REG:M
6.5.18	Broadcast intersection — Traffic control	X	X	M	X	X	M	M
6.5.19	Broadcast intersection — Traffic control by lane/approach	X	X	M	X	X	M	M
6.5.20	Broadcast road conditions	M	M	M	O	O	O	O
6.5.21	Broadcast intersection — Signal group	M	M	M	M	M	M	M
6.6.1	Broadcast GNSS augmentations Detail (**Location**)	M	M	M	M	M	M	M
6.6.2	Broadcast GNSS augmentations Detail — NMEA <**Location**>	IO.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)
6.6.3	Broadcast GNSS augmentations Detail — RTCM <**Location**>	IO.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)	O.1(1)
6.7.1	Broadcast Signal Phase and Timing Information	IM	M	X	M	M	X	X
6.7.2	Broadcast Signal Phase and Timing — Message Identifier	IM	M	X	M	M	X	X
6.7.3	Broadcast Signal Phase and Timing — Intersection Identifier	IM	M	X	M	M	X	X

Table B.5 *(continued)*

Requirements		Safety related use cases						
ID	**Title**	**SA1**	**SA2**	**SA3**	**SA4**	**SA5**	**SA6**	**SA7**
6.7.4	Broadcast Signal Phase and Timing — Intersection Status	IX	X	X	M	X	X	X
6.7.5	Broadcast Signal Phase and Timing — Timestamp	IM	M	X	M	M	X	X
6.7.6	Broadcast manoeuvre — Signal group	IM	M	M	M	M	M	M
6.7.7	Broadcast manoeuvre — Manoeuvre state	IM	M	M	M	M	M	M
6.7.8	Broadcast manoeuvre — Vehicular state	IM	M	X	M	M	X	X
6.7.9	Broadcast Manoeuvre — Pedestrian State	IX	X	X	O	M	X	X
6.7.10	Broadcast Manoeuvre — Special State	IX	X	X	O	X	X	X
6.7.11	Broadcast Manoeuvre — Time of Change - Minimum	IM	M	X	M	M	X	X
6.7.12	Broadcast Manoeuvre — Time of Change - Maximum	IM	M	X	M	M	X	X
6.7.13	Broadcast Manoeuvre — Succeeding Signal Indications	IO	M	X	O	O	X	X
6.7.14	Broadcast Manoeuvre — Succeeding Signal Indication Time of Change	IO	M	X	O	O	X	X
6.7.15	Broadcast manoeuvre pending manoeuvre start time	M	M	O	O	O	O	O
6.7.16	Broadcast Manoeuvre — Pedestrian Detect	IO	O	O	O	M	O	M
6.7.17	Broadcast Manoeuvre — Pedestrian Call	IO	O	O	O	O	O	M
6.7.18	Broadcast manoeuvre — Optimal speed information	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.7.19	Broadcast manoeuvre — Signal progression information	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.7.20	Broadcast Manoeuvre — Egress Lane Queue	N/A	N/A	N/A	O	O	N/A	N/A
6.7.21	Broadcast Manoeuvre — Egress Lane Storage Availability	N/A	N/A	N/A	O	O	N/A	N/A
6.7.22	Broadcast Manoeuvre — Wait Indication	N/A	N/A	N/A	O	O	N/A	N/A
6.8	Broadcast Cross Traffic Sensor Information	X	X	X	M	X	M	X
6.9	Broadcast Vulnerable Road User Sensor Information	X	X	X	X	M	O	M
6.10	Broadcast Dilemma Zone Violation Warning	M	X	X	X	X	X	X
6.12	Message identifier	M	M	M	M	M	M	M
6.13.1	Broadcast Intersection — Computed Lane/Approach	IX	X	X	O	O	O	O
6.15.1	Minimum Transmission Rate — Broadcast Roadway Geometrics Information	M	M	M	M	M	M	M
6.15.2	Maximum Transmission Rate — Broadcast Roadway Geometrics Information	M	M	M	M	M	M	M

Table B.5 *(continued)*

Requirements		Safety related use cases						
ID	**Title**	**SA1**	**SA2**	**SA3**	**SA4**	**SA5**	**SA6**	**SA7**
6.15.3	Default Transmission Rate — Broadcast Roadway Geometrics Information	M	M	M	M	M	M	M
6.16.1	Minimum Transmission Rate — GNSS augmentation Details Broadcasts	M	M	M	M	M	M	M
6.16.2	Default Transmission Rate — GNSS augmentation Details Broadcasts	M	M	M	M	M	M	M
6.17.1	Minimum Transmission Rate — Broadcast Signal Phase and Timing Information	M	M	X	M	M	X	X
6.17.2	Maximum Transmission Rate — Broadcast Signal Phase and Timing Information	M	M	X	M	M	X	X
6.17.3	Default Transmission Rate — Broadcast Signal Phase and Timing Information	M	M	X	M	M	X	X
6.18.1	Minimum Transmission Rate — Broadcast Cross Traffic sensor Information	X	X	X	M	X	M	X
6.18.2	Maximum Transmission Rate — Broadcast Cross Traffic sensor Information	X	X	X	M	X	M	X
6.18.3	Default Transmission Rate — Broadcast Cross Traffic sensor Information	X	X	X	M	X	M	X
6.19.1	Minimum Transmission Rate — Broadcast Vulnerable Road User Sensor Information	X	X	X	X	M	X	M
6.19.2	Maximum Transmission Rate — Broadcast Vulnerable Road User Sensor Information	X	X	X	X	M	X	M
6.19.3	Default Transmission Rate — Broadcast Vulnerable Road User Sensor Information	X	X	X	X	M	X	M

B.6 Mobility/sustainability related use case to requirements matrix

Table B.6 — Mobility/sustainability related use case to requirements matrix

Requirements		Mobility/sustainability related use cases								
ID	Title	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS9	MS10
6.5.1	Broadcast Area Geometrics	IM	IM	IM	M	M	M	M	M	M
6.5.2	Broadcast Roadway Geometrics — Message Identifier	IM	IM	IM	M	M	M	M	M	M
6.5.3	Broadcast Intersection — Identifier	IM	IM	IM	M	M	M	M	M	M
6.5.4	Broadcast Intersection — Reference Point	IM	IM	IM	M	M	M	M	M	M
6.5.5	Broadcast Intersection — Lane Default Width	IM	IM	IM	M	M	M	M	M	M
6.5.6	Broadcast Intersection — Egress Lanes	IO	IO	IO	O	O	M	M	M	M
6.5.7	Broadcast Intersection — Approach Lanes	IM	IM	IM	M	M	M	M	M	M
6.5.8	Broadcast Intersection — Lane Number	IM	IM	IM	M	M	M	M	M	M
6.5.9	Broadcast Intersection — Lane Centerline Coordinates	IM	IM	IM	M	M	M	M	M	M
6.5.10	Broadcast Intersection — Vehicle Lane Manoeuvres	IM	IM	IM	M	M	M	M	M	M
6.5.11	Broadcast Intersection — Pedestrian Lane Manoeuvres	IM	IM	IM	O	O	O	O	O	O
6.5.12	Broadcast Intersection — Special Lane Manoeuvres	IX	IX	IX	X	X	X	X	X	X
6.5.13	Broadcast Intersection — Version Identifier	IM	IM	IM	M	M	M	M	M	M
6.5.14	Broadcast Intersection — Crossings	IO	IO	IO	O	O	X	X	X	O
6.5.15	Broadcast Intersection — Lane Width	IO	IO	IO	O	O	O	O	O	O
6.5.16	Broadcast Intersection — Node Lane Width	IO	IO	IO	O	O	O	O	O	O
6.5.17	Broadcast Intersection — Egress Connection	IO	IO	IO	O	O	O	O	O	M
6.5.18	Broadcast intersection — Traffic control	M	M	M	M	M	M	M	M	M
6.5.19	Broadcast intersection — Traffic control by lane/approach	M	M	M	M	M	M	M	M	M
6.5.20	Broadcast road conditions	IO	IO	IO	M	M	O	O	O	O
6.5.21	Broadcast intersection — Signal group	M	M	M	M	M	M	M	M	M

Table B.6 *(continued)*

Requirements		Mobility/sustainability related use cases								
ID	**Title**	**MS1**	**MS2**	**MS3**	**MS4**	**MS5**	**MS6**	**MS7**	**MS9**	**MS10**
6.6.1	Broadcast GNSS augmentations (**Location**)	M	M	M	M	M	M	M	M	M
6.6.2	Broadcast GNSS augmentations Detail — NMEA <**Location**>	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)
6.6.3	Broadcast GNSS augmentations Detail — RTCM <**Location**>	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)	0.1(1...*)
6.7.1	Broadcast Signal Phase and Timing Information	IM	IM	IM	M	M	M	M	M	M
6.7.2	Broadcast Signal Phase and Timing — Message Identifier	IM	IM	IM	M	M	M	M	M	M
6.7.3	Broadcast Signal Phase and Timing — Intersection Identifier	IM	IM	IM	M	M	M	M	M	M
6.7.4	Broadcast Signal Phase and Timing — Intersection Status	IM	IM	IM	M	M	M	M	M	M
6.7.5	Broadcast Signal Phase and Timing — Timestamp	IM	IM	IM	M	M	M	M	M	M
6.7.6	Broadcast Manoeuvre — Lane Data	IM	IM	IM	M	M	M	M	M	M
6.7.7	Broadcast manoeuvre — Manoeuvre state									
6.7.8	Broadcast Manoeuvre — Vehicular State	IM	IM	IM	M	M	M	M	M	M
6.7.9	Broadcast Manoeuvre — Pedestrian State	IO	IO	IO	O	O	O	O	O	O
6.7.10	Broadcast Manoeuvre — Special State	IX	IX	IX	X	X	X	X	X	X
6.7.11	Broadcast Manoeuvre — Time of Change — Minimum	IM	IM	IM	M	M	M	M	M	M
6.7.12	Broadcast Manoeuvre — Time of Change — Maximum	IM	IM	IM	M	M	M	M	M	M
6.7.13	Broadcast Manoeuvre — Succeeding Signal Indications	IO	IO	IO	O	O	O	O	O	O
6.7.14	Broadcast Manoeuvre — Succeeding Signal Indication Time of Change	IO	IO	IO	O	O	O	O	O	O
6.7.15	Broadcast manoeuvre pending manoeuvre start time	IX	IX	IX	X	X	M	M	M	X

Table B.6 *(continued)*

Requirements		Mobility/sustainability related use cases								
ID	**Title**	**MS1**	**MS2**	**MS3**	**MS4**	**MS5**	**MS6**	**MS7**	**MS9**	**MS10**
6.7.16	Broadcast Manoeuvre — Pedestrian Detect	IO	IO	IO	O	O	O	O	O	O
6.7.17	Broadcast Manoeuvre — Pedestrian Call	IO	IO	IO	O	O	X	X	X	X
6.7.18	Broadcast manoeuvre — Optimal speed information	IX	IX	IX	M	M	X	X	X	O
6.7.19	Broadcast manoeuvre — Signal progres-sion information	IX	IX	IX	O	M	X	X	X	X
6.7.20	Broadcast Manoeuvre — Egress Lane Queue	X	X	X	X	X	X	X	X	M
6.7.21	Broadcast Manoeuvre — Egress Lane Storage Availability	X	X	X	X	X	X	X	X	M
6.7.22	Broadcast Manoeuvre — Wait Indication	X	X	X	X	X	X	X	X	M
6.12	Message Identifier	IM	IM	IM	M	M	M	M	M	M
6.13.1	Broadcast Intersection — Computed Lane	IO	IO	IO	O	O	O	O	O	O
6.15.1	Minimum Transmission Rate — Broad-cast Roadway Geometrics Information	IX	IX	IX	M	M	M	M	M	M
6.15.2	Maximum Transmission Rate — Broad-cast Roadway Geometrics Information	IX	IX	IX	M	M	M	M	M	M
6.15.3	Default Transmission Rate — Broadcast Roadway Geometrics Information	IX	IX	IX	M	M	M	M	M	M
6.16.1	Minimum Transmission Rate — GNSS augmentation Details Broadcasts	M	M	M	M	M	M	M	M	M
6.16.2	Default Transmission Rate — GNSS aug-mentation Details Broadcasts	M	M	M	M	M	M	M	M	M
6.17.1	Minimum Transmission Rate — Broad-cast Signal Phase and Timing Information	IM	IM	IM	M	M	M	M	M	M
6.17.2	Maximum Transmission Rate — Broad-cast Signal Phase and Timing Information	IM	IM	IM	M	M	M	M	M	M
6.17.3	Default Transmission Rate — Broadcast Signal Phase and Timing Information	IM	IM	IM	M	M	M	M	M	M
6.18.1	Minimum transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B.6 *(continued)*

Requirements		Mobility/sustainability related use cases								
ID	**Title**	**MS1**	**MS2**	**MS3**	**MS4**	**MS5**	**MS6**	**MS7**	**MS9**	**MS10**
6.18.2	Maximum transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.18.3	Default transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.19.1	Transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.19.2	Maximum transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.19.3	Default transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Annex C
(informative)

Requirements traceability matrix

Table C.1 — Requirements traceability matrix

Requirement		Design					Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Con-form-ance**	**Support/ project re-quirement**	**Addi-tional require-ment**
6.1.1	Broadcast public safety vehicle information (Safe1)	BSM (P1)	N/A	N/A	MessageTypes	BasicSafetyMessage	M.4(1)	Yes/No	
6.1.1	Broadcast public safety vehicle information (Safe2)	CAM	N/A	N/A	CAM	CoopAwareness	M.4(1)	Yes/No	
6.1.2	Broadcast emergency response indication <Safe1>	BSM (P2)	supplemental	SupplementalVehicleExtensions	classDetails	VehicleClassification	M	Yes/No	
6.1.2	Broadcast emergency response indication <Safe1>	BSM (P2)	vehicleAlerts	EmergencyDetails	lightsUse	LightbarInUse	M	Yes/No	
6.1.2	Broadcast emergency response indication <Safe2>	CAM	camParameters	CamParameters	specialVehicleContainer	SpecialVehicleContainer	M	Yes/No	
6.1.2	Broadcast emergency response indication <Safe2>	CAM	emergencyContainer	EmergencyContainer	lightbarSirenInUse	LightBarSirenInUse	M	Yes/No	
6.2.1 6.2.2	Transmit pre-empt request	SRM	N/A	N/A	MessageTypes	SignalRequestMessage	M	Yes	
6.2.1 6.2.2	Transmit pre-empt request	SRM	request	SignalRequest	requestType	PriorityRequestType	M	Yes	
6.2.3	Request signal pre-empt — Message identifier	SRM	MessageFrame	SEQUENCE	&id	DSRCmsgID	M	Yes	
6.2.4	Request signal pre-empt — Intersection identifier	SRM	request	SignalRequest	Id	IntersectionReferenceID	M	Yes	
6.2.5	Request signal pre-empt — Approach lane	SRM	request	SignalRequest	inBoundLane	IntersectionAccessPoint	M	Yes	
6.2.6	Request signal pre-empt — Egress lane	SRM	request	SignalRequest	outBoundLane	IntersectionAccessPoint	O	Yes/No	
6.2.7	Request signal pre-empt — Vehicle class	SRM	type	RequestorType	role	BasicVehicleRole	O	Yes/No	
6.2.7	Request signal pre-empt — Vehicle class	SRM	type	RequestorType	subRole	RequestSubRol	O	Yes/No	
6.2.7	Request signal pre-empt — Vehicle class	SRM	type	RequestorType	request	RequestImportanceLevel	O	Yes/No	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Con-form-ance	Support/ project re-quirement	Addi-tional require-ment
6.2.8	Request signal pre-empt — Time of service	SRM	requests	SignalRequest-Package	minute	MinuteOfTheYear	O	Yes/No	
6.2.8	Request signal pre-empt — Time of service	SRM	requests	SignalRequest-Package	second	Dsecond	O	Yes/No	
6.2.9	Request signal pre-empt — Vehicle identity	SRM	requestor	RequestorDescrip-tion	id	VehicleID	M	Yes	
6.2.10	Request signal pre-empt — Vehicle location and speed	SRM	position3D	Position3D	lat	Latitude	O	Yes/No	
6.2.10	Request signal pre-empt – Vehicle location and speed	SRM	position3D	Position3D	long	Longitude	O	Yes/No	
6.2.10	Request signal pre-empt — Vehicle location and speed	SRM	speed	TransmissionAnd-Speed	speed	Velocity	O	Yes/No	
6.2.10	Request signal pre-empt — Vehicle location and speed	SRM	position	RequestorPosi-tionVector	heading	Angle	O	Yes/No	
6.2.11	Request signal pre-empt — Cancellation	SRM	request	SignalRequest	requestType	PriorityRequestType	M	Yes	
6.2.12	Request signal pre-empt — Transaction identifier	SRM	request	SignalRequest	requestID	RequestID	M	Yes	
6.2.13	Request signal pre-empt — Duration	SRM	requests	SignalRequest-Package	duration	DSecond	O	Yes/No	
6.3.1	Broadcast priority request-ing vehicle information	BSM (P1)	N/A	N/A	MessageTypes	BasicSafetyMessage	M	Yes	
6.4.1	Transmit priority request	SRM	N/A	N/A	MessageTypes	SignalRequestMes-sage	M	Yes	
6.4.1	Transmit priority request	SRM	request	SignalRequest	requestType	PriorityRequestType	M	Yes	
6.4.2	Transmit priority request — Message identifier	SRM	MessageFrame	SEQUENCE	&id	DSRCmsgID	M	Yes	
6.4.3	Transmit priority request — Intersection identifier	SRM	request	SignalRequest	id	IntersectionReferen-ceID	M	Yes	

Table C.1 *(continued)*

Requirement		Design						Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Conformance	Support/ project requirement	Additional requirement
6.4.4	Transmit priority request — Approach lane	SRM	request	SignalRequest	inBoundLane	IntersectionAccessPoint	M	Yes	
6.4.5	Transmit priority request — Egress lane	SRM	request	SignalRequest	outBoundLane	IntersectionAccessPoint	O	Yes/No	
6.4.6	Transmit priority request — Vehicle class	SRM	type	RequestorType	role	BasicVehicleRole	O	Yes/No	
6.4.6	Transmit priority request — Vehicle class	SRM	type	RequestorType	subRole	RequestSubRol	O	Yes/No	
6.4.6	Transmit priority request — Vehicle class	SRM	type	RequestorType	request	RequestImportanceLevel	O	Yes/No	
6.4.7	Transmit priority request — Time of service	SRM	requests	SignalRequestPackage	minute	MinuteOfTheYear	O	Yes/No	
6.4.7	Transmit priority request — Time of service	SRM	requests	SignalRequestPackage	second	Dsecond	O	Yes/No	
6.4.8	Transmit priority request — Vehicle identity	SRM	requestor	RequestorDescription	id	VehicleID	M	Yes	
6.4.9	Transmit priority request — Vehicle location and speed	SRM	position3D	Position3D	lat	Latitude	O	Yes/No	
6.4.9	Transmit priority request — Vehicle location and speed	SRM	position3D	Position3D	long	Longitude	O	Yes/No	
6.4.9	Transmit priority request — Vehicle location and speed	SRM	speed	TransmissionAndSpeed	speed	Velocity	O	Yes/No	
6.4.9	Transmit priority request — Vehicle location and speed	SRM	position	RequestorPositionVector	heading	Angle	O	Yes/No	
6.4.10	Transmit priority request — Service information	SRM	requestor	RequestorDescription	transitOccupancy	TransitVehicleOccupancy	O	Yes/No	
6.4.10	Transmit priority request — Service information	SRM	requestor	RequestorDescription	transitStatus	TransitVehicleStatus	O	Yes/No	
6.4.11	Transmit priority request cancellation	SRM	request	SignalRequest	requestType	PriorityRequestType	M	Yes	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Conformance	Support/ project requirement	Additional requirement
6.4.12	Request signal pre-empt — Priority request level	SRM	type	RequestorType	request	RequestImportanceLevel	O	Yes/No	
6.4.13	Transmit priority request — Transaction identifier	SRM	request	SignalRequest	requestID	RequestID	M	Yes	
6.4.14	Request signal priority — Duration	SRM	requests	SignalRequestPackage	duration	DSecond	O	Yes/No	
6.4.15	Request signal priority — Transit schedule	SRM	Requestor	RequestorDescription	transitSchedule	DeltaTime	O	Yes/No	
6.5.1	Broadcast area geometrics	MAP	N/A	N/A	MessageTypes	MapData	M	Yes	
6.5.2	Broadcast roadway geometrics — Message identifier	MAP	MessageFrame	SEQUENCE	&id	DSRCmsgID	M	Yes	
6.5.2	Broadcast roadway geometrics — Message identifier	MAP	MSG_MapData	MapData	msgIssueRevision	MsgCount	M	Yes	
6.5.3	Broadcast intersection — Identifier	MAP	intersections	IntersectionGeometry	id	IntersectionReferenceID	M	Yes	
6.5.4	Broadcast intersection — Reference point	MAP	intersections	IntersectionGeometry	refPoint	Position3D	M	Yes	
6.5.4	Broadcast intersection — Reference point	MAP	refPoint	Position3D	lat	Latitude	M	Yes	
6.5.4	Broadcast intersection — Reference point	MAP	refPoint	Position3D	long	Longitude	M	Yes	
6.5.4	Broadcast intersection — Reference point	MAP	refPoint	Position3D	elevation	Elevation	O	Yes/No	
6.5.5	Broadcast intersection — Lane default width	MAP	intersections	IntersectionGeometry	laneWidth	LaneWidth	O	Yes/No	
6.5.6	Broadcast intersection — Egress lanes	MAP	laneSet	GenericLane	egressApproach	ApproachID	O	Yes/No	
6.5.7	Broadcast intersection — Approach lanes	MAP	intersections	IntersectionGeometry	laneset	GenericLane	M	Yes	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Conformance	Support/ project requirement	Additional requirement
6.5.7	Broadcast intersection — Approach lanes	MAP	laneSet	GenericLane	ingressApproach	ApproachID	M	Yes	
6.5.8	Broadcast intersection — Lane number	MAP	laneSet	GenericLane	laneID	LaneID	M	Yes	
6.5.8	Broadcast intersection — Lane number	MAP	laneSet	GenericLane	ingressApproach	ApproachID	M	Yes	
6.5.9	Broadcast intersection — Lane centerline coordinates	MAP	nodes	NodeXY	delta	NodeOffsetPointXY	M	Yes	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	laneSet	GenericLane	manoeuvres	AllowedManeuvers	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	laneAttributes	LaneAttributes	laneType	LaneTypeAttributes	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	laneAttributes	LaneAttributes	sharedWith	LaneSharing	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	laneSet	GenericLane	overlays	OverlayLaneList	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	connectingLane	ConnectingLane	manoeuvre	AllowedManeuvers	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	connectingLane	ConnectingLane	userClass	RestrictionClassID	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	userClass	RestrictionClassID	id	RestrictionClassID	M.2(1...)	Yes/No	
6.5.10	Broadcast intersection — Vehicle lane manoeuvres	MAP	userClass	RestrictionClassID	users	RestrictionUser-TypeList	M.2(1...)	Yes/No	
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	MAP	laneSet	GenericLane	manoeuvres	AllowedManeuvers	O	Yes/No	
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	MAP	laneAttributes	LaneAttributes	laneType	LaneTypeAttributes	O	Yes/No	
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	MAP	laneAttributes	LaneAttributes	sharedWith	LaneSharing	O	Yes/No	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Con-form-ance**	**Support/ project re-quirement**	**Addi-tional require-ment**
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	MAP	laneAttributes	LaneAttributes	directionalUse	LaneDirection	O	Yes/No	
6.5.11	Broadcast intersection — Pedestrian lane manoeuvres	MAP	laneSet	GenericLane	overlays	OverlayLaneList	O	Yes/No	
6.5.12	Broadcast intersection — Special lane manoeuvres	MAP	laneSet	GenericLane	manoeuvres	AllowedManeuvers	O	Yes/No	
6.5.12	Broadcast intersection — Special lane manoeuvres	MAP	laneAttributes	LaneAttributes	laneType	LaneTypeAttributes	O	Yes/No	
6.5.12	Broadcast intersection — Special lane manoeuvres	MAP	laneAttributes	LaneAttributes	sharedWith	LaneSharing	O	Yes/No	
6.5.12 6.5.12	Broadcast intersection — Special lane manoeuvres	MAP	laneAttributes	LaneAttributes	directionalUse	LaneDirection	O	Yes/No	
6.5.12	Broadcast intersection — Special lane manoeuvres	MAP	laneSet	GenericLane	overlays	OverlayLaneList	O	Yes/No	
6.5.13	Broadcast intersection — Version identifier	MAP	intersections	IntersectionGeom-etry	revision	MsgCount	M	Yes	
6.5.14	Broadcast intersection — Crossings	MAP	intersections	IntersectionGeom-etry	laneSet	GenericLane	O	Yes/No	
6.5.15	Broadcast intersection — Lane width	MAP	intersections	IntersectionGeom-etry	laneWidth	LaneWidth	O	Yes/No	
6.5.16	Broadcast intersection — Node lane width	MAP	attributes	NodeAttributeSet	dWidth	Offset-B10	O	Yes/No	
6.5.17	Broadcast intersection — Egress connection	MAP	connectingLane	ConnectingLane	lane	LaneID	O	Yes/No	
6.5.17	Broadcast intersection — Egress connection	MAP	connectingLane	ConnectingLane	manoeuvre	AllowedManeuvers	O	Yes/No	
6.5.18	Broadcast intersection — Traffic control	MAP	intersections	IntersectionGeom-etry	laneSet	GenericLane	O	Yes/No	
6.5.18	Broadcast intersection — Traffic control	MAP	connectingLane	ConnectingLane	manoeuvre	AllowedManeuvers	O	Yes/No	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Con-form-ance**	**Support/ project re-quirement**	**Addi-tional require-ment**
6.5.19	Broadcast intersection — Traffic control by lane	MAP	intersections	IntersectionGeom-etry	laneSet	GenericLane	O	Yes/No	
6.5.19	Broadcast intersection — Traffic control by lane	MAP	connectingLane	ConnectingLane	manoeuvre	AllowedManeuvers	O	Yes/No	
6.5.20	Broadcast road conditions	BSM (P2)	weatherReport	Sequence	isRaining	NTCIP.EssPrecipYe-sNo	O	Yes/No	
6.5.20	Broadcast road conditions	BSM (P2)	weatherReport	Sequence	friction	NTCIP.EssMobileFric-tion	O	Yes/No	
6.5.21	Broadcast intersection — Signal group	MAP	connectsTo	Connection	signalGroup	SignalGroupID	M	Yes	
6.6.1	Broadcast GNSS augmenta-tions detail (**location**)	Choice	NA	NA	NA	NMEAcorrections or RTCMcorrections	M	Yes	Choice: NMEA: Y/N RTCM: N/Y
6.6.2	Broadcast GNSS augmen-tations detail — NMEA <**location**>	NMEA	NA	NA	MessageTypes	NMEAcorrections	O.1(1)	Yes/No	
6.6.3	Broadcast GNSS augmenta-tions detail — RTCM <**loca-tion**>	RTCM	NA	NA	MessageTypes	RTCMcorrections	O.1(1)	Yes/No	
6.7.1	Broadcast signal phase and timing information	SPaT	NA	NA	MessageTypes	SPAT	M	Yes	
6.7.2	Broadcast signal phase and timing — Message identifier	SPaT	MessageFrame	SEQUENCE	&id	DSRCmsgID	M	Yes	
6.7.3	Broadcast signal phase and timing — Intersection identifier	SPaT	intersections	IntersectionState	id	IntersectionReferen-ceID	M	Yes	
6.7.4	Broadcast signal phase and timing — Intersection status	SPaT	intersections	IntersectionState	status	IntersectionStatus-Object	M	Yes	
6.7.5	Broadcast signal phase and timing — Timestamp	SPaT	intersections	IntersectionState	moy	MinuteOfTheYear	M	Yes	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Con-form-ance	Support/project re-quirement	Addi-tional require-ment
6.7.5	Broadcast signal phase and timing — Timestamp	SPaT	intersections	IntersectionState	timeStamp	DSecond	M	Yes	
6.7.6	Broadcast manoeuvre — Signal group	SPaT	states	MovementState	signalGroup	SignalGroupID	M	Yes	
6.7.7	Broadcast manoeuvre — Manoeuvre state	SPaT	states	MovementState	signalGroup	SignalGroupID	M	Yes	
6.7.7	Broadcast manoeuvre — Manoeuvre state	SPaT	states	MovementState	state-time-speed	MovementEvent	M	Yes	
6.7.8	Broadcast manoeuvre — Vehicular state	SPaT	state-time-speed	MovementEvent	eventState	MovementPhaseState	M	Yes	
6.7.9	Broadcast manoeuvre — Pedestrian state	SPaT	state-time-speed	MovementEvent	eventState	MovementPhaseState	O	Yes/No	
6.7.10	Broadcast manoeuvre — Special state	SPaT	regional	NA.Reg-MovementState	specialSignalState	SpecialSignalState	O	Yes/No	
6.7.11	Broadcast manoeuvre — Time of change – minimum	SPaT	timing	TimeChangeDetails	minEndTime	TimeMark	M	Yes	
6.7.12	Broadcast manoeuvre — Time of change - maximum	SPaT	timing	TimeChangeDetails	maxEndTime	TimeMark	O	Yes/No	
6.7.13	Broadcast manoeuvre — Succeeding signal indications	SPaT	state-time-speed	MovementEvent	eventState	MovementPhaseState	O	Yes/No	
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	SPaT	timing	TimeChangeDetails	minEndTime	TimeMark	O	Yes/No	
6.7.15	Broadcast pending manoeuvre start times	SPaT	timing	TimeChangeDetails	nextTime	TimeMark	O	Yes/No	
6.7.16	Broadcast manoeuvre — Pedestrian detect	SPaT	maneuverAssistList	Connection-ManeuverAssist	pedBicycleDetect	PedestrianBicycle-Detect	O	Yes/No	
6.7.17	Broadcast manoeuvre — Pedestrian call	SPaT	regional	NA.Reg-ConnectionManeuverAssist	pedBicycleCall	PedestrianBicycle-Call	O	Yes/No	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Con-form-ance**	**Support/ project re-quirement**	**Addi-tional require-ment**
6.7.18	Broadcast manoeuvre — Op-timal speed information	SPaT	speeds	AdvisorySpeed	type	AdvisorySpeedType	O	Yes/No	
6.7.18	Broadcast manoeuvre — Op-timal speed information	SPaT	speeds	AdvisorySpeed	speed	SpeedAdvice	O	Yes/No	
6.7.19	Broadcast manoeuvre — Sig-nal progression information	SPaT	speeds	AdvisorySpeed	type	AdvisorySpeedType	O	Yes/No	
6.7.19	Broadcast manoeuvre — Sig-nal progression information	SPaT	speeds	AdvisorySpeed	speed	SpeedAdvice	O	Yes/No	
6.7.20	Broadcast manoeuvre — Egress lane queue	SPaT	maneuverAs-sistList	Connection-ManeuverAssist	queueLength	ZoneLength	O	Yes/No	
6.7.21	Broadcast manoeuvre — Egress lane storage availa-bility	SPaT	maneuverAs-sistList	Connection-ManeuverAssist	availableStorage-Length	ZoneLength	O	Yes/No	
6.7.22	Broadcast manoeuvre — Wait indication	SPaT	maneuverAs-sistList	Connection-ManeuverAssist	waitOnStop	WaitOnStopLine	O	Yes/No	
6.11.1	Broadcast signal preferential treatment status	SSM	NA	NA	MessageTypes	SignalStatusMessage	M	Yes	
6.11.2	Broadcast preferential treat-ment — Message identifier	SSM	MessageFrame	SEQUENCE	&id	DSRCmsgID	M	Yes	
6.11.3	Broadcast preferential treatment — Intersection identifier	SSM	status	SignalStatus	id	IntersectionReferen-ceID	M	Yes	
6.11.4	Broadcast preferential treat-ment — Intersection status	SSM	status	SignalStatus	sigStatus	Signa lStatusPackage	M	Yes	
6.11.5	Broadcast preferential treatment — Prioritization request status	SSM	signalStatus	SignalStatusPack-age	status	PrioritizationRe-sponseStatus	M	Yes	
6.11.6	Broadcast preferential treat-ment — Vehicle source	SSM	requestor	SignalRequestorID	id	VehicleID	M	Yes	

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	Title	Msg	Parent identifier	Parent type	Identifier	Identifier type	Con-form-ance	Support/ project re-quirement	Addi-tional require-ment
6.11.7	Broadcast preferential treatment — Transaction identifier	SSM	requestor	SignalRequestorID	iequest	RequestID	M	Yes	
6.12	Message identifier	BSM	coreData	BSMcoreData	msgCount	MsgCount	M	Yes	
6.12	Message identifier	BSM	coreData	BSMcoreData	id	TemporaryID	M	Yes	
6.13.1	Broadcast intersection — Computed lane	MAP	computed	ComputedLane	referenceLaneId	LaneID	O	Yes/No	
6.13.1	Broadcast intersection — Computed lane	MAP	computed	ComputedLane	offsetXaxis	choice: small, large	O	Yes/No	Choice: small: Y/N large: N/Y
6.13.1	Broadcast intersection — Computed lane	MAP	computed	ComputedLane	offsetYaxis	choice: small, large	O	Yes/No	Choice: small: Y/N large: N/Y
6.13.1	Broadcast intersection — Computed lane	MAP	computed	ComputedLane	rotateXY	Angle	O	Yes/No	
6.14.1	Maximum transmission rate — Request signal preferential treatment	SRM	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.14.2	Maximum response time — Request signal preferential treatment	SSM	N/A	N/A	N/A	N/A	O	Yes/No	ms
6.14.3	Minimum transmission rate — signal status message	SSM	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.14.4	Minimum transmission period — signal status message	SSM	N/A	N/A	N/A	N/A	O	Yes/No	Period of s
6.15.1	Minimum transmission rate — Broadcast roadway geometrics information	MAP	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz

Table C.1 *(continued)*

Requirement		Design						Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Con-form-ance**	**Support/ project re-quirement**	**Addi-tional require-ment**
6.15.2	Maximum transmission rate - Broadcast roadway geometrics information	MAP	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.15.3	Default transmission rate — Broadcast roadway geomet-rics information	MAP	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.16.1	Minimum transmission rate — GNSS augmentation details broadcasts	NMEA	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.16.1	Minimum transmission rate — GNSS augmentation details broadcasts	RTCM	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.16.2	Default transmission rate — GNSS augmentation details broadcasts	NMEA	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.17.2	Default transmission rate — GNSS augmentation details broadcasts	RTCM	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.17.1	Minimum transmission rate — Broadcast signal phase and timing information	SPaT	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.17.2	Maximum transmission rate — Broadcast signal phase and timing information	SPaT	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.17.3	Default transmission rate — Broadcast signal phase and timing information	SPaT	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.18.1	Minimum transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz

Table C.1 *(continued)*

Requirement		Design					Project	Implementation	
ID	**Title**	**Msg**	**Parent identifier**	**Parent type**	**Identifier**	**Identifier type**	**Conformance**	**Support/ project requirement**	**Additional requirement**
6.18.2	Maximum transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.18.3	Default transmission rate — Broadcast cross traffic sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.19.1	Minimum transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.19.2	Maximum transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz
6.19.3	Default transmission rate — Broadcast vulnerable road user sensor information	N/A	N/A	N/A	N/A	N/A	O	Yes/No	Rate of Hz

Annex D
(normative)

Extension procedures

The SAE J2735™ data dictionary is constructed with a mechanism for extending messages for local (i.e. regional) needs. The goals of the mechanism are described in SAE J2735™:2016, 11.1 and preserve the separation of the SAE J2735™ content from regional extensions. Rules for extending the data dictionary are laid out in SAE J2735™:2016, 11.2 as are examples.

Another aspect of SAE J2735™ extensibility is a set of messages to support the development and testing of new C-ITS applications without the need to update the base data dictionary. Specifically, SAE J2735™ states that the test messages "are intended to allow the development of entirely new messages for serving use cases and applications not covered by the existing message set." These messages are completely extendable using existing data dictionary content and/or new content necessary for supporting the application.

Users of this document shall conform to the extension requirements contained in SAE J2735™ as defined in SAE J2735™:2016, 11.2 when extending the messages and data frames defined in this document. As data elements are not extendable, extending this document's data dictionary shall be done by creating new data elements and types or reusing existing data elements and types.

It is critical that any extension of the messages be vetted and tested due to the impacts of increasing message sizes have on bandwidth utilization and timing relationships.

Annex E
(normative)

Profile A for J2735™

E.1 General

This annex addresses the use cases, requirements, and traceability matrices as applied to one region. The use cases are listed in Annex A, the requirements are listed in Clause 6, and the traceability matrices are documented in Annex B and Annex C. When implementing this document using Profile A, Annex C shall be normative.

The ISO/TS 19091 MAP, SPaT, SRM, and SSM messages shall conform to the structure specified in SAE J2735™-201603with the additions as specified in this annex. Note that each J2735™ mandatory data frame and data element shall be present in the message to maintain conformance with J2735™ at the data dictionary level regardless of their inclusion in the requirements traceability matrix. All transmitted BSM messages, while beyond the scope of this document, shall conform to the J2735™ data dictionary requirements for BSM messages, as well as performance requirements in the SAE J2945 series.

E.2 MAP

E.2.1 SAE J2735™ MAP elements

ISO/TS 19091 MAP message shall satisfy the mandatory requirements for the MSG_MapData message specified in SAE J2735™, as well as implement each mandatory and selected optional requirement as listed in Annex C. Each ISO/TS 19091 data element that is not specified within SAE J2735™ shall be incorporated into the J2735™ message structure and satisfy the J2735™ requirements for extending the J2735™ message.

E.2.2 Profile A MAP elements

This annex does not augment the base MAP message with any regional extensions.

E.2.3 Profile A MAP performance requirements

The ISO/TS 19091 MAP message shall meet the mandatory performance requirements as selected in Annex C. Note that future minimum performance requirements specified in the SAE J2945 series may be required to maintain conformance.

E.2.4 Profile A MAP ASN.1

No additional data elements are required.

E.3 SPaT

E.3.1 SAE J2735™ SPaT elements

ISO/TS 19091 SPaT message shall satisfy the mandatory requirements for the MSG_SignalPhaseAndTiming message specified in SAE J2735™, as well as implement each mandatory and selected optional requirement as listed in Annex C. Each ISO/TS 19091 data element that is not specified within SAE J2735™ shall be incorporated into the J2735™ message structure and satisfy the J2735™ requirements for extending the J2735™ message.

E.3.2 Profile A SPaT elements

This annex supplements the base SPaT message by adding regional content to the connection manoeuvre assist for pedestrian/bicycle phase calls, for movement states to address fixed (e.g. tracked) guideway special lanes.

E.3.3 Profile A SPaT performance requirements

The ISO/TS 19091 SPaT message shall meet the mandatory performance requirements as selected in Annex C. Note that future minimum performance requirements specified in the SAE J2945 series may be required to maintain conformance.

E.3.4 Profile A SPaT ASN.1

E.3.4.1 Data frame: DF_NA.Reg_ConnectionManeuverAssist

Use: The regional definition of any extensions to this data frame, if required. Used to allow each region to add additional content to a given data frame to suit regional needs. In such use, the required elements are defined below to augment the base technical specification. Each region will define this data concept and the containing namespace, as it requires.

ASN.1 Representation:

```
NA.Reg-ConnectionManeuverAssist ::= SEQUENCE {
   pedBicycleCall     PedestrianBicycleCall OPTIONAL,
   ...
   }
```

Used by: This entry is used directly by one other data structure in this document, a DF called DF_Regional_ConnectionManeuverAssist <ASN> <>. In addition, this item may be used by data structures in other ITS standards.

E.3.4.2 Data frame: DF_NA.Reg-MovementState

Use: The regional extension to allow North America to define additional content for a given data frame to suit regional needs, if required.

ASN.1 Representation:

```
NA.Reg-MovementState ::= SEQUENCE {
   specialSignalState    SpecialSignalState OPTIONAL,
   ...
   }
```

Used by: This entry is used directly by one other data structure in this document, a DF called DF_MovementState <ASN> <>.

E.3.4.3 Data element: DE_PedestrianBicycleCall

Use: The PedestrianBicycleCall data concept is used to provide an indication that pedestrians and/or bicyclists who have requested service are therefore in the vicinity of the intersection.

ASN.1 Representation:

```
PedestrianBicycleCall ::= BOOLEAN --
                 -- true if ANY Pedestrians or Bicyclists have activated the
                 -- crossing signal
```

Used by: This entry is used directly by one other data structure in this document, a DF called DF_REG-ConnectionManeuverAssist <ASN> <>. In addition, this item may be used by data structures in other ITS standards.

E.3.4.4 Data element: DE_SpecialSignalState (SAE J2735™ Revised NOV2009 - 218 -)

Use: A data element indicating the **current** signal state of a particular, known special lane type (such as a train). Used in the SPaT frame.

ASN.1 Representation:

```
SpecialSignalState ::= ENUMERATED {
       unknown             (0),
       notInUse            (1), -- (B0001) default state, empty, not in use
       arriving            (2), -- (B0010) track-lane about to be occupied
       present             (3), -- (B0100) track-lane is occupied with vehicle
       departing           (4), -- (B1000) track-lane about to be empty
       ...
       } -- one byte
```

E.4 SRM

E.4.1 SAE J2735™ SRM elements

ISO/TS 19091 SRM message shall satisfy the mandatory requirements for the MSG_SignalRequestMessage message specified in SAE J2735™, as well as implement each mandatory and selected optional requirement as listed in Annex C. Each ISO/TS 19091 data element that is not specified within SAE J2735™ shall be incorporated into the J2735™ message structure and satisfy the J2735™ requirements for extending the J2735™ message.

E.4.2 Profile A SRM elements

This annex supplements the base SRM message by adding the regional requestor description to identify the location of the requesting connected vehicle.

E.4.3 Profile A SRM performance requirements

The ISO/TS 19091 SRM message shall meet the mandatory performance requirements as selected in Annex C. Note that future minimum performance requirements specified in the SAE J2945 series may be required to maintain conformance.

E.4.4 Profile A SRM ASN.1

No additional elements required.

E.5 SSM

E.5.1 SAE J2735™ SSM elements

ISO/TS 19091 SSM message shall satisfy the mandatory requirements for the MSG_SignalStatusMessage message specified in SAE J2735™, as well as implement each mandatory and selected optional requirement as listed in Annex C. Each ISO/TS 19091 data element that is not specified within SAE J2735™ shall be incorporated into the J2735™ message structure and satisfy the J2735™ requirements for extending the J2735™ message.

E.5.2 Profile A SSM elements

This annex does not augment the base SSM message with any regional extensions.

E.5.3 Profile A SSM performance requirements

The ISO/TS 19091 SSM message shall meet the mandatory performance requirements as selected in Annex C. Note that future minimum performance requirements specified in the SAE J2945 series may be required to maintain conformance.

E.5.4 Profile A SSM ASN.1

None

E.6 Examples — Profile A PICS

See Annex C to select the optional requirements necessary for fulfilling the use case needs as listed in Annex B.

Annex F
(normative)

Profile B for J2735™

F.1 General

This annex provides a simplified message profile concerned with MAP, SPaT, SRM, and SSM for some regions, typically Japan, where the signal control systems do not operate lane-by-lane control in general. This means that the message profile described in this annex addresses use cases which require not lane unit description but approach unit description. Use cases, which this message profile will be applied to, are shown in Table F.1.

Table F.1 — List of use cases related to this annex

ID	Title
SA1	Dilemma zone protection
SA2	Red light violation warning
SA3	Stop sign violation warning
SA4	Turning assistant — Oncoming traffic
SA5	Turning assistant — Vulnerable road user avoidance
SA6	Non-signalized crossing traffic warning
SA7	Crossing vulnerable road user advisory (non-signalized)
MS4	Traffic signal optimal speed advisory
MS5	Signalized corridor eco-driving speed guidance
MS6	Idling stop support
MS7	Start delay prevention

F.2 Normative references

The following referenced documents are normatively referenced in this annex. And these shall supersede the normative references listed in the main part of this document.

ISO 26684, *Intelligent transport systems (ITS) — Cooperative intersection signal information and violation warning systems (CIWS) — Performance requirements and test procedures*

ISO 22951, *Data dictionary and message sets for preemption and prioritization signal systems for emergency and public transport vehicles (PRESTO)*

ARIB STD-T109, *700 MHz Band Intelligent Transport Systems*

ITS FORUM RC-010, 700 MHz Band Intelligent Transport Systems — Extended Functions Guideline, published on March 15, 2012

F.3 MAP message specification

F.3.1 General

Use: This MAP_OpB message is used to convey geometric information of the intersection. This includes such items as an intersection description, ingresses, egress pathways, and connected sub-links.

ASN.1 Representation:

```
Map_OpB ::= SEQUENCE{
  commonHeader   CommonHeader,
  identifier  IntersectionIdentifier,
  positionReferencePoint  REG_Position3D_JPN,
  apprAttribute SEQUENCE (SIZE(1..8))  OF ApproachAttribute,
  ingress  SEQUENCE(SIZE(0..8))  OF IngressApproach,
  egress  SEQUENCE(SIZE(0..8))  OF EgressPathway,
  ...
}
```

F.3.2 Identification of the data elements and data frames

F.3.2.1 General

This subclause provides information to identify the specific data concepts, with references to the data elements and data frames related to MAP contained in SAE J2735™.

F.3.2.2 List of data frames contained in SAE J2735™

DF_LatitudeDMS2

DF_LongitudeDMS2

DF_REG_Position3D_JPN

DF_TimeMark_JPN

F.3.2.3 List of data elements contained in SAE J2735™

DE_ApproachID

DE_StationID

DE_Angle_JPN

DE_Day_JPN

DE_DayOfWeek_JPN

DE_DegreesLat_JPN

DE_DegreesLong_JPN

DE_Elevation_JPN

DE_Holiday_JPN

DE_Hour_JPN

DE_Minute_JPN

DE_MinutesAngle_JPN

DE_Month_JPN

DE_MsgCount_JPN

DE_Second_JPN

DE_SecondAngle_JPN

DE_SummerTime_JPN

DE_TenthSecond_JPN

DE_Year_JPN

F.3.3 Definition of the data frames

F.3.3.1 General

This subclause provides information to define the specific data frames related to this annex.

F.3.3.2 DF_ApproachAttribute

Use: The "ApproachAttribute" is used to describe the general information of each approach of an intersection.

ASN.1 Representation:

```
ApproachAttribute::= SEQUENCE{
  apprID  ApproachID,
        -- ID information of an approach at an intersection
        -- The number shall be unique in the specified intersection
  apprDirection  Angle_JPN,
        -- Connection angle of approach with intersection
  apprType  ApproachType,
        -- Type of the approach to indicate the existence of ingress and egress
  identifier-I  IngressIdentifier,
        -- This data provides the data to identify ingress belonging to this approach
  identifier-E  EgressIdentifier,
        -- This data provides the data to identify egress belonging to this approach
  ...
}
```

F.3.3.3 DF_BranchAttribute

Use: The "BranchAttribute" is used to describe the attribute information of a branch sub-link.

ASN.1 Representation:

```
BranchAttribute ::= SEQUENCE{
  brnDirection  Angle_JPN,
            -- Connection angle of branch road with Branch Node (defined in
            -- DE_NodeAttribute_OpB)
  nodeList  SEQUENCE (SIZE(0..64))  OF Node_OpB,
        -- Information of each node belonging to this branch
  ...
}
```

F.3.3.4 DF_BranchSublink

Use: The "BranchSublink" is used to describe the information of branch sub-link connected with a branch node, where this sub-link branches from ingress.

ASN.1 Representation:

```
BranchSublink ::= SEQUENCE{
  brnID  BranchSublinkID  OPTIONAL,
  brnAttribute  SEQUENCE  (SIZE(1..8))  OF BranchAttribute,
  ...
}
```


F.3.3.5 DF_CommonHeader

Use: The "CommonHeader" data structure is used to describe the information of RSE and the general information of message.

ASN.1 Representation:

```
CommonHeader ::= SEQUENCE{
  communicationType  CommunicationType,
         -- Information about the communication types
  Identifier  VersionIdentifier,
         -- The data to identify message version
  identifier  RSEIdentifier,
         -- Specific information about the RSE,
         -- which includes ID and the prefecture code where RSE is installed
  operationMode          OperationMode,
         -- Operation status (test mode or live mode)
  msgID              MessageID_OpB,
         -- ID information to identify a message type
  msgcount              MsgCount_JPN,
         -- A sequence number within a stream of messages from the same sender
  time                TimeMark_JPN,
         -- Information about when the message is generated
         -- It contains the information of the year, the month, the day,
         -- summer time or not, holiday or not,  day of the week, the hour,
         -- the minute, the second and the tenthsecond
  msgSize             MessageSize,
         -- Data size of a message
  ...
}
```

F.3.3.6 DF_DivergenceAttribute

Use: The "DivergenceAttribute" is used to describe the attribute information of a divergence pathway.

ASN.1 Representation:

```
DivergenceAttribute ::= SEQUENCE{
  apprType ApproachType,
        -- Type of the approach to indicate the existence of ingress and egress
  divDirection Angle_JPN,
        -- Connection angle of Divergence pathway with Divergence Node
        -- (defined in DE_NodeAttribute_OpB)
  ...
}
```

F.3.3.7 DF_DivergencePathway

Use: The "DivergencePathway" is used to describe the information of pathways connected with a divergence node, where these pathways diverge from ingress. This is used to describe the out-of-service location.

ASN.1 Representation:

```
DivergencePathway::= SEQUENCE{
  divId  DivergencePathwayID  OPTIONAL,
  divAttribute  SEQUENCE  (SIZE(1..8))  OF DivergenceAttribute,
  ...
}
```

F.3.3.8 DF_DownstreamIntersectionAttribute

Use: The "DownstreamIntersectionAttribute" is used to describe the attribute information about one of the downstream intersections belonging to egress pathway.

ASN.1 Representation:

```
DownstreamIntersectionAttribute::= SEQUENCE{
 id IntersectionID_OpB,
        -- ID information of an intersection in the specified prefecture
 ingress  IngressApproach,
        -- An ingress information of a downstream intersection
 ...
}
```

F.3.3.9 DF_EgressPathway

Use: The "EgressPathway" is used to describe the information of egress pathway.

ASN.1 Representation:

```
EgressPathway ::= SEQUENCE{
  egressId EgressPathwayID OPTIONAL,
          -- ID information of the egress pathway
          downstreamIntersectionAttribute SEQUENCE (SIZE(1..16)) OF
DownstreamIntersectionAttribute,--Attribute of each downstream intersection belonging to
egress pathway
  ...
}
```

F.3.3.10 DF_EgressIdentifier

Use: The EgressIdentifier contains data to identify egress pathway belonging to the approach that is EgressID and/or the storage address.

ASN.1 Representation:

```
EgressIdentifier::= = SEQUENCE {
 egressId     EgressPathwayID OPTIONAL,
 address   StorageAdress OPTIONAL,
                -- Byte length from the head of message
 ...
}
```

F.3.3.11 DF_IngressApproach

Use: The "IngressApproach" is used to describe the ingress information of an approach.

ASN.1 Representation:

```
IngressApproach::= SEQUENCE{
  ingressId     IngressID OPTIONAL,
  nodeList  SEQUENCE (SIZE(0..64)) OF Node_OpB,
  diverge SEQUENCE (SIZE(0..64)) OF DivergencePathway,
  brnSublink SEQUENCE (SIZE(0..64)) OF BranchSublink,
  mrgSublink SEQUENCE (SIZE(0..64)) OF MergeSublink,
  ...
}
```


F.3.3.12 DF_IngressIdentifier

Use: The "IngressIdentifier" contains data to identify ingress approach that is IngressID and/or the storage address.

ASN.1 Representation:

```
IngressIdentifier::= = SEQUENCE {
   ingressId   IngressID  OPTIONAL,
   address   StorageAdress  OPTIONAL,
                -- Byte length from the head of message
   ...
}
```

F.3.3.13 DF_IntersectionIdentifier

Use: The "IntersectionIdentifier" is used to uniquely define an intersection within a country. This includes prefecture code, road type, and the ID.

ASN.1 Representation:

```
IntersectionAttribute ::= SEQUENCE{
  prefectureID  PrefectureID,
         -- Prefecture information
  roadType  RoadType,
         -- Road type information to indicate the intersection and non-intersection
  intersectionID  IntersectionID_OpB,
         -- ID information in the specified prefecture
...
}
```

F.3.3.14 DF_MergeSublink

Use: The "MergeSublink" is used to describe the information of merge sub-link connected with a merge node, where this sub-link merges into an ingress.

ASN.1 Representation:

```
MergeSublink::= SEQUENCE{
  mrgID  MergeSublinkID,
  mrgDirection  Angle_JPN,
        -- Connection angle of Merge approach with Merge Node (defined in
        -- DE_NodeAttribute_OpB)
  nodeList SEQUENCE (SIZE(0..64)) OF Node_OpB,
  ...
}
```

F.3.3.15 DF_Node_OpB

Use: The "Node_OpB" is used to describe the position information of a point in a representative lane of an ingress with the attributes information.

ASN.1 Representation:

```
Node_OpB::= SEQUENCE{
 nodeID NodeID,
         -- ID information of a node, uniquely defined within a MAP message.
 nodeAttribute NodeAttribute_OpB,
         -- Type information of a node
 nodePosition  REG_Position3D_JPN,
         -- A data concept which provides a definitive and precise location of a node
 nodeDirection  Angle_JPN,
         -- Current heading of the orientation from one node to the next node
```

```
 laneCount  LaneCount,
          -- Number of Lanes in a node
 identifier SublinkIdentifier,
          -- This is used to identify divergence pathway oRSEb-link connected with a
          -- node
 ...
}
```

F.3.3.16 DF_RSEIdentifier

Use: The “RSEIdentifier” is used to describe the specific information about the RSE, which includes the prefecture information and the ID.

ASN.1 Representation:

```
RSEIdentifier::= SEQUENCE{
 prefectureID  PrefectureID,
            -- Prefecture information
 RSEID           StationID,
            -- RSE ID is uniquely defined in each prefecture
 ...
}
```

F.3.3.17 DF_SublinkIdentifier

Use: The “SublinkIdentifier” contains data to identify Sublink that is SublinkID and/or the storage address.

ASN.1 Representation:

```
SublinkIdentifier::= = SEQUENCE {
   id         SublinkID OPTIONAL,
   address    StorageAdress OPTIONAL,
                -- Byte length from the head of message
   ...
}
```

F.3.4 Definition of the data elements

F.3.4.1 General

This subclause provides information to define the specific data elements related to this annex. (Some data elements which are the same as the data elements in SPaT message are defined in B.4.)

F.3.4.2 DE_ApproachType

Use: The “ApproachType” is used to describe the type of the approach to indicate the existence of ingress and egress.

ASN.1 Representation:

```
ApproachType::= ENUMERATED{
   Egress only           (0),
   Ingress only          (1),
   Ingress and egress    (2),
...
}
```


F.3.4.3 DE_BranchSublinkID

Use: The "BranchSublinkID" data element is used to relate the index of Branchsublink.

ASN.1 Representation:

```
BranchSublinkID::=INTEGER(0..255)
     -- The value 255 shall be used for invalid
```

F.3.4.4 DE_CommunicationType

Use: The "CommunictionType" is used to identify the communication types for future usage.

ASN.1 Representation:

```
CommunicationType::= ENUMERATED{
  TypeA  (1),
  TypeB  (2),
  TypeC  (3),
...
}
```

F.3.4.5 DE_DivergencePathwayID

Use: The DivergencePathwayID data element is used to relate the index of a divergence pathway.

ASN.1 Representation:

```
DivergencePathwayID::=INTEGER(0..255)
      -- The value 255 shall be used for invalid
```

F.3.4.6 DE_EgressPathwayID

Use: The EgressPathwayID data element is used to identify the egress pathway belonging to approach of targeted intersection.

ASN.1 Representation:

```
EgressPathwayID::=INTEGER(0..255)
      -- The value 255 shall be used for invalid
```

F.3.4.7 DE_IngressID

Use: The IngressID data element is used to identify the ingress belonging to approach of targeted intersection.

ASN.1 Representation:

```
IngressID::=INTEGER(0..255)
      -- The value 255 shall be used for invalid
```

F.3.4.8 DE_IntersectionID_OpB

Use: The "IntersectionID_OpB" is used to identify targeted intersection.

ASN.1 Representation:

```
IntersectionID_OpB::=INTEGER(0..32767)
         -- The value is uniquely defined in each prefecture.
```

```
        -- The value 0 shall be set to the end of intersection belonging to each egress
        -- pathway
```

F.3.4.9 DE_MergeSublinkID

Use: The MergeSublinkID data element is used to relate the index of a Mergesublink.

ASN.1 Representation:

```
MergeSublinkID::=INTEGER(0..255)
-- The value 255 shall be used for invalid
```

F.3.4.10 DE_MessageID_OpB

Use: The "MessageID_OpB" is used to describe the type information of a message.

ASN.1 Representation:

```
MessageID::= ENUMERATED{
  MAP               (1), --Each message has own ID
  ServiceSupport        (2),
  SPAT              (3),
  ……
...
}
```

F.3.4.11 DE_MessageSize

Use: The "MessageSize" is used to describe the data size of a message in byte length.

ASN.1 Representation:

```
MessageSize::=INTEGER(1..65535)
```

F.3.4.12 DE_NodeAttribute_OpB

Use: The "NodeAttribute_OpB" is used to describe the type information of a node.

ASN.1 Representation:

```
NodeAttribute_OpB::= ENUMERATED{
   Start Node (with IR beacon)                      (1),
-- Set at starting point of ingress of targeted intersection, where an IR beacon
-- is installed.
   Start Node (without IR beacon)                   (2),
-- Set at starting point of ingress of targeted intersection without an IR beacon
   ConnectNode                                             (3),
-- The travel distance between nodes shall be within the certain value. This node
-- is set to bridge other nodes to meet this value.
   DivergenceNode                                       (4),
-- Set at the divergence-pathway connection point
   BranchNode                                            (5),
-- Set at the branch sub-link connection point
   Merge Node                                            (6),
-- Set at the merge sub-link connection point
   Stop-line Node (ingress)                             (7),
-- Set at stop-line of ingress of targeted intersection
   Stop-line Node (downstream intersection)       (8),
-- Set at stop-line of ingress of downstream intersection
   Start Node (downstream intersection)           (9),
-- Set at starting point of ingress of downstream intersection
   End Node                                                (10),
```



```
-- Set at end point of the egress-pathway
...
}
```

F.3.4.13 DE_NodeID

Use: The "NodeID" is used to identify a node in a message set.

ASN.1 Representation:

```
NodeID::=INTEGER(1..255),
-- The unique ID numbers for each MAP message
-- The value 255 shall be used for invalid
```

F.3.4.14 DE_OperationMode

Use: The "OperationMode" is used to describe the operation status.

ASN.1 Representation:

```
OperationFlag::= ENUMERATED{
 Test mode    (0),
 Live mode    (1),
 ...
}
```

F.3.4.15 DE_PrefectureID

Use: The "PrefectureID" is used to describe the prefecture information. There are 47 prefectures in Japan.

ASN.1 Representation:

```
PrefectureID ::= ENUMERATED{
  Prefecture1  (1),        --Each ID is assigned to each prefecture
  Prefecture2  (2),
  ……
  Prefecture47  (47),
...
}
```

F.3.4.16 DE_RoadType

Use: The "RoadType" is used to describe the road type information to indicate the intersection and non-intersection.

ASN.1 Representation:

```
LocationType::=ENUMERATED {
  Intersection                (0),
  Non-intersection         (1),
...
}
```

F.3.4.17 DE_StorageAddress

Use: The StorageAddress data element provides the storage address of the corresponding data that is byte length from the head of message. This is used by IngressStorageAddress, EgressStorageAddress, SublinkStorageAddress, SignalGroup.

ASN.1 Representation:

```
StorageAdress::= INTEGER(1..65535)
  -- The value 65535 shall indicate an invalid value
```

F.3.4.18 DE_SublinkID

Use: The SublinkID data element is used to relate the index of a sublink.

ASN.1 Representation:

```
SublinkID::=INTEGER(0..255)
 -- ID for divergence pathway, branch sub-link and merge sub-link are assigned
respectively
 -- The value 255 shall be used for invalid
```

F.3.4.19 DE_VersionIdentifier

Use: This version identifier is used to identify the version of the message provided by RSE.

ASN.1 Representation:

```
VersionIdentifier::=INTEGER(1..15)
```


F.3.5 Performance requirements of MAP message related to this annex

F.3.5.1 Transmission rate requirements

F.3.5.1.1 Minimum transmission rate

MAP message is the static information. Therefore, the requirement of minimum transmission rate is that connected vehicles receive MAP message no less than once before entering service-in-location.

F.3.5.1.2 Maximum transmission rate

An RSE broadcasts MAP message to connected devices no more than once every 100 ms.

F.3.5.2 Nodes design requirements

Node design requirements shall be defined respectively according to use case category (e.g. prioritization, safety, and mobility) and service level (e.g. information, caution, and warning). As for caution level safety related use cases, each node location should be expressed by the absolute coordinate with an accuracy of less than ±1,75 m error and the location of connecting the two consecutive nodes should be less than 30 m.

F.3.6 Requirements to message traceability matrix of map message

Table F.2 shall define the requirements to message DE/DF traceability matrix of MAP message related to this annex.

Table F.2 — Requirements to message DE/DF traceability matrix

ID	Title	DF	DE	Conformance	Comments
6.5.1	Broadcast roadway geometrics	N/A	N/A	M	
6.5.2	Broadcast roadway geometrics — Message identifier	CommonHeader	StationID	M	
6.5.2	Broadcast roadway geometrics — Message identifier	CommonHeader	MessageID_OpB	M	
6.5.2	Broadcast roadway geometrics — Message identifier	CommonHeader	MsgCount_JPN	M	
6.5.3	Broadcast intersection — Identifier	IntersectionIdentifier	PrefectureID	M	PrefectureID and IntersectionID_OpB are used to identify a unique intersection in the country.
6.5.3	Broadcast intersection — Identifier	IntersectionIdentifier	IntersectionID_OpB	M	
6.5.4	Broadcast intersection — Reference point	REG_Position3D_JPN	LatitudeDMS2	M	Reference point is used to express a point equivalent to the centre of the intersection. All nodes are expressed in not offset value from the reference point but in absolute position.
6.5.4	Broadcast intersection — Reference point	REG_Position3D_JPN	LongitudeDMS2	M	
6.5.4	Broadcast intersection — Reference point	REG_Position3D_JPN	Elevation_JPN	M	
6.5.5	Broadcast intersection — Lane/approach default width	Undefined	undefined	X	Related use cases do not require lane/approach width.
6.5.6	Broadcast intersection — Egress lanes/approach	ApproachAttribute	ApproachID	M	
6.5.6	Broadcast intersection — Egress lanes/approach	ApproachAttribute	Angle_JPN	M	
6.5.6	Broadcast intersection — Egress lanes/approach	ApproachAttribute	ApproachType	M	
6.5.6	Broadcast intersection — Egress lanes/approach	EgressIdentifier	EgressID	O	Either EgressStorageAddress or EgressID is used as an identifier.
6.5.6	Broadcast intersection — Egress lanes/approach	EgressIdentifier	EgressStorageAddress	O	
6.5.7	Broadcast intersection — Ingress lanes/approach	ApproachAttribute	ApproachID	M	
6.5.7	Broadcast intersection — Ingress lanes/approach	ApproachAttribute	Angle_JPN	M	
6.5.7	Broadcast intersection — Ingress lanes/approach	ApproachAttribute	ApproachType	M	

Table F.2 *(continued)*

ID	Title	DF	DE	Conform-ance	Comments
6.5.7	Broadcast intersection — Ingress lanes/approach	IngressIdentifier	IngressID	O	Either IngressStorageAddress or IngressID is used as an identifier.
6.5.7	Broadcast intersection — Ingress lanes/approach	IngressIdentifier	IngressStorageAddress	O	
6.5.8	Broadcast intersection — Lane/approach number	ApproachAttribute	ApproachID	M	
6.5.9	Broadcast intersection — Lane/approach centerline coordinates	Node_OpB	REG_Position3D_JPN	M	All nodes are expressed in absolute position.
6.5.10	Broadcast intersection — Vehicle lane/approach manoeuvres	undefined	undefined	X	A manoeuvre is expressed by a pair of ingress and egress. If needed, a separate message including traffic regulation information equivalent to the “valid manoeuvre types” is provided.
6.5.11	Broadcast intersection — Pedestrian crossing lane/approach manoeuvres	undefined	undefined	X	
6.5.12	Broadcast intersection — Special lane/approach manoeuvres	undefined	undefined	X	
6.5.13	Broadcast intersection — Version identifier	CommonHeader	VersionIdentifier	M	
6.5.14	Broadcast intersection — Crossings	undefined	undefined	X	A separate message including the position of crossing and the travel distance to there is provided for SA5 and SA7 use cases.
6.5.15	Broadcast intersection — Lane/approach width	undefined	undefined	X	Related use cases do not require lane/approach width
6.5.16	Broadcast intersection — Node lane/approach width	undefined	undefined	X	
6.5.17	Broadcast intersection — Egress connection	undefined	undefined	X	A manoeuvre is expressed by a pair of ingress and egress.
6.5.18	Broadcast signal control zone	undefined	undefined	X	
6.5.19	Broadcast pre-empt or priority scheme	undefined	undefined	X	

Table F.2 *(continued)*

ID	Title	DF	DE	Conform-ance	Comments
6.5.20	Broadcast pre-empt or priority scheme — Valid lane	undefined	undefined	X	No related use cases
6.5.21	Broadcast pre-empt or priority scheme — Valid zone	undefined	undefined	X	
6.5.22	Broadcast intersection — Traffic control	undefined	undefined	X	
6.5.23	Broadcast intersection — Traffic control by lane	undefined	undefined	X	
6.5.24	Broadcast weather and pavement conditions	undefined	undefined	X	
6.5.25	Broadcast intersection — Signal group	undefined	undefined	X	Referenced signal group is identified by a pair of ingress and egress.
6.6.1	Broadcast GNSS augmentations details	undefined	undefined	X	
6.6.2	Broadcast GNSS augmentation detail — NMEA	undefined	undefined	X	
6.6.3	Broadcast GNSS augmentation detail — RTCM	undefined	undefined	X	
6.8	Broadcast cross traffic sensor information	undefined	undefined	X	A separate message including cross traffic sensor information is provided for SA6.
6.9	Broadcast vulnerable road user sensor information	undefined	undefined	X	A separate message including vulnerable road user sensor information is provided for SA5 and SA7 use cases.
6.10	Broadcast dilemma zone violation warning	undefined	undefined	X	This annex assumes that a vehicle itself judges dilemma zone violation warning using SPaT and MAP information from RSE for SA1 use case.
6.13	Broadcast intersection — Computed lane/approach	undefined	undefined	X	No related use cases

F.4 SPaT message specification

F.4.1 General

Use: This SPAT_OpB message is used to convey the current status of one signalized intersection. Along with the MAP_OpB message, the receiver of this message can determine the current state of the signal phase, as well as the state of the signal phase in a future time.

ASN.1 Representation:

```
SPAT_OpB ::= SEQUENCE{
    header           CommonHeader,
    identifier    IntersectionIdentifier,
    status         IntersectionStatusObject_OpB,
    counter        EventCount,
    approach         SEQUENCE (SIZE(1.. 8)) OF ApproachState,
    signalgroup    SEQUENCE (SIZE (1.. 12)) OF SignalGroupState_V,
    signalgroup    SEQUENCE (SIZE (1.. 8)) OF SignalGroupState_P,
  ...
}
```

F.4.2 Identification of the data elements and data frames

F.4.2.1 General

This subclause provides information to identify the specific data concepts, with references to the data elements and data frames related to SPaT contained in the SAE J2735™.

F.4.2.2 List of data elements contained in SAE J2735™

DE_ApproachID

DE_SignalGroupID

DE_MsgCount_JPN

DE_MaxTimetoChange

DE_MinTimetoChange

F.4.3 Definition of the data frames

F.4.3.1 General

This subclause provides information to define the specific data frames related to this annex.

F.4.3.2 DF_ApproachState

Use: The ApproachState contains current green light indication and corresponding signal groups for this approach to refer to.

ASN.1 Representation:

```
ApproachState ::= SEQUENCE{
    id               ApproachID,
    indication    GreenLightIndication,
                  -- Visual traffic green light indication information
    identifier    SEQUENCE(size(1..20)) of SignalGroupIdentifier,
              -- SignalGroup is connected to pairs of ingress of this approach and
              -- egresses of every approaches of intersection
              -- This data element provides the data to identify corresponding
              -- SIgnalGroup that are SignalGroupID and/or the storage address
              -- Firstly, SignalGroup for vehicle for egress of this approach
              -- (i.e. U-turn) is set.
```

```
            -- Subsequently, SignalGroups for vehicle for other egresses are set
            -- in order in a clockwise direction
            -- Secondly, corresponding SignalGroups for pedestrian are set as well
 ...
}
```

F.4.3.3 DF_GreenLightIndication

Use: The GreenLightIndication contains the current visual traffic green light indication for each approach which oncoming vehicles face.

ASN.1 Representation:

```
GreenLightIndication ::= SEQUENCE{
    status        availableStatus,
                     -- Data availability status
    currentGreen  CurrentGreenIndication,
                    -- Visual traffic green light indication for each approach
    ...
   }
```

F.4.3.4 DF_SignalGroupEvent_V

Use: The SignalGroupEvent_V contains details about signal event for vehicle. It is a signal light status such as traffic light indication and remaining time to the next state.

ASN.1 Representation:

```
SignalGroupEvent_V ::= SEQUENCE{
    ball   BallLight,
             -- Phase state of ball light
      arrow  ArrowLightIndication,
               -- Indication of arrow light
    mintime     MinTimetoChange,
                  -- the minimum time (in units of 0.1 seconds) remaining
                  -- for a signal phase value
    maxtime     MaxTimetoChange,
                  -- the maximum time (in units of 0.1 seconds) remaining
                  -- for a signal phase value
...
}
```

F.4.3.5 DF_SignalGroupEvent_P

Use: The SignalGroupEvent_P contains details about signal event for pedestrian. It is a signal light status such as traffic light indication and remaining time to the next state.

ASN.1 Representation:

```
SignalGroupEvent_P ::= SEQUENCE{
    ped         PedSignalPhaseState,
                  -- Phase state of pedestrian light
    mintime     MinTimetoChange,
                  -- the minimum time (in units of 0.1 seconds) remaining
                  -- for a signal phase value
    maxtime     MaxTimetoChange,
                  -- the maximum time (in units of 0.1 seconds) remaining
                  -- for a signal phase value
...
}
```


F.4.3.6 DF_SignalGroupIdentifier

Use: The SignalGroupIdentifier contains data to identify SignalGroup that is SignalGroupID and/or the storage address of it that is byte length from the head of message.

ASN.1 Representation:

```
SignalGroupIdentifier::=  SEQUENCE {
   id           SignalGroupID OPTION,
 address    StorageAdress OPTION,
                -- storage address that is byte length from the head of message
...
}
```


F.4.3.7 DF_SignalGroupState_V

Use: The SignalGroupState_V contains details of states of SignalGroup for vehicle. It is a sequence of vehicle signal events from the current to a future time for each SignalGroup. This is applied to manoeuvres, which are expressed with pairs of ingress and egress.

ASN.1 Representation:

```
SignalGroupState_V ::= SEQUENCE {
   id         SignalGroupID,
                 -- Vehicle SignalGroupID
                 -- Note; vehicle and pedestrian SignalGroupID are assigned respectively
   state    SEQUENCE(size(1..12)) of SignalGroupEvent_V,
                 -- Consisting of sets of signal group data with:
                 -- a)  VehicleSignalPhaseState
                 -- b)  TimeChangeDetails
                 -- Note one or more of the signal events may be for
                 -- a future time and that this allows conveying multiple
                 -- predictive phase and signal timing for various uses
                 -- for the current signal group
     ...
   }
```

F.4.3.8 DF_SignalGroupState_P

Use: The SignalGroupState_P contains details of states of SignalGroup for pedestrian. It is a sequence of pedestrian signal events from the current to a future time for each SignalGroup. This is applied to manoeuvres, which are expressed with pairs of ingress and egress.

ASN.1 Representation:

```
SignalGroupState_P ::= SEQUENCE {
   id         SignalGroupID,
                 -- Pedeatrian SignalGroupID
-- Note; vehicle and pedestrian SignalGroupID are assigned respectively
   state    SEQUENCE(size(1..12)) of SignalGroupEvent_P,
                 -- Consisting of sets of signal group data with:
                 -- a)  PedestrianSignalPhaseState
                 -- b)  TimeChangeDetails
                 -- Note one or more of the signal events may be for
                 -- a future time and that this allows conveying multiple
                 -- predictive phase and signal timing for various uses
                 -- for the current signal group
     ...
   }
```

F.4.4 Definition of the data elements

F.4.4.1 General

This subclause provides information to define the specific data elements related to this annex. Some data elements which are the same as the data elements in MAP message are defined in B.3

F.4.4.2 DE_AvailableStatus

Use: The AvailableStatus provides data availability

ASN.1 Representation:

```
AvailableStatus::= ENUMERATED{
    data not available  (0),
```

```
    data available      (1),
  ...
}
```

F.4.4.3 DE_ArrowLightIndication

Use: The ArrowLightIndication provides Permissive-Movement-Allowed direction indicated by arrow light.

ASN.1 Representation:

```
ArrowLightIndication::= ENUMERATED{
    sharp left (0x80),
    left (0x40),
    soft left (0x20),
    straight (0x10),
    soft right (0x08),
    right arrow (0x04),
    sharp right (0x02),
    U-turn (0x01),
  ...
}
```


F.4.4.4 DE_BallLight

Use: The BallLight provides the overall current signal state and an indication for a vehicle if this state is permissive or protected as indicated by ball light.

ASN.1 Representation:

```
BallLight::= ENUMERATED{
  unavailable (0),
      -- This state is used for unknown or error
permissive-Movement-Allowed (1),
      -- Driver Action:
      --   Proceed with caution,
      --   must yield to all conflicting traffic
      -- Conflicting traffic may be present
  permissive-clearance (2),
      -- Driver Action:
      --   Prepare to stop.
      --   Proceed if unable to stop,
      --   Clear Intersection.
      -- Conflicting traffic may be present
      stop-And-Remain (3),
      -- Driver Action:
      --   Stop vehicle at stop line.
      --   Do not proceed.
    caution-Conflicting-Traffic (4),
      -- Driver Action:
      --   Proceed with caution
  stop-Then-Proceed (5),
      -- Driver Action:
      --   Stop vehicle at stop line.
      --   Do not proceed unless it is safe.
  reserve (6),
 ...
}
```

F.4.4.5 DE_CurrentGreenIndication

Use: The CurrentGreenIndication provides visual information indicated by traffic green light.

ASN.1 Representation:

```
CurrentGreenIndication::= ENUMERATED{
    Green Ball (or Yellow flash Ball)   (0xff),
    sharp left arrow (0x80),
    left arrow (0x40),
    soft left arrow (0x20),
    straight arrow (0x10),
    soft right arrow (0x08),
    right arrow (0x04),
    sharp right arrow (0x02),
    U-turn arrow (0x01)
  ...
}
```

F.4.4.6 DE_EventCount

Use: The EventCount data element is used to provide a sequence number within a stream of SPaT messages and from the same sender. A sender may initialize this element to any value in the range 0 to 255 when sending the first SPaT message. When the specific events of signal control occur, which are traffic light change or status change except for simple countdown of remaining time, EventCount is set to equal to one greater than the value used in the most recent SPaT message. For this element, the value after 255 is zero. The receipt of a non-sequential EventCount value (from the same sending device and message type) implies that one or more messages from that sending device may have been lost, unless EventCount has been reinitialized due to an identity change.

ASN.1 Representation:

```
EventCount ::= INTEGER (0..255)
```

F.4.4.7 DE_IntersectionStatusObject_OpB

Use: The Intersection Status Object contains SPaT message status information.

ASN.1 Representation:

```
IntersectionStatusObject_OpB ::= ENUMERATED{

   not working (0),
     -- SPAT system is not working at this time
   working(1),
     -- 1   SPAT system is working at this time
   ...
}
```

F.4.4.8 DE_PedSignalPhaseState

Use: The DE_PedSignalPhaseState provides the overall current signal state and an indication for pedestrian if this state is permissive or protected indicated by pedestrian light

ASN.1 Representation:

```
PedSignalPhaseState::= ENUMERATED{
   unavailable (0),
      -- This state is used for unknown or error
  permissive-Allowed (1),
      -- Pedestrian Action:
      --   Proceed with caution,
  permissive-clearance (2),
      -- Pedestrian Action:
      --   Stop crossing.
      --   Proceed if overreach halfway
      --   Turnback if not overreach halfway
  stop-And-Remain (3),
      -- Pedestrian Action:
```

```
      --   Stop and wait for crossing
      --   Do not proceed.
  reserve (4),
  ...
}
```

F.4.5 Performance requirements of SPaT message related to this annex

When signal phase and timing is updated at a signalized intersection where connected vehicles are approaching, RSE needs to provide the signal phase and timing information to connected vehicles immediately. This annex suggests the transmission rate requirement that RSE should broadcast SPaT message to connected vehicles once every 100 ms.

F.4.6 Requirements to message traceability matrix of SPaT message

Table F.3 shall define the requirements to message DE/DF traceability matrix of SPaT message related to this annex.

Table F.3 — Requirements to message DE/DF traceability matrix

ID	Title	DF	DE	Conformance	Comments
6.7.1	Broadcast signal phase and timing information	N/A	N/A	M	
6.7.2	Broadcast signal phase and timing — Message identifier	CommonHeader	StationID	M	
6.7.2	Broadcast signal phase and timing — Message identifier	CommonHeader	MessageID_OpB	M	
6.7.2	Broadcast signal phase and timing — Message identifier	CommonHeader	MsgCount_JPN	M	
6.7.3	Broadcast signal phase and timing — Intersection identifier	IntersectionIdentifier	PrefectureID	M	PrefectureID and IntersectionID_OpB are used to define a unique intersection in the country.
6.7.3	Broadcast signal phase and timing — Intersection identifier	IntersectionIdentifier	IntersectionID_OpB	M	
6.7.4	Broadcast signal phase and timing — Intersection status	SPAT_OpB	IntersectionStatusObject_OpB	M	
6.7.5	Broadcast signal phase and timing — Timestamp	TimeMark_JPN	year, month, day, hour, minute, tenthSecond	M	
6.7.6	Broadcast manoeuvre — Signal group	SignalGroupIdentifier	SignalGroupID	O	SignalGroup to refer can be identified by the storage address of it that is byte length from the head of message.
6.7.7	Broadcast manoeuvre — Manoeuvre state	undefined	Undefined	×	
6.7.8	Broadcast manoeuvre — Vehicular state	SignalGroupEvent_V	BallLight	M	Sequence of "signal group events" of the future from the current phase for each manoeuvre is provided as "signal group status".
6.7.8	Broadcast manoeuvre — Vehicular state	SignalGroupEvent_V	ArrowLightIndication	M	
6.7.9	Broadcast manoeuvre — Pedestrian state	SignalGroupEvent_P	PedSignalPhaseState	O	
6.7.10	Broadcast manoeuvre — Special state	undefined	Undefined	×	
6.7.11	Broadcast manoeuvre — Time of change — Minimum	SignalGroupEvent_V	MinTimetoChange	M	
6.7.11	Broadcast manoeuvre — Time of change — Minimum	SignalGroupEvent_P	MinTimetoChange	O	

Table F.3 *(continued)*

ID	Title	DF	DE	Conformance	Comments
6.7.12	Broadcast manoeuvre — Time of change — Maximum	SignalGroupEvent_V	MaxTimetoChange	M	
6.7.12	Broadcast manoeuvre — Time of change — Maximum	SignalGroupEvent_P	MaxTimetoChange	O	
6.7.13	Broadcast manoeuvre — Succeeding signal indications	SignalGroupEvent_V	BallLight	M	Sequence of “signal group events” of the future from the current phase for each manoeuvre is provided as “signal group status”.
6.7.13	Broadcast manoeuvre — Succeeding signal indications	SignalGroupEvent_V	ArrowLightIndication	M	
6.7.13	Broadcast manoeuvre — Succeeding signal indications	SignalGroupEvent_P	PedSignalPhaseState	O	
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	SignalGroupEvent_V	MinTimetoChange	M	Sequence of “signal group events” of the future from the current phase for each manoeuvre is provided as “signal group status”.
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	SignalGroupEvent_V	MaxTimetoChange	M	
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	SignalGroupEvent_P	MinTimetoChange	O	
6.7.14	Broadcast manoeuvre — Succeeding signal indication time of change	SignalGroupEvent_P	MaxTimetoChange	O	
6.7.15	Broadcast manoeuvre pending manoeuvre start time	SignalGroupEvent_V	MinTimetoChange	M	Sequence of “signal group events” of the future from the current phase for each manoeuvre is provided as “signal group status”.
6.7.15	Broadcast manoeuvre pending manoeuvre start time	SignalGroupEvent_V	MaxTimetoChange	M	
6.7.16	Broadcast manoeuvre — Pedestrian detect	undefined	Undefined	×	A separate message including pedestrian sensor information is provided for SA5 and SA7 use cases.
6.7.17	Broadcast manoeuvre — Pedestrian call	undefined	Undefined	×	
6.7.18	Broadcast manoeuvre — Optimal speed information	undefined	Undefined	×	This annex assumes that optimal speed is calculated by OBE itself in MS4 use case
6.7.19	Broadcast manoeuvre — Signal progression information	undefined	Undefined	×	

Table F.3 *(continued)*

ID	Title	DF	DE	Con-form-ance	Comments
6.7.20	Broadcast manoeu-vre — Egress lane queue	undefined	Undefined	×	A separate message including vehicle sensor information is provided for SA4 and SA6 use cases.
6.7.21	Broadcast manoeu-vre — Egress lane storage availability	undefined	Undefined	×	
6.7.22	Broadcast manoeu-vre — Wait indication	undefined	Undefined	×	

F.5 SRM message specification

SRM message related to this annex is compliant with ISO 22951.

All the requirements regarding SRM listed in Annex C are optional or excluded.

F.6 SSM message specification

F.6.1 General

This annex does not address SSM message.

F.6.2 Requirements to message traceability matrix of SSM message

All the requirements regarding SSM listed in Annex C are optional or excluded.

F.7 PICS list for this annex

See Table F.2 and Table F.3 to select the optional requirements necessary for fulfilling the use case needs as listed in Annex F.

Annex G
(normative)

Profile C for J2735™

G.1 General

This annex defines a profile for the MAP, SPaT, SRM, and SSM messages defined in SAE J2735™. This profile defines data extensions to the messages and includes additional explanations for the usage of the messages in the context of this profile.

The data elements of this profile (module: "AddGrpC") are included via the extension framework specified in SAE J2735™ and are identified by "AddGrpC".

G.2 Normative references

For this profile, all normative references defined in former subclauses of this document are not applicable. The following normative references apply.

The MAP, SPaT, SRM and SSM message definitions defined in the ASN.1 module "DSRC" from SAE J2735™ are mandatory. All other ASN.1 Modules from SAE J2735™ are informative.

Additional normative references relevant for this profile:

[G1] ETSI/TS 102 894-2 V1.2.2; Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer; common data dictionary.

[G2] EN 302 637-2 V1.3.2; Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service.

G.3 Conformance

For this profile, all conformance requirements defined in former subclauses of this document are not applicable. An application deployed in conformance to this profile shall be compliant as follows.

— AddGrpC {iso (1) standard (0) signalizedIntersection (19091) profilec (2) addgrpc (0) version (1)} and

— REGION {iso (1) standard (0) signalizedIntersection (19091) profilec (2) region (1) version (1)} together with

— DSRC {iso (1) standard (0) signalizedIntersection (19091) profilec (2) dsrc (2) version (1)} shall be considered a normative package for this Profile C for J2735™.

The module DSRC {iso (1) standard (0) signalizedIntersection (19091) profilec (2) dsrc (2) version (1)} is provided for readability and ease of deployment using this ProfileC for J2735™. This module imports the regional extensions directly from the Profile C modules. Since it has an OID it can be referred to by other standards (e.g. ETSI/TS 103 301).

G.4 Message content revision strategy

The SPaT and MAP message are related each other. If, for example, the signalling of the lanes changes, the related data frames of the SPaT and MAP have to be updated using the same revision number. This ensures a valid set of messages with a correct relation of the signal states (SPaT) to the intersection geometry (MAP). For achieving this goal, the data element "revision", which is included in the data frames "DF_IntersectionGeometry" and "DF_IntersectionState", is used. The intersection states transmitted within a SPaT message are related to the intersection geometry with the same revision identification.

G.5 Data extensions "addGrpC"

The following subclause defines the data frames and elements which extend the messages defined in the ASN.1 module "DSRC" from SAE J2735™. They use, additionally, data elements from the common data dictionary [G1] (ASN.1 module "ITS-Container").

G.5.1 Data frames

G.5.1.1 ConnectionManeuverAssist-addGrpC

The data frame "ConnectionManeuverAssist-addGrpC" includes positioning support from the infrastructure to the vehicle.

— "itsStationPositions" defines a list of ITS stations (e.g. vehicles) and their corresponding position on the driving lane as defined in the lane topology of the "MAP" message. It enables accurate, real-time positioning support to the moving ITS entities by the infrastructure.

— "rsuGNSSOffset" defines the real-time positioning deviation of the received GNSS position from the high precision reference position in X/Y coordinates.

ASN.1 representation:

```
ConnectionManeuverAssist ::= SEQUENCE {
   itsStationPositionList    ItsStationPositionList    OPTIONAL,
   rsuGNSSOffset             NodeOffsetPointXY    OPTIONAL,
   ...
}
```

G.5.1.2 ConnectionTrajectory-addGrpC

The data frame "ConnectionTrajectory-addGrpC" defines the trajectory for travelling through the conflict area of an intersection. The trajectory is defined by two or more nodes. The starting node is the node of the ingress lane towards the conflict zone. The ending node is the first node of the connected egress lane.

"Nodes" defines a list of nodes for the trajectory. It defines a geometric trajectory from an ingressing to a connected egressing lane. The position offset value of the first node of the trajectory is defined in relation to the node of the ingress lane. The position of the last node matches the position of the first node of the egressing lane.

ASN.1 representation:

```
ConnectionTrajectory-addGrpC ::= SEQUENCE {
   Nodes          NodeSetXY,
   ...
}
```

G.5.1.3 Control-addGrpC

The data frame "Control-addGrpC" is used to support special vehicles. It includes control points for public transport prioritization. These control points are currently implemented by legacy systems using hardware sensors mounted on the roadside. For C-ITS migration of legacy prioritization systems, these control points are introduced in the map.

"ptvRequest" defines control types attached to a node on a lane used by public transport for triggering the transmission of messages (e.g. prioritization request).

ASN.1 representation:

```
Control-addGrpC ::=  SEQUENCE {
   ptvRequest        PtvRequestType,
   ...
}
```

G.5.1.4 IntersectionState-addGrpC

The data frame “IntersectionState-addGrpC” defines a list of prioritization responses for, for example, public transport acceleration.

ASN.1 representation:

```
IntersectionState-addGrpC ::= SEQUENCE {
   activePrioritizations  PrioritizationResponseList  OPTIONAL,
   ... }
```

G.5.1.5 MapData-addGrpC

The data frame “MapData-addGrpC” defines a list of three-dimensional positions of signal heads in an intersection. It enables vehicles to identify the signal head location for optical evaluation of the traffic light. Combined with the “SPaT”/“MAP” messages, it enables to enhance safety decision in critical situations.

ASN.1 representation:

```
MapData-addGrpC ::= SEQUENCE {
   signalHeadLocations  SignalHeadLocationList  OPTIONAL,
   ...
}
```

G.5.1.6 Position3D-addGrpC

The data frame “Position3D-addGrpC” includes the altitude data element defined in the common data dictionary [G1].

ASN.1 representation:

```
Position3D-addGrpC ::= SEQUENCE {
   Altitude   Altitude,
   ...
}
```

G.5.1.7 PrioritizationResponse

The data frame “PrioritizationResponse” is used to provide the prioritization status response and the signal group identifier for a specific ITS station (e.g. vehicle).

ASN.1 representation:

```
PrioritizationResponse ::= SEQUENCE {
   stationID      StationID,
   priorState     PrioritizationResponseStatus,
   signalGroup    SignalGroupID,
   ...
}
```

G.5.1.8 PrioritizationResponseList

The data frame “PrioritizationResponseList” defines a list of prioritization response entries.

ASN.1 representation:

```
PrioritizationResponseList ::= SEQUENCE SIZE(1..10) OF PrioritizationResponse
```

G.5.1.9 RestrictionUserType-addGrpC

The data frame “RestrictionUserType-addGrpC” defines the driving restriction based on toxic emission type.

ASN.1 representation:

```
RestrictionUserType-addGrpC ::= SEQUENCE {
   Emission     EmissionType   OPTIONAL,
   ...
}
```

G.5.1.10 SignalHeadLocationList

The data frame "SignalHeadLocationList" defines a list of traffic light signal heads locations in relation to the intersection reference position.

ASN.1 representation:

```
SignalHeadLocationList ::= SEQUENCE (SIZE(1..64)) OF  SignalHeadLocation
```

G.5.1.11 SignalHeadLocation

The data frame "SignalHeadLocation" defines the XYZ position of a signal head within an intersection and indicates the related signal group identifier.

ASN.1 representation:

```
SignalHeadLocation ::= SEQUENCE {
   nodeXY             NodeOffsetPointXY,
   nodeZ              DeltaAltitude
   signalGroupID      SignalGroupID,
   ...
}
```

G.5.1.12 SignalStatusPackage-addGrpC

The traffic control centre (TCC) may advice a public transport vehicle (e.g. bus) to synchronize his travel time. This may happen when, for example, two busses, due to special traffic conditions, are out of schedule; the first might be too late, the second too fast. This means that the second is driving just behind the first and is empty as all passengers are within the first one. To avoid this often-occurring situation, the TCC sends out time synchronization advices to the public transport vehicles using the signal status message.

ASN.1 representation:

```
SignalStatusPackage-addGrpC ::= SEQUENCE {
   synchToSchedule      DeltaTime OPTIONAL,
   ...
}
```

G.5.1.13 ItsStationPosition

The data frame "ItsStationPosition" is used to provide real-time positioning information to a specific ITS station (e.g. vehicle, pedestrian, bicycle) by infrastructure equipment. The position information includes, for example, the driving, crossing lane and/or the X/Y coordinates in relation to the reference position of the "MAP". The time indicates the time the position has been computed by infrastructure equipment (e.g. RSU). If the positioning computation is derived from the received radio messages of an ITS station, the time stamp from the messages shall be used as time reference.

ASN.1 representation:

```
ItsStationPosition ::= SEQUENCE {
   stationID            StationID,
   laneID               LaneID               OPTIONAL,
   nodeXY               NodeOffsetPointXY    OPTIONAL,
   TimeReference        TimeReference        OPTIONAL,
   ...
}
```

G.5.2 Data elements

G.5.2.1 EmissionType

The data element "EmissionType" element defines an enumerated list of toxic emission types for vehicles.

ASN.1 representation:

```
EmissionType ::= ENUMERATED {
   euro1,
   euro2,
   euro3,
   euro4,
   euro5,
   euro6,
   ...
}
```

G.5.2.2 PtvRequestType

The data element "PtvRequestType" element defines a list of activation requests used for C-ITS migration of legacy public transport prioritization systems. The activation points are used while approaching to an intersection.

ASN.1 representation:

```
PtvRequestType ::= ENUMERATED {
   preRequest,
   mainRequest,
   doorCloseRequest
   cancelRequest,
   emergencyRequest
   ...
}
```

G.5.2.3 TimeReference

The data element "TimeReference" element defines a value in milliseconds since 2004-01-01T00:00:00:000Z as defined in [G1]. The value of the DE shall be wrapped to 65 536. This value shall be set as the remainder of the corresponding value of "TimestampIts" divided by 65 536 as below:

TimeReference = TimestampIts mod 65 536.

ASN.1 representation:

```
TimeReference ::= INTEGER { oneMilliSec(1) } (0..65535)
```

G.6 Framework for including extension data

Due to intercontinental harmonization of the SAE J2735™ messages like SPaT, MAP, SRM, SSM, a flexible extension mechanism has been introduced to SAE J2735™, to allow the extension of additional data elements with focus on a specific region (e.g. Europe, Japan, US, etc.). This is done using ASN.1 object identifiers as described in SAE J2735™. The following example shows how to extend the messages of DSRC module defined by SAE J2735™.

The goal of the example is to extend the intersection state of the "SPaT" message. The data frame "DF_IntersectionState" defines an optional data element "regional" used for extension. The type of this "regional" data element is "Reg-IntersectionState" and is defined in the region control module "REGION". The data element "Reg-IntersectionState" includes the regional data element "IntersectionState" which is defined in the module "AddGrpC". If in future, additional data elements are needed for extension, they will be defined in the module "AddGrpC" and added to "Reg-IntersectionState" after the "IntersectionState-addGrpC" entry.

Module DSRC (defined by SAE J2735™):

```
IntersectionState ::=  SEQUENCE {
   Name                 DescriptiveName          OPTIONAL,
   Id                   IntersectionReferenceID,
   revision             MsgCount,
   status               IntersectionStatusObject,
   moy                  MinuteOfTheYear          OPTIONAL,
   timestamp            DSecond                  OPTIONAL,
   enabledLanes         EnabledLaneList          OPTIONAL,
   states               MovementList,
   maneuverAssistList   ManeuverAssistList       OPTIONAL,
   priority             SignalControlState       OPTIONAL,
   pre-empt             SignalControlState       OPTIONAL,
   regional             RegionalExtension {{REGION.Reg-IntersectionState}} OPTIONAL,
   ...
}
```

Module REGION:

```
Reg-IntersectionState     REG-EXT-ID-AND-TYPE ::= {
   {IntersectionState-addGrpC IDENTIFIED BY addGrpC} ,
   ...
}
```

Module “AddGrpC”:

```
IntersectionState-addGrpC ::=  SEQUENCE {
   activePrioritizations PrioritizationResponseList OPTIONAL,
   ...
}
```

G.7 Extension data frame control structure “REGION”

G.7.1 Reg-ConnectionManeuverAssist

This data element is used to extend the data frame “DF_ConnectionManeuverAssist” from SAE J2735™ with data content defined by “ConnectionManeuverAssist-addGrpC” of this profile (see G.5.1.1).

ASN.1 representation:

```
Reg-ConnectionManeuverAssist     REG-EXT-ID-AND-TYPE ::= {
   {ConnectionManeuverAssist-addGrpC   IDENTIFIED BY addGrpC} ,
   ...
}
```

G.7.2 Reg-GenericLane

This data element is used to extend the data frame “DF_GenericLane” from SAE J2735™ with data content defined by “ConnectionTrajectory-addGrpC” of this profile (see G.5.1.2).

ASN.1 representation:

```
Reg-GenericLane           REG-EXT-ID-AND-TYPE ::= {
   {ConnectionTrajectory-addGrpC   IDENTIFIED BY addGrpC} ,
   ...
}
```

G.7.3 Reg-IntersectionState

This data element is used to extend the data frame “DF_IntersectionState” from SAE J2735™ with data content defined by “IntersectionState-addGrpC” of this profile (see G.5.1.4).

ASN.1 representation:

```
Reg-IntersectionState   REG-EXT-ID-AND-TYPE ::= {
   {IntersectionState-addGrpC IDENTIFIED BY addGrpC} ,
   ...
}
```

G.7.4 Reg-MapData

This data element is used to extend the message "MSG_MapData" from SAE J2735™ with data content defined by "MapData-addGrpC" of this profile (see G.5.1.5).

ASN.1 representation:

```
Reg-MapData  REG-EXT-ID-AND-TYPE ::= {
   {MapData-addGrpC  IDENTIFIED BY addGrpC},
   ...
   }
```

G.7.5 Reg- NodeAttributeSetXY

This data element is used to extend the message "NodeAttributeSetXY" from SAE J2735™ with data content defined by "Control-addGrpC" of this profile (see G.5.1.3).

ASN.1 representation:

```
Reg-NodeAttributeSetXY        REG-EXT-ID-AND-TYPE ::= {
  { Control-addGrpC  IDENTIFIED BY addGrpC} ,
  ...
}
```

G.7.6 Reg-Position3D

This data element is used to extend the data frame "DF_Position3D" from SAE J2735™ with data content defined by "Position3D-addGrpC" of this profile (see G.5.1.6).

ASN.1 representation:

```
Reg-Position3D     REG-EXT-ID-AND-TYPE ::= {
   {Position3D-addGrpC IDENTIFIED BY addGrpC} ,
   ...
}
```

G.7.7 Reg-RestrictionUserType

This data element is used to extend the data frame "DF_RestrictionUserType" from SAE J2735™ with data content defined by "RestrictionUserType-addGrpC" of this profile (see G.5.1.9).

ASN.1 representation:

```
Reg-RestrictionUserType      REG-EXT-ID-AND-TYPE ::= {
   {RestrictionUserType-addGrpC IDENTIFIED BY addGrpC} ,
   ...
}
```

G.7.8 Reg-SignalStatusPackage

This data element is used to extend the data frame " DF_SignalStatusPackage " from SAE J2735™ with data content defined by " SignalStatusPackage-addGrpC" of this profile (see G.5.1.9).

ASN.1 representation:

```
Reg-SignalStatusPackage      REG-EXT-ID-AND-TYPE ::= {
   { SignalStatusPackage-addGrpC IDENTIFIED BY addGrpC} ,
   ...
}
```

G.8 Usage of the SAE J2735™ messages, data frames, and elements

The following subclauses give a guidance of usage and additional details related to the basic message sets (SPaT, MAP, SRM, SSM) defined in the module "DSRC" of SAE J2735™ in the context of this profile. If the data frame/data element is not listed below, the definition from SAE J2735™ apply.

